Special Wildland Firefighting Tactics (SWiFT): How a Conventional Military Approach Can Bring an Unconventional End to Destructive Wildfires

A Monograph

by

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14. ABSTRACT

This monograph argues that the US Air Force (USAF) can utilize fighter/bomber aircraft capabilities and Air National Guard (ANG) infrastructure to help extinguish deadly US wildland fires while saving billions of dollars typically lost in the destruction. Explosive weapons technology and sonic booms create overpressure waves of air that "blow-out" fires much like a birthday candle. These concepts are proved using both anecdotal and scientific evidence from the US, Russia, and Sweden. The USAF already uses both ANG and reserve Modular Airborne Firefighting System (MAFFS) equipped C-130s to help extinguish wildfires in the continental US and territories. Current Air Force North and ANG infrastructure is ready to accept this new mission with minor changes to processes and authorities. Combining the infrastructure and technology together creates the SWiFT program. When operational, SWiFT can help save lives and precious land typically consumed by fire. This monograph also addresses social issues and effects from enacting SWiFT along with considerations leaders can take to ensure public approval. Lastly this monograph describes the next steps the USAF can take to begin testing and creation of the SWiFT program.

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Abstract

Special Wildland Firefighting Tactics (SWiFT): How a Conventional Military Approach Can Bring an Unconventional End to Destructive Wildfires, by Maj Joseph E. Gagnon, 41 pages.

This monograph argues that the US Air Force (USAF) can utilize fighter/bomber aircraft capabilities and Air National Guard (ANG) infrastructure to help extinguish deadly US wildland fires while saving billions of dollars typically lost in the destruction. Explosive weapons technology and sonic booms create overpressure waves of air that "blow-out" fires much like a birthday candle. These concepts are proved using both anecdotal and scientific evidence from the US, Russia, and Sweden. The USAF already uses both ANG and reserve Modular Airborne Firefighting System (MAFFS) equipped C-130s to help extinguish wildfires in the continental US and territories. Current Air Force North and ANG infrastructure is ready to accept this new mission with minor changes to processes and authorities. Combining the infrastructure and technology together creates the SWiFT program. When operational, SWiFT can help save lives and precious land typically consumed by fire. This monograph also addresses social issues and effects from enacting SWiFT along with considerations leaders can take to ensure public approval. Lastly this monograph describes the next steps the USAF can take to begin testing and creation of the SWiFT program.

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Abbreviations

AC	Aerial Attack Coordinator
ANG	Air National Guard
C2	Command and Control
CalFire	California Department of Forestry and Fire Protection
CAT	Category
DoD	Department of Defense
FAA	Federal Aviation Administration
GBU	Guided Bomb Unit
GOES	Geostationary Operational Environmental Satellite
IC	Incident Commander
MAFFS	Modular Airborne Firefighting System
Mk82	Mark 82
NASA	National Aeronautics and Space Administration
NDAA	National Defense Authorization Act
OPCON	Operational Control
NIFC	National Interagency Fire Center
PL	Preparedness Level
psf	Pounds Per Square Foot
RFA	Request for Assistance
SECDEF	Secretary of Defense
SWiFT	Special Wildland Firefighting Tactics
USFS	United States Forestry Service
USNORTHCOM	United States Northern Command
VIIRS	Visible Infrared Imaging Radiometer Suite
WFF	Wildland Firefighting

Figures

Introduction: “SWiFT”

“If at first the idea is not absurd, then there is no hope for it.”

—Albert Einstein

There has been a slow 2023 California wildfire season for the California Department of Forestry and Fire Protection (CalFire) operations center. As July moves to August, firefighting operations will move into higher gear with the increasing wind speeds and higher temperatures. In Los Angeles, the biweekly state wildfire operations meetings have an air of positivity. State and local firefighting meeting representatives tend to move quickly through their presentations showing fires popping up all around the state. Everyone agrees that the number of fires has not changed over the last fifteen years, but this year, the number of large or dangerous wildfires is zero. CalFire leadership consensus is clear: the United States Air Force’s (USAF) new Special Wildland Firefighting Tactics (SWiFT) capability is saving lives and keeping the state safe.

As the meeting ends, a CalFire operator receives information on a possible fire north of Los Angeles in Ventura County, California. The operator logs the fire into the CalFire database and assesses the situation. The fire is located in a forested area fifteen miles from the closest known residence. Although the fire is in a remote area, the winds are high, and the terrain shows dangerous characteristics that can lead to rapid wildfire growth. This new fire seems to meet all the new parameters required for a USAF SWiFT mission. The CalFire operator relays the information to his leadership and quickly agree that all pre-determined parameters are met for USAF intervention. CalFire sends a request for aircraft support to the operations center at United States Northern Command (USNORTHCOM) in Colorado Springs, Colorado and the Federal Aviation Administration (FAA) representative in the same location. The USNORTHCOM operations floor chief and FAA representative quickly analyze the fire location, pick the closest aircraft Air National Guard (ANG) base, and send the alert message.

The Fresno, California-based 144th Fighter Wing' scramble' siren sounds for the third time in twenty-four hours. Two alert F-16 pilots run to their aircraft as fast as possible. The pilots begin to envision their mission as they strap into their ejection seats and start their engines. The maintenance crews pull chocks from the wheels and salute the taxiing aircraft. The lead pilot looks through the glass canopy over the horizon to see a small billow of smoke atop one of the southern mountain ranges. The sky is clear in the Californian early August afternoon allowing the pilots to see for miles. As the two aircraft taxi to the runway, they get a radio update from CalFire telling them the approximate fire location and that it threatens a small mountain town. They also receive information on wind direction and the size of the fire. With that information, the two F-16 pilots begin to formulate a plan. The airfield tower clears the two fighter jets for takeoff on a direct course to the fire over 100 miles away. The SWiFT team is airborne.

En route to the fire, the aircraft travel over the speed of sound. Their speed places them anywhere in a 100 miles radius in under eight minutes. In those eight minutes, the pilots ensure their guided munitions are turned on and are showing ready for release. The fire extinguishing bombs are just like any other low-lethality weapons used in combat and just as incredibly accurate. The bombs are said to extinguish any wildfire within 100 meters of its impact point. As the aircraft approach the aircrew hear a radio call from Los Angeles Center controllers, "all aircraft in vicinity of Ventura county, evacuate the area immediately, Air Force firefighting aircraft are inbound and will be releasing ordnance from an altitude of fifteen thousand feet." The pilots scan their radars in the vicinity of the fire for civilian air traffic but see nothing. Eight minutes pass, the two fighter pilots arrive at the immature two-acre fire and begin their search for civilians near the potential impact point.

The search concludes with no sight of civilians, with the pilots beginning their bombing runs. From fifteen thousand feet, they can drop the munitions one-by-one with pinpoint accuracy. Aiming at the front of the fire, they know that a single munition will not extinguish the flames but will significantly reduce its size. The wingman is the first to release. She aims, receives clearance to release, then drops her weapon. The firefighting weapon guides from high above directly on its target using global positioning system (GPS) guidance. The ground proximity sensor tells the munition to explode at the height of twenty feet above the ground to ensure maximum effect. As the weapon detonates, the carbon fiber skin disintegrates, allowing a shock wave to spread over 100 meters across the ground and over top of the flaming trees. Within seconds the pilots can see the northern half of the fire is gone. With more passes on the southern half of the flames, the lead pilot extinguishes the fire entirely. After a few low passes ensuring no other flames, a water-carrying helicopter arrives to douse the charred remains.

After the low passes, the pilots receive a digital message from USNORTHCOM showing another fire's location. Although they have no ordnance remaining, they can utilize a secondary firefighting technique: a sonic boom. Once the aircraft arrive at the new fire, the pilots analyze the fire's terrain and location. The analysis is time-consuming, but necessary, to ensure a supersonic pass can be safely executed. After a brief conversation over the radio, both pilots agree to a north to south 300-foot pass over the fire location. They relay the information to the Los Angeles Center and set up for the pass. The lead aircraft takes a mutual support role remaining high above the fire as the wingman descends low, north of the flames. As the wingman turns south, pointing at the fire, she places her throttle in maximum afterburner, ensuring Mach 1 or greater speed. As the supersonic overpressure wave passes over the forest, a small dirt trail and leaves can be seen lofting from the ground. Once the sonic boom overpressure wave reaches the fire, it pushes the flames off their heat source immediately, extinguishing all flame in the area. The wingman begins to climb as the lead pilot looks down to give an overall assessment. The pilots execute additional low supersonic passes. Other ground-based fire units arrive to continue to fight the now smoldering ashes.

The pilots return to their base in less of a hurry than when they left. While in flight, the F-16s contact CalFire over the radio to report their actions and assessed effect. After landing, a video teleconference (VTC) after-action is completed with CalFire, USNORTHCOM, and the

FAA. Lessons learned are recorded and shared with other firefighting aircraft units to ensure proper continuity. The aircraft are refueled, re-armed with the same type of ordnance, and placed waiting for the next call to action. While the day may is over for all involved in this story, the fires continue to ignite and burn. However, with the new USAF capabilities, the nation's infrastructure no longer faces a wildfire threat.

This vignette is as much hypothetical as it is plausible. What is not plausible, but real, is the destruction wildfires have recently brought to the United States. The 2020 wildfires in California, Oregon, and Colorado devastated to both civilian neighborhoods and local, state, and federal infrastructure. The 2018 fire season was the deadliest and most destructive wildfire season on record for California, with almost two million acres burned, over 24,000 structures damaged or destroyed and at least 100 confirmed fatalities.[1] Although the 2019 fire season saw a slight reduction in damage, the 2020 wildfires in California, Oregon and Colorado are beginning to reach epic proportions regarding size and damage caused to state and local infrastructure. The five largest fires in California history burned in 2020.[2] Global climate change contributing to an increase in average temperatures that reduce rainfall in already dry areas adds to the frictions in traditional firefighting techniques.

The Active Duty (AD) USAF and ANG can bring a firefighting capability with fighter and bomber aircraft that no other organization or platform can deliver. Weapons of war with large overpressure blast waves can be turned against destructive fires. Current state and federal command and control (C2) infrastructure can be used to ensure safe weapons delivery and efficient processes. Civilian and military tactics can be combined to create a new way to fight

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[1] Kyle Mizokami, "Should the U.S. Air Force Bomb Forest Fires?" *Popular Mechanics,* August 8, 2018, accessed 12 August 2020, https://www.popularmechanics.com/military/weapons/a22674251/air-force-bomb-forest-fires/.

[2] Kim Christensen, "NIFC 2020 Overview" (virtually presented at the annual meeting for USNORTHCOM WFF AAR, December 15, 2020).

fire. It is time to capitalize on these capabilities and use new non-traditional techniques to ensure the United States' safety against destructive wildfires.

Section 1 of this monograph details the relationship between sonic boom overpressure waves and flame extinguishment. Chapter 1 also uses a small historical vignette and experiments conducted in this field to show how the relationship may be proven correct. Establishing the science first will establish a basis for further testing and research in this area. Chapter 2 will describe the relevance of the ANG infrastructure and show the reader how current ANG C2 can be utilized to increase efficiency and decrease the cost of instituting the new program. Understanding the ANG will then allow the reader to understand how the AD Air Force, state, and local infrastructures can integrate into the new capability. Chapter 3 centers on the social and environmental issues with using these proposed capabilities. Mitigating as much risk in the name of safety and social acceptability will be necessary to maximize this new idea's potential.

Chapter 1 – The Science

The application of military technology in non-military uses is an everyday occurrence for almost all humans. A most common innovation is the advent and use of duct tape. In World War 2, Vesta Stout, an ammunition plant worker, developed a new adhesive to seal boxes carrying weapons and ammunition. The new tape was water repellent and easy to remove, allowing soldiers to access the boxes quickly.[3] The military application soon became an everyday household item. Duct tape seals boxes, not just for the military, but for all people. The use of duct tape has expanded from sealing chemical biohazard suits to aiding in wart removal.[4] Adaptations of other military inventions, such as radar and the computer, are used differently from their initial

[3] Jasmin Kim, "The History Behind Duct Tape," *Business Insider,* January 25, 2019, accessed 13 August 2020, https://www.businessinsider.com/duct-tape-strong-versatile-adhesive-stick-anything-2019-1.
[4] Dean R. Focht III, MD, Carole Spicer, RN, Mary P. Fairchok, MD, "The Efficacy of Duct Tape vs Cryotherapy in the Treatment of Verruca Vuldaris," *JAMA Perdiatrics* (October 2002), 971-974, accessed 14 August 2020, https://jamanetwork.com/journals/jamapediatrics/article-abstract/203979.

intended use.[5] It is not hard to believe that a military-grade weapon or military produced sonic booms can be adapted to meet a civilian need.

To understand how a SWiFT team can use an aerial delivered munition or sonic boom to stop a wildfire from spreading requires a basic understanding of fire, explosions, and the experimental findings in the field of shockwaves and fire suppression. Fire requires three elements to exist: fuel, heat, and oxygen. A fire's fuel can consist of anything that will burn or accelerate a fire, such as wood or gasoline. Fuels have different chemical properties that will cause different burn rates (i.e., gasoline will burn much faster than a hardwood tree). This paper will assume the fuel of a forest fire is any low-lying grass and any forested tree. The second element, heat, is delivered from a specific source. This heat source is what starts the fire. Forest fires start naturally or with unnatural human actions such as arson or fireworks. For this paper, we will assume the fire is started by a human or naturally by lightning. The third element of fire, oxygen, is delivered from the air around us. Although this is a near consistent element, the only differing factor from fuel and heat is the speed at which the oxygen is physically moving or wind. The faster the wind, the faster the fire will grow and move across the ground. The faster the fire grows, the less time an aircraft has to use an explosion to extinguish the fire.

This paper will reference the most commonly used Air Force munition, a Mark 82 (Mk82) bomb, when referring to an explosion. A Mk82 is a 500lb class weapon, approximately four feet long, with an outer steel casing filled with explosive. This explosive is usually Tritonal, which is a composition of Trinitrotoluene (TNT) and aluminum powder. The Mk82 has a fuse or ignition source on its front, side, or tail. The fuse starts a chemical reaction through the Tritonal, which builds pressure in the steel casing. When the steel casing can no longer hold the pressure, it breaks apart in an explosion of fragmented steel and energy.

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[5] Allison Lex, “9 Things Invented for Military Use that You Now Encounter in Everyday Life,” *Mental Floss,* October 21, 2012, accessesd 15 August 2020, https://www.mentalfloss.com/article/31510/9-things-invented-military-use-you-now-encounter-everyday-life.

"Frag" or fragmentation is caused by the bomb's steel casing breaking up into thousands of different sized pieces. The steel pieces spread out in a circular 'frag pattern.' In fighting a fire, fragmentary objects are useless and potentially harmful to the forest and any inhabitants. However, to counter the Mk82 frag pattern, using a BLU-129 Very Low Collateral Damage Weapon (VLCDW) could be used to minimize the number of fragmentary objects. The BLU-129 uses a carbon fiber casing to house the explosive material rather than a steel casing. Upon detonation, the carbon fiber casing disintegrates from the blast, releasing the overpressure wave. The energy is in the form of a shockwave visible to the naked eye (Figure 1).

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Figure 1. Explosive Shockwave. Socraticmethod88, "Visible Shockwave from an Explosion," Reddit, November 12, 2019, https://i.redd.it/jbx7x4a66em21.jpg.

A shockwave is the combination of an overpressure energy wave and the air trailing behind it. The overpressure is a sharp change in pressure caused by an explosion or an object moving faster than sound, like a bullet or fast-moving aircraft. Another term for shockwave is "overpressure wave." Overpressure waves travel above Mach 1, about 761mph at sea level, also known as the speed of sound. Trailing an overpressure wave created by an explosion is a large amount of air (Figure 1). Overpressure waves are measured in kilopascals (kPa) and referred to as "peak overpressure." Peak overpressure refers to how much pressure the wave exerts above normal atmospheric pressure at sea level, which equals 100 kPA. When the overpressure wave dissipates to zero peak overpressure, it ceases to exist. Mk82 bombs produce as much as 117kPa at sixteen meters from the detonation point.[6] This peak overpressure and the air behind it, traveling near supersonic speeds and is powerful enough to knock over people, vehicles, and buildings. The previously mentioned BLU-129 allows for a slightly higher peak pressure due to the carbon fiber casing's reduced strength. While a fire is much different from a standing building, it is plausible that an overpressure wave can knock out a flame from its source.

In 2016, an experiment found what part of an explosion's properties could extinguish a flame. In New Mexico, scientists placed a 1.42m length 100-grain detonating cord (detcord) inside a steel "shock tube" (Figure 2).[7] The shock tube was then placed in front of a propane flame. The detcord was exploded and caused a shockwave to depart the shock tube. Slow-motion video and retroreflective recordings (Figure 3) showed the flame being carried away from the propane fuel source without reignition. The shock tube was placed at different distances from the propane flame and offset laterally. Except for one test, the propagating shockwave extinguished all flames. More importantly, the overpressure wave carried the flame away from the fuel source without the trailing air ever touching the flame. This important experiment shows that an overpressure wave is extinguishing the flame, not the air behind it. Using these findings, we can understand that an explosion that can create a more massive overpressure wave is more important than creating a large plume of air behind it.

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[6] Geneva International Centre for Humanitarian Demining, *Explosive Weapon Effects* (Geneva: Explosive Weapons Project 2015-2016), 47, accessed 16 August 2020, https://www.gichd.org/fileadmin/GICHD-resources/rec-documents/Explosive_weapon_effects_web.pdf.

[7] P.M. Giannuzzi, M.J. Hargather, G.C. Doig, "Explosive-driven Shock Wave and Vortex Ring Interaction with a Propane Flame," *Shock Waves,* no. 26, (2016): 852.

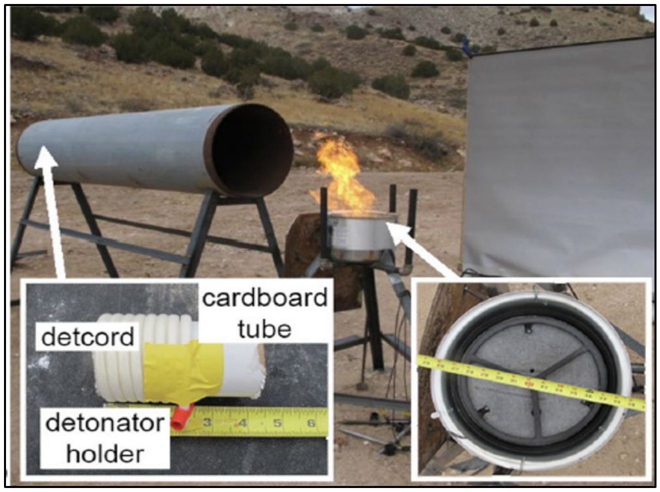

Figure 2. Experiment Setup. P.M. Giannuzzi, M.J. Hargather, G.C. Doig, "Explosive-driven Shock Wave and Vortex Ring Interaction with a Propane Flame," *Shock Waves*, no. 26, (2016): 852.

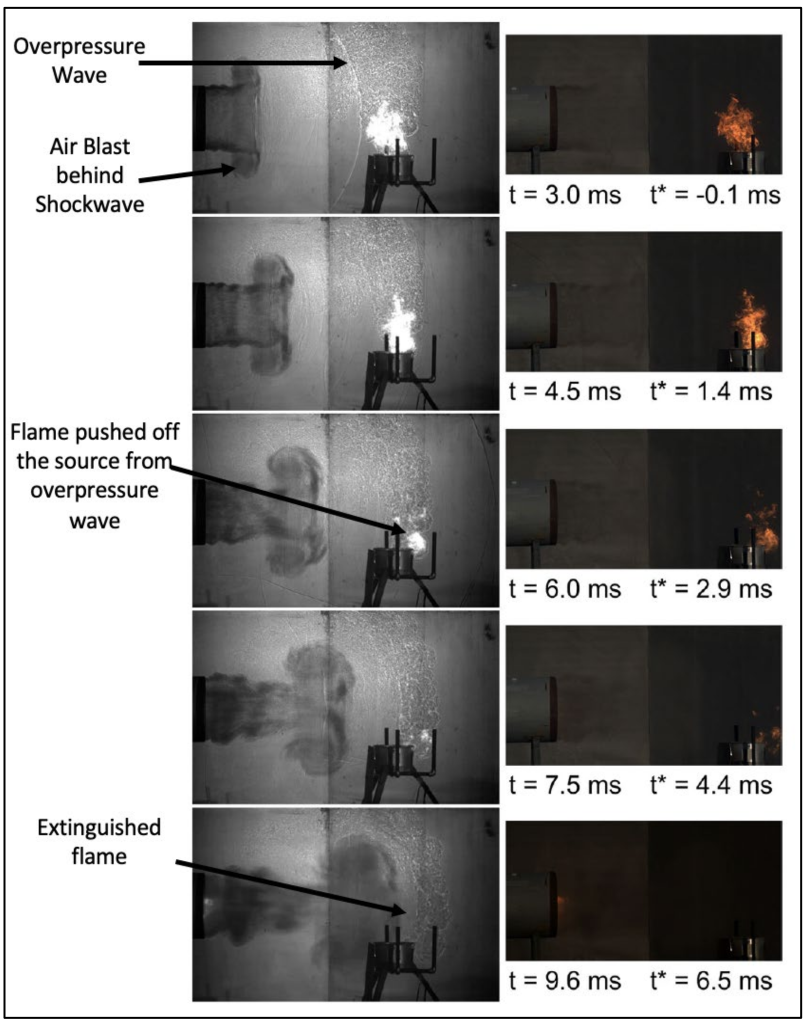

Figure 3. Overpressure Wave Extinguishing a Flame. P.M. Giannuzzi, M.J. Hargather, G.C. Doig, "Explosive-driven Shock Wave and Vortex Ring Interaction with a Propane Flame," *Shock Waves*, no. 26, (2016): 854.

A 1992 experiment conducted in Siberia, Russia, also showed an explosion's shockwave could extinguish a forest fire.[8] Scientists created two thirty-meter forest bands. One fire band was burned, and the other, acting as the control group, was not. A small cylindrical charge exploded on the first fire band that was set aflame. The second band ran the same explosion without any flame to observe differences in falling debris. The entire first band fire extinguished when the explosion was complete. The second band explosion showed slightly less fallen debris than the first band. This experiment was successful in showing a shockwave extinguishing a controlled fire. Another discovery was that the shockwave pressure intensified when it interacted with the front of the forest fire and the charred carbon remains it was producing. The Russian scientists concluded the intensification was due to the shockwave interaction with an explosion of gas-fuel products and air of the already burning fire. The gas-fuel products are remnants of the forest pyrolysis or charred remains. These remains are re-ignited upon interaction with the shockwave and oxygen in the area. The amount the shockwave was intensified is unknown and remains open for interpretation and experiment. However, other empirical evidence exists to support the SWiFT idea.

Swedish Air Force Vignette

On 25 July 2018, a Swedish Air Force JAS-39 Gripen fighter aircraft successfully extinguished a small forest fire after it guided a GBU-12 laser-guided 500lb bomb onto the flames. The fire, located on a Swedish military bombing range, had crept onto the impact area outside the range boundaries. The fire crews were unable to fight the fire due to the possibility of unexploded ordnance on the military range. The aircraft was airborne with live ammunition for a training mission and received permission to drop their weapons on the fire in hopes of putting it

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[8] A.M. Grishin, "Interaction of Shock Waves with Tree Crowns and the Front of Crown Forest Fires," *Shock Waves,* (1995): 411.

out. Although data was scarce regarding the event, the weapon reportedly had a "very good effect" on the fire.[9]

As the GBU-12 impacted near the fire center, it let out a massive shockwave of energy in a propagated circular pattern. Much like a ripple on a pond, this shockwave continued to spread out over time and space until it dissipated its energy and cease to exist. During the initial blast, the shockwave had enough velocity and power to knock over trees in its path. The peak overpressure of an Mk82 bomb body, the one used in a laser-guided GBU-12, is around 117kPa at sixteen meters from the point of detonation with wind speeds traveling approximately 200m/s.[10]. At thirty-one meters, the peak overpressure reduces to 34kPa, reducing wind speed to approximately 70m/s. This data means that a blast wave circle with a sixty meter diameter propagates a pressure wave that can collapse most buildings. The Swedish Air Force case study involved the use of a steel casing and yet remained moderately successful.

There are other options available in the world of military technology. The Mk82 and BLU-129 are considered conventional explosion weapons using a small amount of fuel combined with a large oxidizer. The opposite of conventional explosions is thermobaric explosions. Thermobaric weapons are only filled with fuel and use the surrounding oxygen around the bomb to create an explosion rather than a fuel-oxidizer mix inside a standard conventional weapon. A thermobaric bomb is unlike a conventional US Air Force bomb in that it has a lower peak pressure at the time of the explosion, but the duration of the pressure wave is longer.[11] This data means less damage will be caused to the surrounding area but retains a strong enough pressure

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[9] Dave Cenciotti, "Watch a Gripen Jet Drop a GBU-12 Bomb to Stop a Forest Fire Raging Near a Military Range in Sweden," *Business Insider,* July 25, 2018, accessed 17 August 2020, https://www.businessinsider.com/watch-a-gripen-jet-drop-a-gbu-12-bomb-to-stop-a-forest-fire-in-sweden-2018-7.

[10] Geneva International Centre for Humanitarian Demining, *Explosive Weapon Effects* (Geneva: Explosive Weapons Project 2015-2016), 47, accessed 17 August 2020, https://www.gichd.org/fileadmin/GICHD-resources/rec-documents/Explosive_weapon_effects_web.pdf.

[11] Kristian Oskar Vuorio, "The Use of Thermobaric Weapons," *Finland Defense University*, March 2015: 7, accessed 18 August 2020, https://www.researchgate.net/publication/322553927_Use_of_Thermobaric_Weapons.

wave to extinguish flames. This pressure wave is longer in dimension than a standard conventional weapon allowing more extinguishing time. Thermobaric weapons may be a better option and will require further study. The use of violent weapons is a social downside, but there is a way to create an overpressure wave without a bombs' assistance.

Sonic Booms

Overpressure waves may knock a flame off its source, but not all overpressure waves are created from an explosion. An alternate way to create an overpressure wave is by using aircraft traveling faster than sound speed. Understanding sonic booms require knowledge of sound waves. Sounds travel in waves, much like the ripples on a pond except that sound travels in a three-dimensional sphere.[12] When a sounds wave is transmitted, it creates a change in pressure through a medium like air. Any change in wavelength or volume represents a change in air pressure. The louder the sound, the larger the change in pressure. When an object travels faster than the speed of sound, it creates an overpressure wave commonly referred to as a sonic boom (Figure 4). A supersonic aircraft's sound waves are compressed at the edge of a shock cone that trails behind the aircraft, creating the sonic boom. A human being can hear the sonic boom overpressure wave passing by them in the form of a loud, deep sounding boom. This boom is the sound of multiple sound waves hitting the eardrum at one time rather than average individual sounds waves heard one after another. If close enough to the sonic boom source, a rush of air passes by after the sonic boom shock wave.

[12] Educational Video Library, "Sonic Boom Explained – How is it Created," March 31, 2017, accessed 19 August 2020, https://www.youtube.com/watch?v=1pf-Is2S1_Q.

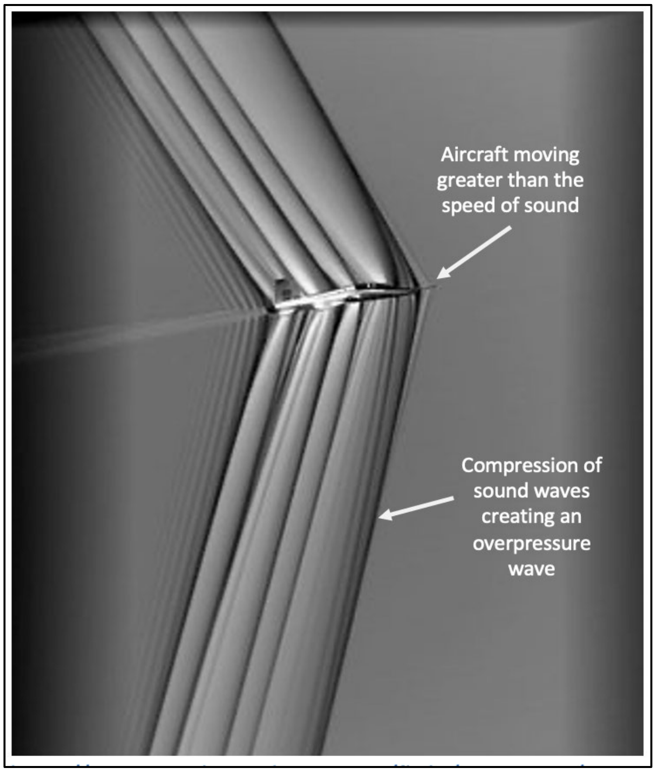

Figure 4. Supersonic Aircraft Shockwave. Yvonee Gibbs, “NASA Armstrong Fact Sheet: Sonic Booms,” *NASA*, August 14, 2017, https://www.nasa.gov/centers/armstrong/news/FactSheets/FS-016-DFRC.html.

As an aircraft flies over Mach 1, a three-dimensional shock cone trails behind the aircraft. The shockwave's width upon impact with the earth's surface is roughly one mile for every 1000 feet of altitude.[13] Meaning an aircraft at 20,000 ft above the earth's surface will have a sonic boom cone that is twenty miles wide or ten miles on each side perpendicular to a plane's flight path. The shockwave on the ground and the overpressure wave are measured in pounds per square foot (psf). Sonic booms flown at 100 feet have produced overpressure waves up to 144 psf or 6.89 kPa.[14] While the pressure change near an explosion is much more significant than from a sonic boom, it may be possible that the lower pressure change can knock a flame off its source. Unfortunately, the New Mexican and Russian experiments did not record the pressure of the

[13] Yvonee Gibbs, “NASA Armstrong Fact Sheet: Sonic Booms,” *NASA*, August 14, 2017, accessed 19 August 2020, https://www.nasa.gov/centers/armstrong/news/FactSheets/FS-016-DFRC.html.
[14] National Aeronautics and Space Administration, *NASA FACTS: Sonic Booms,* accessed 16 September 2020, https://www.nasa.gov/centers/dryden/pdf/120274main_FS-016-DFRC.pdf.

overpressure wave at impact with the flame. It is difficult to know whether a sonic boom overpressure wave is powerful enough to extinguish a flame.

Using a sonic boom overpressure wave is a more palatable option for the public than using an explosive weapon. Any aircraft that can fly over Mach 1 creates a sonic boom. An aircraft such as the B-1 bomber produces a high-pressure sonic boom due to their broader cross-section or size. The cost of a sonic boom option would also be much cheaper than using aerial delivered weapons.

While inconclusive, using a conventional weapon, a thermobaric bomb, or a sonic boom, enough research shows that these options show a significant ability to combat forest fires. The USAF, Department of Defense (DoD), and state governments need to fund direct testing of all three methods to measure their effectiveness. After proving the science, the Federal government and state governments can decide if this new technique has merit. If merit exists, then a C2 infrastructure will need to be established to provide oversight of operations and ensure safe business practices. The next chapter will discuss what C2 may look like using current federal and state-run infrastructures.

Chapter 2 – Procedures, Command, Control and Infrastructure

In the early morning of 24 April 1980, Operation Eagle Claw commenced with the lift-off of three USAF MC-130s carrying over one hundred US special forces troops and civilians.[15] The joint special forces mission was to combine Air Force aircraft and refuelers, Army special operations soldiers, and Navy helicopters. Together, these forces would leave Oman's shores, fly into hostile Iranian territory, rescue American hostages, and safely fly out. Unfortunately, problems met the mission immediately that led to failure in less than forty-eight hours. Although scarred by the joint special operation Eagle Claw's failure, the end of April 1980 contains lessons

[15] Mark Bowden, "The Desert One Debacle," *The Atlantic*, May 2006, accessed 21 August 2020, https://www.theatlantic.com/magazine/archive/2006/05/the-desert-one-debacle/304803/

to be learned. The first mission of its kind, designed to rescue American hostages held in Iran, is studied by Army Command General Staff College students and multiple military universities as an example of what not to do.

The Holloway Report, commissioned in 1980, described why Eagle Claw was unsuccessful. Lack of C2 at intermediate leadership levels, lack of comprehensive full-scale training, and the ad hoc nature of the organization and planning are common themes used in the report to describe how the military can learn from the past events.[16] The commission came to a simple conclusion "by not utilizing existing Joint Task Force organization, the Joint Chiefs of Staff had to start, literally, from the beginning…before attaining even the most rudimentary mission readiness." The USAF can use the Holloway Report's lessons to frame the challenges of developing a C2 infrastructure to fight forest fires using SWiFT. The USAF can create a simple yet efficient firefighting system by utilizing and modifying existing federal and state firefighting infrastructures and command relationships. In addition, any SWiFT participants must conduct detailed, comprehensive training with all participants to find any shortfalls and uncover inefficient practices.

This chapter will address the logical sequence of a firefighting mission and propose the process of C2 and the design of a modified military firefighting infrastructure. The fast-moving nature of aircraft and fires requires rapid information passage and quick decision making by ground and airborne crews. Events such as fire detection, information passage, decision making, and action authorization will portray critical areas of the sequence. These key areas also emphasize the foundational theme of centralized control, decentralized execution. Infrastructure must also be flexible to changing conditions of the environment. Ensuring the most efficient form of C2 will promote likely success in these new firefighting missions.

[16] Special Operations Review Group, Joint Chiefs of Staff, May 1980.

Current Fire Detection and Reporting

The ability to quickly extinguish a fire is dependent on the time in which the firefighting asset arrives. The earlier assets reach the fire's ignition, the better the extinguishment chances are based on its size and intensity. There are many types of detection capabilities to ensure the earliest possible arrival of the flames. The most common fire detection source is reported visible fires, as citizens identify a distant fire and call an emergency line.[17] These reports are useful, but do not detect all fires, especially those not big enough to be seen by a passerby or hiker. Another method of detecting wildfire is through the use of digital cameras. These cameras are usually placed in austere locations atop mountain peaks. The high elevation usually gives video cameras a 360-degree view of the terrain. Used by fire officials and civilians, these cameras can see the flame at short distances and smoke at further distances. The relatively low resolution, immobility, and reliance on long-range wireless networks can create problems with detecting a fire while it is still small enough to extinguish with minimal effort. Civilian technologies, such as heat cameras and visual smoke detection cameras, are available. When placed in the right position, these cameras can detect fires at other ranges and smaller strengths.

The last method of detection is through the use of orbital satellites. NASA uses the GOES-West satellite to detect fires in western US coastal states, the NASA VIIRS satellite to see small and big fires in the Amazon jungle.[18] Fusing all detection methods together can place firefighting C2 infrastructure on the quickest path to fire detection. Companies such as Northrop Grumman created programs to combine all the detection methods into an easy to use system that

[17] Peter Hannam, "Satellites, Sensors, and Drones Could Put Out Bushfires Within an Hour," *The Sydney Morning Herald*, September 15, 2020, accessed 30 September 2020, https://www.smh.com.au/national/satellites-sensors-and-drones-could-put-out-bushfires-within-an-hour-20200914-p55viv.html.

[18] Shanna Hanbury, "Game Changer: NASA Data Tool Could Revolutionize Amazon Fire Analysis," *Mongabay*, September 15, 2020, accessed 30 September 2020, https://news.mongabay.com/2020/09/game-changer-nasa-data-tool-could-revolutionize-amazon-fire-analysis/.

can rapidly dispatch fire prevention and firefighting units. C2 personnel could then use this in-place infrastructure to alert Air Force aircraft to a fire location.

Current State-Federal Firefighting Relationships and C2

The current state wildland firefighting (WFF) infrastructure uses Federal support only when the state and local governments determine that their firefighting capabilities have been exceeded or exceeded in the near future, known as "surge capacity."[19] Once made, this determination results in a request for Federal services through predetermined channels. The Federal government makes a decision and what services to provide. Much like any bureaucracy, the relationship between local, state, and national firefighting infrastructures can be confusing. Figure 5 can aid in further understanding.

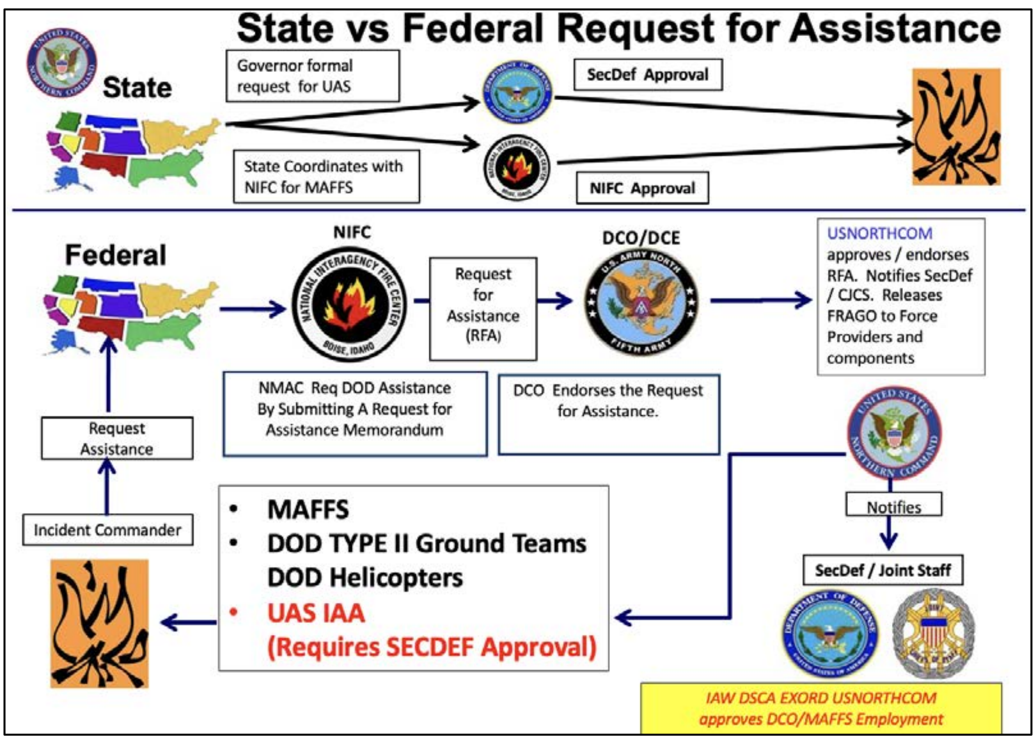

Figure 5. MAFFS RFA Sequence. US Northern Command, *WFF Process*, August 2020, 1.

After receiving report of a fire, the first decision to be made is: who is in charge? The location of the fire determines this decision. Suppose a fire occurs on Federal lands such as

[19] Major Benjamin Vail, phone conversation to author, November 23, 2020.

national parks or military bases. In that case, a Federal organization such as the US Forestry Service (USFS) or the Bureau for Land Management (BLM) will take the lead. If the fire is on state land, then a state organization, such as CalFire in California, will lead. After picking the lead organization, the next step is to determine whether crews will fight the fire. If the determination is in the affirmative, then the C2 process begins. Though federal and state organizations are different in infrastructure, appearance, and funding, the C2 is agnostic. C2 infrastructure for tactical control of firefighting is always conducted in the same way by the same organization independent of where the fire is. This allows fires to be fought in the same way independent of where the fire is burning.[20] At this point, a state organization such as CalFire take C2 for the operation.

As CalFire takes the lead, they will then make decisions based on the given current conditions. The current number of fires actively fought, wind speeds, weather forecasts and many other criteria are looked at to determine the level of response. Depending on the number of assets available, CalFire will decide where to send civilian rotary-wing aircraft and fixed-wing aircraft. Due to the Economy Act of 1932, governments may not choose to use DoD or Federal resources before exhausting cheaper civilian resources such as aerial tankers, helicopters, and ground crews. This law explains why we do not see many military WFF assets and their late commitment to WFF operations. One exception to the Economy act is the Stafford Act.[21] Under Section 420 of this Act the President of the United States may commit federal personnel and equipment to any fire that he/she determines to be a major disaster. If the fire is not deemed a major catastrophe by the President than WFF operations must continue through state and federal communication lines.

To set up for WFF operations, CalFire will designate an Incident Commander (IC). The IC becomes the officer-in-charge for that specific fire. The IC will determine what resources are

[20] Major Benjamin Vail, phone conversation to author, November 23, 2020.
[21] Robert T. Stafford Disaster Relief and Emergency Assistance Act, Public Law 93-288, 116th Cong., S.3418 (January 1, 2021).

needed and how crews will operationally fight the fire. If the IC determines that aerial assistance is required, then he/she will request specific types of aerial assets through CalFire based on size and capability. CalFire will also establish an airborne Aerial Attack Coordinator (AC) flying overhead to coordinate all aerial activities in conjunction with the IC. CalFire will then put a "callout" via a common operating computer program for specific types and sizes of assets. The aerial assets range between rotary-wing and fixed-wing and vary in size. The size is categorized by how many gallons of water or fire retardant carried in one load. Civilian companies with these capabilities monitor the callouts, determine if they can meet the requirement, and answer the request with their assets.

After the aerial firefighting vehicles arrive on the scene, they adhere to the on-scene AC's tactical orders. The AC directs all on-location WFF aircraft to their appropriate holding areas. When the WFF aircraft are ready to drop their load, they must meet up and follow a smaller lead aircraft. The lead aircraft flies directly over the designated drop area and releases a puff of smoke marking a point where the trailing WFF aircraft release their water or fire retardant. The WFF aircraft, trailing close behind the lead aircraft, follows the same flight path as the lead and releases their retardant or water at the same point as the small puff of smoke. After releasing their load, the aircraft continues to execute more drops or returns to their base of operations to reload. Rotary wing aircraft follow a similar procedure, but are directed to small spot fires due to their limited carrying capacity.

As resources are stretched thin and the number of fires increases over the windy fire season, individual states may need help from other providers. The request for assistance (RFA) process begins when the state government determines that they need Federal resources. The initial request for Federal assistance is sent to the National Interagency Fire Center (NIFC), headquartered in Boise, Idaho. As the fire season begins, NIFC personnel monitor fire activity and resources throughout the country. The data gathered while monitoring allows NIFC to set national preparedness levels (PL) one through five. The PLs "help assure that firefighting resources are ready to respond to new incidents. As the levels rise, more federal and state employees become available for fire mobilization if needed."[22] The NIFC also owns organic firefighting assets and capabilities.

If the NIFC runs out of its organic resources or anticipates the need for more assistance, then the NIFC will send an RFA to the DoD. This RFA varies by type of asset requested. The "Chairman Joint Chiefs of Staff Defense Support of Civilian Authorities Execution Order" (CJCS DSCA EXORD) categorizes (CAT) assets one through four.[23] Each CAT has different approval authority. The higher the CAT, the higher the approval required. Typically states will request either CATII or CATIII assets. CATII assets are grounds teams, helicopters, and C-130 Modular Airborne Firefighting System (MAFFS), requiring approval from the USNORTHCOM commander (CDRUSNORTHCOM)[24]. CATIII assets like Unmanned Aerial Systems (UAS) require Secretary of Defense (SECDEF) approval. Fighter or bomber aircraft would most likely fall into CATIII but would be better suited for CATII due to the lower approval authority.

The state government first forwards the RFA to the federal government via the NIFC. The NIFC has separated the country into ten Geographic Area Coordination Centers (GACC). Whichever GACC is associated with the RFA, will receive the RFA. The GACC will then forward the RFA to NIFC headquarters in Boise, Idaho. A Defense Coordinating Official (DCO), located at NIFC headquarters, will validate and forward the request to USNORTHCOM and notify/forward it to SECDEF. Servicing the RFA is determined by the approval authority. The approval authority will determine how and when to allocate resources. CDRUSNORTHCOM, as the supported commander, holds operation control (OPCON) or tactical control (TACON) of Title 10 assets supporting NIFC WFF. CDRUSNORTHCOM has coordinating authority for National Guard (NG) crews and support personnel in Title 32 status. NG units remain under C2

[22] "National Preparedness Levels," Fire Information, National Interagency Fire Center, accessed 12 November 2020, https://www.nifc.gov/fireInfo/fireinfo_prepLevels.html.
[23] Timothy Russell, USNORTHCOM NCJ3, conversation with author, 3 November 2020.
[24] Ibid.

of their governors unless federalized.[25] The only current USAF airborne firefighting asset is the ANG C-130 modular airborne firefighting system (MAFFS) (Figure 6).

Figure 6. C-130 with MAFFS. "Modular Airnorne Firefighting System," Wikipedia Foundation, last modified January 9, 2021, https://upload.wikimedia.org/wikipedia/commons/5/5e/C-130_Waterdrop.jpg.

If the RFA requires the use of C-130 MAFFS, the CDRUSNORTHCOM has two choices: a Title 10 reserve squadron in Colorado Springs or one of three ANG Title 32 squadrons in the US. It is incumbent upon the commander to use the reserve squadron first since he/she holds OPCON over the Title 10 units. It is harder to use the Title 32 units since state governors own them and require governor approval or mobilization from the SECDEF. State governors can activate their own MAFFS equipped squadron after assessing national needs for MAFFS aircraft.[26]

Three states own an ANG MAFFS capability; California, Nevada, and Wyoming. Each of the states has an ANG squadron trained and equipped to execute the MAFFS mission on 24-hour notice. Most states have a standing Operations Order (OPORD) with Air Force North (AFNORTH) allowing governors to pass coordinating authority to AFNORTH and use this capability rapidly. When a governor decides to mobilize their units, they do not have to follow the

[25] Timothy Russell, USNORTHCOM NCJ3, conversation with author, 3 November 2020.
[26] US Department of Agriculture, *Modular Airborne Fire Fighting System (MAFFS) Deployment, Operations and Training*, Forest Service, 6 August 2019, accessed 30 November 2020, https://www.nifc.gov/nicc/logistics/references/MAFFS_Operations_Plan.pdf

same C2 channels described above but must still adhere to the Economy Act. Governors may not use the MAFFS until all civilian assets are used, commonly referred to as "surge capacity."[27] If a state that does not own a military MAFFS capability, and wants it or needs more MAFFS resources, they must go through the RFA process. Once the WFF mission is complete, the same control authority executes the deactivation and redeployment of assets. If the WFF system adopts fighter and bomber aircraft to extinguish forest fires, then these two forms of C2, state and federal, can be utilized.

Modification to the Current System

Taking a note from the Holloway Report, the USAF can utilize many of the established processes and procedures for SWiFT. Using the in-place infrastructure will reduce the new mission's additional costs and allow the current WFF subject matter experts to be directly involved in Swift execution. The current system's direct coordination and C2 with ground crews increase safety mitigation techniques to ensure that air and ground crews are unharmed by falling explosives. The addition of a trained military terminal controller can help to mitigate risk of damage to people and property. State organizations and the USAF can quickly establish training between the associated civilian ground and aircrews as they are part of the current infrastructure. With this in mind, some distinct procedures and rules would ensure the new fighter/bomber mission's success.

The first significant addition to the WFF system is to allow the SWiFT aircraft on the ground or airborne to have direct access to the digital operational environment via digital maps used by C2 centers such as CalFire. The military has seen a drastic change in operational reach and an increase in tactical and operational capability by allowing the warfighter to see what the commanders see; and vice versa. Through systems such as digital data links, satellite communications, and common operating systems (COS), decision-makers and tactical operators

[27] Major Benjamin Vail, phone conversation to author, November 23, 2020.

can see the "big picture" together, which reduces confusion and increases efficiency. Introducing these concepts to WFF operators and decision-makers will reduce the amount of time it takes a message to be passed from the decision-maker to the operator. For example, a WFF aircraft may receive notifications that are too old to be acted upon by the time they receive them. In determining if the message is current, they may also miss an opportunity to extinguish a fire that is of more importance. Digital systems embedded in SWiFT aircraft can reduce message passage duration by instantly receive messages from C2 decision-makers via satellite or radio. This concept is even more critical for fighter/bomber aircraft that can arrive on the scene of a fire much faster than any other aircraft or ground-based platform.

The second significant change would entail new rules allowing for military aircraft first, rather than last. By generating a modification to the 1932 Economy Act and allowing states to use fighter/bomber aircraft at any point during the fire season, the mission would see a greater chance of success. Because there is a limited number of bombs and their effective theoretical radius is around a one-hundred-meter radius, this new tactic is best suited for small fires in remote areas. If the Economy Act is not changed or modified, then fighter/bomber aircraft would wait until all civilian options are exhausted and then brought into fighting large forest fires with many bombs and sonic booms. Resources would quickly become diminished as they are used in a method counter to the intended use.

In conjunction with the first, another significant change is creating a new agreement between the SECDEF and state governors to use reserve and ANG fighter/bomber aircraft that are trained and equipped to fight fires with the latest techniques. Typically, a fighter/bomber aircraft would be CATIII or higher, requiring SECDEF approval for use. This standing agreement would be in place during designated fire seasons. The agreement would change SWiFT aircraft from CATIII to CATII, and utilize those aircraft and crews rather than squadrons. The aircraft and crews would "deploy" to state hot spots during fire months and fly 24-hour operations over each state or maintain an alert posture while awaiting the launch order from a state official to extinguish a fire. An alert posture can ensure the aircraft can launch in a predetermined amount of time to affect a wildfire in the state. This procedure is done daily in many coastal states for national defense. An alternative to this agreement is to change the authority delegated within the CJCS DSCA EXORD. This change would allow the USNORTHCOM Commander to request and receive forces from the services and approve RFAs. Both of these actions would be on behalf of the SECDEF. Either of the options would contribute to a faster approval process.

Once this type of mission is approved, SMEs would create a new set of aircraft launch criteria to allow efficient and safe operations. The measures would be used by C2 operators to quickly decide if the use of USAF fighter/bomber aircraft is necessary and safe in a given fire and its surrounding environment. Figure 7 is an example of the proposed criteria.

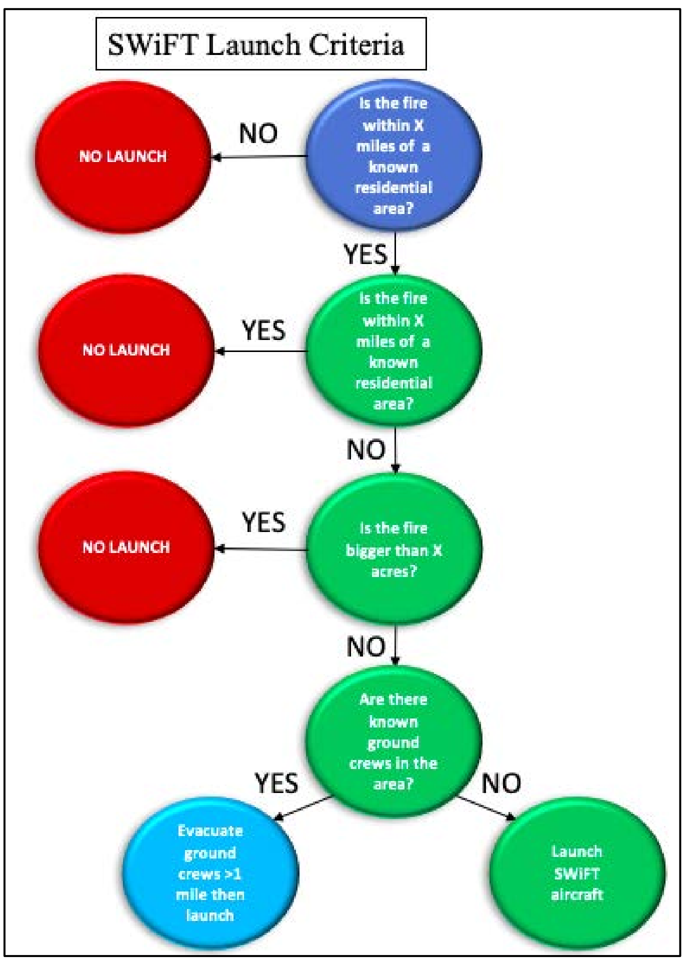

Figure 7. Possible SWiFT Launch Decision Tree. Author.

WFF training is another robust infrastructure in place and used by state and federal assets to practice current and new firefighting techniques. Every spring, CalFire, USFS, and the California ANG participate in a week-long training exercise to remain proficient in their skills and prepare for the upcoming fire season. These exercises usually include a civilian air attack aircraft coordinating all airdrops on a simulated fire along with a civilian lead aircraft that directs the C-130 MAFFS aircraft where to drop their load. This kind of training is precisely what the new mission would need to ensure all participants' safety. Although a week is modest, additional training would need to be in place to teach the unique processes involved and brief ground crews on new tactics, techniques, and procedures (TTP) when operating within the vicinity of large ordnance missions.

To avoid problems like those experienced in operation Eagle Claw, the USAF should utilize processes and infrastructure currently in place across the nation. These processes would have stood the test of time and are adaptable to change in the operating environment. The training system and C2 would need to be adjusted to account for the increased danger to ground and aircrews, but this is the inherent nature of wildland firefighting.

Chapter 3 – Combating Public Fear and Mitigating Risk

"If I had asked the public what they wanted they would have said a faster horse"

—Henry Ford

A mother kisses her 15-year-old daughter goodbye as she departs for a Friday evening with her boyfriend. As they parade down the front yard walkway, she yells, "make sure you are home by ten!" The mother softly closes the door, locks the latch, and looks up at the living room wall clock. "5 pm," she says under her breath, "five hours, and she'll be home." The apprehensive mother continues with her evening as planned, making dinner with the family, calling grandpa to see how he feels. Every few moments, she cannot help but think about what her daughter is up to; this is the first time she has allowed her teenager out this late. She wonders if she is ok and thinks about texting her to make sure. No, she thinks, her daughter will just be annoyed and probably not answer back. Nevertheless, what if she is not having a good time? Or worse, what if she is in trouble? Maybe that is why she has not called or texted since she has left. The mother decides to send a text "how is the date going?" she asks. No reply. Maybe she is in trouble, she thinks. "Are you ok?" she sends. No reply. The mom is starting to worry. All of the news stories and NETFLIX shows she has seen about missing children and murder continue to haunt her. She wonders, will my baby be ok?

This story is an example of "probability neglect."[28] Probability neglect describes a pattern of behavior in which "the amount of concern is not adequately sensitive to the probability of harm."[29] The mother's concern for the daughter's well-being is much different from the probability that harm will come to her child. The mother's emotional thoughts and social understanding of the potential of harm are blocking the reality of probability. The probability can be expressed as a fraction, where the numerator is the number of harmful events and the denominator being total events. The numerator is much less than the denominator, but the mother "neglects" the denominator while only thinking about the numerator. She is allowing her emotions to get the better of her while forgetting about reality. Placing importance on emotion over reality can happen to large segments of the public during times of change.

The 1989 "Alar Scare" occurred when apple growers began to spray a chemical known as Alar on their produce to create a better product.[30] While this was happening, media reports of potential cancer risks from the chemical permeated throughout the United States. The public began to protest and denounce the chemical's use with the fear of climbing its way to Congress. The apple industry sustained a large loss from the scare and stopped using the chemical. Later research showed that, while the chemical was a possible carcinogen, the chances of contracting

[28] Daniel Kahneman, *Thinking Fast and Slow* (New York, Farrar, Straus, and Giroux, 2011), 144.
[29] Ibid.
[30] Ibid, 143.

cancer were meager and within or near the Environmental Protection Agency (EPA) standards.[31] This event is not only an example of probability neglect but of Daniel Kahneman's "availability" and "affect" heuristics. The world-renowned psychologist has used these concepts to explain why humans tend to make choices based on feeling rather than knowing. The Alar example shows how, much like the mother and her daughter, the public can make decisions based on "how they feel" rather than "what they think." In Alar's case, the public did not have the information readily available to allow them to analyze data on the chemical, so they instead relied on easily "available" emotional information. The lack of information and public pressure led congressional leaders to outlaw the use of a chemical that could have potentially been good for the country and the economy.

To help the public accept the benefits of SWiFT, military and civilian leaders must avoid concepts like probability neglect and affect and availability heuristics. Ensuring the public knows the benefits and risks associated with the new system will allow the public to make their own information-based decision on accepting the SWiFT program. Public leaders must garner support from constituents across city and state lines to ensure the fewest political. Common doubts will be in play in the public's minds, such as unnecessary government intervention, unwanted military presence in the non-military matter, environmental protections, misallocation of funding, and, of course, corruption. These many valid public concerns need mitigation before enacting any new military-civilian relationship.

The trust in civilian-military (civ-mil) relationships vary from state to state and county to county. These relationships leverage help to launch the SWiFT concept. Some "politically conservative" states may be the best target for beginning the new program. Wildfires in conservative states such as Wyoming, Utah, and Montana present both social and ecological

[31] Nathaniel Sheppard Jr., "New Studies May Rekindle Apple Dispute," *Chicago Tribune*, March 30, 1989, accessed 30 September 2020, https://www.chicagotribune.com/news/ct-xpm-1989-03-30-8903300926-story.html

environment that may be friendly. The 153rd Airlift Wing in Cheyenne, Wyoming, maybe the best candidate in the state, already has a WFF C-130 MAFFS trained unit and an established infrastructure for fighting wildfires. Introducing the new program in the "friendliest" operational environment will then help other states garner support.

Another technique that will help improve public relations is naming the program, which is non-threatening to the public and avoids using the word bomb. The name should bring comfort to the local populace but still show the intent of the program. One possible name is Special Wildland Firefighting Tactics. The use of the word "special" implies that the program is new and unique. "Wildland Firefighting" is used to reinforce the purpose of the program. Recent experiences with forest fires will most likely draw support for new tactics. Avoiding the use of words that associate the military with the program can help avoid negative biases. While this is not the only option friendly program name may allow the public to accept it as necessary and not harmful.

The military must make available all information on the program for unfamiliar people and are fearful of the unknown. The information must show how the program's science works, much like chapter two of this monograph. Other information such as the cost, funding the program, and why it is better than current firefighting techniques must all be publicized to show nothing to hide. Those who may be skeptical of government programs will need this information to better understand that this new technique protects the public and public infrastructure rather than hidden meaning. To ensure that the message is fair, leadership must complete proper environmental testing and the surrounding public from localized blasts.

Explosions carry an inherent risk to anything within the blast area, along with many second and third-order effects that can spring up in the future. The most prevalent risk with this new WFF technique is to nature. States have established procedures to clear areas prior to allowing aircraft to drop water or fire retardant. SWiFT would require a more thorough search and closure based on a higher chance of injury from blasts. The impacts of explosions on the local forest, its inhabitants, and the ecological environment must be determined and mitigated before their use. While it is safe to assume that most animals tend to run away from fires, and thus the explosion area, it is hard to determine what the impacts are to the soil composition, insects, and root systems. Whatever the environmental impacts the EPA determines, they must be disseminated to the public to allow for fair opinion. Mitigation of risks to humans, wildland firefighters, and local infrastructure through established best practices and the development of new practices will ensure safety. The military executes combat close air support (CAS) worldwide daily, and their technical knowledge on the weapon capabilities is unmatched. Combining the CAS and technical knowledge with civilian safety protocols can mitigate immediate risks to the public and firefighters.

The public concern for safety will be one of the most challenging hills to climb for this endeavor. There may be only one shot to get this new technique off the ground and into the air, so civilian and military leaders need to make sure all bases are covered. Helping the public avoid pitfalls like the availability heuristic and probability neglect can ensure that decisions are made based on analysis and information rather than emotion. By showing the benefits outweigh the risks, we may help stop massive loss to forest fire damage.

Numerous steps such as funds appropriation, weapon testing and environmental impact studies must be taken to begin building the SWiFT idea into something tangible. The evidence provided in Chapter one shows enough data to make a credible hypothesis: an overpressure wave created by either a Mk82 explosion or supersonic shockwave can extinguish all or parts of a wildland forest fire. Pairing this hypothesis with the ability to protect state infrastructure from devastating wildfires can provide the necessary narrative to those in Congress and the military to begin appropriating funds for testing.

The testing must be done in conditions that most closely match those of a WFF in the western US. Weapons testing areas located in the southern portions of the country like Florida and Alabama may be avoided due to the flat terrain, humid conditions and low wind speeds.

Testing areas such as Arizona, New Mexico and California are better suited to ensure the best replication of dry environments ladened with conifer style trees. These areas also tend to be far away from local populace where threat of actual wildfire is low. The testing must also be executed in conjunction with WFF SMEs from state organizations to ensure the fire replicates that of actual California, Oregon or Colorado wildfires. The testing areas must also be approved for low altitude supersonic flying speeds. There are few areas in the continental US where these types of speeds are allowed at low altitude. The combination of all these characteristics may be difficult to find in one area but is possible.

Funding must be secured to execute the weapons testing and environmental studies. The cost of weapons testing will remain very low due the current existence both aircraft, weapons, SMEs and land. The preponderance of cost will be in the studies required to ensure less harm than good to our natural areas where the fires occur. These types of studies can take years to complete due to numerous living organisms and repeating third and fourth order affects. If funding is secured environmental studies in California and Oregon must begin immediately to ensure the SWiFT program can start as soon as it is ready.

Funding for this program is can be obtained through the yearly National Defense Authorization Act (NDAA). The NDAA is signed by the US Congress every year and represents the DoD's annual budget for the following year. When a program like SWiFT is signed into the NDAA it will be accompanied by authorization and appropriation. The yearly authorization bill and appropriation bill will define which agency is responsible for the SWiFT program and will also allocate the funds. The first request for SWiFT into the NDAA may be for testing funds and environmental impact funds. These funds would be microscopic compared to the annual DoD budget.

Conclusion

SWiFT may sound like a novel idea, but the concept this paper describes is not entirely new. USAF Lt Col Mike Benitez wrote a 2018 Popular Mechanics article about the same idea. During the research for this paper the author was contacted by numerous people that were either researching something similar or were just interested in the topic. There is no doubt that this small population of citizens interested in new firefighting techniques is much bigger what is we perceived. The research mentioned in Chapter 2 is evidence that others are trying to find a way to prevent or extinguish wildfires outside of current techniques. The scientific community is always searching for new ideas and concepts to solve current naturally occurring problems.

The philosopher Thomas Kuhn described change in the science field as Paradigmatic Change Theory.[32] The theory describes the scientific community, and other human communities, as operating under specific paradigms. These paradigms can be thought of as established ways of thinking. Ways that have been vetted over time through and used in discourse throughout the specific community. The theory also describes how paradigm change over time. This change or paradigm shift occurs when a crisis occurs that the current paradigm cannot solve. Thus, a new paradigm, or way of thinking, is necessary to solve the crisis. Once the crisis is solved with the new paradigm then the paradigm shift is complete.

SWiFT is the new paradigm and the 2020 record setting wildfires is the crisis. The time is here to begin testing new WFF techniques and SWiFT can lead the way. Along with other authors and interested parties, this paper can be another source of evidence that leads the way for new ideas and funding to protect the world's infrastructure.

[32] Thomas S. Kuhn, *The Structure of Scientific Revolutions, 3rd Edition* (Chicago, IL: University of Chicago Press, 1996) 5-75.

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