OPTIONALLY PILOTED HELICOPTERS

A PRIMER ON A POTENTIALLY GAME-CHANGING TECHNOLOGY THAT PROMISES TO SAVE LIVES, PROPERTY, AND MONEY IN WILDLAND FIRE

Purpose

This background paper is a primer on the subject of optionally piloted helicopters (OPH) and their potential to bring game-changing technology to wildland fire that promises to save lives, property, and money. Able to perform all the functions of a traditional helicopter in the piloted mode, OPH have provided expanded mission coverage and proven their ability to operate in hazardous environments without risking the safety of pilots. In the wildland fire mission, OPH hold the promise of becoming the first ***"direct-action"*** unmanned aircraft systems (UAS), capable of conducting manned initial/extended attack and logistics support flights during traditional manned flight operating periods, while also filling historical aerial coverage gaps at night and during daytime periods of reduced visibility due to smoke.

This paper outlines the distinct differences between small-unmanned aircraft systems (sUAS) used to collect data, discern information, and develop actionable knowledge. These ***"indirect action"*** sUAS serve an important role and have already proven their worth in only two seasons of sustained application in the wildland fire mission. Their unique attributes, current successes, and future use are discussed.

The paper will also discuss the topic of optionally piloted airplanes and their possible future integration in the air tanker role. Specifically, the non-technological barriers to their widespread integration and use are addressed.

Background

To date, the U.S. Department of Interior's (DOI) Office of Aviation Services (OAS), in cooperation with the UAS industry and academia, has successfully carried out a number of demonstration projects to study the effectiveness of unmanned aircraft systems and optionally piloted helicopter technology to improve wildland fire management operations and enhance the safety of firefighters. These include:

1. 2014 Optionally Piloted Helicopter demonstration at the New York State FAA UAS Test Site (industry funded). Video. News coverage: A, B, C, D, E, F, G. Presentation to November, 2015 Drone World Expo.
2. 2015 Optionally Piloted Helicopter demonstration in representative terrain and atmospheric conditions at the Lucky Peak Helibase outside Boise, Idaho (industry funded). Video 1 of 2, Video 2 of 2.. News coverage: A, B, C, D, E, F, Report.

3. 2015 small UAS (sUAS) demonstration on the Paradise Fire, Olympic National Park, WA (industry funded). News coverage: A, B, C. Report.
4. 2015 sUAS demonstration on the Tepee Springs Fire, Idaho (industry funded). News coverage: A, B, C, D, E, F. Report.
5. 2016 sUAS aerial ignition demonstration on the Homestead National Monument, Nebraska (university and government funded). News coverage: A, B, C, D, E. Report.
6. 2016 sUAS operational test and evaluation on the North Fire, New Mexico (government funded). Report.
7. 2017 sUAS operational test and evaluation on the Boundary Fire, Arizona (government funded). Report.
8. 2017 sUAS operational test and evaluation on the Young Fire, California (government funded). Report.
9. 2017 sUAS operational test and evaluation on the Umpqua Complex Fire, Oregon (government funded). Report. Slide with narrated embedded video.
10. 2018 demonstration test of sUAS in the delivery of emergency equipment, Boise, Idaho. Preliminary results presentation with video.
11. 2018 field test of sUAS aerial ignition platform. Overview, Briefing Paper and Field Report.

Since the initiation of its UAS program in 2006, DOI has successfully integrated sUAS technology across more than 30 different mission applications, including wildland firefighting. In 2017, wildland fire comprised 35% of all DOI manned aircraft flying and 14% of all UAS flights. OAS has trained wildland firefighters from around the country as DOI fleet UAS operators and provided them with access to DOI UAS fleet assets; led the development of an interagency fire UAS operations guide to facilitate coordination between federal and state agencies when using UASs on wildland fires; prototyped the deployment of small UASs embedded with wildland firefighters to enhance their tactical situational awareness; and developed and fielded the first commercial drone services contract for wildland fire support.

Wildfire – The WAR on the Home Front – Wildfire has always been a natural part of our ecosystem, but increasingly wildfire is resulting in significant loss of life, homes, businesses, and property that contributes to billions in economic loss, annually. In 2017, there were over 71,000 wildfire starts. These wildfires burned nearly 10 million acres, destroyed approximately 11,000 homes and businesses, and resulted in the direct death of more than 50 people and the indirect death of hundreds more due to post-fire landslides and the health effects of smoke inhalation. The cost to suppress these fires in 2017 was approximately $3 billion. Notably, this number does not include the cost to prepare personnel and equipment for the fire year, the cost to initially stabilize or later rehabilitate burned lands and rebuild homes and businesses, or the economic loss that results from the loss of land and businesses.

While **it takes trained wildland firefighters on the ground to extinguish wildfires,** aviation has played a significant role in slowing the fire's advance and supporting firefighters in the containment of wildfires for over 88 years. However, there are significant aspects of that aerial support that have not changed since that first suppression drop from an aircraft in 1930. Active suppression of wildfires from the air remains **largely a clear air, daytime endeavor**. As a result, historically aviation only provides active suppression and logistics support to the fire and firefighters **for approximately 1/3rd of the available day**. Typically, aerial suppression and logistics flights don't launch until after 10:00 AM, long after fire behavior has increased with the rising temperatures, lower humidity, and higher winds that traditionally occur as the sun climbs higher in the sky. When winds are light and the inversion endures, smoke from wildfires becomes particularly thick and persistent; it can shut down traditional manned flight operations for days on end. This results in wildfires being able to burn and grow, unsuppressed from the air for long periods. This limitation threatens firefighter and community safety.

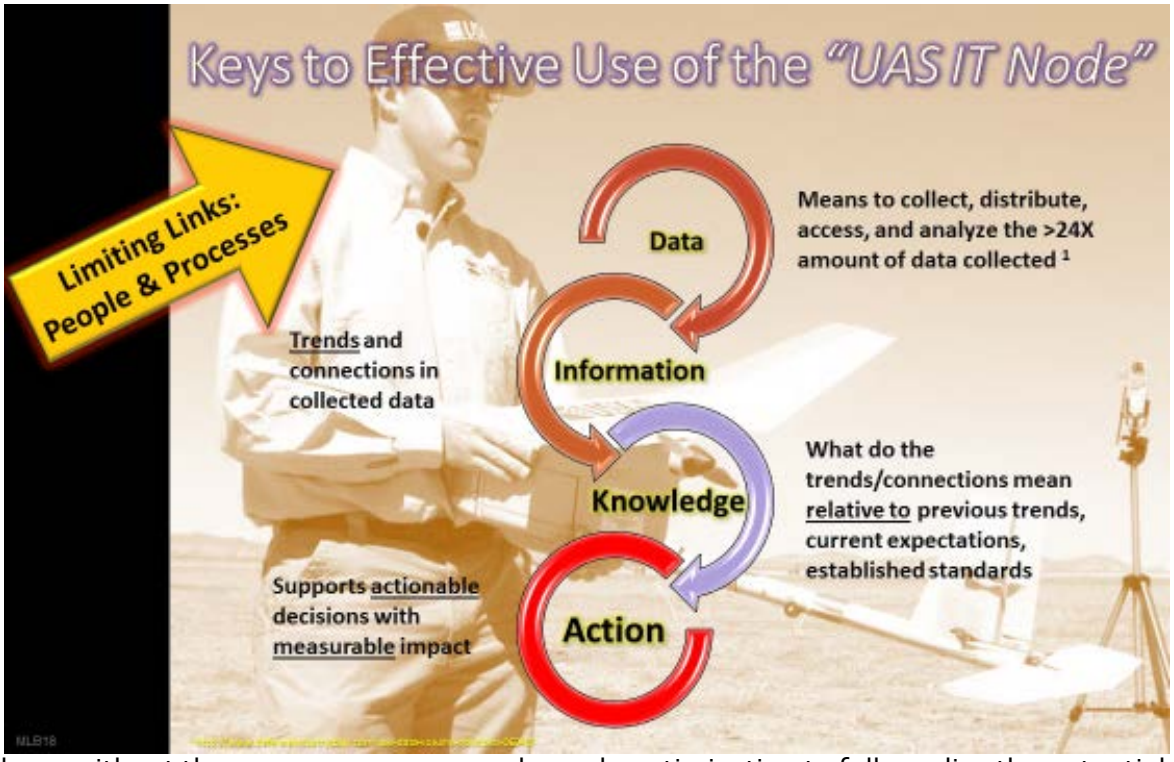
Additionally, **nearly 20% of wildfires are first discovered outside periods of traditional aviation coverage**. This traditional gap in aerial coverage provides **up to 16 hours** for those fires to grow from a small ignition start to some of the largest and most deadly fires.

Sorry, We'll Get Water on That Fire, Later - Imagine a similar situation in the structural firefighting world. Your house catches fire after dark. The firefighters show up with their axes and ladders. However, the fire truck with the hoses and the ability to pump water to assist in extinguishing your house fire are unable to show up and support, because it is night. I doubt any of us would find this acceptable, but the fact is we have lived with this for 88 years when it comes to wildland firefighting.

Night Vision Devices – While some have suggested the use of aircraft and pilots equipped with night vision devices (NVD's) as a potential solution, several factors make this option problematic. First, to become safe and effective in flying with NVD's requires an expensive, lengthy and graduated training regimen to obtain the required skills and regular proficiency flying under NVD's to maintain qualifications. You start by flying under a full moon and then, as your proficiency builds, progress to training flights on reduced moon phase nights until you are a fully qualified NVD pilot under "mean starlight." Despite lengthening fire years, aerial firefighting remains a largely seasonal activity. Maintaining safety and proficiency in NVD's would require a deliberate additional investment in preseason training, increasing the cost of sustaining this capability. However, the biggest argument against NVD's as "the" solution to the up to 16 hour daily gap in aerial firefighting coverage is that ½ of the coverage gap occurs during daylight hours, when reduced visibility due to thick and persistent smoke currently prevents air support. NVD's are useless during daylight, even in smoke.

Indirect Support – Runway Independent, Small Unmanned Aircraft: Runaway independent, Small sUAS currently provide all-visibility fire perimeter mapping, hotspot detection, real-time direction, and other decision support products at the tactical, division, and incident commander level. Launched from within the Temporary Flight Restriction (TFR) placed over most large fires by the Federal Aviation Administration (FAA), these aircraft do not require the special FAA provisions (i.e. chase plane) required of runway dependent UAS that must transit from airports to the fire and back again for refueling/recharging.

Small UAS provide **data** points that when connected identify trends (**information**), and when compared with previous observations or expectations develop **knowledge**, which then informs **actions**. These are powerful tools for increasing the **speed** and **fidelity** of decision making on the fire, but they suffer from two limiting links. Those two are (1) the traditional wildland fire decision-making processes and (2) the people who have trained and operated within those practices for years. If your decision-making process and training are built around receiving fire perimeter maps and hotspot location data that are 18-24 hours old, then they won't work when you have more accurate data that is less than 18-24 minutes old. To derive the most out of sUAS in the data-to-information-to-knowledge-to-action role processes and training must be adapted to leverage the **shorter cycle times** and **higher data fidelity** sUAS have brought to the wildland fire space. While sUAS can improve the performance and outcome of wildland firefighting, the majority of current sUAS models can largely only accomplish this indirectly.



Alone, without the necessary process and people optimization to fully realize the potential of this widespread "democratization" of the data, information, and knowledge that directs action from the third dimension, sUAS will not widely realize their potential to positively affect wildland firefighting outcomes.

Direct Support sUAS – Currently, OAS is field-testing the first sUAS to provide direct support to firefighters. Building on the success of the 2016 Aerial Ignition sUAS test at Homestead National Monument, OAS collaborated with industry to develop an sUAS-based aerial ignition capability. In the current fire year (2018), OAS UAS Division personnel conducted successful operational firings on the Taylor and Klondike Fires, supporting burnout operations in steep

(75 degree slopes) terrain and heavy timber and underbrush. This direct sUAS capability reduces the hazard to firefighters who might otherwise be called on to hand fire the burnout on such slopes. It also eliminates the risk of using manned helicopters in this hazardous mission. Since 2005, two helicopters and five lives have been lost conducting aerial ignition.

Direct Support UAS – Optionally Piloted Aircraft – Optionally piloted aircraft have been around for decades, often used as military drones or targets, yet possessing the flexibility to fly with a pilot, adding to the aircraft's versatility. Optionally piloted aircraft offer several advantages over built from scratch unmanned aircraft. First, they are built with features and system redundancies designed to ensure the safety of their human occupants. These features and redundancies increase their reliability and ability to sustain flight even in the face of degraded operations. Second, they are equipped with avionics that allow them to be "electronically seen" and tracked by other aircraft and ground control stations, reducing their chances of an unintended encounter with another aircraft. Finally, they are visually larger than today's small drones and coupled with their installed lighting, make them far easier to see and avoid than most UAS. It is important to remember, **any aircraft can be modified to operate as an optionally piloted aircraft**. While the following discusses one platform that has achieved this capability, other aircraft, similarly configured would also be of interest.

Optionally Piloted Aircraft in Afghanistan – In war in Afghanistan, the U.S. Marine Corps faced a significant challenge in providing necessary logistics support to their forward operating bases. The enemy's use of improvised explosive devices (IED's) made the use of ground convoys dangerous and uncertain. While helicopters could avoid this threat by flying necessary supplies from secure bases to forward operating areas, pilots and their helicopters were desperately needed for the combat missions for which they were trained and designed. Taking a page from the history of optionally piloted aircraft in the military, the Marines collaborated with industry to take a commercial helicopter designed and used for

large cargo lifts (Kaman's KMAX helicopter) and convert it into an optionally piloted helicopter capable of providing over-the-horizon logistics support to forward posts, without a pilot aboard. During a three-year deployment to Afghanistan, two optionally-piloted KMAX helicopters delivered over 4.5 million pounds of cargo, without a pilot.

Optionally Piloted Helicopters in Aerial Wildland Firefighting Missions – The use of optionally piloted aerial helicopters could become an important component of the DOI wildland firefighting effort by supporting the unmanned delivery of aerial suppressant/retardant, cargo, and supplies to

firefighters on the line, particularly in remote areas or in situations where conditions limit manned aerial support. They could also perform the emergency extraction of injured firefighters during nighttime operations and periods of reduced visibility when manned aircraft are unable to fly on wildland fires. This would also leverage approximately $123M in previous Department of Defense research, development, test, evaluation, and operational funding used to field this capability with the U.S. Marine Corps in Afghanistan, in a helicopter used for aerial firefighting support for years.

Infrared Technology/Fire Detection/Earlier Initial Attack and Sustained Extended Attack - Optionally piloted aircraft, equipped with infrared technology that provides the ability to see at night and through smoke at night or during daylight periods of reduced visibility, can increase direct aerial attack, logistics, and emergency extraction support coverage. Many fires start in the late afternoon and aerial resources are unable to get to them before the following

morning. UAS's that are able to take direct tactical action on a fire during the night of the first operational period will greatly increase the chance of suppressing a fire in the early stages.

Logistics Support to Firefighters – Firefighters in the field often rely on helicopters to provide necessary resupply of food, water, fuel, and equipment. Unfortunately, the same issues of night and reduced visibility that currently prevent manned helicopters from engaging in active fire suppression up to two-thirds of each day (16 hours) also keeps them from providing critical logistics support to firefighters on the line. As a result, firefighters can find themselves in the field, but unable to fight the fire, waiting for conditions to improve so that manned helicopters can deliver needed supplies. Equipped with infrared and other technologies that enable it to see through the smoke, navigate and fly safety, an optionally piloted helicopter could deliver needed supplies 24/7 in all visibility. The KMAX helicopter used by the Marines had the capability to carry and precisely deliver four separate loads to distinct GPS locations on each flight.

Firefighter Safety – Emergency Extraction – Wildland firefighting is a dangerous endeavor. Between 2006 and 2016, nearly 41 accidents involving firefighters in the field, resulting in nearly 18 deaths occurred annually. In addition to the hazards from the fire and the heat, firefighters are at risk from injuries due to falling trees/tree parts, rolling rocks loosened by the fire, and accidents involving firefighting equipment such as chain saws. Often, a determining factor in the outcome of these accidents is the time required to get injured firefighters to adequate medical care. In response to this, firefighters have increasingly requested the addition of emergency personnel extraction capabilities to wildfire helicopter contracts as a way to reduce the time to get injured firefighters to appropriate medical facilities. Unfortunately, as with current fire suppression and logistics support, available technology and safety considerations limit the availability of emergency extraction support to approximately 8 hours of each 24-hour period. As a result, firefighters are without this potentially lifesaving support for up to 16 hours each day. Optionally piloted helicopters would have the potential to operate 24 hours a day. In the 2014 test flights of an optionally piloted helicopter in representative wildfire missions, the aircraft was able to safely and successfully deliver and retrieve a human-rated basket capable of carrying up to 16 people. This capability could also be useful in rescuing firefighters in danger of a burn over scenario when manned aircraft are unable to fly. Having optionally piloted aircraft in the field could greatly

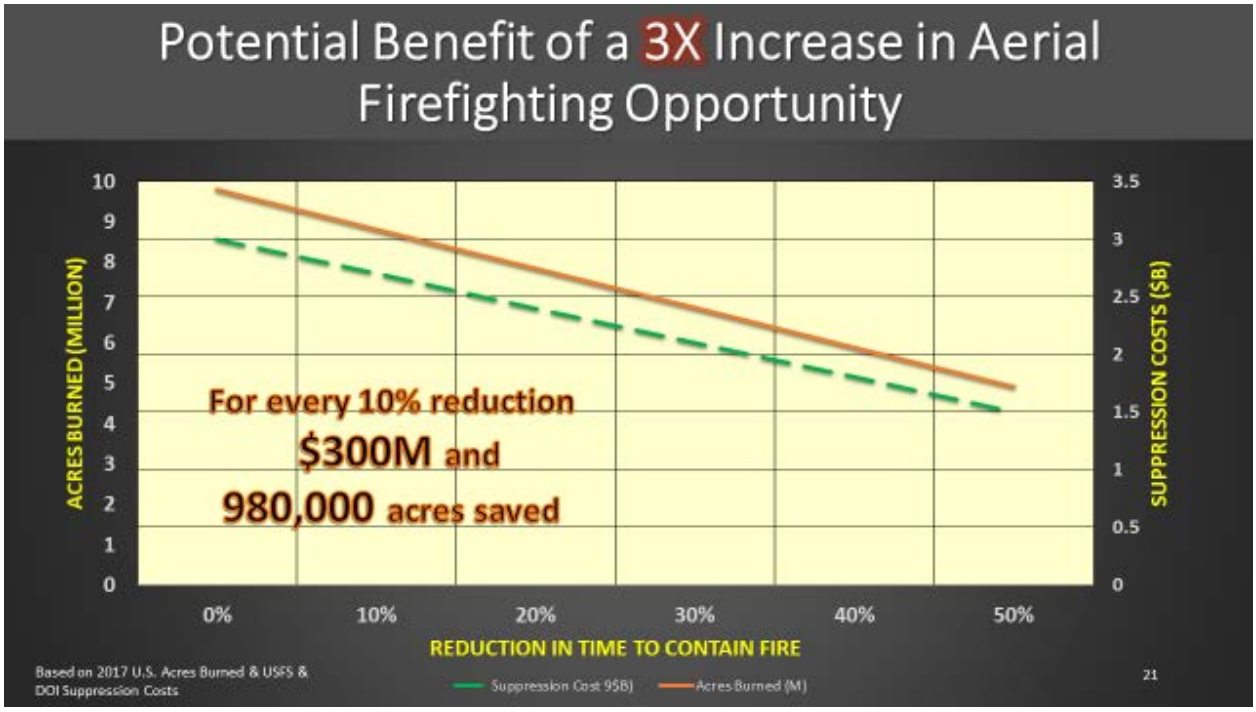
reduce firefighter injuries and deaths due to accidents by being able to transport injured/threatened firefighters to safety and medical facilities from remote locations.

Expected Future Outcomes – Optionally Piloted Helicopters – Optionally piloted helicopters, able to operate during the up to 16 hours (67%) each day when ground firefighters are not currently supported by manned aviation offer the promise of significant performance, cost, and safety outcomes.

Increased and Measured Performance - Expanded initial attack/extended attack and logistic support capability from optionally piloted helicopters represents a potential **200% increase** in **available direct aerial support time on the fire**. The optionally piloted helicopter technology tested in wildland fire mission scenarios in 2014 and 2015 was capable of dropping **over 3,200 gallons of water per hour per aircraft** (water source within several miles of the fire). Over the course of the up to 16 hours each day when traditional manned aircraft are unable to operate, a single optionally piloted helicopter of this variety could deliver **up to 51,200 gallons of water**. Night and early morning periods of reduced visibility when traditional firefighting aircraft don't fly are also periods of typically **diminished winds, lower temperatures**, and **higher relative humidity levels**. This is when the fire is most vulnerable and water/retardant delivered during these periods has increased effectiveness. Infrared imaging equipment used by optionally piloted aircraft to navigate and target their water drops has also demonstrated an ability to provide quantitative outcome effectiveness assessments of these drops by measuring the area covered and the difference in temperature achieved. This would represent a first in fire aviation and **would enable managers to gauge the outcome effectiveness of each drop and use this information to make next-drop adjustments as necessary**. One of the guiding principles of the ***National Cohesive Wildland Fire Management Strategy*** is ***"safe aggressive initial attack is often the best suppression strategy to***

keep unwanted wildfires small and costs down." Optionally piloted helicopters also have the potential to attack fires discovered near the end or outside of traditional daily aviation coverage. Wildfires, particularly those caused by lightning strikes often occur outside the traditional hours of aerial firefighting support. As was mentioned earlier, an examination of fire discovery times from 2015 through currently available 2017 data indicates nearly **20%** of all fires are discovered outside traditional air support hours. Of these, **66%** are discovered between the end of traditional flight operations and midnight, giving these fires the greatest opportunity to grow unchecked by aerial suppression. Conducting initial attack with optionally piloted aircraft, immediately rather than up to 16 hours later, when visibility would permit manned aircraft operations has the potential to prevent these fires from becoming the large, destructive wildfires that consume more than **90%** of wildfire suppression budgets. The ability of optionally piloted helicopters to expand available initial/extended attack and logistics support to firefighters by up to **200%**, provide a first, real time assessment of drop outcomes, and eliminate extended periods of time when nearly **20%** of newly discovered fires are allowed to grow unchecked by aerial resources offers game-changing potential to improve wildland firefighting performance through less time and reduced area to contain wildfires. Based on 2017 wildfire data, even a **10%** improvement in performance in reducing the area to contain wildfires would result in 980,000 less acres burned, annually.

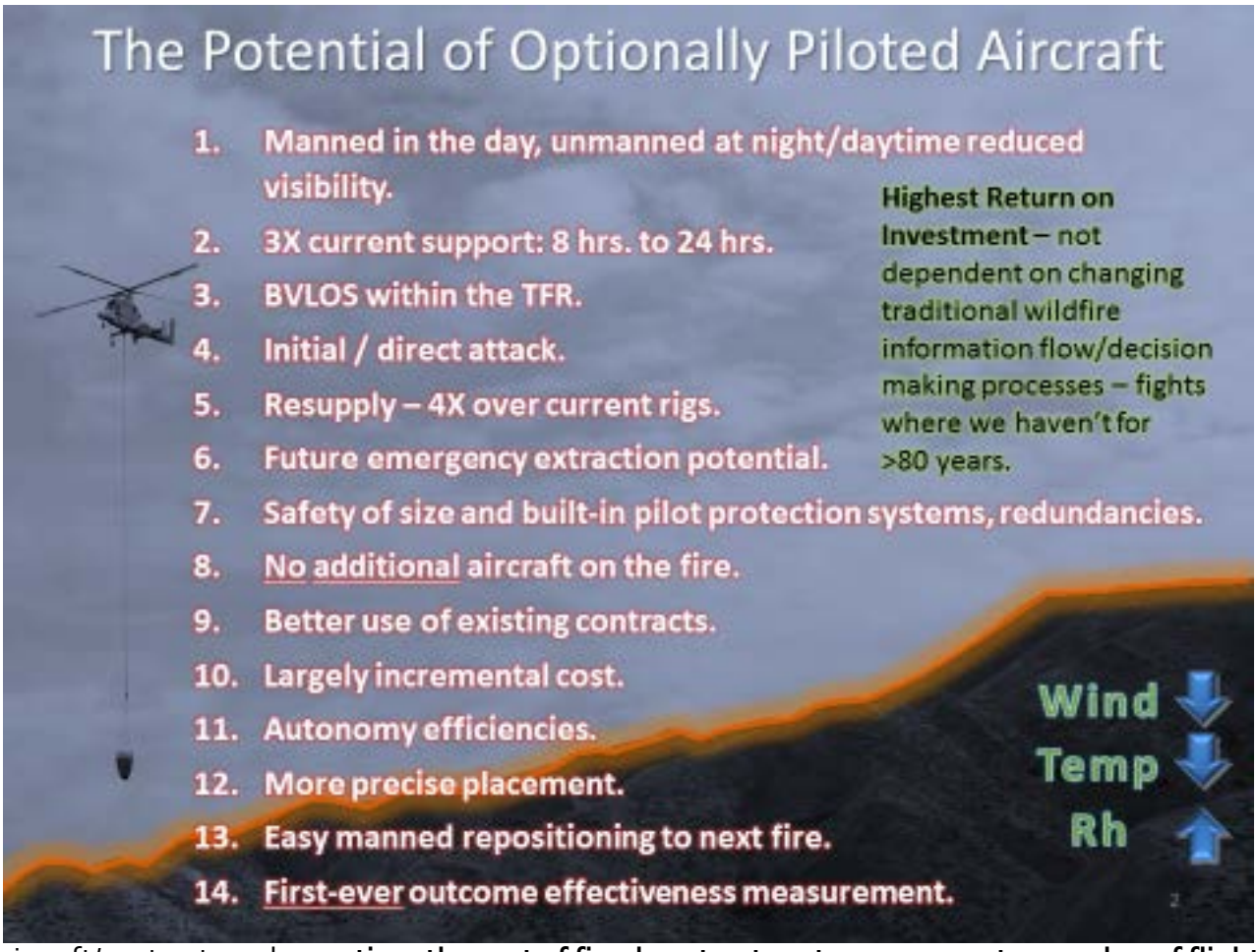
Cost – Optionally piloted helicopters also hold great potential to reduce wildfire costs. Through expected performance improvements discussed in the previous paragraph, wildfires should be contained quicker, with fewer acres burned than before. This should reduce personnel,



suppression, and subsequent emergency stabilization (ES) and burned area emergency response (BAER) costs. Based on 2017 DOI and USFS wildfire suppression expenditures, **just a 10%** reduction in suppression costs from **tripling** the aerial support opportunity would result in **a savings of $300M, annually**. While the expanded operations available through optionally piloted helicopters would result in some additional costs, these would largely be incremental, associated with the additional hours these helicopters are capable of covering (the cost to retrofit existing helicopters with this technology would quickly be paid for with the increased flight hours companies would enjoy.

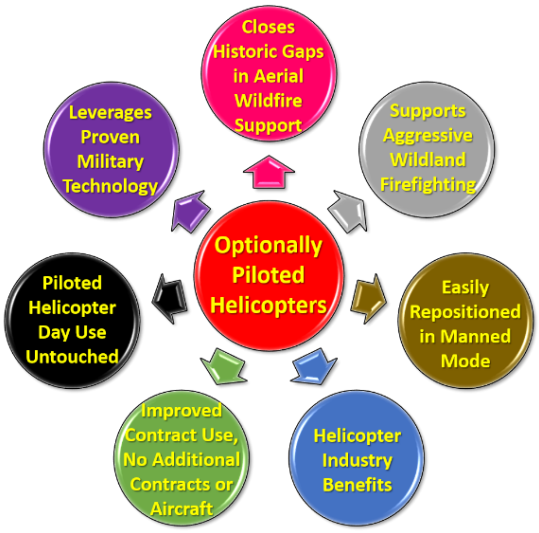
Currently, DOI and USFS contract nearly a dozen manned KMAX helicopters, annually. These are the same model converted to optionally piloted versions by DOD, used by the U.S. Marine Corps for logistics in Afghanistan, and successfully demonstrated in wildland fire tests in 2014 and 2015.

Concept of Operations for Integration with Current Wildland Firefighting Operations - The concept of operations for the use of optionally piloted helicopters on wildfire would be to operate them through the **same contract vehicles,** as we do today, with **no additional contracts or aircraft**. During traditional periods of manned aircraft operations on wildfire, **these aircraft would operate in the manned configuration with the same pilots that currently operate them today**. During night and daytime periods of reduced visibility when manned aircraft are unable to operate, these same helicopters would operate in the unmanned mode, controlled by a separate operator on the ground (possibly controlling up to three optionally piloted helicopters at one time). This eliminates the need for additional



aircraft/contracts and **amortizes the cost of fixed contract costs over a greater number of flight hours**. Commercial vendors offering optionally piloted helicopters would enjoy greater utilization

and attendant profitability, while the employing agencies would benefit from reduced time/costs to contain and rehabilitate burned areas. Once the fire is contained, optionally piloted helicopters would fly with their pilot to the next fire, eliminating the current regulatory and coordination issues with attempting to fly UAS within the NAS. Communities protected by optionally piloted helicopters should experience less economic loss through fewer acres, homes, and businesses burned.

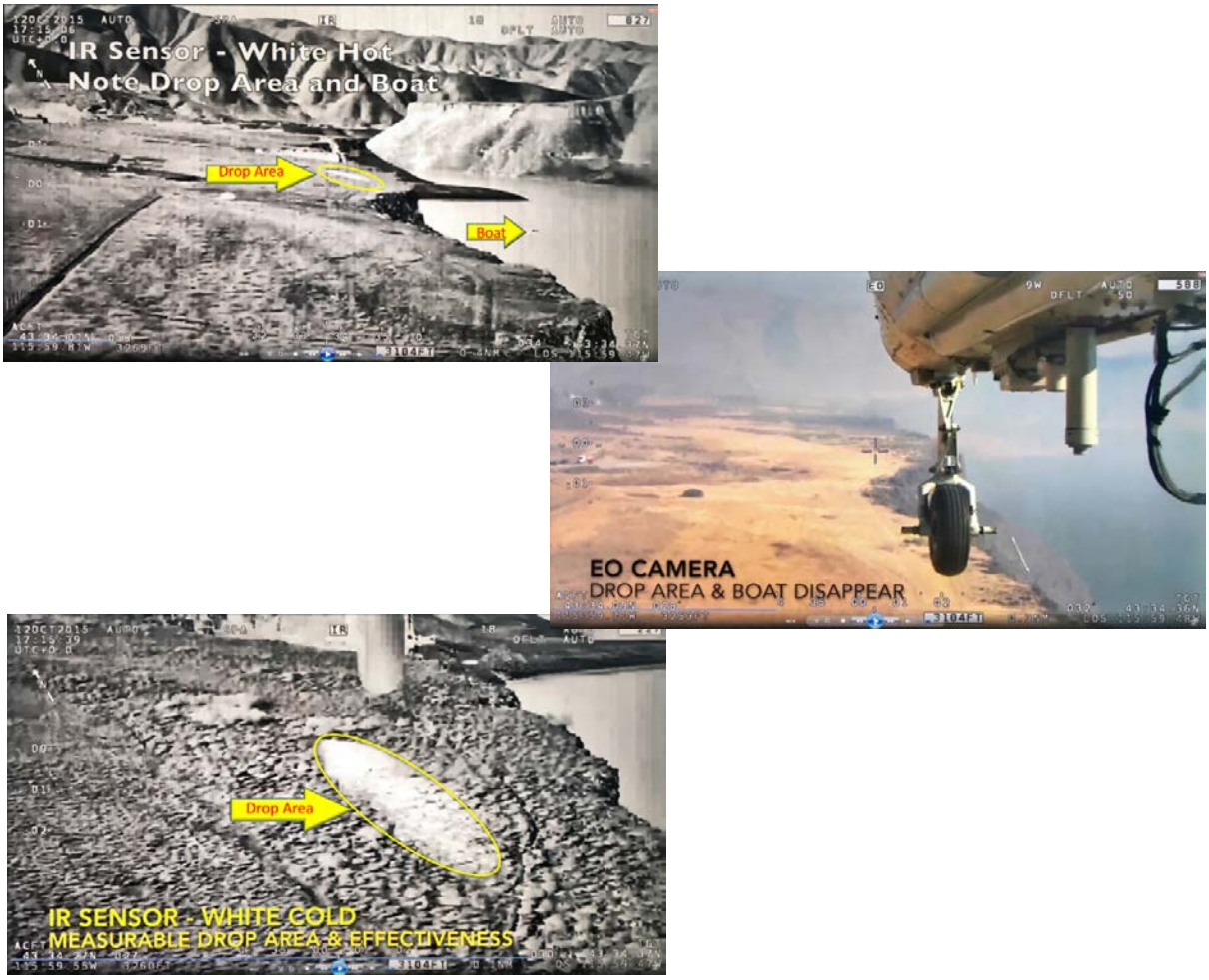


Why Not Optionally Piloted Fixed Wing Air Tankers and Scoopers? – If optionally piloted helicopters hold such promise to fill the approximately 16 hours a day when traditional manned aircraft are unable to support wildland firefighters, what about applying the same technology for fixed wing air tankers and water scoopers? While optionally piloted fixed wing aircraft have been around longer than optionally piloted helicopters, there are two significant barriers to integrating them into the wildand fire mission space. First, since UAS are not fully integrated into the National Airspace System (NAS), flying these air tankers and scoopers from the airports where they are based and serviced to the fire requires extensive prior planning and establishment of significant additional provisions (e.g. chase plane, restricted air corridors that could impact commercial air traffic, etc.) to ensure the safe transit of these aircraft from and back to their airports (and water sources in the case of scoopers). Second, the flying and residential public's acceptance of large, unmanned aircraft flying from commercial airports has not been fully studied and tested. There are numerous cases where optionally piloted aircraft have been required to fly in the manned configuration from commercial and even military airports and either reconfigured to the optionally piloted mode at remote fields or have the crew bail out after setting the aircraft up to fly unmanned. While optionally piloted air tankers and scoopers could eventually overcome these barriers, it is more likely the incorporation of advanced sensors, precision navigation, and synthetic vision could first permit the use of manned tankers at night and in

reduced daylight periods before full UAS integration into the NAS and public acceptance of large UAS on commercial airports is achieved.

Optionally Piloted Helicopters in Wildland Fire – Current Status and Next Steps – The 2014 and 2015 industry-funded demonstrations of optionally piloted helicopter technology in a variety of wildland fire missions confirmed the promise of this technology to close a large gap in current aerial firefighting support. These demonstrations were part of Phase 1 and Phase 1 Amendment #1 of the 2015 Interagency Unmanned Aircraft Systems Technology Demonstration Overview, signed by the federal agencies responsible for setting requirements for wildland fire aviation (four DOI bureaus and the U.S. Department of Agriculture, Forest Service). While both optionally piloted helicopter flight demonstrations met the required exit criteria of their respective test phases, the interagency wildland fire community prioritized available resources on the integration of sUAS in wildfire ahead of the continued integration of optionally piloted helicopter technology. As a result, follow-on testing and operational integration phases have not been conducted.

2015 Optionally Piloted Helicopter Demonstration – Boise, Idaho



Optionally Piloted Helicopter Technology

Summary

- Since aviation first supported wildland firefighters over 88 years ago, significant gaps in aerial outcome data, ground resupply, and initial and extended attack have remained during periods of night and daytime reduced visibility, approximately 2/3rds of the day.
- Small unmanned aircraft systems (sUAS) provide data, information, and knowledge at the tactical/division/strategic levels in the day, at night, and during periods of reduced visibility.
- However, sUAS productivity and success is largely dependent on having intake, analyses, and decision-making processes tailored to take advantage of the speed, volume, diversity, and detail of available drone-derived data. This requires a fundamental cultural shift of processes and people. These are the limiting links of sUAS in the wildland fire mission.
- Currently, the only use of sUAS in a direct fire support role is in the aerial ignition mission (prescribed burns, burnouts, back fires, etc.). This is currently in operational testing.
- In comparison, optionally piloted helicopters (OPH) promise to close the gaps in current direct support during the **~16 hours** where no direct aerial support has existed for 88 years.
- Developed and successfully fielded by the U.S. Marine Corps, OPH offer the following ***"first-ever" game changers*** for night and during daylight periods of reduced visibility:
    - Initial attack on the ~20% of all fires discovered after traditional air operations cease.
    - Extended attack when fires are most vulnerable (temperature, winds down, Rh up).
    - 24/7 emergency extraction capability for injured firefighters.
    - 24/7 logistical resupply to firefighters on the line.
    - First-ever outcome measurement of suppressant drop effectiveness.
- OPH successfully completed demonstrations in various wildland fire missions in 2014 and 2015 as part of an interagency UAS Technology Demonstration Program.
- DOI and interagency priorities on integrating sUAS put further OPH testing on hold.
- OPH would triple (**3X**) the available time in direct aerial support of fires and firefighters.
- Based on 2017 data, every 10% reduction in the time and space to contain wildfires would equal approximately **$300M** in suppression funding saved, and **980,000 acres** not burned.
- OPH use would leverage ~$123M already invested by DOD in development and operations.
- OPH would operate as manned aircraft in the day, as helicopters do today. At night and into daylight periods of reduced visibility, OPH would fly in the unmanned mode, operated from the ground, providing direct attack and logistic support to the fire. OPH would not increase the number of aircraft on the fire, but would increase aircraft utilization, amortize contract costs over more flight hours, provide increased revenue for vendors, and fill critical initial/direct attack, resupply, and emergency extraction coverage gaps.
- Following the successful 2014 and 2015 OPH demonstrations, the interagency fire community prioritized integration of sUAS in wildland fire.