

Analysis of Input from Wildfire Incident Experts to Identify Key Risks and Hazards in Wildfire Emergency Response

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The United States Department of Agriculture (USDA) describes wildland fires as, “a force of nature that can be nearly as impossible to prevent, and as difficult to control, as hurricanes, tornadoes and floods.” Existing challenges in managing wildland fires often put first responders’ lives at risk. The emergence of drones and their capabilities to supplement human efforts could alleviate some, if not all, of those risks that first responders face during wildfire management efforts. However, the process of adding drones to wildfire response has come with its own challenges as well. NASA’s System-Wide Safety Project is working towards overcoming these challenges to enable routine transfer of risk from responders to aviation assets. The concept of operations and model-based systems engineering (MBSE) effort for this shift is underway. To inform and to validate the MBSE effort, we delivered a questionnaire to wildland firefighting experts on the hazards they currently face. This questionnaire has given us insight and a better understanding of the challenges related to the use of drones from a first responder’s point of view. We are using this information to better address responders’ concerns, develop a safety management system, and eliminate the roadblocks that prevent the use of drones in wildfire management.

I. Nomenclature

<i>EO/IR</i>	=	Electro-Optical/Infra-Red
<i>FAA</i>	=	Federal Aviation Administration
<i>FBAN</i>	=	Fire Behavior Analyst
<i>FF</i>	=	Firefighter
<i>FSF</i>	=	Flight Safety Foundation
<i>FTA</i>	=	Fire Traffic Area
<i>IASMS</i>	=	In-time Aviation Safety Management Systems
<i>ICS</i>	=	Incident Command Center
<i>LOA</i>	=	Level of Automation
<i>MAC</i>	=	Mission Assignment Coordinator
<i>MBSE</i>	=	Model-Based Systems Engineering
<i>NARI</i>	=	National Aeronautics Research
<i>NAS</i>	=	National Airspace System
<i>NASA</i>	=	National Aeronautics and Space Administration
<i>NWCG</i>	=	National Wildfire Coordinating Group
<i>SD</i>	=	Safety Demonstrator
<i>SFC</i>	=	Services, Functions and Capabilities
<i>SME</i>	=	Subject Matter Expert
<i>SWS</i>	=	System-Wide Safety

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<i>TC</i>	=	Technical Challenge
<i>UAS</i>	=	Unmanned Aerial System
<i>USFS</i>	=	United States Forest Forest Service
<i>UxS</i>	=	Unmanned Systems

II. Introduction

THE System-Wide Safety (SWS) Project has a goal to explore, to discover and to understand how safety could be affected by the growing complexity of advanced aviation systems. SWS researchers are working in conjunction with the Federal Aviation Administration (FAA), the Flight Safety Foundation (FSF) and the National Aeronautics and Space Administration (NASA)'s National Aeronautics Research Institute (NARI), among other entities, to develop what is called the In-time Aviation Safety Management Systems (IASMS). [1]. The need for an IASMS stems from the anticipation that the National Airspace System (NAS) is expected to change drastically in the near future, and today's Safety Management Systems (SMS) in place, although very effective, cannot scale and adapt to the changes the NAS will undergo. The IASMS is a federated architecture of safety systems, a data-driven integrated safety system of systems. An IASMS, as envisioned by the National Academies and recommended for development to NASA, has a goal to "detect and predict elevated risk states that arise from a confluence of factors, none of which by itself would be noteworthy" (ISSA Conops).

SWS divides its current work towards achieving the IASMS into Technical Challenges (TCs). TC1 focuses on evolving today's terminal risk area safety monitoring and assessment towards more predictive capabilities. TC2 focuses on the development of IASMS Services, Functions and Capabilities (SFCs) for emerging operations. TC3 automates Verification and Validation (V&V) for commercial operations. TC4 focuses on techniques to enable increasingly-autonomous systems assurance. TC5 focuses on building out the first end-to-end operational IASMS for targeted public-benefit use cases. TC5 use cases are encapsulated in the Safety Demonstrator (SD) series, ranging from 1 to 4, for operational IASMS. SD1, which is the focus of this research, has a goal of investigating and developing the "data and safety framework for rapid response for disaster relief in operations similar to wildfire fighting scenarios and deliver recommendations to the FAA" using the IASMS concept. In February of 2022, NARI and NASA's Science Mission Directorate (SMD) conducted a two-day wildfire stakeholder engagement workshop [2]. The purpose of the workshop was to:

- Hear wildfire management stakeholders articulate their visions for successful wildfire management.
- Create and strengthen the diverse interdisciplinary community through areas of technology, social science, commercialization, geography, land and resource management, ecosystem and land planning, health and air quality, risk and resilience assessment, and more.
- Identify the following:
 - Barriers the community has in integrating science, technology, and knowledge.
 - Where NASA can help enable collaborative programs and partnerships across the fire lifecycle, including preparedness and adaptation, response, and recovery.
 - Key opportunities and priorities to make progress in pre-, during, and post-fire.
 - Partnerships and programmatic activities to guide near term action.

During this workshop, a response form was distributed to wildfire management stakeholders. The purpose of this form was to gain insights from the wildfire management community, specifically first responders, on the use of drones (unmanned vehicles weighing less than 55 lbs at takeoff) in wildfire response. Wildfire response is being defined as actions taken to extinguish a fire, beginning with its discovery. The information collected will support the development of a safety model for wildfire scenarios that include drones as part of the overall operation and will help to identify key safety issues and challenges with the introduction of drones in wildfire responses. The response form was anonymous and no personal data, such as email and IP addresses of participants, were collected. Exactly ten (10) wildfire management subject matter experts submitted a response. The relatively low number of respondents can be asserted to the fact that the majority of the respondents (90%) have over ten (10) years of experience in wildfire response. While it would have been preferable to have a bigger sample size, the respondents were all subject matter experts (SME) with combined years of experience in wildfire management of roughly a century. This effort was conducted by members of NASA's System-Wide Safety Project.

The overarching goal is to establish a Model-Based Systems Engineering (MBSE) approach to evaluating and mitigating the different key hazards associated with the introduction of drones in wildfire management efforts, and the broader Advanced Air Mobility, in general. To that effect, System-Wide Safety researchers have started a system-modeling

analysis of hazards pertaining to the use of Unmanned Aerial Systems [3].

III. Data Collection

A. Tool

To collect data, we provided respondents with a standard Google form. The form consisted of five (5) sections:

- Background (pertaining to background such as type of first responder, role, or years of service)
- General Questions (pertaining to general challenges as a first responder to wildfire incidents)
- Drones for Wildfire Response (pertaining to the respondents' general opinions on the use of drones for firefighting)
- Experience with Drones (pertaining to the respondents' experience with drones)
- Experience Flying Drones (to gauge our respondents' personal or professional backgrounds using drones)

Not all questions required an answer to proceed, and some sections and subsections in the questionnaire would be automatically skipped based on an answer to a leading a question. The form was completely anonymous, and there was no means to collect any personal data or identifiers that could tie responses back to any of the respondents. Prior to distribution, we had volunteers complete the questionnaire to ensure that there was no privacy breach and to also have an estimate of how long it would take to complete the form. The average time recorded was ten (10) minutes.

B. Respondents' Background

The background questions included the category of first responders, role as a first responder and years of experience in wildfire response. Knowing the title, years of service and experience in wildfire response will help shed light on some key issues in participants' willingness or reticence to include drones in their efforts. There is an existing generational gap as it pertains to the use of technology, in general, and robots, in particular, to help humans offload risks associated with their daily activities. Eight (8) out of the ten (10) respondents identified themselves as working in firefighting only, one (1) in firefighting and emergency medical response and one (1) in firefighting and law enforcement. The background questions all required an answer.

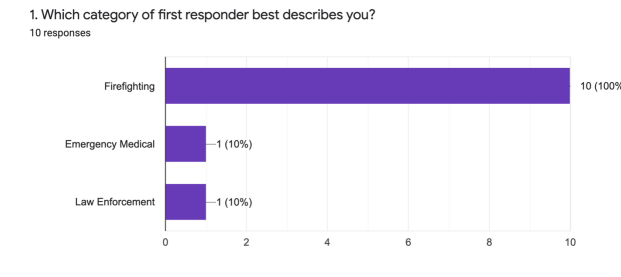


Fig. 1 Responses to the question “Which category of first responders best describe you?”

When it comes specific roles in firefighting, all ten (10) had different answers:

- Firefighter, Predictive services
- Wildland fire management and emergency response. Primarily line operations.
- Intel
- UXS Support
- Incident meteorologist
- Firefighter, FBAN, Chief Predictive Services
- Dispatch/MAC coordinator
- Firefighter
- Incident Commander, Operations Chief, Risk Assessments
- Manned fixed and rotor wing aircraft

To the question how many years of service they had in wildfire response, 90% of the respondents (9 of them) indicated they had over ten (10) years and the remaining 10% had less than 5 years of experience. This is quite significant and adds more weight to the collected information. It also further explains the low number of participants.

The last question in this section was to find out how many years of experience the respondents had in wildfire response. Ninety percent (90%) of the respondents had over ten (10) years of experience, while only one out the ten people surveyed had less than five (5) years of experience.

C. General Questions

The general questions set consisted of four (4) questions aiming to identify challenges, as well as hazards respondents face in their wildfire management efforts. There were also questions pertaining to the existing and desired processes and techniques that could contribute to a more effective and efficient response to an active fire incident. These questions were all optional. To the question, “What are the most common, day-to-day challenges you face as a wildfire fighter?”, nine (9) responses were recorded:

- Connectivity
- Intelligence gathering
- Equipment Failures, Rapid changes in orders, new incidents while over another incident, Chain of command issues
- Access to airspace
- Changes in weather, not enough resources, changing priorities
- Communications and Data
- Inoperability/Communication Gaps/Real Time Data/Situational Awareness
- Interoperability between agencies and organizations. Specifically, communications during initial attack.

Answers to the question “What are the primary hazards you face as a wildfire fighter?”, the ten responses below were recorded:

- Hubris
- Driving
- Plane crash, getting the wrong data and providing incorrect deliverables
- Lack of communications
- Falling trees, limbs, rapid changes in weather. Lightning and thunderstorms
- Hubris
- Wildland fire fighting is inherently dangerous. There are too many hazards to describe.
- Hubris
- In general, the fire environment it’s self as well as unpredicted/uncommunicated fire behavior. General hazards associated with aerial delivery of fire personnel, suppression products and supplies
- Weather as it relates to aircraft and fire behavior

The response “hubris” appeared three (3) times (30%) and weather-related hazard appeared twice (20%).

To the question, “What techniques and processes do you currently have that contribute to an effective and efficient response to an active fire incident?”, the ten responses below were recorded:

- Common communications and standards
- Pre incident planning and strategizing
- Crisis management, Superior multitasking, Remote sensing, radio knowledge, running sensors, GIS management, analysis, and projection
- Utilization of Uncrewed Systems (UXS) for Environmental and Fire Intelligence, and for communications network.
- Weather models, satellite, radar, fire spread models
- Good solid FF tactics, SA built up before the fire.
- Standard operating procedures. The ICS system. NWCG. Appropriate data at the right time
- Good solid FF techniques
- In general, we have been very successful in responding to wildland fires.
- Risk assessments, Foreflight is very helpful for weather/traffic for aircraft response.

The last question in this section was, “Can you imagine other processes and techniques that you do not currently have that would contribute to an effective and efficient response to an active fire incident?” Nine (9) responses were recorded as listed below:

- More spatial and temporal RGB and Infrared imagery
- Real time resource tracking
- New Gimbals and new sensors
- Expanded utilization of Uncrewed Systems (UXS) for Environmental and Fire Intelligence and for air drops.
- Drones feeding back real time intel would be helpful. More accurate fire spread models.

- Universal Connectivity, so a Common Operating Picture can be just that
- Yes
- Better satellite resolution on temporally and spatially
- A higher degree of data transition, in real time, to ground personnel and bridging the gaps in inoperability communications.

D. Drones for Wildfire Response

In this section, the focus was on respondents' views and opinions of the insertion of drones in wildfire response. The goal was to gauge what type of operations would benefit the most from drones, if they perceive drones sources of additional risks, if the inclusion of drones had any value added, along with the levels of automation (LOA) needed, should drones be introduced. We will define LOA as the level of automation to which a task is automated, ranging from complete human control to complete computer control. Figure 2 details the responses to the question "which of these operations might benefit from the inclusion of drones?"

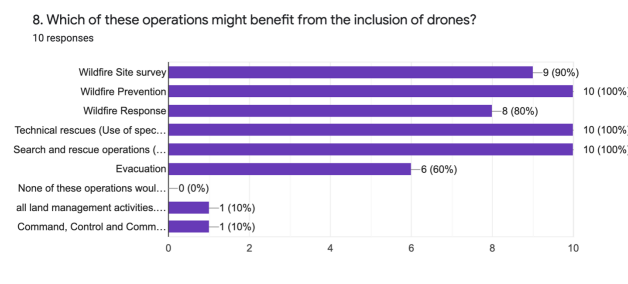


Fig. 2 Answers to the question “Which of these operations might benefit from the inclusion of drones?”.

Ninety percent (90%) of the respondents see drones as possibly adding value to wildfire suppression operations, whereas the remaining 10% did not see drones bringing any value.

Respondents were then asked to give a reason why they see or do not see drones as adding values in wildfire suppression operations. Their answers were as follow:

- I think UAVs could minimize the risk of human casualties in aviation accidents over incidents, and provide good readings from sensors if equipped with the proper technologies
- It's another tool we can use with limited human risk.
- Ability to "see" difficult terrain and what the fuels really look like. Could monitor troop movements. Give real time intel on firing operations as well as wildfire spread, especially when smoke is hampering normal aircraft operations.
- Already proven effective
- UAS offers a partial solution to many problems in wildland fire and other emergency operations. Providing real time situation awareness, firing operations support. EO/IR sensor support. Can be integral in mesh networks for low connectivity areas. Larger UAS have the potential capacity to support logistically and through suppression efforts
- More real time data.... safe, effective, interoperability with other aircraft is key though
- Drones have the ability to conduct some operations that currently cannot be done safely by personnel or can do so in a more effective manner.
- more near real time data
- It can add valuable data safely, if incorporated correctly into Aerial Operations, if not you create a very dangerous situation for the manned aerial platforms
- Continuous 24 hours operations.

When asked if they believed including drones in wildfire suppression operations would introduce new risks, 90% answered “yes,” and the remaining 10% answered “no”.

The following question gave respondents the opportunity to give their reasons for their answer to question 10, and they answered as follow:

- More iron in the sky, the higher likely hood it could come together

- An additional aircraft in an already busy airspace that historically is prone to accident/incident. More to manage for aerial supervision. More for manned pilots to be aware of. These risks are manageable but do exist.
- It could risk the jobs of a number of different people in the firefighting industry.
- Drone integration would be managed as with their manned counterparts. Risk is reduced as there is nobody in the aircraft when that aircraft has a mishap or crash.
- It could impact the helicopters and tankers that are dropping. Could a drone crash start a new fire?
- More iron in the sky increases risk of an aviation mishap. People who want data they don't need will increase this. It will also slow down the pace of operations for those who think they need something and are second guessing orders that have already vetted the safety of the operation.
- Airspace management in the fire traffic area. And....uninvited drones in a FTA
- More risk to other aviation assets
- By definition any added equipment will have new risks to operations. Does that risk, cancel or reduce the risk of other hazards to an acceptable level is the question; the answer to that depends upon each individual scenario.
- The Fire traffic area is already an incredibly congested airspace. Adding more aircraft can put our manned aircraft at additional risk.

In order to better identify and mitigate all possible hazards wildfire fighters could face during fire suppression operations, respondents were asked to list potential hazards inherent to drone inclusion, in addition to the existing hazards. They responded as follow:

- Data overload, rogue drone operations (hubris)
- Incorrect data collection and possible misrepresentation of incidents and data because of no human operation
- Drones will be hazard and risk mitigators when properly inserted into the battlespace. The increased endurance and capabilities will further reduce risk to firefighters on the ground.
- Can reach to point of too much information. Paralysis by analysis when at some point you simply need to make decisions vs gathering intel.
- Machines fail, don't need drones falling on FF. Don't want helicopters and drones working in the same space.
- They are another tool. You have to be aware of them and integrate them into your operations. Human factors. Air traffic management in the FTA.
- More iron that can collide with other aviation assets or potential start new fires when they fail
- Conflicted air space with maned aircraft and the over reliance on that aircraft would be my top 2.
- Reliance on technology.

One of the main challenges in including drones in wildfire suppression operations is to determine to what extent to automate. To get the points of view of subject matter experts, respondents were asked what they believe to be the minimum LOA required for drones to be beneficial. Figure 6 displays the collected answers. As seen in Figure 3, there was no consensus on required minimum LOA.

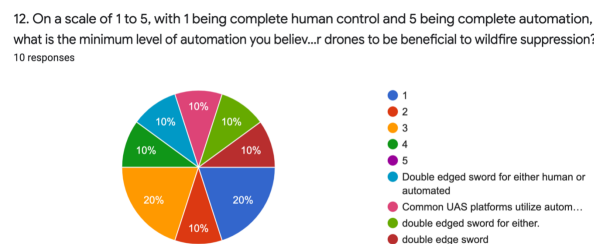


Fig. 3 Responses to the question “What is the minimum level of automation you believe drones to be beneficial to wildfire suppression?”

When asked to provide the reasons behind their choices of LOA, eight (8) out of ten (10) respondents answered. Their responses are displayed below:

- Humans make mistakes, machines fail
- I believe the amount of automation is dependent upon the mission profile. UAS aerial ignitions need more human control to complete the dynamic mission successfully. A fixed wing UAS could be overhead in a circle for hours to provide network and connectivity support.

- I believe that complete human control is paramount in interpreting data and making sure that sensors are run correctly
- For the simplest missions 2 will be fine. More automation for more complex missions.
- I see no problems with humans controlling/monitoring the drones.
- For now, human interaction with wildfire is critical. Fire is unpredictable.
- Human error and machines fail
- Wildland fire management is a highly dynamic environment. The ability to adjust and respond with the tools used needs to be commiserate.

To end this section, we asked respondents what they say as obstacles preventing the use of drones in wildfire fighting. Below are their responses:

- Other aircraft
- Cross jurisdictional boundaries- i.e., cooperative agencies cannot fly UAS on federally controlled incidents due to red tape and gate keeping. The federal agencies control the trainings for certification as well as the certification. Locally this is less of a barrier but at the large wildfire (type 3+) this is an issue. This issue does have large aspects of training and the need for safety attached
- TFR restrictions
- Airspace access and air boss coordination.
- USFS and FAA policy
- Hubris from ground resources
- We currently use drones in wildland firefighting
- Hubris
- Agency Regulations and Security Requirements.
- Limited range and flight time.

E. Experience with Drone Programs

In this section, the focus was to gauge if the respondents' respective units had formal drone programs. The goal was to gather data on the pros and cons of having drone programs, some of the issues their units had to resolve before establishing drone programs, associated risks, among others. The first question in this section was to ask the respondents if their unit had a formal drone program. Seven (7) answered "Yes" (70%) and the remaining three (3) (30%) answered "No." A "No" answer would take the respondent to the next question, so the rest of the questions in this section was answered by a total of 7 respondents.

The next question in this section asked the capacity in which drones were used in their unit. All respondents indicated that their unit used drones in wildland fire management. Five (5) out of seven (7) indicated that they used drones in Survey and Rescue efforts (71.4%), while 6 chose Reconnaissance (85.7%) and one indicated Hurricane response (14.3%), as seen in Figure 4. Respondents had the option to choose all answers that applied.

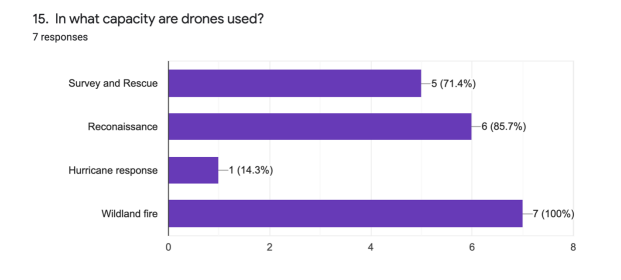


Fig. 4 Responses to the question "In what capacity are drones used?"

The following question addressed the effects the addition of drones had on the overall operational risks. Three of the seven respondents indicated that the risk has not changed (37.5%). Two respondents think the risk has decreased (25%), while two others believe it has increased (25%). Only one indicated they were not sure or unable to evaluate (12.5%). The pie chart in Figure 5 depicts that.

To the question "What have been the biggest concerns to overcome with drone use for wildfire suppression in your unit," six (6) responses were recorded. They are as follow:

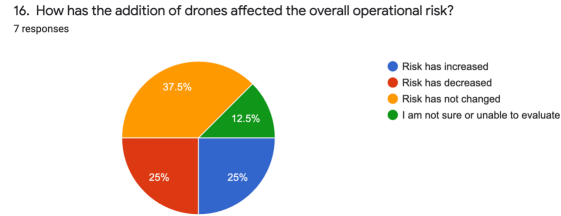


Fig. 5 Responses to the question “How has the addition of drones affected the overall operational risk?”

- Costs of equipment
- Implementing UAS when fire fighters already have multiple other missions that take priority; Operating UAS on federally controlled incidents.
- Interfering with aerial suppression assets
- There really are not too many concerns, it is more a regulatory issue
- People launching drones without permission or communication
- Shift of risk from ground resources to Aerial resources.

When asked what measures were used to alleviate the concerns they enumerated, there were four respondents. They responded as follow:

- Fences, operations w/o other flying aircraft in the area, good communication
- Training and demonstration of use
- Control over the personnel and units that can operate drones, training, and strict policy.
- Control over persons with ability to launch drones, training, very clear policies

The last question in this section was to ask the respondents what they thought the best approach would be. The options to choose from were “complete reliance on manned aviation systems,” “complete reliance on drones” and “combination of both systems.” All seven (7) chose “combination of both systems”

F. Experience Flying Drones

In the final section of the questionnaire, we surveyed the respondents’ experience flying drones. The first question of the section asked respondents if they had experience flying drones. If a “No” were selected, it would mark the end of the questionnaire while a “Yes” would yield two additional questions. Sixty percent (60%) of the respondents (a total of 6) indicated that they did not have any experience flying drones while the remaining 40% (total of 4) responded yes.

The next question was to find out the capacity in which they flew drones. Respondents could choose between “Hobby” and/or “Emergency Response” with the option to also add other non-listed capacities. The results are shown in Figure 6. Note that they had the option to “check all that apply.”

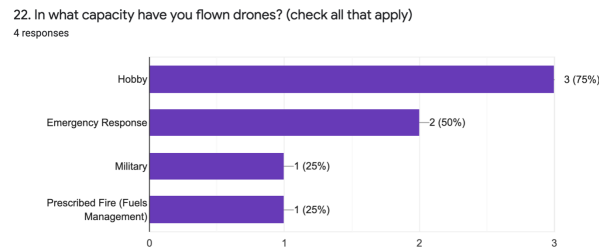


Fig. 6 Responses to the question “In what capacity have you flown drones?”

The final question of this section and the form aimed to gather data on how long those respondents with experience flying drones have flown drones for, in any capacity. Two respondents indicated one (1) to five (5) years, one (1) indicated less than a year, and another one chose over five (5) years. See Figure 7.

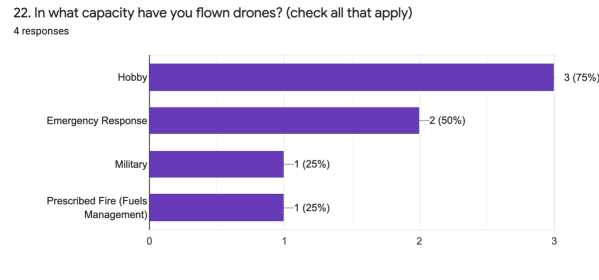


Fig. 7 Responses to the question “How long have you flown drones in any capacity?”

IV. Data Analysis - Discussions

Data analysis consisted of identifying and describing recurring themes found across the four categories of questions: general questions, drones for wildfire response, experience with drone programs and experience flying drones.

General Questions

The general questions were foundational concepts that explored respondent perceptions about challenges as a wildfighter, hazards during wildfire incidents, and proven techniques and processes that enable effective and efficient execution during a response to an incident. A key set of overarching themes were recurrent throughout the “General Questions” section of the questionnaire: resources, communication, strategic direction, real-time data, weather conditions, aerial support, and hubris. The recurrence of these themes across the general questions and the related respondent discussion points highlight an interrelation between these themes.

The question “What are the most common, day-to-day challenges you face as a wildfire fighter?” uncovered a handful of thematic issues to include a lack of resources, communication challenges, fluctuation in strategic directions and lack of real-time data. Respondents pointed out that resources, both human and equipment, are hot commodities during wildfire management operations. While human resources tend not to be always readily available, equipment failures are also an issue. They also emphasized communication issues they face during operations. Those communication issues generally stem from gaps that exist between different “agencies and organizations” present during fire management efforts. Different organizations and agencies tend to have different strategies that they pass down to ground professionals, ultimately leaving them with the task of synchronizing their efforts mid-operations.

When considering the primary hazards facing wildfire fighters, the respondents highlighted rapid change in weather conditions, introduction of aerial components, and hubris as additional themes. Hubris can be defined as excessive pride or self-confidence. In the wildfire firefighting context, it denotes an underestimation of risks and hazards that could turn into an occupational hazard, possibly leading to fatalities. Changing weather conditions coupled with hazards inherent to plane crashes, can cause changes in effort prioritization, leading to changes in strategic directions. Another key overall theme was lack of or limited real-time data. A vast majority of the ten respondents emphasized the importance, yet scarcity, of having real-time data to make informed decisions.

When it comes to identifying existing techniques and processes that contribute to an effective and efficient response to an active fire incident, the themes were the strategic and tactical processes respondents pointed to the presence of standard operating procedures (pre and post-incidents), as well as the existence of technology and software. They emphasized the positive impact of tools such as Foreflight, the ICS system or NWCG for strategic and/or tactical processes. They also mentioned the effectiveness of utilizing Uncrewed Systems (UXS). As for identifying non-existing processes and techniques that would help in the wildfire management process, a resounding theme was once again real-time data. Roughly 80% of the responses to this question called for the need of real-time data of some sort (intelligence, resource tracking, etc.). The respondents talked about a need for more accurate fire spread models as well, along with the use of UXS for environmental and fire intelligence, and for airdrops.

Drones for Wildfire Response

Section 3 of the questionnaire, “Drones for Wildfire Response,” provided an opportunity to collect data on the use of drones in wildfire management, from a first responder perspective. This section consisted of a mixture of closed-ended

questions, immediately followed by open-ended questions which would give the respondents an opportunity to give a rationale behind their respective choices. The first question in this section was to find out main operations that could be positively impacted by the inclusion of drones in wildfire management. Prevention, technical rescues and search and rescue efforts were chosen overwhelmingly (100% of responses), followed by site survey and response (90%). It is to be noted that all respondents had some favorable opinion regarding the inclusion of drones in wildfire management efforts. When asked that same question with the slight difference of leaving it general and just asking if the inclusion of drones would add value to wildfire suppression management, nine (9) out of ten (10) respondents responded “yes” while only one respondent (1) dissented. The themes mainly centered around real-time data and intelligence gathering. Some respondents also pointed to the possibility of reducing human casualties. Respondents noted that while they believe drones can be value-adding tools, their safe integration in aerial operations is essential to avoid rendering manned aerial platforms more dangerous. Similarly, 90% of respondents believe that introducing drones in wildfire suppression efforts would also add new risks. One of the primary concerns nearly everyone pointed to was that drones would overcrowd an already congested airspace. Respondents believe that the airspace will not just consist of drones that have a need to be there for incident support or management, and that first responders would have to be concerned about rogue or “uninvited” drones. While most of the respondents who believe that the inclusion of drones will introduce new risks refer to risks related to physical safety, one respondent sees drones as a competitor to firefighters. This respondent believes that the risk introduced can be economic as drones will “risk the jobs of a number of people in the firefighting industry.” The one person who does not see drones as adding new risks acknowledges that there are associated risks, but believes that those risks are manageable the same way manned aircrafts can be managed. This respondent further indicates that not only the associated risks are manageable, but also risks faced by humans during manned operations can be offloaded onto drones. Lastly, in this section, we asked the respondents to indicate the minimum level of automation they believe is required for drones to be beneficial to wildfire suppression. Level of automation was defined by the degree to which a task is automated, ranging from complete human reliance to complete computer reliance. The responses were mixed, 20% of the respondents indicating complete reliance on humans, 10% indicating complete reliance on drones, and the remaining 70% indicating a hybrid model including both drones and humans. When given the opportunity to offer insight on their choices, their responses were focused on the unpredictability of wildfires. While respondents acknowledge that drones would be very helpful, they also note that humans are needed to make in-time decisions to adapt to fire spreads.

Experience with Drones Programs

In Section 4, Experience with Drones Programs, we had the opportunity to ask the respondents if their units have a formal drone program, operating certified and authorized drones in emergency response situations. Seven (7) of the ten (10) respondents indicated that they did. Those having said their units have a formal drone program also indicated the capacity in which their unit uses drones. Wildland fire and reconnaissance were chosen overwhelmingly (100% and 85.7%, respectively), followed by survey and rescue (85.7%) and hurricane response (14.3%). As it pertains to levels of risks inherent to the use of drones, 37.5% of those who indicated their units have a formal drone program stated that risk has not changed. Twenty-five (25%) believe risk has decreased, another 25% believe risk has increased, and the remaining 12.5% indicated they either were not sure of the risk or unable to evaluate. When asked what the greatest benefits of drone use for wildfire suppression were in their units, respondents mentioned better situational awareness and real or near real-time data. Safety was also a recurring theme. Respondents believe drones were able to carry out tasks that could be dangerous if carried out by humans. Even though our subject matter experts see the use of drones in their units as very beneficial, they also pointed out that there were some concerns to overcome for their safe and effective implementation. Key concerns were drones interfering with other assets already in the airspace, task prioritization, cost-related issues, or uncontrolled flights.

Experience Flying Drones

In the final section of the questionnaire, we gauged the respondents’ respective experiences flying drones in any capacity, formal or informal. Sixty-percent (60%) of them indicated that they had experience flying drones. When asked in what capacity, 75% said they flew drones as a hobby, 50% indicated emergency response, while 25% indicated military and another 25% said prescribed fire (fuel management). Finally, they were asked how long they flew drones in any capacity, 50% said one (1) to five (5) years, 25% had over five (5) years of experience, and the remaining 25% said less than a year.

V. Conclusion

The wildfire workshop highlights the existing collaboration between NASA and wildfire management professionals. By means of the workshop, we asked wildfire response SME questions related to the introduction of drones in wildfire management to alleviate some of the key risks first responders face in wildfire fighting scenarios. Data were collected from a total of ten (10) respondents, and nine (9) out of those 10 indicated they had at least 10 years of experience in wildfire management response. The information generated from experts aggregating around one hundred (100) years of experience.

VI. Future Work

Next, we will use the results from this study to set up a model of safety management system and its requirement for the use of drones in wildfire response using an MBSE approach. The data collected will also allow SWS researchers to take better and more informed steps in identifying, monitoring, assessing and mitigating hazards inherent to wildfire management efforts, thus, reducing risks first responders face. As responses collected were totally confidential, we were not in measure to trace them back to any particular respondent for clarification to some of the opened-ended questions. In future work, we intend to conduct a similar workshop in which we will be able to present our data to subject matter experts for discussion and analysis. This will not only provide a better understanding of some of some key concepts we uncovered, but it will also serve as a means to validate the data collected and how we interpreted it.

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