Methods Of Infrastructure Protection in The Face of Forest Fire

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ABSTRACT: This research paper explores the evolving perspectives on forest fires, their impacts on critical infrastructure, and potential solutions to mitigate damage. Initially viewed as natural and beneficial, forest fires became a threat with changing policies in the early 1900s, exacerbated by climate change. Recent devastating wildfires highlight the need for innovative approaches to protect lives and infrastructure. The study introduces the FirePod, a novel solution that safeguards homes from forest fires. The research evaluates the applicability of FirePod compared to existing protection methods, considering advantages, disadvantages, and real-world implications. The analysis reveals that each method has unique strengths and weaknesses, making identifying a universally superior solution challenging. However, FirePod's automated deployment system and potential to address the difficulties associated with other methods position it as a promising innovation.

KEYWORDS: Earth and Environmental Sciences; Forest Fire; Infrastructure Protection; FirePod.

Introduction

Forest fires are a regular occurrence in nature and beneficial for the forest ecosystem. Though these types of fires may have seemed destructive, they play a vital role in rejuvenating the environment. They clear away old growth, paving the way for new life to emerge, enrich the soil with nutritious ash, and create openings for sunlight to reach the forest floor.

As time has passed, however, our perspective on forest fires has shifted. In the early 1900s, a dramatic change occurred in the United States. With the establishment of the US Forest Service and the "1910s Fires", Fire suppression became the national policy, and efforts focused on extinguishing fires as soon as they ignited.[1] This policy reduced the immediate extent of forest fires but consequently led to a dangerous accumulation of highly flammable dead trees and brush on the forest floor. Our intervention essentially disrupted nature's natural balance. Additionally, global warming and its effect in creating increased drought(s) and a more extended fire season are boosting the risk of potential wildfire ignition.[2]

In today's society, the challenge of balancing our need to protect lives and infrastructures alongside the necessity of nurturing our forests has become increasingly evident. Spanning just 17 years, nearly 100,000 structures have been destroyed by wildfires and hundreds of billions of dollars' worth of damage—a stark reminder of the challenging task before us.[3] The question remains: How can we solve this seemingly impossible problem?

Table 1: The severity of damage resulting from forest fires. The fires listed in the left column are some of the historically known fires that occurred in the Greater North American area.

	Types of Damages			
Fire Names	**Economic Damage**	**Deaths**	**Destroyed Infrastructure**	**Acres Burned**
Camp Fire, 2018[4]	422 Billion Dollars	85 Civilian Fatalities	18,000 + Structures	153,336 Acres
August Complex, California[5]	319.8 Million Dollars	1 Death	935 Structures	1,032,648 Acres
Elephant Hill Wildfire, BC[6]	8+ Billion Dollars	*No record*	123+ Structures	474,442 Acres
2020 California Wildfire Season[5]	12.079 Billion Dollars	33 Deaths	10,000+ Structures	4,300,000 Acres

Literature Review of Existing Systems

This section will discuss three preexisting infrastructures followed by our newly developed hybrid solution to infrastructure protection called FirePod.

I. SPRINKLER SYSTEM:

Key Issue:

One of the main problems with forest fires causing damage to infrastructure is that firebrands and airborne debris can breach windows, and convective heat and embers can penetrate utility openings, gaps around doors, and other openings. This can lead to the interior of a building catching fire even when the exterior does not.[7]

1. Interior Sprinkler System:

Figure 1: Sprinkler system layout inside an infrastructure. This is currently one of the most widely used fire protection systems (Walnut Creek).[8]

DOI: 10.36838/v6i8.4

Before addressing the exterior sprinkler system that one might refer to in preparing for a forest fire, it is crucial to know the sprinkler system that people are fond of, the interior sprinkler system, as shown in Figure 1. Residential fire sprinklers, designed for homes, are triggered by heat detection using a glass bulb containing an expandable glycerin-based liquid. When this liquid is exposed to heated air, it expands, shattering the glass and initiating a response to release water. According to Patterson, these sprinklers remain active until manually deactivated, effectively extinguishing flames.[9] Despite their high effectiveness in reducing deaths and property damage by over 65 percent, the discharge of 60 gallons of water per minute poses a risk of substantial interior water damage. Such damage can compromise the structural integrity of homes, causing wood absorption, rot, and potential collapse.[10] Moreover, untreated water damage may adversely affect electrical systems, corrode plumbing, and lead to the destruction of ceilings and walls, fostering mold growth.[10]

2. Exterior Sprinkler System:

The purpose of an exterior fire sprinkler is to "saturate the exterior of the building", as can be seen in Figure 2, in addition to its surroundings, to "minimize the opportunity for ignition".[7,11] It commonly operates through either a low-voltage heat detector or the manual enabled by the owner. The standard location for installing exterior fire sprinklers is the roof, "under the eave at the edge of the roof and on the property, in which case the sprinklers are directed at the home from multiple locations surrounding it".[11]

According to Fire Safe Marin, the exterior fire sprinklers should protect the infrastructure from three primary wildfire exposures: Wind-Blown Embers, Radiant Heat, and Direct Flame Contact.[12]

The sprinklers can be set up to use water piping either through the attic, roof, or externally along the structure. If the preference is for interior pipes, the passage suggests that exterior sprinklers can still be incorporated alongside them. Additionally, it proposes considering a standalone system equipped with a pressurized holding tank to ensure a reliable water supply. The importance of referring to information on water supply for interior fire sprinklers is emphasized.[7]

Figure 2: Exterior sprinkler system. This sprinkler system has the added benefit of protecting the outside of the building as well as the inside (Blaze Control).[13]

Frontline Wildfire Defense:

The Frontline Wildfire Defense System integrates specialized hardware and robust software into a comprehensive package, providing the means to face wildfire season confidently. This all-encompassing solution is accessible through a smart mobile app as shown in Figure 3 below.[14]

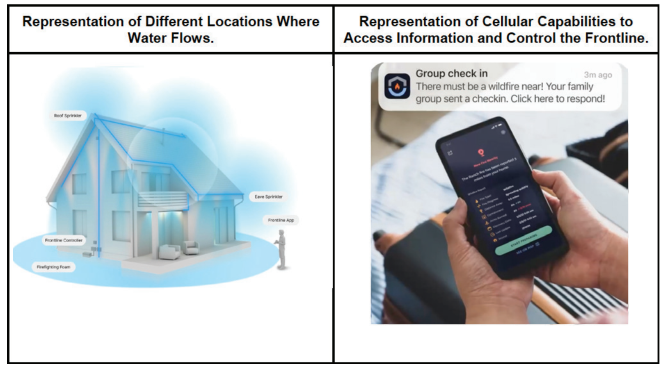

Figure 3: Illustration of the device location and functionality. The smartphone app works as a control tower (Frontline Wildfire Defense).[14]

Summary of the Product:

Frontline Wildfire prioritizes the safety and lives of the owners of the infrastructure through the ability to track approaching wildfires and "the all-new Auto Activation feature [that] automatically turns on your Frontline system when a fire is within seven miles".[15] In addition, according to Frontline, each Frontline system is equipped with WiFi, cellular, and satellite connectivity, along with a dedicated backup battery demonstrated from the images of the Frontline website shown in Figure 3.[15] Even in the event of a power outage or a loss of cell service, you can maintain connectivity to your Frontline system, ensuring you can protect your home from any location.

Incorporating this feature significantly impacted the design of the FirePod's safety system, enabling the integration of advanced technological applications. Specifically, this allows for the manual deployment of the device with the simple press of a button. The research conducted on the Frontline system was instrumental in broadening our conceptual framework, facilitating the inclusion of remote safety features. This enhancement ensures that infrastructure owners can confidently evacuate the area, and ensure their property remains protected through automated and reliable safety mechanisms.

II. FOAM SYSTEMS:

Figure 4: Foam Sprinkler System. This differs from the interior and exterior sprinkler system by utilizing chemicals rather than water as a depressant (SV Fire Systems).[16]

In 1902, a Russian engineer and chemist, Aleksandr Loran, developed the first firefighting foam while looking for a solution to combat "petroleum-based fires for which water is wholly ineffective". He invented the firefighting foam that smothers and blankets oil and other flammable liquids-based fires.[17] Beginning in the 1960s, the Naval Research Laboratory or "NRL" in cooperation with the 3M Company" started to develop the existing foam.[17] This collaboration and further modification of the foam allowed the development of the current form of Aqueous-forming foam known as "AFFF". The surfactant in the NRL's AFFF, which is fluorochemical-based, lowers the surface tension of water. This enables the formation of foam that creates an aqueous film on the surface of hydrocarbon fuel, as shown in Figure 4. This film serves to suppress vapors, deprive the fuel surface of oxygen, and inhibit evaporation, thereby preventing the subsequent reignition of the fuel.

The foams can be split into Class A foam and Class B foam. According to STAG, Class B firefighting foams are employed to tackle fires involving flammable or combustible fuels of Class B. On the other hand, Class A foams find application in wildfires, as do other Class A combustibles like wood and paper. The inception of Class A foams occurred during the 1980s in response to the demand for effective control of wild forest fires. The surfactants utilized in Class A foams exhibit a particular attraction to carbon, enhancing the efficiency of the foam/water solution in penetrating burning combustibles such as trees and wood.[17]

In referencing Courteney Weed from Reliable Fire and Security, foam suppression systems share a design similarity with wet sprinkler systems, wherein stored water travels through a network of pipes before being released through nozzles. Incorporating a foaming agent sets foam systems apart from conventional wet sprinkler setups. Unlike traditional systems, the foaming agent is stored independently of the water, and the blending of the two occurs within the piping system just before discharge. "The foaming agent is added or ejected into the water at the very last moment before discharge. When the water mixes with the foaming agent, expansion occurs, creating an immense foam coverage to fill expansive areas".[18]

1. Foam Sprinklers and Nozzles:

Minimax specializes in manufacturing stainless steel nozzles designed for low-expansion foam extinguishing systems. These exclusive nozzles are crucial in producing low-expansion foam, commonly used in storage areas. Nozzles are preferred for applications such as protecting filling stations, filling tank vehicles, or safeguarding specific objects like hydraulic units or indoor areas such as drum stores.[19]

2. Foam Maker/Foam Chamber/Foam Pourer:

The "Tank Foam RTK" kit by Minimax, consisting of coordinated components—foam maker, foam chamber, and foam pourer—is specially designed to protect flammable liquids in fixed roof tanks.[19] This system generates low-expansion foam that is compatible with a variety of common foaming agent concentrates.

3. Foam Monitor:

Designed for external use, the foam monitor is employed to combat fires from a safe distance and proactively cool objects at risk of ignition. Depending on the version, the monitor can be aligned with the target manually, electrically, or hydraulically using remote control technology.

4. High Expansion Foam Generator:

Generators are responsible for producing high-expansion foam, which safeguards storage areas. This type of foam floods the entire room, displacing air and depriving the fire of oxygen, similar to carbon dioxide extinguishing systems.

5. Direct Alarm Foam:

Direct Alarm foam components simplify alarm testing procedures. Weekly tests utilize water from the pump distributor before the proportioner, eliminating the need to discharge and dispose of a foam/water mix.

6. Foaming Agent Concentrate:

Minimax offers a comprehensive range of foaming agents including protein and synthetic varieties. These foaming agents are suitable for tackling solid, liquid, and alcohol/solvent fires.[19]

III. FIRE BLANKETS:

Firezat, Inc. is currently the leading company, prominently featured in sources like TIME magazine, for its ability to transform a material resembling aluminum foil into an effective solution for protecting infrastructure from fire.

Fire Shields are crafted to establish a fire-resistant barrier using aluminum, safeguarding structures from burning embers and intense heat. They prevent embers from becoming trapped at 90-degree corners and shield walls, roof eaves, and areas where burning debris may be blown against a building.

The materials utilized in creating Firezat's fire-resistant fabric are undisclosed on the website. However, it is acknowledged as an aluminum fabric, revealing aluminum as a key component.

To implement Firezat, one must manually wrap the house using various tools such as chicken wire, cutters, tape measure, ladders, step stools, staple guns, staples, needle-nose pliers for staple removal, tie wire, sunglasses for daytime deployment, and a soaker hose for water deployment. The installation is recommended during early morning or late evening to avoid strong winds. The process requires caution when using ladders, working on roofs, transporting materials, and handling tools. Chicken wire, known for its affordability and reusability, serves as an effective way to protect structures from wind gusts.

Firezat can be applied to various structures, including houses, barns, dog houses, or anything one wishes to shield from the threat of wildfires.

Figure 5: Black Bar Lodge. It is a structure wrapped in protective foil to prevent wildfire damage (Sonner). [20]

In summary, Fire Blankets (Firezat) are aluminized structure wraps designed to protect lower-storied houses from wildfires. Unlike foams and gels, Firezat does not require water or elec-

DOI: 10.36838/v6i8.4

tricity for application and can be manually installed. Firezat is reusable and environmentally friendly, making it a sustainable fire protection option. It can withstand direct flame exposure for up to 20 minutes, providing valuable time for occupants to evacuate or for firefighters to arrive and contain the fire.

FirePod:

FirePod is a new prototype that may provide fire protection by utilizing a deployed mechanism to protect infrastructures before a destructive forest fire spreads, as shown in Table 1. FirePod is presented as a potential solution to safeguarding a variety of infrastructures, from housing to small-scale buildings, from the threat of forest fires. It offers homeowners an easy and automated way to swiftly deploy fire-resistant material upon receiving a forest fire warning. The instant solution by FirePod will allow them to seek shelter and increase the chances of avoiding injury, saving their lives. Furthermore, FirePod's effectiveness in shielding structures from fire is an additional layer of reassurance to protecting infrastructure.

FirePod is a cutting-edge solution for homeowners to safeguard their homes and infrastructures in the face of a forest fire threat. It also aims to address the limitations of existing fire protection technologies. When a forest fire warning is received, FirePod owners can activate the device via a mobile app or a button installed in their home. Upon activation, FirePod deploys fire-resistant materials named 'Fire Zat' outward at an angle, achieved through an air pressure system similar to the deployment method of a webcaster (net) gun. This deployment is assisted by weighted balls attached to the end of the fire-retardant material, ensuring precise and swift coverage of the entire house with exceptional consistency.

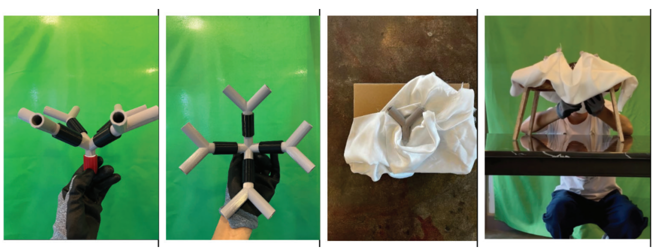

Figure 6: Images of FirePod Prototype. These images present a 360-degree view.

The goal of FirePod is to allow homeowners to immediately seek shelter in the nearest alternate refuge and increase their chances of avoiding injury instead of attempting to protect their homes from the flames. Ultimately, the assurance of this protective technology will not only help preserve an infrastructure but save the lives of many people in wildfire pathways.

In addition to the occurrence of infrastructure damage near areas of forest fires, it is essential to note that the growing forest fires are not the sole reason for increased infrastructure damage. The contribution of the Wildland-Urban Interface, or "WUI", plays a significant role in this phenomenon. In the wildland-urban interface (WUI), houses and vegetation intermingle, creating the most pronounced wildfire problems.[4] It is reported that the WUI in the United States increased in only two decades from 1990-2010 "in terms of both number of new houses (from 30.8 to 43.4 million; 41% growth) and land area (from 581,000 to 770,000 km2; 33% growth)".[24] With a significant increase in infrastructure in the WUI, more infrastructures are likely to be located near the dangers of forest fires. This also includes areas within the perimeter of recent wildfires (1990–2015) where the number of houses rose from 177,000 in 1990 to 286,000 in 2010, which inevitably increases the chances of wildfire ignitions.

Why FirePod?

At the start of creating FirePod, the aim was to solve forest fires using upcycled burnt trees from previous forest fires. As a result, the initial solution was to establish fences made of burnt wood around areas in the forest that were most prevalent in a forest fire to enclose the fire before it became too large to stop. However, while researching the qualities of the burnt wood material that would have been utilized for the fences, it showed that not only was charred wood more flammable than normal wood due to its dryness, but the forest fire itself was a natural process of the environment that humans should not hinder. In continuation of the research, forest fire should only be controlled if, for explicit reasons, it directly impacts human life. In conclusion, the FirePod was created to prevent damage and a negative impact on human life while allowing the natural spread of forest fires.

Advantages and Disadvantages of Existing Systems Compared to FirePod:

Table 2: Summarized information on the available products currently on the market. Each factor affects the adoption rate of the available fire protection and extinguishing resources.

SYSTEM	PROS	CONS	FirePod in Comparison
Indoor and Outdoor Sprinkler System	1. Efficient method of infrastructure protection utilizing less water and decreasing mortality rate.[7]	1. High winds cause a missed target of the fine water droplets released from sprinkler systems.	1. Does not cause water damage; Automated and immediate activation reduces delay risk. Not directly affected by wind or lack of a water supply.
	2. Worth the money saving over $42 million in property value.[12] Water damage is less expensive to repair than property loss.[7]	2. Power loss of water sources, whether from a neighborhood or personal supply. Purchase and installation can be expensive.[10]	2. Automated detection and activation without need for manual intervention; Enhances safety and response time.
	3. Automatic detection of temperatures allows homeowners to evacuate. Technology can be utilized to activate and protect buildings through a device application.	3. Temperature complications due to aggressive wind or freezing of water pipes during winter weather. Accidental activation may occur without a fire present.[7]	3. Functions in all temperatures; Reliable activation without risk of accidental triggers.
Foam Systems	1. Functionality of the Foam to reduce oxygen and smother fires.[19] Reduces impact on inhalation of carcinogens through smoke.[22]	1. Harmful chemicals to humans and the environment through absorption into soil and water systems, causing health issues over time in human and animal life.[21]	1. Uses fire-resistant materials; avoids harmful chemicals.
	2. Maximizing water usage in the foam to penetrate burning fuel faster.[22]		2. Does not rely on water, thus minimizing resource consumption and environmental impact.
Fire Blanket	1. Reusability of the Firezat material makes a cost-effective protection measure.[23] Protects structures from temperatures up to 1,022 degrees Fahrenheit.	1. Difficult manual application which requires precision and numerous people leaving room for error. Duration limitations of 20 minutes.	1. Mechanical deployment allows evacuation safety in cases of forest fires. Reducing labor and error costs during installation.
	2. Environmentally friendly.	2. Limited coverage suitable for small-scale infrastructures and not equipped for multiple-level buildings. Limited adaptability to rapidly changing or dynamic fires.	2. Provides broad coverage and is adaptable to different infrastructure sizes and types, ensuring comprehensive protection.

Methods

This research explores the applicability of FirePod in mitigating the impacts of wildfire on critical infrastructure and compares it with existing products designed for wildfire infrastructure protection.

After conducting examinations of various methods for protecting infrastructure from forest fires, we compared the advantages and disadvantages of these devices by exploring how FirePod could offer a solution to the main issue. Researching the pros and cons of the pre-existing solutions to the infrastructure allowed a narrower array of solutions and guidelines that led to the success of creating FirePod (Table 2). For instance, the recognition that strong wind impacted the efficiency of the pre-existing solution of fire sprinklers, FirePod was created to have a weight attached to the end of the fabric to resist the wind and wrap the house with precision. This FirePod project took approximately two years and is ongoing in research development.

Concerning the future aspirations for FirePod, the end goal is to continue developing and creating an efficient prototype that can fully operate within an actual residential setting. In the long-term vision, the goal is to make FirePod accessible to the market, allowing homeowners and infrastructure proprietors to purchase FirePod, ensuring both protection of property and a reduction of expenses while facilitating prioritization of the safety and well-being of the customers.

Creation Process:

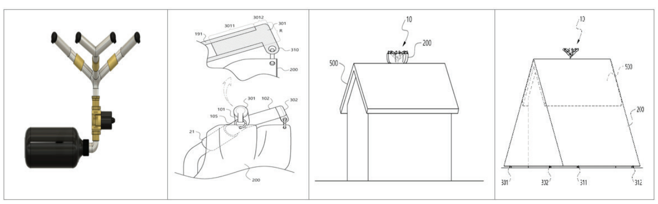

Figure 7: Sketches of FirePod and how it works. From left, FirePod, Fire Zat connected with the nozzles, FirePod installed on rooftops, and Fire Zat covering the entire house after FirePod has been launched.

3D Modeling Was Used to Create the Prototype for FirePod:

- ***Design:***

The design process was executed using Fusion 360, which allowed for precise modeling before actual prototyping.

- ***3D Printing:***

The Prusa MK3s 3D printer was utilized with PLA filament to create the prototype components. The decision to use this printer and filament was due to their reliability and the level of detail they offer, which was essential for creating accurate and functional parts.

- ***Prototyping:***

The prototype design involved multiple components, which were individually printed and then assembled. The necessity of splitting the design into smaller parts was due to the printer's capacity limitations and the need for easy troubleshooting.

- ***Additional Hardware:***

An air pressure system and a solenoid valve were integrated to control the deployment mechanism. The solenoid valve was critical for regulating air pressure and ensuring synchronized deployment of the fire-resistant fabric.

After sketching the designs from Figure 2, I recognized that they must be 3D printed as they have several different components. As seen in Figure 3, we chose to create a 3D model before implementing the design in a prototype to ensure: 1) it was a great way to accurately see what the final design would look like with the correct measurements, materials, and other components; 2) prevent the waste of material or monetary resources while trying to create a prototype that may have many design errors resulting in scrapped attempts that could have been avoided by planning in further detail; 3) 3D printing the materials were a necessary step as the components required for the FirePod did not exist in outside in the general market, thus needing to be custom made.

- ***Sections that were 3D Modeled:***

As mentioned, since the original FirePod for the IRL house was downsized to create a FirePod prototype seen in Figure 1, most of the components had to be 3D printed. Some components of the FirePod “prototype were not” 3D printed, including the air tank that provided air pressure and the trigger that was activated by pressing a button.

- ***Reasoning for Printing Structure:***

The 3D parts were not printed as a whole. There are two main reasons why the entire model was sectioned into numerous individual components rather than one:

1. **Printer Limitations:** Due to the maximum capacity of the 3D printer in the design lab, it was not feasible to print the entire component as a whole. The printer could not manage 1/4th of its size.
2. **Efficiency and Troubleshooting:** By splitting the FirePod into many different sections, we could identify and address any possible errors with efficiency. For instance, if one section of the FirePod was not working, we could reprint that isolated component rather than reprinting the entire structure.

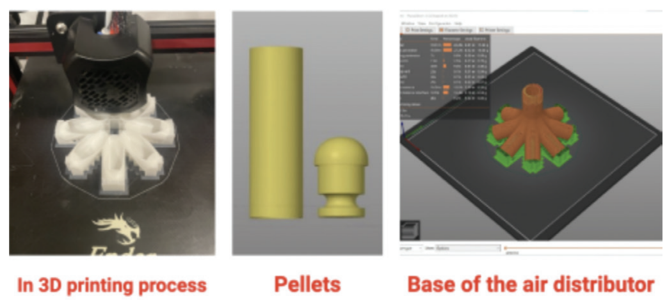

Figure 8: Process of 3D printing the prototype. Air distributor, pellets, and the base of the air distributor were created.

Result and Discussion

Final Design:

The FirePod was specifically designed to offer an automated and user-friendly solution for deploying fire-resistant materials over a house during a wildfire. The final prototype incorporates a CO_2 tank for air pressure and a solenoid valve for precision control.

By incorporating these findings, we highlight the FirePod's potential as a reliable and innovative solution for safeguarding homes against wildfires. Comparative analyses with existing methods and a comprehensive examination of test results fortify our discussion on the FirePod's efficacy and avenues for future enhancements.

DOI: 10.36838/v6i8.4

Testing:

- ***3D printed part testing:***
  We conducted tests to assess the effectiveness of the 3D-printed parts. Initially, we examined whether a single pipe would detach from the bullet upon deployment. Subsequently, we tested the simultaneous release of all pipes from the bullets, first using manual mouth deployment and then through automated control.
- ***Electronics:***
  The inclusion of a solenoid valve was crucial in our design. It enabled precise control over the air pressure, ensuring the synchronous release of all pellets. The solenoid valve, interfaced with a relay switch via radio frequency, 4 channels, and a button (refer to Figure 9), facilitated the automation of pellet deployment.

Figure 9: Wireless Remote and Solenoid Valve (Ali Express, Amazon).[25,26]

- ***Pellet Structure:***
  Factors such as the shape, weight, and material of the pellets play pivotal roles in the efficiency of the FirePod. Optimization of these variables is imperative to enhance its performance in deploying fire-resistant materials over structures during wildfires.

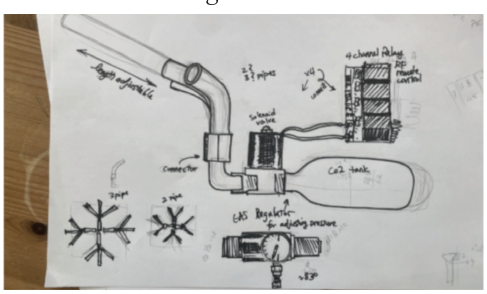

Figure 10: Sketch of Prototype 3D Print connected to CO_2 Tank. It features all the key components of the device.

As shown in Figure 10, 1/4 of the snowflake and its mechanics are shown, allowing it to shoot the nukes. The CO_2 tank is connected to the snowflake, while the solenoid valve ensures the gas is only released when commanded. The goal is to add a gas regulator to adjust how far the nukes are shot away, considering how large the house is (Figure 10).

Additionally, research a method of covering the snowflake with a fireproof coating or changing the materials to ensure they can stay functioning the next time a wildfire occurs.

Trials:

- Number of Tests:

Multiple tests were conducted to assess the FirePod's performance under varying conditions. Alterations in air pressure and deployment speed were systematically explored to identify optimal settings for maximum coverage and effectiveness.

*- **Variations in Conditions:***

Test results revealed performance discrepancies based on fluctuations in air pressure and deployment speed. Our efforts in testing these conditions enabled us to understand that higher air pressure facilitated a swifter deployment. Thus, adjustments to the pellet design were necessary to enhance accuracy and consistency in coverage.

FirePod Limitations:

- Technical Errors:

The FirePod system relies on a complex integration of hardware, software, and mechanical components. The complexities of these components introduce potential points of failure, such as software bugs, hardware malfunctions, and mechanical failures.

- Solution:

To mitigate these risks, rigorous testing protocols must be implemented. This includes pre-deployment in various environmental situations to identify areas of weakness and potential malfunction. Incorporating redundant systems can ensure that if one component fails, others can compensate. Regular maintenance schedules are crucial, involving thorough inspections and servicing of the hardware and software.

Automated self-diagnostics can also be built into the system to continuously monitor performance and detect anomalies early. By identifying and resolving issues promptly, the system's reliability can be significantly enhanced.

- Dependence on Power:

In the event of a power outage, the FirePod may become non-operational, compromising its ability to protect the infrastructure during critical times.

- Solution:

The FirePod will contain a battery backup system that can sustain the operation during power outages. Additionally, solar power technology can be implemented as a potential way to create a green method for the FirePod's power source in cases of power failure. Solar power technology can be beneficial in maintaining the backup system battery at full working capacity.

- Deployment Accuracy:

The FirePod's deployment mechanism may be affected by environmental factors such as high winds or physical obstructions, leading to improper deployment and reduced effectiveness in fire protection.

- Solution:

The deployment mechanism should be designed to compensate for environmental factors. This can be achieved by using weighted edges on the deployment materials to prevent wind from blowing them off course. Aerodynamic designs can help maintain stability and accuracy during deployment. Additionally, advanced sensors and control algorithms can be incorporated to adjust the deployment in real-time, ensuring precise coverage even in challenging conditions. By accounting for these environmental variables, the FirePod can ensure accurate and effective deployment.

By addressing these limitations, the FirePod can provide a more reliable and effective solution for protecting infrastructures from forest fires compared to existing methods. The implementation of rigorous testing and maintenance protocols are crucial steps to overcoming any challenges and maximizing the usage of the FirePod's performance in real-world conditions and emergencies.

Conclusion

In conclusion, among the three analyzed solutions, regarding Table 2, it is quite challenging to select the best method of infrastructure protection due to all of these solutions having their strengths but overwhelming weaknesses. This brings up the discussion of FirePod and its stance on its ability to become a feasible solution in infrastructure protection. More specifically, a great percentage of the cons for Firezat were regarding its difficulty applying to the infrastructure. The support of an automated device that distributes the Fire Shield efficiently and effectively on the infrastructure allows the solutions of fire blankets to be a great reference when considering the protection of both the infrastructure and the prioritization of the owners of the infrastructure.

Continuing the advancement of FirePod, the focus will remain on identifying FirePod's current strengths and addressing its potential weaknesses. More specifically, further research includes exploring not only the technological strengths of FirePod but also its economic feasibility. For example, research into the business's eligibility for government subsidies is a strategic move to alleviate concerns about FirePod's anticipated high cost.

The successful development and distribution of the FirePod will enable the cost-efficient protection of valuable assets while allowing forest fires to occur, providing space for nature to complete its rejuvenation process naturally.

Acknowledgments

Thank you to Dr. Anne-Laure Strong for her guidance and assistance in this paper. I would also like to thank Miriam Choi (Bold Lab Instructor) for her technical support in building FirePod.

References

1. Forest History. The 1910 Fires. https://foresthistory.org/research-explore/us-forest-service-history/policy-and-law/fire-u-s-forest-service/famous-fires/the-1910-fires/ (accessed 2023-12-09).
2. Wildfires and Climate Change. Center for Climate and Energy Solutions. https://www.c2es.org/content/wildfires-and-climate-change/ (accessed 2023-12-23).
3. Barrett, K. Wildfires destroy thousands of structures each year. Headwaters Economics. https://headwaterseconomics.org/natural-hazards/structures-destroyed-by-wildfire/ (accessed 2023-12-24).
4. State of California. "Remembering the Camp Fire." Cal Fire, www.fire.ca.gov/our-impact/remembering-the-camp-fire. Accessed 23 Dec. 2023.
5. WFCA. "10 Largest Wildfires in U.S. History." Western Fire Chiefs Association, 8 Nov. 2023, wfca.com/wildfire-articles/biggest-wildfires-in-us-history/. Accessed 18 Dec. 2023.
6. CBC News. "Elephant Hill Wildfire Was Most Likely Caused by a Smoker, Investigations Find | CBC News." CBC News, CBC/Radio Canada, 5 May 2020, www.cbc.ca/news/canada/british-columbia/elephant-hill-wildfire-cause-investigation-smoking-1.5554355. Accessed 23 Dec. 2023.
7. FEMA. Home Builder's Guide to Construction in Wildfire Zones. U.S. Department of Homeland Security. Fact Sheet No. 15. https://wildfiretoday.com/documents/FEMA_home_builders_guide_wildfire_zones.pdf
8. Walnut Creek Fire Protection, digital image, accessed 2023-12-26 https://fireprotectionwalnutcreek.com/fire-sprinkler-services/
9. Patterson, G., Ree, J. How Do Residential Fire Sprinkler Systems Work? Shutgun. https://shutgun.ca/how-do-residential-fire-sprinkler-systems-work/ (accessed 2023-12-12).
10. Simms, N. J.; Sumner, J. High Temperature Corrosion. Elsevier eBooks 2022. https://doi.org/10.1016/b978-0-12-822944-6.00012-8.
11. Residential Fire Sprinkler System: Pros vs Cons. RAD Fire. Radfiresprinklers.com. https://www.radfiresprinklers.com/pros-and-cons-residential-sprinklers/ (accessed 2023-11-28).
12. Fire Safe Marin. Exterior Sprinkler Systems. https://firesafemarin.org/harden-your-home/exterior-sprinklers-and-coatings/#gsc.tab=0 (accessed 2023-12-09).
13. Blaze Control Bushfire Sprinkler Systems. digital image, https://www.blazecontrol.com.au/fixed_systems.html (accessed 2023-12-26)
14. Frontline Wildfire Defense. Frontline Wildfire App. Digital Image, https://www.frontlinewildfire.com/frontline-wildfire-app/ (accessed 2023-12-23)
15. Wildfire Sprinkler System for ultimate home protection. Frontline. https://www.frontlinewildfire.com/protect-home-with-roof-wildfire-sprinkler-system/ (accessed 2023-12-23).
16. SV Fire Systems. Foam Water Sprinkler. Digital Image, https://svfiresystems.com/Foam-Water-Sprinkler.html (accessed 2023-12-26)
17. Stag, M. G. History and Development of Firefighting Foams. https://stagliuzza.com/news/history-and-development-of-firefighting-foams/ (accessed 2023-12-12).
18. Van Kampen, M. What is Foam in Fire Suppression? - Reliable Fire & Security. Reliable Fire & Security, May 4, 2022. https://reliablefire.com/what-is-foam-in-fire-suppression/ (accessed 2024-05-16).
19. Minimax GmbH. Minimax.com. https://www.minimax.com/pl/en/technologies/foam-extinguishing-systems/foam-extinguishing-system/ (accessed 2023-12-23).
20. Sonner, Scott. WPTV. Aluminum Wrap Used to Protect Homes in California Wildfires, Digital Image, accessed 2023-12-23, https://www.wptv.com/news/national/aluminum-wrap-used-to-protect-homes-in-california-wildfires
21. Barak, M. Foam-Based Fire Protection: An Overview. Bermad.com. https://blog.bermad.com/fire-protection/foam-based-fire-protection (accessed 2023-12-23).
22. Avsec, R. 5 reasons to fight fire with foam. FireRescue1. https://www.firerescue1.com/fire-products/suppression-equipment/articles/5-reasons-to-fight-fire-with-foam-YeBYwuSWESVwNV8X/ (accessed 2023-12-23).
23. Firezat. Wildfire Protection Services. Firezat Inc. https://www.firezat.com/ (accessed 2023-12-24).

DOI: 10.36838/v6i8.4

24. Radeloff, V. C.; Helmers, D. P.; H. Anu Kramer; Mockrin, M. H.; Alexandre, P.; Avi Bar-Massada; Butsic, V.; Hawbaker, T. J.; Sebastián Martinuzzi; Syphard, A. D.; Stewart, S. I. Rapid Growth of the US Wildland-Urban Interface Raises Wildfire Risk. Proceedings of the National Academy of Sciences of the United States of America. (2018) 115 (13), 3314–3319. https://doi.org/10.1073/pnas.1718850115.
25. Ali Express. Smart Remote-Control Receiver, Digital Image, https://ko.aliexpress.com/i/1005002733593675.html?gatewayAdapt=glo2kor (accessed 2023-12-26)
26. Amazon. Electronic Solenoid Valve, Digital Image, https://www.amazon.com/Electric-Solenoid-Valve-Pneumatic-Water/dp/B0CNYYKRTD (accessed 2023-12-23)

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