Unmanned Aerial Systems (UASs) and Earthquake Damage Assessments

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CERTIFICATION STATEMENT

I hereby certify that this paper constitutes by own product, that where the language of others is set forth, quotation marks so indicate, and that the appropriate level of credit is given where I have used the language, ideas, expressions, or writings of another.

Signed: 

Abstract

The problem was Lake Stevens Fire (LSF) did not know if the use of unmanned aircraft systems (UASs) to perform damage assessments following an earthquake would improve current damage assessment practices. The purpose of the research is to determine if employing UASs following an earthquake would improve current damage assessment practices. The descriptive research method was used to answer the following four research questions: (a) what are the risks of an earthquake occurring in Lake Stevens, Washington; (b) what are the current damage assessment practices used by LSF following an earthquake; (c) how effective is the use of UASs to perform damage assessments following an earthquake for other organizations; (d) should LSF deploy UASs following an earthquake to perform damage assessments? The procedures used for this research included a literature review to evaluate the success of UASs deployment following earthquakes and other disasters, interviews with industry experts regarding the regulations, use, and effectiveness of UASs, and a UAS demonstration flight. The results of the research indicated that the deployment of a UAS following an earthquake to perform damage assessments would improve current practices and ultimately improve emergency operations. The author recommended establishment of a UAS program to perform damage assessments following earthquakes and other disasters. Additionally, the author recommended the development of operational policy for UAS deployment, ongoing training, and response partnerships with other agencies. Furthermore, expanded operational use beyond disaster assessment of the UAS was recommended.

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Introduction

The UAS or commonly referred to as a drone has become more widely used in commercial and recreational applications. With advances in technology, the UAS is fairly easy to use and can be operated at a relatively low cost. This research examines the possible use of a UAS to perform damage assessments following an earthquake in the LSF service area.

The problem was LSF did not know if the use of unmanned aircraft systems UAS to perform damage assessments following an earthquake would improve current damage assessment practices. The purpose of the research is to determine if employing UASs following an earthquake would improve current damage assessment practices. The descriptive research method was used to perform the research in this project.

The research questions are the following: (a) what are the current damage assessment practices used by LSF following an earthquake; (b) how effective is the use of UASs to perform damage assessments following an earthquake for other organizations; (c) How effective is the use of UASs to perform damage assessments following an earthquake for other organizations; and (d) should LSF deploy UASs following an earthquake to perform damage assessments?

Background and Significance

LSF provides all-hazards emergency services including emergency medical, rescue, fire suppression, and community risk reduction services to the citizens and visitors of Lake Stevens, Washington. Lake Stevens is a typical Pacific Northwest residential community situated around its namesake lake, located eight miles east of the City of Everett and 37 miles north of Seattle. The LSF service area encompasses approximately 46 square miles and provides service to a population of 42,958 (U.S. Census Bureau, 2015) in the communities of Lake Stevens, Hartford, Frontier Village, Cavalero, Glennwood, Georgetown, Machias, Forest Glade, Soper Hill, Sunnyside, and Ebey Island.

LSF emergency responders deploy 24 hours a day, 365 days a year from three fire stations in

the District. Station 81 is located in downtown Lake Stevens and is typically staffed with six people assigned to a paramedic unit, a cross staffed engine/aid unit, and the battalion command unit. Station 82 is located in Frontier Village and is typically staffed with five people assigned to a paramedic unit and a cross staffed engine/aid unit. Station 83 is located in the Machias area and is staffed with three people assigned to a cross staffed engine/aid unit.

LSF has 81 employees and a shared Community Resource Paramedic with Snohomish County Fire District 7. There are 41 career responders assigned to emergency response including three Battalion Chiefs, six Captains, 14 Paramedics, and 18 firefighters. The career firefighters work a 48/96 schedule (48 hours on-duty and 96 hours off-duty). Emergency response staffing is improved by 26 part-time firefighters who work a 12-hour shift schedule.

LSF administrative uniformed personnel include a fire chief, deputy chief of operations, deputy chief/fire marshal, battalion chief of training, assistant fire marshal/community risk reduction officer, and a community resource paramedic. Civilian administrative staff includes a director of administration, director of communications, billing manager, facility maintenance technician, fleet mechanic, and three office assistants.

The threat of geologic problems including earthquakes are ever-present in the Pacific Northwest, and the community of Lake Stevens is not an exception. The U.S. Geological Survey's (USGS) website addresses Pacific Northwest Geologic Mapping and Urban Hazards. Two of the Earth's large crustal plates, the Juan De Fuca Plate and the North America Plate converge just off the shore of Western Washington to form the Cascadia Fault, also known as the Cascadia Subduction Zone (USGS, 2016).

The USGS addresses the fact that contemporary geologic research has revealed that the threat and magnitude of large-scale seismic events in the Pacific Northwest have increased. Geologists have determined that the Cascadia Fault ruptures eight to nine times every 500 to 600 years resulting in earthquakes with substantial magnitudes. The last known earthquake of this

magnitude occurred in 1700 (USGS, 2016). These numbers indicate the high probability that the Pacific Northwest is due for an earthquake of a large magnitude in the near future.

The USGS describes the effects of an earthquake includes surface rupture, ground shaking, liquefaction, and earthquake-induced landslides (USGS, 2016). Each of these resulting events would yield significant damage and obstacles for emergency response.

According to the Snohomish County Hazard Mitigation Plan, Chapter 13 (2015), the hazard profile for earthquakes includes an expectation for earthquakes with a Magnitude of eight to occur in the future. The plan lists devastating results following an earthquake including injury and death due to the collapse and failure of structures. Other resulting problems include loss of communications, electricity, utilities, and water supply disruption. Further damage could come in the form of fires, landslides and the release of hazardous materials. The plan goes on to mention that Snohomish County has more earthquakes on average than the rest of Washington State. Additionally, Snohomish County has a 268% greater chance of having an earthquake than the overall United States average (Snohomish County, 2015).

According to Deputy Chief of Operations Huff, LSF does not currently have a damage assessment plan for earthquakes or other natural disasters. In response to fires, emergency medical incidents, and other responses, LSF uses the Snohomish County Incident Management System (IMS) Procedures approved by the Snohomish County Fire Chief's Association. However, there is no reference to damage assessments following earthquakes or other natural disasters (Snohomish County Fire Chief’s Association, Snohomish County IMS Procedure, 2016).

Following an earthquake or other natural disaster, a rapid assessment of the resulting damage would support LSF's mission of “serving people, saving life, protecting property, and safeguarding the environment” (Lake Stevens Fire, 2016). During any emergency, having as much information possible in as short of time possible contributes to a better outcome for the delivery of emergency services which in turn supports the LSF mission (LSF, 2016).

This research supports the course content of Executive Analysis of Fire Service Operations in Emergency Management (EAFSOEM) as it specifically addresses potential improvements to preliminary damage assessment (PDA) procedures for Lake Stevens Fire. Unit Three of the EAFSOEM student manual addresses damage assessment and more specifically the importance of a rapid preliminary damage assessment (PDA). A PDA is performed to determine as much information regarding life and health, structures, critical infrastructure, government facilities, transportation infrastructure, utilities, the impact to emergency operations, and the scope and intensity of overall damage. (Federal Emergency Management Association (FEMA, 2016, pgs. 3-3 – 3-6).

The analysis contained in this project supports Goals 2 and 3 of the U.S. Fire Administration's Strategic Plan. The problem statement and research support Goal 2 "Promote Response, Local Planning, and Preparedness for All Hazards" because the problem statement specifically addresses response, planning, and preparedness for earthquakes. Additionally, this research supports Goal 3 "Enhance the Fire and Emergency Services' Capability for Response to and Recovery from All Hazards" because the problem statement and research support improvement to the enhancement and capability of the emergency response of (LSF) following an earthquake (FEMA, 2014).

Literature Review

The U.S. Geological Survey's website defines earthquakes as a situation where "two blocks of the earth slip past each other." The website further describes why the earth shakes:

> While the edges of faults are stuck together, and the rest of the block is moving, the energy that would normally cause the blocks to slide past one another is being stored up. When the force of the moving blocks finally overcomes the *friction* of the jagged edges of the fault and it unsticks, all that stored up energy is released. The energy radiates outward from the fault in all directions in the form of *seismic waves* like ripples on a

> pond. The seismic waves shake the earth as they move through it, and when the waves reach the earth's surface, they shake the ground and anything on it, like our houses and us (USGS, 2017).

The threat of geologic problems including earthquakes are ever-present in the Pacific Northwest and the community of Lake Stevens is not an exception. The USGS website addresses Pacific Northwest Geologic Mapping and Urban Hazards. Two of the Earth's large crustal plates, The Juan De Fuca Plate and the North America Plate converge just off the shore of Western Washington to form the Cascadia Fault, also known as the Cascadia Subduction Zone (USGS, 2017).

As mentioned above, the USGS warns that the threat and magnitude of large-scale seismic events in the Pacific Northwest have increased. Geologists have determined that the Cascadia Fault ruptures eight to nine times every 500 to 600 years resulting in earthquakes with strong magnitudes. The last known earthquake of this magnitude occurred in 1700 (USGS, 2017). These numbers indicate the high probability that the Pacific Northwest is due for an earthquake of a large magnitude in the near future.

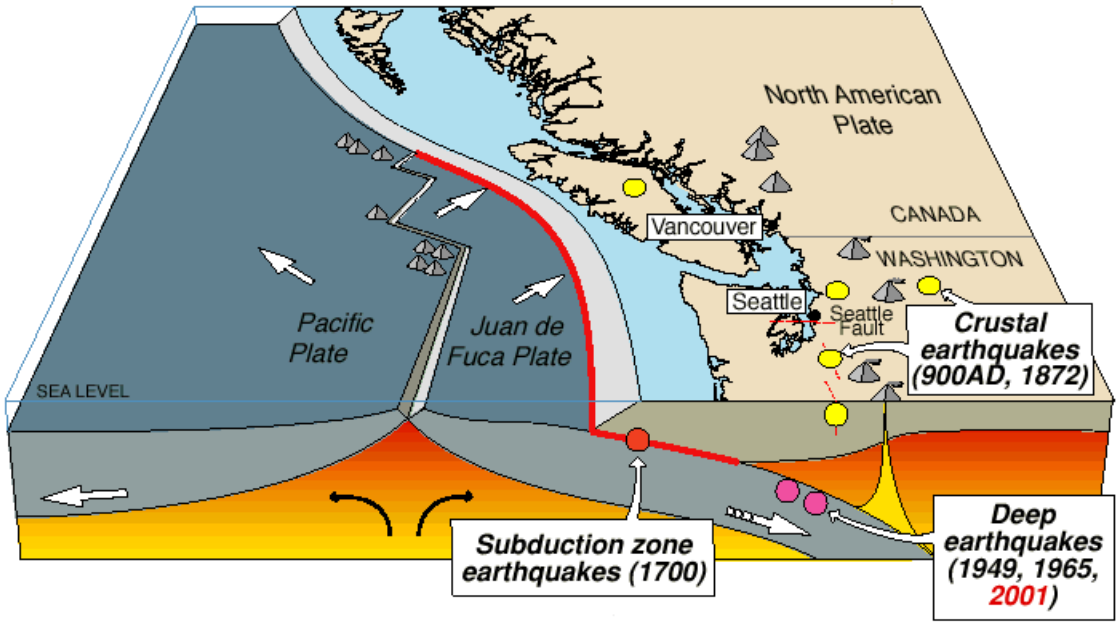
Depending on the magnitude, earthquakes can be devastating to life, homes, and critical infrastructure. According to the USGS, the effects of an earthquake includes surface rupture, ground shaking, liquefaction, and earthquake-induced landslides (USGS, 2017). Each of these resulting events would yield significant damage and obstacles for emergency responders.

The Snohomish County Hazard Mitigation Plan addresses the hazard profile for earthquakes which includes an expectation for earthquakes with a magnitude of eight to occur in the future in Snohomish County. The plan lists devastating results following an earthquake including injury and death due to the collapse and failure of structures. Other resulting problems include loss of communications, electricity, utilities, and water supply disruption. Further damage could come in the form of fires, landslides and the release of hazardous materials. The

plan addresses the fact that Snohomish County has more earthquakes on average than the rest of Washington State. Additionally, the plan states that Snohomish County has a 268% greater chance of having an earthquake than the overall United States average (Snohomish County, 2015).

Regarding the specific risk hazards to the City of Lake Stevens, the Snohomish County Hazard Mitigation Plan states the following, “water tables within valley areas and along some slopes are very shallow and heavily treed. Earth movement could result in massive tree falling, specifically in residential areas, and landslides, especially during winter/wet season. In industrial areas, there are non-reinforced cinderblock structures that may not withstand an earthquake” (Snohomish County, 2015).

Figure 1: Western Washington Earthquakes, (Snohomish County, 2015)



On March 22, 2014, in a location approximately 27 miles north of Lake Stevens, Snohomish County experienced a devastating landslide near the town of Oso. The Oso landslide is an excellent example of a disastrous geological event that can result after an earthquake. The landslide covered approximately one-half a square mile and included about 18 million tons of

earth material including sand, till, and clay. Forty-three people died in the landslide (USGS, 2016).

Local fire districts provided the immediate response to the Oso landslide. Subsequent responders included Snohomish County, the Washington State Emergency Management Division (EMD), FEMA, the Washington State Department of Natural Resources (DNR), the Washington State Department of Transportation (DOT), National Oceanographic and Atmospheric Administration (NOAA), the U.S. Army Corps of Engineers, The Stillaguamish Tribe of Indians, and the USGS (USGS, 2016).

The author has found no documentation that a UAS was used by initial emergency responders to assess the damage of the Oso Landslide.

Figure 2: Aerial Photograph of Oso Landslide, (USGS, 2016)

The Damage Assessment Operations Manual published by FEMA in 2015 supports the operations and plans of the National Response Framework (NRF) and the Robert T. Stafford Disaster Relief and Emergency Assistance Act. While the intended audience for the manual is

emergency management practitioners, private sector stakeholders, and non-governmental organization stakeholders, the manual offers some guidance for LSF. The document addresses the need for expeditious and accurate damage assessments, but cautions that rushing local damage assessment processes can lead to errors resulting in prolonged processing of federal assistance (FEMA, 2015).

The Damage Assessment Operations Manual contains an example of an initial assessment form titled, *Initial Assessment Street Sheet*, containing the following components: city, county, state, disaster type, date, address of a structure, and levels of damage. This form is used by FEMA and other agencies to assess long-term damage and costs but could be used as a reference to create a form for emergency responders to employ immediately following an earthquake or other disaster.

A thorough review of the LSF Policy Manual and an interview with LSF Deputy Chief of Operations Larry Huff revealed that there is no prescribed damage assessment policy or practice following an earthquake for LSF (Huff, 2017).

LSF Battalion Chief Perry Putnam completed an applied research project (ARP) in February 2014 for the Executive Fire Officer Program (EFOP) at the National Fire Academy (NFA) titled, *Creating a Structural Assessment Guideline for Lake Stevens Fire*. The ARP discovered that there was no standard or policy for LSF personnel to guide them regarding a damage assessment following a natural disaster. Putnam's excellent work yielded a draft guideline and a damage assessment form to be used by emergency responders.

Putnam advocated for an adopted guideline to help personnel assess structural damage following a disaster. Putnam went on to say that the guideline should address initial assessments of the structural damage and they should be called "Windshield Surveys." In performing the initial assessments, responders should be equipped with criteria to evaluate and prioritize the

areas damaged in the community. Putnam's recommended guideline also contained a form that emergency responders could use in performing the "Windshield Surveys" (Putnam, 2014).

He supported the concept that the guideline should address the methodology of performing the assessment. Putnam advocated for establishing a high priority for assessing structures with issues of high occupancy, life safety, and critical infrastructure. Finally, Putnam supported the establishment of classifying the damage into five categories which include Destroyed, Major, Minor, Affected, and Inaccessible (Putnam, 2014).

In his paper, *Drone Applications for Supporting Disaster Management*, published in the World Journal of Engineering and Technology, Restas advocated for the use of UASs following natural disasters. Restas discusses the advantages of utilizing UASs for disaster mitigation. UASs can be useful in preplanning mitigation efforts because a UAS can be deployed to map potential risk areas. UASs are an excellent tool for reconnaissance and damage assessment because they are relatively quick to implement and can survey a large area in a short amount of time. Cameras on UASs can provide visual documentation of the area assessed (Restas, 2015, pgs. 316 - 321).

Specific to earthquakes, Restas discussed the concept that a rapid mapping and reconnaissance of affected areas is important in the decision-making process determining the deployment of rescue resources. Restas supports the idea that UASs can provide effective data regarding the damage to structures. He went on to say that human survival following injuries sustained from an earthquake is dependent upon time and rapid reconnaissance leads to a higher survivability of injured people (Restas, 2015).

In her article *Drones Take Flight* published in Risk Management Magazine, Tuttle addressed the use of UASs commercially and the concept of risk management. Tuttle mentioned that an Erie Insurance Company asked the Federal Aviation Administration for permission to

use drones to evaluate damaged structures. Erie addressed the notion that sending a UAS to evaluate damaged structures is safer than sending humans (Tuttle, 2015).

UASs are proving to be effective for hurricane relief. Following Hurricane Irma of late summer 2017, the online magazine Geospatial World reported that the FAA had authorized 132 operators of drones to assist in Florida. Florida Power and Light deployed 49 UAVs to assist in restoring power to 4.4 million people. The article went on to quote FAA Director Michael Huerta, "I don't think it's an exaggeration to say that the hurricane response will be looked back upon as a landmark in the evolution of drone usage in this country" (Geospatial World, 2017).

In 2015, Falconer wrote about the importance of acquiring emergency data regarding collateral damage and casualties promptly in his article *Unmanned Aerial Vehicles* for Fire Engineering Magazine. He promoted the use of UASs to accomplish this. Additionally, he cited the ability to fly UASs into environments that could be hazardous to humans. Falconer used the example of a hazardous spill where a UAS could be deployed to acquire critical information about the spill. Additionally, he mentioned the fact that the rotors of UASs displace a relatively small amount of air in their rotors which results in little impact to air movement (Falconer, 2015).

In the comprehensive article *Drones and Fire Service* published in October 2016 for Fire Engineering, Larson wrote that "having eyes in the sky during emergency operations protects citizens and the fire crews, which then provides a significant benefit to public safety agencies." Larson supports the concept that UASs are effective for searching large areas that may be difficult to search by responders. Search patterns are relatively easy to develop with UASs and responders can monitor the search from a mobile device via the UASs' video camera. Additionally, Larson advocates the use of UASs for structure and wildfires. He notes that the Safety Officer can monitor situations that may be located in a hazardous environment. Larson

goes on to discuss the advantage of UAS's performing searches inside structures before responders enter to assure the environment is safe for entry (Larson, 2016).

Larson continues to discuss the advantages of utilizing UAS for fire investigations, natural disasters, emergency management, crew resource management, and water rescue operations. He mentions that with the many good uses of a UAS, there comes significant responsibility and compliance with regulations of the Federal Aviation Administration (FAA). Specifically, FAA's 14 CFR Part 107 which became effective on August 29, 2016. Emergency response organizations desiring to operate UAVs must attain a Public Aircraft Operations Certificate of Authorization. Fire Districts fall under Title 49 of the United States Code 4012 which addresses the legal requirements to operate UASs. An initial step to operate UASs is to apply to the FAA through Concept of Operations online application. Once approved, a Public Safety COA will allow operation of UASs 55 pounds or less with limitations noted in FAA's 14 CFR Part 107 (Larson, 2016).

The training of UAS operators for emergency response agencies is the same as commercial operators. Requirements for pilots include being at least 16 years of age, English speaking, proper medical condition, and the ability to pass an aeronautical knowledge exam. Extensive documentation and ongoing training is required as well. (Larson, 2016)

Review of the FAA's 14 CFR Part 107 updated September 14, 2017, confirmed Larson's findings above. Part 107 addresses Small Unmanned Aircraft Systems and contains four Subparts: Subpart A-General, Subpart B-Operating Rules, Subpart C-Remote Pilot Certification, and Subpart D-Waivers (FAA, 2017).

Snohomish County Fire District 22 (SCFD 22) is located on the north border of LSF and provides mutual and automatic aid in the LSF service area. Under the leadership of Chief and Snohomish County Search and Rescue Helicopter Pilot Travis Hots and Assistant Chief Jeremy Stocker, a UAS program was initiated in August of 2016 for SCFD 22. This author met with

Assistant Chief Jeremy Stocker to discover the benefits of a UAS program and specifically address the problem statement of this ARP.

SCFD 22 purchased a UAS at the cost of approximately $1,500. The UAS has a camera that records video which is displayed on a PDA at the pilot controls. The UAS has about 28 minutes of flight time per battery. SCFD 22 is considering the purchase of a new UAS which will cost approximately $7,500, a DJI Inspire II with three cameras: (a) a forward-looking camera; (b) a downward looking camera; and (c) an infrared (FLIR) camera that records heat signatures.

Regarding the certification costs for a UAS, Chief Stocker cited a $5.00 UAS registration fee and approximately $4,000 to engage a consultant in assisting the district with the application process. Chief Stocker emphasized the importance of understanding that the certification and training process is lengthy. Certification can take up to 40 hours of staff time and training can take 20 to 40 hours. He recommended I speak with FAA Specialist Steve Pansky to assist with the UAS certification process.

The SCFD 22 UAS has been utilized at the following incidents: (a) a search for a possible drowning victim in Granite Falls, WA; (b) wildland fire in Mansfield, WA- The UAS was deployed to view bulldozer operations above the crew's location near a cliff; (c) a wildland fire in Quincy, WA; (d) a house fire in Lake Stevens, WA on August 20, 2017 – The UAS was deployed to assist LSF crews in reconnaissance, incident status management, and responder safety; and (d) a house fire in Snohomish County.

Chief Stocker was specifically asked the question. “Following an earthquake, would the deployment of a UAS to perform a damage assessment be beneficial to responders?” Chief Stocker replied yes and went on to discuss the benefits of a UAS in performing a damage assessment:

- A UAS would provide a good overhead view of any incident.

- A UAS would facilitate entry into a hazard area that would be difficult or prohibitive for humans.
- A UAS could access fires.
- A UAS provides rapid assessment.
- A UAS is useful when staff is limited.
- A UAS may be used as an “eye” to direct personnel to safety.
- A UAS would be a good risk and needs assessment tool.
- A UAS would provide good situational awareness.
- A UAS can perform a precise grid search.
- A UAS is an excellent tool for reconnaissance and observation.
- A UAS provides a significant economy of time for reconnaissance compared to personnel performing reconnaissance on the ground.
- A UAS equipped with FLIR can be beneficial for search and rescue.
- A UAS would be especially useful if roads are blocked and there are accessibility problems.
- The help of conventional aircraft would be limited.

Referring to the Oso Landslide of 2014, Chief Stocker commented that deployment of a UAS as soon as possible would have been a benefit in assisting responders with initial damage assessments at the devastating landslide.

During the interview, Stocker deployed his UAS and performed a simulated search of an adjacent neighborhood. In a matter of five minutes, his UAS was able to search an area of approximately three city blocks. This demonstration supported the concept that emergency responders could deploy a UAS with relative ease to evaluate a neighborhood's damage following an earthquake or another disaster.

While considering deployment of a UAS program for LSF, it is important to review the mission of the organization and the annual expense budget. The 2017 expense budget for LSF is $11,253,622. (LSF, 2017) The LSF Mission Statement contained in the Strategic Plan for 2017 states the following: Serve people, save lives, protect property, and safeguard the environment (LSF, 2017).

On August 20, 2017, at 9:59 a.m. LSF responded to a house fire at 9231 19th Pl, SE, Lake Stevens, WA. Mutual aid was provided by SCFD 22. (Lake Stevens Fire Incident Database, 2017) Assistant Chief Jeremy Stocker of SCFD 22 responded and deployed a UAS to assist the incident commander, Battalion Chief Perry Putnam with reconnaissance of the structure fire. Battalion Chief Putnam reported that the use of the UAS was helpful in providing reconnaissance to areas of the structure that were difficult to access. The UAS was able to assist Putnam with hazard assessment and the location of fire and smoke. B.C. Putnam appreciated the real-time information the UAS provided regarding the conditions of the fire and the structure (Putnam, 2017).

Putnam noted that the UAS provides an optimal vantage point of an incident and importantly the location and status of personnel. Putnam commented that it would be best to have an independent operator of the UAS and not the incident commander due to the intensive workload of the tasks of piloting the UAS and managing the incident (Putnam, 2017).

Putnam also supported the concept that a UAS would be a benefit to providing a damage assessment following an earthquake because a UAS can view many structures, in a large geographic area, in a rapid manner. Additionally, hazards and bystanders could be avoided by using a UAS (Putnam, 2017).

Figure 3: UAS View of Structure Fire, 8/20/2017, 9231 19th Pl, SE, Lake Stevens, WA, (SCFD 22, 2017)

On September 25, 2017, the author received an email from FAA Specialist Steve Pansky that highlights the extensive criteria needed to engage in a certified commercial UAS program. Panksy's email contains very detailed information regarding the process and certification criteria LSF would have to execute to become certified under Federal regulations including 14 Code of Federal Regulation (CFR) Part 107.

Mr. Pansky's email addresses the following:

- Compliance with 14 Code of Federal Regulation (CFR) Part 107
- Initiating application through a Certificate of Waiver/Authorization
- Developing a UAS program, including policy, guidelines, training, concepts of operation, cost-benefit analyses, and community acceptance

- Document preparation
- Pilot qualifications and training
- Contacting the Snohomish County Prosecutor to begin application
- Initial and ongoing training

A thorough evaluation of Pansky's email about federal regulations concludes that the process of certification is lengthy and comprehensive, but achievable (Pansky, 2017).

Procedures

The author selected the topic of this ARP based on three major factors: (a) elevated risk hazard of a substantial earthquake impacting the LSF service area; (b) the rising technology and operational potential of UASs; and (c) the 2014 ARP of LSF Battalion Chief Perry Putnam. Putnam wrote *Creating a Structural Assessment Guideline for Lake Stevens Fire.* The ARP contains a guideline for performing structural assessments following disasters and a corresponding form personnel can use to document structural assessments.

The descriptive research method was used to answer the following four research questions: (a) What are the risks of an earthquake occurring in Lake Stevens Washington? (b) What are the current damage assessment practices used by LSF following an earthquake? (c) How effective is the use of UASs to perform damage assessments following an earthquake for other organizations? (d) Should LSF deploy UASs following an earthquake to perform damage assessments?

The descriptive research method was utilized to accomplish the following research:

- A literature review was performed to evaluate the risk of an earthquake occurring and the success of UASs deployment following earthquakes and other disasters.
- Interviews were conducted with industry experts regarding the regulations, use, and effectiveness of UASs.

- A demonstration flight was conducted with a SCFD 22 UAS

To address the first research question: What are the risks of an earthquake occurring in Lake Stevens Washington, the author reviewed data from the USGS, the Snohomish County Department of Emergency Management.

The second research question was, what are the current earthquake damage assessment practices used by LSF following an earthquake? To answer this question, the author reviewed the LSF policy manual and interviewed LSF Deputy Chief. A thorough review of the LSF Policy Manual and an interview with LSF Deputy Chief of Operations Larry Huff revealed that there is no prescribed damage assessment policy or practice following an earthquake for LSF. Additionally, the ARP *Creating a Structural Assessment Guideline for Lake Stevens Fire* written by LSF Battalion Chief Perry Putnam was evaluated.

To answer the third research question, how effective is the use of UASs to perform damage assessments following an earthquake for other organizations, the author interviewed SCFD 22 Assistant Chief Jeremy Stocker regarding his fire district's UAS program. During the interview, Stocker deployed his UAS and performed a mock search of an adjacent neighborhood. Additionally, an LSF fire incident was reviewed where a UAS was deployed. An extensive literature review was completed targeting UAS deployment during disasters and other incidents.

The fourth research question was, should LSF deploy UASs following an earthquake to perform damage assessments? This question was addressed by extensive literature review and interviews. Additionally, review of the LSF Strategic Plan and 2017 Expense Budget was accomplished.

In performing the research the author experienced some limitations. A primary limitation was the ability to find specific answers to the third research question, how effective is the use of UASs to perform damage assessments following an earthquake for other

organizations? The author was unable to locate case studies and specific examples of UAS deployment following an earthquake.

Results

An extensive literature review, interviews, and a demonstration flight of a UAS were accomplished to answer all four research questions. (a) What are the risks of an earthquake occurring in Lake Stevens Washington? (b) What are the current damage assessment practices used by LSF following an earthquake? (c) How effective is the use of UASs to perform damage assessments following an earthquake for other organizations? (d) Should LSF deploy UASs following an earthquake to perform damage assessments?

What are the risks of an earthquake occurring in Lake Stevens Washington?

Review of USGS information yielded that the threat of geologic problems including earthquakes is a risk hazard for the Community of Lake Stevens. Science documents the existence of two of the Earth's large crustal plates, The Juan De Fuca Plate and the North America Plate which converge just off shore of Western Washington to form the Cascadia Fault, also known as the Cascadia Subduction Zone. This fault increases the threat and magnitude of large-scale seismic event in the Pacific Northwest (USGS, 2016).

Geologists have determined that the Cascadia Fault ruptures eight to nine times every 500 to 600 years resulting in earthquakes with strong magnitudes. The last known earthquake of this magnitude occurred in 1700 (USGS, 2016). These numbers indicate the high probability that the Pacific Northwest is due for an earthquake of a large magnitude in the near future.

Specific risk hazards to Snohomish County and the City of Lake Stevens were manifested during the Oso Landslide on March 22, 2014, in a location approximately 27 miles north of Lake Stevens, Snohomish County near the town of OSO. Landslides can occur following an earthquake. The landslide covered approximately one-half a square mile and

included about 18 million tons of earth material including sand, till, and clay. 43 people died in the landslide (USGS, 2016)

Regarding Lake Stevens, the Snohomish County Hazard Mitigation Plan states the following: “Water tables within valley areas and along some slopes are very shallow and heavily treed. Earth movement could result in massive tree falling, specifically in residential areas, and landslides, especially during winter/wet season. In industrial areas, there are non-reinforced cinderblock structures that may not withstand an earthquake (Snohomish County, Snohomish County Hazard Mitigation Plan pg. 257, 2015).

The plan states that Snohomish County has more earthquakes on average than the rest of Washington State. Additionally, the plan states that on average, Snohomish County has a 268% greater chance of having an earthquake than the remainder of the United States (Snohomish County, Snohomish County Mitigation Plan, Chapter 13, 2015).

What are the current damage assessment practices used by LSF following an earthquake?

Research has revealed that there are no policies or practices adopted by LSF to perform damage assessments following earthquakes. (Huff, 2017) Putnam’s ARP Creating a Structural Assessment Guideline for Lake Stevens Fire supports this conclusion and provides a viable solution to LFS’s lack of policy and practice for performing damage assessments (Putnam, 2014).

How effective is the use of UASs to perform damage assessments following an earthquake for other organizations?

Dr. Agostan Restas advocated for the use of UASs following natural disasters. Dr. Restas pointed out that UASs are an excellent tool for reconnaissance and damage assessment because they are relatively quick to deploy and can survey a large area in a short amount of time. Cameras on UASs can provide visual documentation of the area assessed. Specific to

earthquakes Dr. Restas discussed the concept that a rapid mapping and reconnaissance of affected areas is important in the decision-making process determining the deployment of rescue resources. Dr. Restas supports the idea that UASs can provide effective data regarding the damage to structures. He went on to say that human survival following injuries sustained from an earthquake is dependent upon time and rapid reconnaissance leads to a higher survivability of injured people (Restas, 2015).

Following Hurricane Irma, the online magazine Geospatial World reported that the FAA had authorized 132 operators of drones to assist in Florida. Florida Power and Light deployed 49 UAVs to assist in restoring power to 4.4 million people. The article went on to quote FAA Director Michael Huerta “I don’t think it’s an exaggeration to say that the hurricane response will be looked back upon as a landmark in the evolution of drone usage in this country” (Geospatial World, 2017). While this information differs from the immediacy of an assessment following an earthquake, it shows that UASs can be deployed following a disaster to rapidly perform reconnaissance operations.

In Fire Engineering, Joshua Larson wrote that "Having eyes in the sky during emergency operations protects citizens and the fire crews, which then provides a significant benefit to public safety agencies." Larson supports the concept that UASs are effective for searching large areas that may be difficult to search by responders. Search patterns are relatively easy to develop with UASs and responders can monitor the search from a mobile device via the UASs' video camera. Additionally, Larson advocates the use of UASs for structure and wildfires. He notes that the Safety Officer can monitor situations that may be located in a hazardous environment. Larson goes on to discuss the advantage of UAS's performing searches inside structures before responders enter to assure the environment is safe for entry (Larson, 2016). Larson's conclusions would fit well with damage assessments following an earthquake.

Assistant Chief Jeremy Stocker of SCFD 22 reports that his fire district's UAS program has been successful. He has documented incidents where a UAS assisted responders with reconnaissance and monitoring the status of the incident and responder safety. He went on to say that the deployment of a UAS immediately following the Oso Landslide would have been a benefit (Stocker, 2017).

Chief Stocker was specifically asked the question. "Following an earthquake, would the deployment of a UAS to perform a damage assessment be beneficial to responders?" Chief Stocker replied "yes" and cited the benefits of a UAS in performing a damage assessment:

- A UAS would provide a good overhead view of any incident.
- A UAS would facilitate entry into a hazard area that would be difficult or prohibitive for humans.
- A UAS could access fires.
- A UAS provides rapid assessment.
- A UAS is useful when staff is limited.
- A UAS may be used as an "eye" to direct personnel to safety.
- A UAS would be a good risk and needs assessment tool.
- A UAS would provide good situational awareness.
- A UAS can perform a precise grid search.
- A UAS is an excellent tool for reconnaissance and observation.
- A UAS provides a significant economy of time for reconnaissance compared to personnel performing reconnaissance on the ground.
- A UAS equipped with FLIR can be beneficial for search and rescue.
- A UAS would be especially useful if roads are blocked and there are accessibility problems.
- The help of conventional aircraft would be limited.

(Stocker, 2017)

During the interview, Stocker deployed his UAS and performed a mock search of an adjacent neighborhood. In a matter of under approximately five minutes, his UAS was able to search an area of approximately three city blocks. This demonstration supported the concept that emergency responders could deploy a UAS with relative ease to evaluate a neighborhood's damage following an earthquake or most another disaster.

Assistant Chief Stocker's interview and the UAS demonstration supports an LSF initiative to develop a UAS program to perform damage assessments following earthquakes. Additionally, it validates a notion a UAS program could assist LSF operations in other emergency response activities.

At a recent house fire in Lake Stevens, a UAS was deployed and utilized to monitor the fire and the safety of the personnel operating at the incident. The incident commander, B.C. Perry Putnam reported that the use of a UAS was a benefit and assisted him in the safe management of the incident. Putnam went on to advocate for the establishment of a UAS program for LSF to perform damage assessments following earthquakes (Putnam, 2017).

Training, certification, and compliance is intensive for commercial operation of a UAS and literature review combined with Steve Pansky's email confirms this. Specific areas to address in the certification process include the following:

- Compliance with 14 Code of Federal Regulation (CFR) Part 107
- Initiating application through a Certificate of Waiver/Authorization
- Developing a UAS program, including policy, guidelines, training, concepts of operation, cost-benefit analyses, and community acceptance
- Document preparation
- Pilot qualifications and training
- Contacting the Snohomish County Prosecutor to begin application

- Initial and ongoing training

(Pansky, 2017)

Should LSF deploy UASs following an earthquake to perform damage assessments?

The 2017 expense budget for LSF is $11,253,622. The LSF Mission Statement contained in the Strategic Plan for 2017 states the following: Serve people, save lives, protect property, and safeguard the environment. (LSF, 2017) Considering the mission and budget of LSF, a UAS program appears to be cost-effective and supports the mission.

Discussion

LSF is located in a geographic area that is due to experience a significant earthquake. Specifically, the proximity to the Cascadia Fault which ruptures eight to nine times every 500 to 600 years resulting in earthquakes with strong magnitudes. The last known earthquake of this magnitude occurred in 1700. According to scientific data predictions, the area is due for a massive earthquake. (USGS, 2016). The Snohomish County Hazard Mitigation Plan also supports the concept that Lake Stevens is prone to experience a significant earthquake in the near future (Snohomish County, 2015). Planning and having the training and systems available to respond to meet the needs of the community is imperative for LSF.

Earthquakes can cause significant damage to structures, roads, bridges, utilities, and other critical infrastructure. The resulting loss can make it difficult for responders to perform damage assessments of affected areas. Following an earthquake, Lake Stevens could experience blocked or damaged roadways, affected bridges, landslides, and other problems to transportation modes (Snohomish County, 2015). An airborne UAS could navigate above the damage to provide an accurate visual assessment of the impacts.

Following a disaster such as an earthquake, emergency response resources are overwhelmed and limited in the ability to respond. As supported by Restas (2015), a rapid damage assessment following an earthquake will contribute to human survivability. UASs can

be especially effective for fast reconnaissance and damage assessment because they are relatively quick to deploy and can cover a large area in a compressed amount of time. UASs provide real-time images of the impacted areas that can be viewed by incident commanders.

A neighboring fire district, SCFD 22 has found success in their UAS program which was implemented in 2016. Since the program implementation, the district has utilized the drone on five different alarms with relative success (Stocker, 2017). This success could be achieved in Lake Stevens as well.

At the time of the interview, Assistant Chief Stocker deployed his UAS to perform a demonstration flight and simulated search of an adjacent neighborhood. In as little time as approximately five minutes, the UAS passed over a three square block area, and the author was able to evaluate the condition of structures. The relative ease of use demonstrated in this exercise supports the potential of initiating a UAS program for LSF.

At a recent house fire in Lake Stevens, a UAS was deployed and utilized to monitor the fire and the safety of the personnel operating at the incident. The incident commander, B.C. Perry Putnam reported that the use of a UAS was a benefit and assisted him in the safe management of the incident (Putnam, 2017). A video of the fire was taken from the UAS and displayed real-time images of the subject home, smoke from the fire, and the fire department personnel working on the roof. The UAS was deployed quickly and provided accurate information for the incident commander to assess the potential damage to the home and process the strategy and tactics of the incident. Monitoring responder safety was a benefit as personnel could be seen from the vantage point of the UAS. The deployment of the UAS at the house fire supports the concept that a UAS would be beneficial to responders performing a damage assessment following an earthquake. Additionally, the application of utilizing a UAS at house fires and other incidents is supported. Enhanced reconnaissance capabilities and visual tracking

of the operations of responders would improve LSF service, responder safety, and the support of the mission to serve people, save life, protect property, and safeguard the environment.

It is important to recognize the excellent work of Battalion Chief Perry Putnam in his ARP *Creating a Structural Assessment Guide for Lake Stevens Fire*. Putnam's work contains an effective guideline and a corresponding form to assist emergency responders in performing a damage assessment following an assortment of disasters including earthquakes. Putnam's policy and form could easily be incorporated into current LSF operations. The addition of a UAS to augment damage assessments would shorten the time of assessments which could improve patient care. Additionally, more area could be covered in less time which results in a more successful response to incidents.

Recent success in the deployment of UASs following the 2017 hurricane Irma demonstrates the operational adaptability of the UAS. The success of Florida Power and Light to restore power to 4.4 million people was attributed to the deployment of 49 UASs (Geospatial World, 2017) While this example may be related to a longer, less emergent operation than a damage assessment, it exemplifies the abilities of the UAS to navigate the disaster-torn terrain.

While the certification, testing, and ongoing training for a fire district based UAS program is comprehensive, it is achievable and the resulting program would benefit LSF in support of the mission to serve people, save lives, protect property, and safeguard the environment (LSF, 2017). Chief Stocker of SCFD 22 estimates that the cost of a UAS can range from $1,500 to $7,000. He cites staff hours to certify at 40 and training hours at approximately 20 to 40. Given the relatively low costs of the program compared to the LSF expense budget, development of a UAS program could improve service at a relatively low cost.

Larson's (2016) following statement supports a UAS program for emergency response agencies: "Having eyes in the sky during emergency operations protects citizens and the fire crews, which then provides a significant benefit to public safety agencies." Larson expands his

discussion emphasizing safety for personnel in potentially hazardous environments. He mentions that UAS's performing searches inside structures before responders enter to assure the environment is safe for entry. As Larson (2016) points out and as demonstrated by Chief Stocker, a UAS presents an assortment of operational opportunities for emergency responders. Rapid deployment, expedited reconnaissance, and navigating in potentially hazardous, obstructed environments are of particular note. All of which could result in improved emergency operations and responder safety.

Recommendations

Rapid reconnaissance and damage assessment during any incident are critical factors that can determine the success of the operational response and human survival. Additionally, monitoring the safety of responders is a critical element in any emergency operation.

The deployment of a UAS has proven to be a benefit to other emergency response organizations. In support of these concepts and the LSF mission and budget, this author recommends establishment of a UAS program with the following components:

- LSF should implement a UAS program to perform damage assessments following earthquakes and other disasters.
- Operational policy regarding the performance of damage assessments following earthquakes and other disasters should be instituted for LSF.
- The operational policy should include the provision for a dedicated UAS operator.
- The draft policy and assessment form developed by B.C. Perry Putnam should be utilized in the development of operational policy for LSF.
- The use and deployment of the UAS should include response to fires, search and rescue, hazard materials spills, vehicle ejections, potential drownings, and other appropriate incidents.
- Initial and ongoing training should be developed to support a UAS program.

- LSF should consider partnering with SCF22 and other agencies to support a UAS program.

The UAS has proven to be a valuable tool for emergency responders due it its abilities to be deployed rapidly and provide comprehensive reconnaissance of emergency incidents. Given the threat of a massive earthquake occurring in the Community of Lake Stevens, a UAS could help responders perform rapid assessments of damage and injury to people following the event which would result in an improved service and ultimately support human survivability. LSF must prepare for all disasters including earthquakes and should develop a guideline for damage assessments that includes the deployment of a UAS. Additionally, a future UAS program for LSF appears to have the potential to yield many other benefits including improved responder safety and an overall improvement in emergency response service delivery.

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Appendix A.

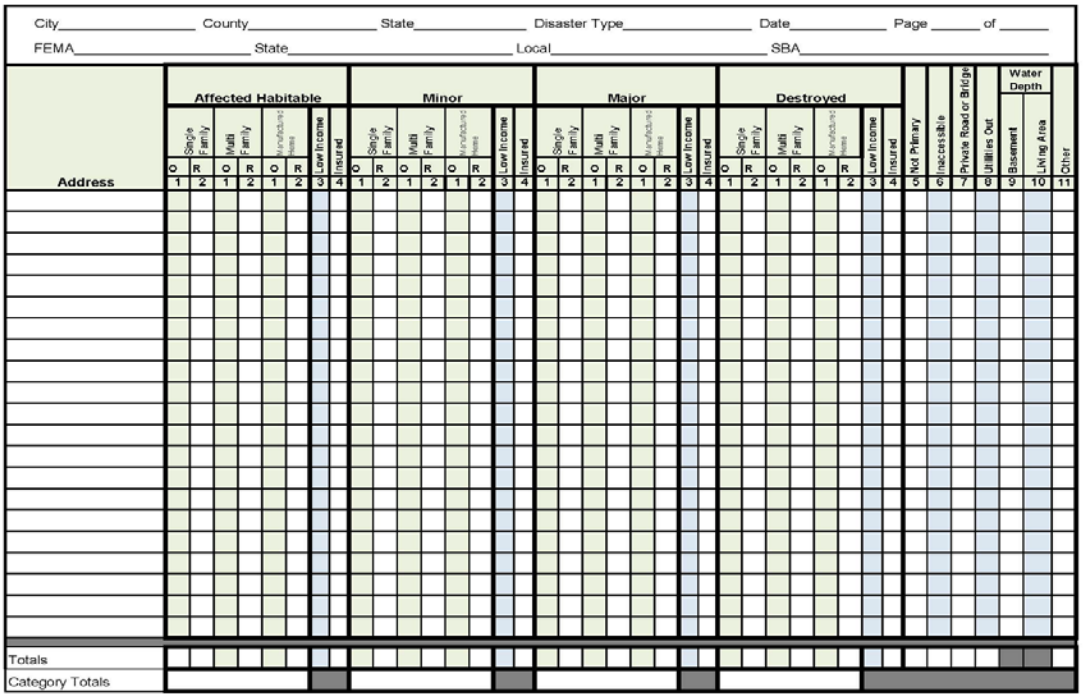
Earthquake Magnitude and Intensity Table

Retrieved from the Snohomish County Hazard Mitigation Plan

TABLE 6-1. EARTHQUAKE MAGNITUDE AND INTENSITY		
Magnitude (Mw)	**Intensity (Modified Mercalli)**	**Description**
1.0—3.0	I	I. Not felt except by a very few under especially favorable conditions
3.0—3.9	II–III	Felt only by a few persons at rest, especially on upper floors of buildings. . Felt quite noticeably by persons indoors, especially on upper floors of buildings. Many people do not recognize it is an earthquake. Standing cars may rock slightly. Vibrations similar to the passing of a truck.
4.0—4.9	IV–V	IV. Felt indoors by many, outdoors by few during the day. At night, some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like a heavy truck striking building. Standing cars rocked noticeably.
5.0—5.9	VI–VII	Felt by all; many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight. .Damage negligible in buildings of good design and construction; slight in well-built ordinary structures; considerable in poorly built or badly designed structures. Some chimneys broken.
6.0—6.9	VIII—IX	Damage slight in specially designed structures; considerable damage in ordinary buildings, with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned. Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations.
7.0 and higher	X and higher	Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations. Rails bent. XI. Few, if any masonry structures remain standing. Bridges destroyed. Rails bent greatly. XII. Damage total. Lines of sight and level are distorted. Objects thrown into the air.

Appendix B

FEMA Initial Assessment Street Sheet Example



City_____ County_____ State_____ Disaster Type_____ Date_____ Page _____ of _____

FEMA_____ State_____ Local_____ SBA_____

Address	Affected Habitable								Minor								Major								Destroyed								Not Primary	Inaccessible	Private Road or Bridge	Utilities Out	Water Depth		Other
	Single Family		Multi Family		Manufactured Homes		Low Income	Insured	Single Family		Multi Family		Manufactured Homes		Low Income	Insured	Single Family		Multi Family		Manufactured Homes		Low Income	Insured	Single Family		Multi Family		Manufactured Homes		Low Income	Insured					Basement	Living Area	
	O	R	O	R	O	R			O	R	O	R	O	R			O	R	O	R	O	R			O	R	O	R	O	R									
	1	2	1	2	1	2	3	4	1	2	1	2	1	2	3	4	1	2	1	2	1	2	3	4	1	2	1	2	1	2	3	4	5	6	7	8	9	10	11
Totals																																							
Category Totals																																							

Appendix C

Putnam's Initial Damage Assessment Guideline

Guideline XXX
Initial Damage Assessment

1.0 SCOPE:

1.1 This policy and procedure shall apply to all employees and individuals performing on behalf of the district.

2.0 PURPOSE:

2.1 To establish a procedure to identify initial damage assessment following a disaster.

3.0 POLICY:

3.1 After a disaster, Lake Stevens Fire shall conduct an initial damage assessment of structures in the jurisdiction to establish extent of damage.

4.0 DEFINITIONS:

4.1 Windshield Survey – A process to systematically evaluate structures quickly and consistently.

5.0 PROCEDURE:

5.1 Geographical Breakdown: The Lake Stevens Fire response area shall be broken down by geographical boundaries. Officers shall determine the best roads to travel based on damage caused by a specific event.

5.1.1 Station 81.

5.1.1.1 Boundaries for initial damage assessment on the North will be 60th street NE to the border of Granite Falls Fire on the East, and Highway 9 on the West.

5.1.1.2 Boundaries for initial damage assessment on the East will be the border with Granite Falls Fire on the East end of the jurisdiction from 60th Street NE to Highway 92, and from Highway 92 down Machias Road to 16th Street NE.

5.1.1.3 Boundaries for initial damage assessment on the South will be from 16th street at Machias Road to 131st Ave NE, down 131st NE to 4th Street NE across to East Lakeshore Road. Station 81 will also assess all of East Lakeshore Road to Machias Cutoff.

5.1.1.4 Boundaries for initial damage on the West will be from 60th Street NE along 99th Avenue NE to Vernon Road.

5.1.2 Station 82.

5.1.2.1 Boundaries for initial damage assessment on the North will be 60th street NE from Highway 9 to the border of Marysville Fire on the West.

5.1.2.2 Boundaries for initial damage assessment on the East will be from Vernon Road, along all roads on Lake Stevens to the Machias Cutoff/East Lake Shore Road intersection on the South, and down 103 Ave SE to the border with Snohomish Fire.

5.1.2.3 Boundaries for initial damage assessment on the South will be from Machias Cutoff/East Lake Shore Road intersection, along South Lake Stevens Road to 20th Street SE, and from 20th Street SE down 103 Ave SE to the border with Snohomish Fire.

5.1.2.4 Boundaries for initial damage on the West will be the border with Marysville Fire and Everett Fire at the Snohomish River.

5.1.3 Station 83.

5.1.3.1 Boundaries for initial damage assessment on the North will be 60th street NE to the border of Granite Falls Fire, and Machias Road on the West to 16th Street NE, then from 131st Ave at 4th Street NE to East Lakeshore Road.

5.1.3.2 Boundaries for initial damage assessment on the East will be the border with Granite Falls Fire and Lake Roesiger Fire from Highway 92 to Dubuque Road.

5.1.3.3 Boundaries for initial damage assessment on the South will be from the border with Snohomish Fire from Lake Roesiger Fire to 103rd Ave NE

5.1.3.4 Boundaries for initial damage on the West will be down 103 Ave SE to the border with Snohomish Fire.

5.2 Priority area for assessment. The following areas, when practical, shall be assessed first. These are in no particular order. Officers should determine prioritization based on time of day and events occurring.

5.2.1 Schools

5.2.2 Rest homes or adult care facilities

5.2.3 Public assemblies, including churches, stores, and other large occupancy assemblies

5.2.4 Apartment buildings

5.2.5 Water towers

5.2.6 Bridges

5.2.7 Utilities

5.3 Activities allowed during assessment. Activities other than the windshield survey should be avoided. The following are allowed:

5.3.1 Activities which can be completed quickly and will result in the stabilization of an event. The action must result in the decrease of or elimination of a catastrophic event such as death or major infrastructure failure.

5.3.2 Activities which take minimal time and effort to complete and directly result in the stabilization of an event. The action must result in the decrease of or elimination of a catastrophic event such as death or major infrastructure failure.

5.4 Damage Levels. There are 5 levels of damage consistent with the American Red Cross criteria as well as FEMA. If a structure meets any criteria in multiple levels, the structure is given the more severe level classification. Personnel shall record the number of structures in assessed based on damage level category on the form attached to this guideline in Appendix A.

5.4.1 Destroyed category:

5.4.1.1 Structures which have collapsed or are not economically feasible to repair.

5.4.1.2 A manufactured home with collapsed or buckled walls.

5.4.1.3 Any structure permanently uninhabitable. This includes structures which cannot be lived in due to landslides or sinkholes.

5.4.1.4 Any structure where the cost to repair it will exceed its value.

5.4.1.5 Flooding of over 48” inside the main floor of a stick built structure and 36” in a mobile or manufactured home.

5.4.2 Major category:

5.4.2.1 Large portions of the roof missing.

5.4.2.2 The frame of a mobile home has been twisted or bowed.

5.4.2.3 Damage to over 50% of the structure, but the structure is still repairable.

5.4.2.4 Damage which will take over 30 days to repair and the structure is uninhabitable during that time.

5.4.2.5 A failure in the foundation, floors, walls or roof or a structure missing one or two walls.

5.4.2.6 Between 24” and 48” of flooding on the first floor in a stick build structure.

5.4.2.7 Between 24” and 36” of flooding on the first floor in a mobile or manufactured home.

5.4.3 Minor category:

5.4.3.1 Repairable damage involving less than 50% of the structure which can generally be completed within 30 days.

5.4.3.2 Multiple broken windows.

5.4.3.3 Large areas of siding missing.

5.4.3.4 Minimal structural damage.

5.4.3.5 Missing roof material or penetrations to the roof which don't appear to affect the structure.

5.4.3.6 Between 6" and 24" of water in the living space of a stick built structure.

5.4.3.7 Between 2" and 24" of water in the living space of a mobile or manufactured home.

5.4.4 Affected category:

5.4.4.1 Missing shingles or siding.

5.4.4.2 Debris around the structure which does not affect livability.

5.4.4.3 Repairs are not needed for the structure to be inhabitable.

5.4.4.4 Less than 6" of water in the living space of a stick built structure.

5.4.4.5 Less than 2" of water in the living space of a mobile or manufactured home.

5.4.5 Inaccessible category.

5.4.5.1 Inability to view the structure due to standing water.

5.4.5.2 Looming dangers such as slides.

5.4.5.3 Impassible bridges or roads.

5.4.5.4 Road covered with water.

5.4.5.5 Private road which are impassible.

5.4.5.6 Sewage issues which restrict access.

6.0 REFERENCE:

6.1 FEMA

6.1.1 http://www.fema.gov/media-library-data/20130726-1856-25045-0599/ia_pda_manual_and_forms.pdf

6.2 American Red Cross

6.1.1 http://xa.yimg.com/kq/groups/21454797/1998792370/name/disaster.pdf

7.0 APPENDIX:

7.1 Example of Damage Assessment Worksheet

Guideline XXX
Initial Damage Assessment

APPENDIX 7.1
Damage Assessment Worksheet

Station 81 82 83		Person Doing Assessment:							
		Dwelling Type	Destroyed	Major	Minor	Affected	Inaccessible	Total	Completed Y/N
Grid		SFD							
Street Name		MH							
		Apt							
Cross Street		Sub Total							
Station 81 82 83		Person Doing Assessment:							
		Dwelling Type	Destroyed	Major	Minor	Affected	Inaccessible	Total	Completed Y/N
Grid		SFD							
Street Name		MH							
		Apt							
Cross Street		Sub Total							
Station 81 82 83		Person Doing Assessment:							
		Dwelling Type	Destroyed	Major	Minor	Affected	Inaccessible	Total	Completed Y/N
Grid		SFD							
Street Name		MH							
		Apt							
Cross Street		Sub Total							
Station 81 82 83		Person Doing Assessment:							
		Dwelling Type	Destroyed	Major	Minor	Affected	Inaccessible	Total	Completed Y/N
Grid		SFD							
Street Name		MH							
		Apt							
Cross Street		Sub Total							

Appendix D

Interview with Assistant Chief Jeremy Stocker, Snohomish County Fire Dist. 22

Wednesday, September 6, 2017, 12:00 p.m.

Kevin O'Brien met with Jeremy Stocker to learn about the UAS program for Snohomish County Fire Dist. 22.

Stocker is commercially certified by the FAA to fly a UAS at emergency incidents.

Dist. 22 implemented a UAS program in August of 2016.

There is significant training and compliance documentation needed with the FAA.

The UAS owned by Dist. 22 cost approximately $1,500 to purchase.

The UAS owned by Dist. 22 has a camera that records video which is displayed on a PDA at the pilot controls. The UAS has approximately 28 minutes of flight time per battery.

District 22 is considering the purchase of a new UAS which will cost about $7,500, a DJI Inspire II with three cameras. (a) A forward-looking camera. (b) A downward looking camera. (c) An infrared (FLIR) camera that records heat signatures.

As UAS must be flown in the sight of the pilot at all times.

The Dist. 22 UAS has been utilized at the following incidents:

- *A search for a possible drowning victim in Granite Falls, WA*
- *A wildland fire in Mansfield, WA- The UAS was deployed to view bulldozer operations above the crew's location near a cliff.*
- *A wildland fire in Quincy, WA*
- *A house fire in Lake Stevens, WA on August 20, 2017 – The UAS was deployed to assist LSF crews in reconnaissance, incident status management, and responder safety*
- *A house fire in Snohomish County*

Chief Stocker recommends speaking with FAA specialist Steve Pansky to assist with UAS certification information. Pansky assisted Dist. 22 with their certification process.

Chief Stocker commented that the deployment of a UAS as soon as possible would have been helpful at the 2014 OSO Landslide to determine magnitude and scope of the slide.

Chief Stocker recommends a visual observer to assist the pilot in the operation of a UAS.

Chief Stocker was specifically asked the question. "Following an earthquake, would the deployment of a UAS to perform a damage assessment be beneficial to responders?"

Chief Stocker replied citing the benefits of a UAS in performing a damage assessment:

- *A UAS would provide a good overhead view of any incident*
- *A UAS would facilitate entry into a hazard area that would be difficult or prohibitive for humans.*
- *A UAS could access fires.*
- *A UAS provides rapid assessment.*
- *A UAS is useful when staff is limited*
- *A UAS may be used as an "eye" to direct personnel to safety.*
- *A UAS would be a good risk and needs assessment tool.*
- *A UAS would provide good situational awareness.*
- *A UAS can perform a precise grid search.*
- *A UAS is an excellent tool for reconnaissance and observation.*
- *A UAS provides a significant economy of time for reconnaissance compared to personnel performing reconnaissance on the ground.*
- *A UAS equipped with FLIR can be beneficial for search and rescue.*
- *A UAS would be especially useful if roads are blocked and there are accessibility problems.*
- *The help of conventional aircraft would be limited.*

Chief Stocker stated that ongoing UAS training includes the following:

- *One flight every thirty days*
- *Flights must occur at least three times every 90 days.*

Chief Stocker mentioned that inclement weather could be a limiting factor for UAS.

Chief Stocked discussed other benefits of a UAS:

- *Incident documentation*
- *Post-incident analysis*

Chief Stocker discussed the costs associated with a UAS

- *Drone registry $5.00*
- *Application process $4,000 for consultant assistance (Approximately 40 hours)*

According to Chief Stocker, you must own your UAS before making application.

Chief Stocker deployed the UAS from the parking lot of Lake Stevens Fire Headquarters. The UAS provided immediate visual footage of three blocks comprised of residential homes in an adjacent neighborhood in approximately one minute.

Appendix E

Email from Steve Pansky Regarding the FAA Certification Process for UASs

Chief O'Brien

As an introduction, I am a contractor with Science Applications International Corporation (SAIC) working for the Federal Aviation Administration Unmanned Aircraft Systems Tactical Operations Section, Emerging Technologies Team, AJV-115. I am the Air Traffic Office (ATO) coordinator for all law enforcement (LEA) Fire, and First Responder Agencies that are interested in implementing Unmanned Aircraft System (UAS) technologies that need to be certificated by the FAA in order to operate within the National Airspace System (NAS). Along with my counterparts, Mr. John Meehan, Management and Program Analyst with the Unmanned Aircraft Integration Office, AUS-430, and Mr. Dave Bear, Aviation Safety Inspector, Flight Standards Service, General Aviation and Commercial Division (AFS-800), we handle law enforcement/fire and first responder Agency UAS requests.

My Colleague, Mr. Meehan, can arrange for a conference call to speak about operating a small unmanned aircraft in the national airspace system. Below is the latest information we provide to individuals and agencies wishing to receive information on how to operate a small unmanned aircraft in the national airspace as a public aircraft operator for a safety agency. This applies to all aircraft regardless of the size and the weight and the altitude they wish to operate at.

INTRODUCTION

There are three ways to legally operate a small unmanned aircraft in the National Airspace System. If the aircraft is flown strictly for hobby or recreational use (See advisory circular 91-57A- Change 1), As a civil or commercial operator under 14 Code of Federal Regulation (CFR) Part 107 or flown as a public aircraft strictly for public missions by a public agency under a Certificate of Waiver/Authorization (COA) issued by the FAA. An individual can conduct public safety agency missions as a civil operator but must comply with all the conditions and provisions of 14 CFR part 107 when conducting those missions (see becoming a UAS pilot https://www.faa.gov/uas/getting_started/fly_for_work_business/becoming_a_pilot/).

The Federal Aviation Administration (FAA) is responsible for processing and approving all requests for Unmanned Aircraft System (UAS) operations in the National Airspace System (NAS). For "Public" UAS operators, this authorization is granted via the issuance of a Certificate of Waiver/Authorization (COA). Typically, Public Safety Agency sUAS flight operations are considered "public aircraft" operations. The guidelines for operating as a "public aircraft" entity are described in the FAA Flight Standards Information Management System (FSIMS) 8900.1 Volume 16. I have attached a word version of that on line document.

When the FAA receives an application for a COA through the FAA's "COA On-line" process, the Agency initiates a review and application assessment. Included in this review and assessment are 1) the type of mission, 2) launch/recovery/operations location(s), 3) operational altitudes, 4) flight procedures, 5) communications, 6) emergency procedures such as lost communication and loss-of-control link, and 7) pilot in command (PIC), flight crew, and observer qualifications and training requirements. The typical COA application approval process is completed within 60 business days of receipt, provided there are no submittal errors, missing information, or safety or airspace issues.

DEVELOPING A UAS PROGRAM

UAS offers a cost-effective alternative to the traditional manned-aviation program for most public safety aviation missions where an airborne asset could be utilized. But before your agency runs out and buys the first "Drone" they see, it is recommended that you prepare for that procurement by doing your homework and getting your community engaged. By developing a clear path to the implementation of your unmanned aircraft program you will be more likely to have a successful outcome.

1. Concept of Operation (ConOps) -The type of sUAS required depends upon an agency's ConOps which can describe a proposed system from the viewpoint of the mission and people who will use it. The ConOps expresses what the Incident Commander intends to accomplish and how it

will be done using available resources. ConOps can be developed in different ways, but usually share the same properties. In general, a ConOps include:

- Statement of the goals and objectives of the system
- Strategies, tactics, policies, and constraints affecting the system
- Organizations, activities, and interactions among participants and stakeholders
- Clear statement of responsibilities and authorities delegated
- Specific operational processes for fielding the system
- Processes for initiating, developing, maintaining, and retiring the system

2. Assess the technologies available that meet your concept of operation.
   - Web search technologies available
   - Communicate with other agencies utilizing UASs
   - Contact manufactures that will meet your needs
   - Understand city, county, state and federal laws surrounding the utilization of UASs
3. Cost/Benefit Analysis- Your agency should determine if the benefits to the procurement of this technology makes fiscal sense in these economic challenging times. The analysis can be extremely simple to an extensive multi-volume document but most assessments contain these major areas:
   - Analysis Summary
   - Project Overview and Background
   - Discussion of Alternatives
   - Alternatives - Goals and Concepts
   - Life-Cycle Costs and Benefits
   - Risk Analysis
   - Cost/Benefit Analysis
   - Project Cost/Benefit Analysis
   - Review/approval Signatures
4. Community Acceptance- The benefits of sUAS technology can quickly become over-shadowed by controversy surrounding its use if the community is not educated on the benefits and operational controls that are in place. Topics of discussion should include:
   - legal guidelines for use of airborne technology
   - A community engagement plan
   - Compliance with City, County, State and federal policies, ordinances and laws.

ACCESS TO COA ON LINE

Before the FAA grants an agency assess to the COA on-Line to begin an application process, the agency (or proponent) will be asked to provide the FAA with a “declaration letter” from the Agencies City, County or State Attorney’s office (Depending of the agency requesting the approval). This document assures the FAA that the Proponent is recognized as a political subdivision of the government of the State under Title 49 of the United Stated Code (USC) section (§) 40102(a)(41)(c) or (d) and that the proponent will operate its Unmanned Aircraft in accordance with 49 USC. § 40125(b) (not for Commercial Purposes). Access to the COA on-line website and the application program cannot be approved until this declaration letter has been validated by the FAA's Legal Office. You must understand that an Agency’s Accountable Executive CANNOT Self-Certify their agency is a “Public” agency. The responsibility for establishing the legal nexus between the state and the agency rests with the City, County or State Attorney General and their appropriate legal counsel. (see attached document)

PREPARING DOCUMENTS FOR THE APPLICATION

The COA on line application process requires that the proponent address several areas that will provide sufficient information for the FAA to make a determination as to the safety of the operations within the NAS. These documents include:

- An executive summary that will describe an overall program objective (ConOps) and an operational summary that addresses the flight mission description the proponent will be executing.
- A System description (description of the UAS technology, the Ground Control Station, Data Link Communication and any FAA Technical Standard Order (TSO) components) including the UAS registration.

- An Airworthiness Release (AWR) statement from the Proponent's accountable executive acknowledging that the Proponent accepts all responsibility for ensuring that the UAS is airworthy and that it will be operated and maintained in strict compliance with the public agencies certification criteria.
- A lost-link procedures document that describes the specific lost-link procedure that will be implemented in the event of a lost-link occurrence (loss of command and control (C2) link).
- A lost communication procedures document that describes what action(s) the Pilot-in-Command (PIC) will take if there is loss of communication between PIC and Air Traffic Control, or lost communication between PIC and the Visual Observer(s) (VO).
- An emergency procedures document that explains the protocols/procedures that will be executed at the site in the event of an emergency (this could include execution of procedures outlined in the manufacturers supplied operator's flight manual, other possible alternative courses of action available for each phase of flight, and any outside agencies or resources for medical and fire or other assistance) Basically, this is a .."What will you do if something bad happens?).
- Registration of the Unmanned aircraft- Title 49 §§ 44101-44104 prohibit operation of unregistered aircraft and establish the requirements for aircraft registration. Public Aircraft are not exempted from the registration requirements. The regulations implementing those requirements are in 14 CFR part 47 for all aircraft, or in 14 CFR Part 48 for small UAS. Under § 47.3, aircraft owned by U.S. citizens, lawfully admitted permanent residents of the United States, and U.S. corporations are eligible for registration and operation. You can register your small UAS under Part 48 by going online at https://registermyuas.faa.gov/ and after registering your agency select the Non-Model button to register your public aircraft. Alternatively, you can register your aircraft under Part 47 using the paper link (see http://www.faa.gov/licenses_ certificates /aircraft_certification/aircraft_registry/UA/). Please be aware that you will not be able to complete the COA online program until your unmanned aircraft is registered.

FLIGHT AIRCREW QUALIFICATIONS

The Federal Aviation Administration (FAA) has reviewed the Public Aircraft Operator criteria and has clarified the exclusion of government entities conducting Public Aircraft Operations (PAO) for the purpose of fulfilling a government function that meets certain criteria specified under Title 49 United States Code, Section 40102(a)(41) & 40125(a)(2). PAO's are limited by the statute to certain government operations within U.S. airspace and must comply with general operating rules including those applicable to all aircraft in the National Airspace System (NAS). Under this clarification the government entities may exercise their own internal processes regarding aircraft certification, airworthiness, pilot, aircrew, and maintenance personnel certification and training.

The public agency will still be required to gain approval from the FAA before operating UAS in the national airspace. However, the public aircraft operator should establish their own training and certification program for their pilots, observers, and aircraft maintenance personnel. When establishing self-certification programs of this kind the government entity conducting the public aircraft operation is responsible for ensuring that the proposed operation can be safely conducted under the terms of their certificate of waiver (COA).

Public operators are encouraged to review Advisory Circular 00-1.1A for information on how to establish internal policies, procedures, protocols and checklists to ensure safety of flight. Additionally, public entities may review pertinent parts of Federal Aviation Regulations (FAR) parts 61, 91, and 107, to familiarize themselves with areas that a certificated pilot must possess knowledge in and follow. The FAA does not prescribe the method that public entities use when developing processes and programs, it is the responsibility of each public entity to determine these processes and programs.

WHAT COA(s) ARE RIGHT FOR YOUR AGENCY

The Unmanned Aircraft Program for public safety was designed to give the proponent a more rapid process for approving UAS operations while expanding the access into the NAS. There are currently three different types of COAs to address the needs of the proponent.

1. Blanket Area Public Safety (BAPS) COA- This Blanket Area Public Safety COA approval will allow small UAS (55 pounds or less) operations during day and Night Visual Meteorological Conditions (VMC) conditions under the following limitations:
   (1) At or below 400 feet AGL; and
   (2) will take place beyond the following distances from the airport reference point (ARP) of a public use airport, heliport, gliderport, or water landing port listed in the Airport/Facility Directory, Alaska Supplement, or Pacific Chart Supplement of the U.S. Government Flight Information Publications.
   a) 5 nautical miles (NM) from an airport having an operational control tower; or
   b) 3 NM from an airport having a published instrument flight procedure, but not having an operational control tower; or
   c) 2 NM from an airport not having a published instrument flight procedure or an operational control tower; or
   d) 2 NM from a heliport

   Under this Blanket Area program the Public Agency will conduct training at training locations that meet the provisions of the COA as addressed above that remain well clear of housing areas, roads, any persons, and watercraft. This allows the agency the ability to conduct the necessary ground and flight training to bring pilots, observers and ground crew members to a high level of UAS flight proficiency and also enables them to develop and conduct training exercises to ensure efficient, standardized coordination among other supporting / responding emergency elements (e.g. coordination for operational missions including search and rescue, disaster control, forensic photography, Fire missions, Law Enforcement, etc.).

   Once this training has been completed, the proponent will be authorized under the same COA to conduct UAS public Safety missions in Compliance with Title 49 USC 40125B at any location within the National Airspace System under the provisions stated within the COA. We believe that utilizing this COA will allow most Public Agencies the ability to meet 75% of their mission objectives.

2. Jurisdictional COA- For those operations that cannot operate within the Blanket area COA criteria or wish to expand their access beyond the Blanket Area COA described above, an expanded COA application can be applied for (Jurisdictional COA) which could include operations in Class D, E and C Airspace as well as operations conducted during the night. When the Jurisdictional COA is issued the proponent need only file a Notice to Airman (NOTAM) prior to flight which identifies a defined operating Area (Radial/DME off a known Navigational Aid) within the construct of the Jurisdictional COA Area and a notification to the appropriate Air traffic Control Facility having jurisdictional responsibility over that airspace (If required).

   Like the Blanket Area COA the jurisdictional COA has a provision that requires the Public Agency to conduct training at training locations that allows the agency the ability to conduct the necessary ground and flight training to bring pilots, observers and ground crew members to a high level of UAS flight proficiency and also enables them to develop and conduct training exercises to ensure efficient, standardized coordination among other supporting / responding emergency elements (e.g. coordination for operational missions including search and rescue, disaster control, forensic photography, Fire missions, Law Enforcement, etc.). Once this training has been completed, the proponent will be authorized under the same COA to conduct UAS public Safety missions in Compliance with Title 49 USC 40125B at any location within the National Airspace System under the provisions stated within the COA.

3. Special Government Interest (Emergency COA)- And if the proposed operating area is not covered under the public safety agencies approved Blanket Area or Jurisdictional COA the public safety agency can request and receive approval from the FAA for an emergency Certificate of Waiver/Authorization that will allow for the one time operation of the UAS at that location based on an eminent risk to life type event where manned aircraft may need to be available or the risk to manned aircraft is too great.

FIRST STEPS

The first step in getting started is to coordinate with your State Attorney General's Office, County or City Attorney (please review the attached email material on public declarations) the need for a public

declaration letter that should be mailed to the FAA (see the FAA agency executive name and address). Once that letter has been reviewed by the FAA's legal office and deemed sufficient an on line access form will be forwarded to the point of contact for the public agency to be completed and returned to the FAA. It currently takes approximately 15 business days for the FAA to establish an account within the online program that is partitioned so as to allow for security of the data being entered by the public agency.

FINAL THOUGHTS

The FAA will be Hosting webinars on the third Wednesday of every month to discuss topics of interest for public safety agencies. This will be a very Basic Agenda:

- Hot Topics
- Operational considerations (COAs, best practices, etc.)
- Enforcement considerations (case studies and legal issues)
- FAQs or Q&A

To register for the webinar please use this info:

Please click on this link to register for the webinar: https://attendee.gotowebinar.com/rt/2990819347423939331

4-1-1 for 9-1-1: Drone Information for Public Safety Personnel

After registering, you will receive a confirmation email containing information about joining the webinar.

And I understand that the magnitude of this information may seem a bit daunting, but we developed this response to try and cover the questions that most interested agencies have starting out. Please feel free to contact Mr. Meehan, Mr. Bear or myself with any questions or if we may be of any further assistance.

Respectfully,

Steve Pansky/SAIC
Senior Aviation Analyst
Aviation Safety (AVS) Safety Technical Support Services (STSS)
Air Traffic and Law Enforcement/SAC-EC Liaison
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From: O'Brien, Kevin [mailto:kobrien@lsfire.org]
Sent: Friday, September 22, 2017 5:08 PM
To: Pansky, Steven CTR (FAA)
Subject: UAS Questions

Hello Mr. Pansky,

My name is Kevin O'Brien and I am researching the potential benefits of utilizing UASs to perform damage assessments following earthquakes. My colleague Jeremy Stocker gave me your contact information.

Would you be available to talk with me about this topic over the phone next week?

Best regards,

Kevin

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Appendix F

Email from Battalion Chief Perry Putnam Regarding the UAS Deployment at a House Fire

Chief,

See the responses below. Let me know if you need anything additional.

Perry

From: O'Brien, Kevin
Sent: Saturday, September 23, 2017 15:31
To: Putnam, Perry <pputnam@lsfire.org>
Subject: ARP Help

Hi Perry,

I'm working on my ARP and I'm wondering if you would please help me with some questions? Below is a photo of a recent house fire you had and hoping to fill in some details.

What was the date, time, and location of the incident?

- 8/20/2017 0959 9231 19th PL SE, Lake Stevens, WA 98258

Was the UAS (drone) reconnaissance helpful to you?

- Yes, due to not being able to gain access to the Charlie side of the structure because of an angry dog

Were you able to assess damage?

- It was more used to assess hazards and location of smoke and fire from the structure

Did the drone help reduce risk during the incident?

- Yes, It provided additional, real time information about fire conditions and structural condition.

Do you think a drone would be helpful in performing a damage assessment following an earthquake?

- Yes. If equipped properly, it would provide the ability to view numerous structures over a wide geographical area quickly, without regard for ground hazards or the public.

Do you have any other thoughts that might help?

- The drone helps provide a view of one of the 7 sides (roof) of a building which usually is more difficult to access. It also provides feedback in real time to the incident commander of the location of the crew and progress of their task. The drawback to it is as an incident commander, it is not practical to operate (fly) the drone at the same time as running an incident. This means you need additional personnel on scene to take advantage of this resource. Also, unless the drone is equipped with a FLIR or night vision camera, its usefulness during night operations is limited.

By the way, I sure appreciate the work you did in your damage assessment ARP! We need to get your guideline and form into practice!

Thanks for your help!

KO'B

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