DRONE RANGER for Fighting Wildfires

Abstract

According to the National Interagency Fire Center, there were a total of 70,423 wildfires reported in the United States in 2024. The **Drone Ranger (DR)** represents a cutting-edge innovation in wildfire mitigation, combining advanced technologies to address the challenges posed by increasingly frequent and destructive wildfires. DR is a thermoelectricity and hydrogen powered drone made of stainless steel with tantalum hafnium carbide coating for unparalleled heat resistance and durability in extreme environments. DR is equipped with infrared cameras to detect heat sources and has a unique AI-trained camera network to monitor forest conditions and fires. DR uses a sophisticated Advanced Pressure Swing Adsorption system to mitigate wildfires filtering out atmospheric nitrogen and recycling wildfire generated carbon dioxide. Despite challenges related to cost and system complexity, the Drone Ranger offers a visionary approach to wildfire management, combining sustainability, technological innovation, and operational effectiveness.

DRONE RANGER for Fighting Wildfires

Present Technology

A wildfire is a large, uncontrolled, destructive fire that spreads quickly over dry biomass and emits many greenhouse gases. In 2023, there were 56,580 wildfires reported in the United States and wildfire smoke exposure is estimated to contribute to nearly 16,000 deaths each year. Forest fires have many effects on the environment like loss of vegetation/habitat, soil erosion and poor air quality. Smoke contains particulate matter, carbon monoxide, and other harmful emissions, causing diseases of the lungs, heart, brain, etc. Wildfires also simultaneously impact the climate by releasing large quantities of carbon dioxide. In 2022, 5.3 billion tons of carbon dioxide and other greenhouse gases were released due to wildfire, contributing to global warming. Approximately $394 billion is spent every year and $15.5 billion worth of property destroyed as of 2022.

Current methods to stop or mitigate wildfires focus on a combination of prevention, early detection, active suppression, and post-fire restoration. Wildfires require a lot of water and fire retardant dropped from planes and helicopters to extinguish them. Firefighting drones, equipped with various sensors and technologies, are being increasingly used to assist in both fire detection and firefighting operations. Surveillance drones, equipped with high-resolution cameras and thermal imaging, help detect hotspots and monitor fire behavior in real-time. Mapping drones create instant maps of the fire, aiding firefighters in understanding its spread and planning containment strategies. Some drones are designed to deliver water or fire retardant to aid in controlling fire. Currently there are 2 types of drones to fight fires: [1] UAV firefighting drone uses bombs to disperse oxygen complemented with a water extinguisher to suppress fires. The major disadvantage of this drone is that it can stay up for 45 mins at a time, can take only one bomb, and carry a small water load of max 15 kg. [2] Search and Rescue Drone [JOUAV CW-30E VTOL] uses thermal cameras and AI to find hotspots but only has 6 hours of flying time, 8 kg payload capacity and 20°C to 50°C operating heat.

Limitation: Although the advantages of firefighting drones are access to remote and hazardous areas, reduced risk to human life, real time accurate data and operational efficiency, but the limited payload capacity and battery life restricting their operational duration must be improved to enable efficient controlling of wildfires. Additionally, using water or foam to control fire is not the best method as the drones can carry only so much water and once used up, water may not be readily available everywhere to replenish the drones to continue extinguishing the fire.

History

The use of drones in firefighting is a relatively recent development, but it has gained significant momentum in the past two decades. Here is an overview of the **history of firefighting drones**:

Around 200 BCE, ancient Rome established the "Vigiles," the first firefighting force, while the Great Fire of London in 1666 spurred the development of organized firefighting methods. In the 18th and 19th centuries, milestones included Benjamin Franklin founding the Union Fire Company in 1736, George Braithwaite's creation of the first steam-powered fire engine in 1829, and Cincinnati forming the first professional U.S. fire department in 1853. Simultaneously, the early concept of drones emerged in 1849 with the Austrian military using unmanned explosive balloons. The World Wars and Cold War era saw rapid advancements, from the 1916 "Aerial Target" pilotless aircraft to 1940s radio-controlled planes and the development of UAVs during the 1950s-60s.

1. Early Development (Pre-2000s) Unmanned Aerial Vehicles (UAVs): The concept of UAVs, which later evolved into drones, dates to the early 20th century and were primarily used for military purposes. In the 1990s advancements in drone technology, like GPS systems, remote sensing, and miniaturized cameras laid the groundwork for the eventual use of drones in fire management.

2. 2000s The Birth of Civilian Drones: By the **early 2000s**, small, lightweight drones were developed and used for disaster management and firefighting. **2001-2002**: Early use of UAV in fire management was by

USDA to monitor wildfires from the air. **2005**: Drones were used to survey wildfires and identify hotspots that were difficult for ground teams to access.

3. 2010s Expansion and Innovation: Drones became more affordable, compact, and equipped with better sensors (thermal cameras, LiDAR, infrared cameras, and gas sensors) which allowed fire detection/mapping /monitoring and air quality and gas monitoring. **2014:** California began experimenting with drones to help manage wildfires. Drones with water-dropping capabilities began to emerge. **2016**: In Canada, drones were used to monitor wildfires in remote areas. **2017-2018**: Australia, Portugal, and US began incorporating drones for surveillance and some firefighting tasks during major wildfire seasons.

4. 2020s Maturity and Integration: By the **early 2020s**, firefighting drones were not only used for surveillance and mapping but also for direct firefighting tasks which included large-scale water-dropping drones, fire retardant and foam delivery to certain areas.

The history of **firefighting drones** shows a rapid evolution from simple surveillance tools to advanced multi-functional machines capable of directly assisting in firefighting efforts.

Future Technology

The innovative Drone Ranger (DR) is a revolutionary, all-encompassing drone that helps combat wildfire by utilizing a cutting-edge Advanced Pressure Swing Adsorption (APSA) system to spray nitrogen filtered out from the atmosphere and carbon dioxide recycled from the wildfire itself, thereby not limiting its payload capacity by carrying the extinguishing agent and allowing the drone to function 24/7. Equipped with infrared cameras and machine learning, this smart DR is hydrogen and TEG powered which allows a long operational life for the DR to extinguish the fires efficiently.

Overview of the Drone Ranger:

a. DR Exterior and Components: The DR is made of **330 stainless steel** (melting point of ~1500°C) with a **tantalum hafnium carbide (THC)** exterior coating (melting point of 4215 °C, used in rocket nozzles) to resist the spread of flames and provide a fireproof coating against the intense heat produced by the fire. DR is equipped with **infrared cameras and smoke detectors** to detect heat sources and help monitor remote or difficult-to-access areas. DR also has a unique **AI-trained camera network** which uses data from cameras, satellites, other drones and meteorologists to monitor forest conditions and fires. DR collects important data on fire behavior, weather conditions, and terrain, which can be used for predicting fire behavior and improving firefighting strategies.

b. Advanced Pressure Swing Adsorption (APSA) System: DR is equipped with a sophisticated fire suppression NITROGEN firing system as nitrogen does not decompose or produce any by-products when exposed to a flame. The APSA system will contain multiple layers of adsorbing materials so that when compressed air at elevated pressure is passed through it, selective adsorption of gases occurs. Air will be drawn from the atmosphere and passed sequentially through adsorbing agents like alkaline pyrogallic acid (APA, adsorb oxygen) → palladium (adsorb hydrogen) → zeolite (adsorb both nitrogen from air and carbon dioxide generated in the fire). The zeolite will then be heated to release the trapped nitrogen and carbon dioxide and directed through a static eliminator nozzle to ensure it is safely and efficiently sprayed onto the wildfire for suppression. This approach will help slow the spread of the fire and extinguish it by reducing the oxygen available to the flames. The lightweight APSA system inside the DR allows it to remain maneuverable and the tantalum hafnium carbide coating will make it resilient in high-temperature environment.

c. Thermoelectric and Hydrogen-Powered Drone for Extended Operation: The DR is powered by hydrogen and thermoelectricity, which makes it energy-efficient and environmentally friendly, CO_2-neutral, only residual product is water vapor which can be cooled to spray on the fire. This energy setup could allow it to operate for extended periods, even in extreme heat conditions. [i] **Hydrogen** offers a high energy density, crucial for DR performance, especially during long missions. The APA and palladium will be heated to release the adsorbed hydrogen and oxygen, respectively, which will be stored in a tank connected to a fuel cell where an electrochemical process allows both gases to produce electrical energy to power the DR.

[ii] **Thermoelectric generator** (TEG) converts heat directly into electrical energy using the Seebeck effect. The TEG could potentially harness heat from wildfire, generating power for its flight and operations. The components of TEG are made of silicon germanium (SiGe) for above 500°C; the hot side (heat source) will be outside the drone and the cold side (heat sink) will be cooled by liquid nitrogen inside the drone. The temperature difference between the hot and cold junctions will create an electric voltage across the 2 sides, which is harnessed as electrical power through the Seebeck effect. This hybrid powering system should be able to provide at least 6000-mile remote operation with flying time up to 20 hours, ensuring continuous operation over large areas of the wildfire.

Breakthrough

1. Maximizing a Small-Scale System for High-capacity, High-efficiency Advanced Pressure Swing Adsorption (APSA) System: For our DR to function effectively, it is critical that it incorporates the APSA process, which relies on adsorbent materials to adsorb the gases essential for firefighting, nitrogen displaces oxygen to reduce its availability, while carbon dioxide suffocates flames. Our advanced PSA (APSA) system uses a 3-layer adsorbing matrix: alkaline pyrogallic acid, palladium and zeolite to adsorb oxygen, hydrogen, nitrogen/carbon dioxide, respectively. The existing adsorbent materials lack the capacity and selectivity needed to capture these gases efficiently under the rapid cycling conditions required for DR operation. To address this, advancements in adsorbent materials, such as nano-engineered adsorbents with increased porosity and hybrid materials combining selectivity and durability, are essential. Additionally, implementing low-energy desorption techniques to regenerate these materials quickly will ensure the APSA process operates rapidly and efficiently. By optimizing the APSA process to prioritize the capture and utilization of nitrogen and carbon dioxide, the DR can achieve the speed and functionality necessary to serve as a fast, eco-friendly, and effective wildfire suppression tool. The complexity of real-time gas separation via the APSA system requires a breakthrough for further optimization to ensure consistent performance under dynamic field conditions. A breakthrough is required to optimize the APSA process into a high-performance system using high-capacity compressor to force large volumes of air through the highly adsorbent beds.

2. Thermoelectric and Hydrogen-Powered Drone for Extended Operation:

One of the main challenges in DR is autonomous and sustainable power for longer flight time to suppress fire continuously without gaps and delay. DR uses the thermoelectricity and hydrogen fuel for extended operations. The efficiency of TEG is relatively low compared to other forms of power generation and depends on the temperature difference and the thermoelectric materials used. A large temperature difference is required to generate a significant amount of electricity. A breakthrough is needed to optimize the efficiency of TEG as well as be able to use the adsorbed hydrogen/oxygen from the atmospheric air to be electrochemically processed easily and efficiently inside a small drone to produce the electrical energy to operate the drone.

Experiment to test if APSA works:

2 contained fires will be ignited using equal amount of same fuel and will be extinguished using [i] water bombs and [ii] nitrogen using our APSA system in DR, to evaluate if nitrogen is a better extinguisher than water. Times to extinguish each fire will determine which is better. We observed that the time taken for water vs. nitrogen to completely put out the fires were 6 minutes vs. 2 minutes, respectively. Additionally, there was a rebound of the fire slightly when water was used as oxygen in the air was not completely displaced when compared to using nitrogen since the APSA system adsorbed the oxygen and hydrogen from

the air prior to spraying the nitrogen over the fire to extinguish it. This proves that our APSA system which sprays nitrogen is a better and stronger fire extinguisher than water in case of wildfire.

Design Process:

1. Pressure Swing Adsorption (PSA) vs Membrane Separation Technique (MST) for nitrogen:

Initially we decided to use the membrane separation method, where air is passed through a semi-permeable membrane that allows oxygen to diffuse through more easily than nitrogen (retained) due to differences in molecular size and diffusivity. However, MSTs often suffer from inconsistent separation efficiency due to membrane fouling, pressure drops, and limited adaptability to varying gas compositions. They also require frequent maintenance and replacement, making them less suitable for real-time applications like firefighting. Moreover, their separation process lacks the precision necessary for handling diverse gas mixtures under dynamic conditions. Other methods like Cryogenic distillation where components of air are cooled to extremely low temperatures, where the different gases liquefy at different points, are a very tedious and non-feasible method inside a drone. So, finally we decided to use the PSA technique where air is passed through a bed of different adsorbent materials under pressure and the adsorbents preferentially adsorbs oxygen, hydrogen, nitrogen and carbon dioxide which later can be released under low pressure to be sprayed via a nozzle to mitigate the wildfire.

2. Why nitrogen as a fire extinguishing agent instead of water?

Since water is one of the most widely used fire extinguishing agents, we wanted to use water bombs. But water needs to be carried inside the DR and will incur a bigger payload and may be difficult to replenish once depleted. We preferred nitrogen for DR because of its abundant availability, inert nature and ability to displace oxygen and suffocate a fire making it an excellent potential fire suppression tool. We also planned to utilize the carbon dioxide generated from the wildfire itself to mitigate the fire, doubling up on the extinguishing agents. We realized that CO_2, when used in conjunction with nitrogen, would not only help to displace oxygen but also work to cool the fire more rapidly, as CO_2 has a higher heat absorption capacity than nitrogen. This combination of gases allowed us to address both the lack of oxygen and the heat from the fire simultaneously, significantly improving the overall fire suppression effectiveness. The use of CO_2 would help to extinguish the fire quicker by reducing the temperature and limiting the combustion process more efficiently. A good combination of gases with unlimited availability in a wildfire will be the best!

3. Thermal cameras vs. Infra-red cameras with AI integration to detect and monitor wildfire:

Thermal cameras are widely used for detecting heat signatures but face significant limitations compared to infrared cameras enhanced with artificial intelligence (AI). Thermal cameras rely on detecting heat differences, which can result in inaccuracies in environments with overlapping heat sources or complex backgrounds. They struggle to distinguish objects of similar temperature, offer lower resolution, and lack computational capabilities for real-time decision-making. In contrast, infrared cameras capture a broader spectrum of infrared light, providing higher resolution and more detailed imaging. When integrated with AI, these cameras can analyze patterns, classify objects, and detect anomalies with precision, such as distinguishing between humans and animals based on motion, shape, and heat distribution in complex settings. AI algorithms also enable adaptive learning, improving detection and recognition performance over time. Infrared cameras with AI overcome the limitations of thermal cameras by offering superior imaging accuracy, real-time object classification, and adaptability to dynamic environments, making them ideal for applications like surveillance, wildlife monitoring, and search-and-rescue operations where precision and reliability are critical. Hence we chose infra-red over thermal cameras for a wildfire mitigation by the DR.

4. Powering the DR:

Initially, we envisioned powering DR with Photoelectrochemical Cells (PECs), which convert solar energy directly into chemical fuel, offering a sustainable and efficient power source. However, the smoke and particulate matter generated by fires would significantly obstruct the sunlight necessary for PECs to function effectively, rendering this approach impractical. We then explored the possibility of utilizing a Thermoelectric Generator (TEG) to harness the heat generated by fires, converting thermal energy into electrical energy. While this approach offered potential, the power output of TEGs is relatively low, limiting their suitability for powering a drone capable of sustained flight and firefighting operations. After careful consideration of these alternative power sources, we determined that a hydrogen generator offers the most promising solution. By extracting hydrogen from the surrounding air, the drone can generate its own fuel, ensuring a reliable and efficient power supply. This combined with the power of TEGs would power the drone efficiently whilst using the resources around us. This approach overcomes the limitations of PECs and TEGs, providing a robust and sustainable power source for DR, enabling it to effectively combat fires in challenging environments.

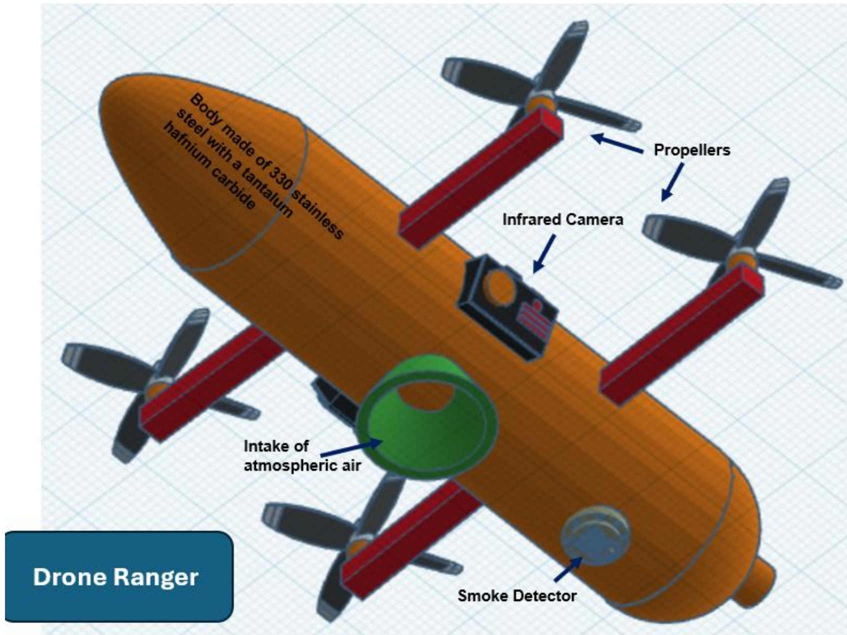
5.Material of the Drone to make it ultimate Fire Resistant

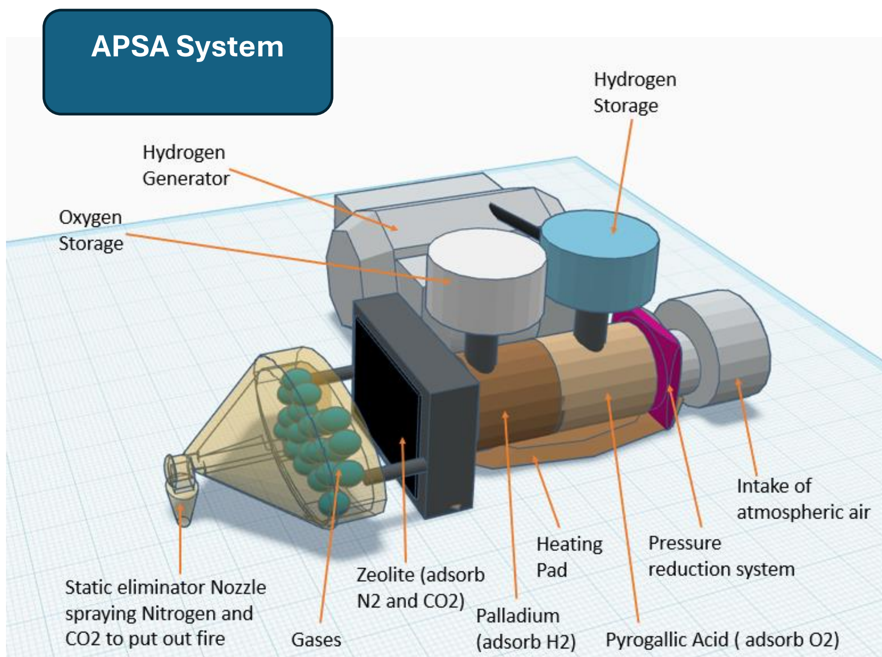
Initially, DR was conceptualized with a nickel-based structure. However, its weight and susceptibility to fire rendered it unsuitable for the rigorous demands of firefighting. While tungsten offered superior heat resistance, its density made it impractical for aerial applications. Stainless steel grade 330 (melting point of ~1500°C), though durable, still lacked the necessary fire resistance. To address these limitations, a groundbreaking solution was devised: a tantalum hafnium carbide exterior coating (melting point of 4215 °C, used in rocket nozzles) was applied to the stainless steel structure to provide a fireproof coating against the intense heat produced by the fire. This innovative approach significantly enhanced the material's fire resistance, enabling DR to withstand the intense heat and flames of wildfires. By combining the strength and durability of stainless steel with the exceptional fire resistance of the coating, DR achieves a robust and reliable design that empowers it to effectively combat wildfires in challenging environments.

Conclusion

Drone Ranger is the latest advancement in firefighting technology, powered by sustainable thermoelectricity and hydrogen, and equipped with sophisticated Advanced Pressure Swing Adsorption system to mitigate wildfires using atmospheric nitrogen and wildfire generated carbon dioxide. DR also actively removes CO_2 from the atmosphere, helping to mitigate the greenhouse gas emissions from wildfires and assists in restoring the balance of ecosystems by reducing carbon footprint. Moreover, the AI-driven system, coupled with infrared cameras, allows for precise detection and prioritization of high-risk areas, enhancing operational efficiency.

However, reliance on renewable energy sources may limit operational capability during unfavorable weather conditions and scaling up the technology to capture significant amounts of nitrogen and carbon dioxide might be challenging and resource intensive. Lastly, the complexity of real-time gas separation via the APSA system requires further optimization to ensure consistent performance under dynamic field conditions. Despite these challenges, the Drone Ranger offers a visionary approach to wildfire management, combining sustainability, technological innovation, and operational effectiveness.


Body made of 330 stainless steel with a tantalum hafnium carbide
Propellers
Infrared Camera
Intake of atmospheric air
Smoke Detector
Drone Ranger


APSA System
Hydrogen Storage
Hydrogen Generator
Oxygen Storage
Intake of atmospheric air
Heating Pad
Pressure reduction system
Zeolite (adsorb N2 and CO2)
Static eliminator Nozzle spraying Nitrogen and CO2 to put out fire
Gases
Palladium (adsorb H2)
Pyrogallic Acid (adsorb O2)

Bibliography:

Current technology

1. *Wildfires and acres* . Wildfires and Acres | National Interagency Fire Center. (n.d.-a). https://www.nifc.gov/fire-information/statistics/wildfires
2. *About Wildfires*. Protective Actions Research. (n.d.). https://community.fema.gov/ProtectiveActions/s/article/Wildfire-What
3. Salas, E. B. (2024, November 27). *Global deaths due to wildfires 2023*. Statista. https://www.statista.com/statistics/1293254/global-number-of-deaths-due-to-wildfires/
4. World Health Organization. (n.d.). *Wildfires*. World Health Organization. https://www.who.int/health-topics/wildfires#tab=tab_1
5. U.S. Department of the Interior. (n.d.). *Wildland firefighting tactics*. National Parks Service. https://www.nps.gov/subjects/fire/wildland-firefighting-tactics.htm#:~:text=When%20a%20fire%20is%20burning,to%20keep%20it%20in%20check.
6. Brown, M. (2023, May 26). *Judge says fire retardant drops are polluting streams but allows use to continue*. PBS. https://www.pbs.org/newshour/nation/judge-says-fire-retardant-drops-are-polluting-streams-but-allows-use-to-continue#:~:text=A%20government%20study%20found%20misapplied,to%20a%202021%20risk%20assessment.
7. *Firefighting drones: How are drones used for fire department?*. JOUAV. (2024, October 16). https://www.jouav.com/blog/drones-in-firefighting.html#:~:text=These%20drones%20are%20equipped%20with,the%20intensity%20of%20the%20flames
8. Wildfire Statistics: Environmental Protection Agency. (2024, June). *Climate Change Indicators: Wildfires*. EPA. https://www.epa.gov/climate-indicators/climate-change-indicators-wildfires
9. NCEI.Monitoring.Info@noaa.gov. (n.d.). *Annual 2022 wildfires report*. Annual 2022 Wildfires Report | National Centers for Environmental Information (NCEI). https://www.ncei.noaa.gov/access/monitoring/monthly-report/fire/202213
10. Nilsen, E. (2023, October 16). *Wildfires are dealing a massive blow to us real estate and homeownership, Congressional report finds*. CNN. https://www.cnn.com/2023/10/16/us/wildfire-cost-us-economy-congressional-report-climate/index.html#:~:text=Climate%20change%2Dfueled%20 wildfires%20are,Committee%2C%20chaired%20by%20 Democratic%20 Sen
11. *Suppression*. U.S. Department of the Interior. (2015, July 1). https://www.doi.gov/wildlandfire/suppression#:~:text=Firefighters%20control%20a%20fire's%20spread,air%20using%20 helicopters%20 or%20 airplanes.
12. Types of current drones: Bradshaw, H. (2024, August 20). *Wildfires: Researchers hope drone swarms will prevent infernos*. BBC News. https://www.bbc.com/news/articles/cg3e4pw294po
13. *Fire fighting drone: Dry powder fire extinguishing boom firefighting drone*. Fire fighting drone | dry powder fire extinguishing boom firefighting drone. (2020, June 16). https://www.uavfordrone.com/product/fire-fighting-drone-with-dry-powder-fire-extinguishing-boom/

14. *Firefighting drones: How are drones used for fire department?*. JOUAV. (2024, October 16). https://www.jouav.com/blog/drones-in-firefighting.html

History

15. Drone Launch Academy. (2024, September 4). *Who invented the drone: UAV history Lesson • Drone Launch Academy*. https://dronelaunchacademy.com/resources/who-invented-the-drone-uav-history-lesson/#:~:text=1935%20%E2%80%93%20The%20First%20Modern%20Drone&text=412%20of%20the%20DH82B%20were,%E2%80%9Cdrone%E2%80%9D%20to%20describe%20UAVs
16. Lambert, T. (2024, February 16). *A brief history of firefighting*. Local Histories. https://localhistories.org/a-history-of-firefighting/
17. *The Evolution of Aerial Firefighting*. The evolution of aerial firefighting: From helicopters to waterbombers. (n.d.). https://www.btlliners.com/the-evolution-of-aerial-firefighting-from-helicopters-to-waterbombers
18. Beverley, G. (2022, November 30). *A not-so-short history of Unmanned Aerial Vehicles (UAV)*. Consortiq. https://consortiq.com/uas-resources/short-history-unmanned-aerial-vehicles-uavs
19. Famous fires - forest history society. (n.d.). https://foresthistory.org/research-explore/us-forest-service-history/policy-and-law/fire-u-s-forest-service/famous-fires/
20. Perkins, S. (2022, June 24). *Earth's oldest known wildfires raged 430 million years ago*. Science News. https://www.sciencenews.org/article/earth-oldest-wildfire-430-million-years-ago-fossil-charcoal

Future technology

21. Li, D., Yao, J., & Wang, H. (1970, January 1). *CO2 selective separation membranes*. SpringerLink. https://link.springer.com/chapter/10.1007/978-3-642-33497-9_9
22. Technologies, R., & Stafford, D. (n.d.). *How do you fireproof metal?*. Fire Retardant Sprays, Paints and Coatings - RDR Technologies. https://rdrtechnologies.com/blog/how-do-you-fireproof-metal/#:~:text=Steel%2C%20especially%20stainless%20steel%2C%20is,in%20temperatures%20up%20to%20700%C2%BAF
23. *Different types of intumescent coatings and their benefits*. Tremco CPG APAC Blog. (n.d.). https://www.tremcocpg-asiapacific.com/blog/different-types-of-intumescent-coatings
24. *A guide to intumescent paint for passive fire protection | IFSEC insider*. IFSEC Insider. (n.d.). https://www.ifsecglobal.com/fire-protection/a-guide-to-intumescent-paint-for-passive-fire-protection/
25. Reolink. (n.d.). *Thermal vs infrared camera: Which is better？*. https://reolink.com/blog/thermal-vs-infrared-camera/?srsltid=AfmBOorY51BrmCOKI7QvQwDJ-5ocrYVlHp5yUUVBdW7Ej5_S59_BudD_#thermal-vs-infrared-camera-key-differences
26. Western Fire Chief Association (2024, July 9). *Thermal imaging camera (TIC) in firefighting*. WFCA. https://wfca.com/preplan-articles/tic-in-firefighting/#:~:text=They%20enable%20firefighters%20to%20see,and%20safety%20of%20firefighting%20operations
27. Enescu, D. (2019, January 21). *Thermoelectric Energy Harvesting: Basic principles and applications*. IntechOpen. https://www.intechopen.com/chapters/65239

28. Drone Outer Body: *304 & 316 stainless steel scrap price per pound in Texas*. scrapworks. (2024, August 22). https://www.scrapworks.com/stainless-steel-scrap-price-texas/
29. *What is the Max operating temperature for stainless steel?*. chemsealinc. (2022, September 23). https://www.chemsealinc.net/blog/what-is-the-max-operating-temperature-for-stainless-steel/#:~:text=Grade%20304%20alloys%20are%20capable,1%2C598%20and%201%2C697%20degrees%20Fahrenheit.
30. Pressure Swing Adsorption: *Advanced nitrogen generation technology: PSA Filtration*. South. (2022, January 6). https://www.southteksystems.com/our-technology/

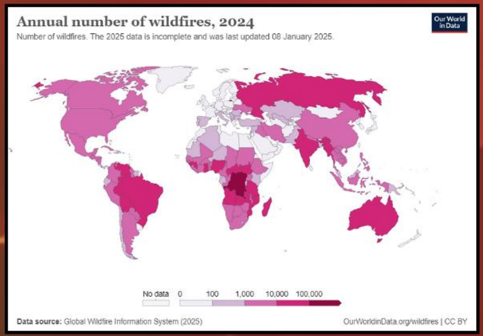
Breakthroughs and Design processes

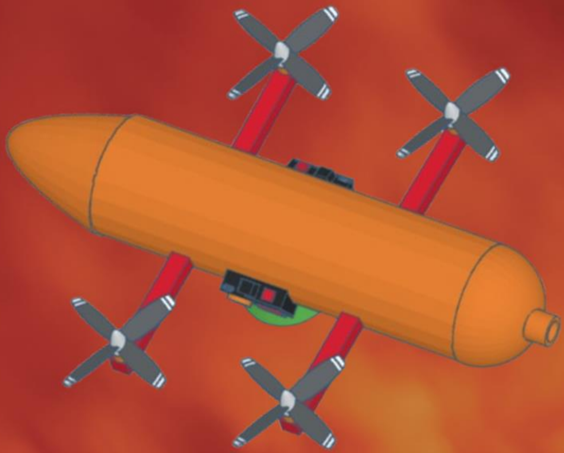
31. *Pressure swing adsorption*. Pressure Swing Adsorption - an overview | ScienceDirect Topics. (n.d.). https://www.sciencedirect.com/topics/engineering/pressure-swing-adsorption

32. *Tantalum hafnium carbide powder (taxhfy-xcy) for sale*. Stanford Advanced Materials. (n.d.). https://www.samaterials.com/tantalum-hafnium-carbide-powder.html
33. ASSDA. (2023, May 16). *Stainless Steel and fire resistance*. Stainless Steel and Fire Resistance. https://www.assda.asn.au/blog/307-stainless-steel-and-fire-resistance
34. *Copper-tungsten alloy fire resistance test: Resilience under flame exposure*. copper-tungsten Alloy Fire Resistance Test: Resilience under Flame Exposure |. (2024, September 2). https://www.chemetalusa.com/copper-tungsten-alloy-fire-resistance-test-resilience-under-flame-exposure/

DRONE RANGER

Fire's End, Nature's Friend, DroneRanger to Defend and Mend





Confronting Global Wildfire Crisis

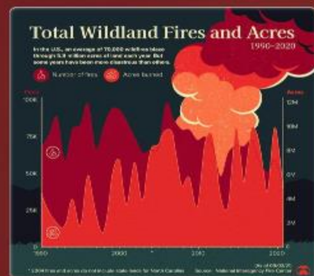
Recommended by the U.S. Department of Agriculture Forest Service and the United Aerial Firefighters Association as the most efficient wildfire fighting drone of the century.

"DroneRanger's unique AI-trained camera network used data from cameras, satellites, and meteorologists to monitor the forest conditions and fires which aided in predicting fire behavior and improving our firefighting strategies."
-Mr. Agni, Director of UAFA

Current Technology

What is a wildfire and what are its effects?

A wildfire is a large, uncontrolled fire that spreads quickly over dry plants and releases harmful gases. In 2023, there were 56,580 wildfires in the U.S., and smoke from these fires is linked to nearly 16,000 deaths each year. Wildfires damage the environment by destroying plants and habitats, causing soil erosion, and reducing air quality. The smoke contains dangerous substances like particulate matter and carbon monoxide, which can harm the lungs, heart, and brain. Wildfires also contribute to climate change by releasing large amounts of carbon dioxide. In 2022, wildfires released 5.3 billion tons of carbon dioxide and other gases. Each year, wildfires cost about $394 billion and destroy $15.5 billion worth of property.



What is currently being done to handle these wildfires?

Current methods to manage wildfires include prevention, early detection, suppression, and post-fire restoration. Fighting wildfires requires large amounts of water and fire retardant, often dropped from planes and helicopters. Increasingly, firefighting drones are being used to help detect fires and support firefighting efforts. These drones use high-resolution cameras and thermal imaging to spot hotspots and track fire behavior in real time. Some drones also create maps to help firefighters plan their actions, while others can drop water or fire retardant directly onto the fire. There are two main types of drones used in firefighting:

1. UAV Firefighting Drone: This drone uses bombs to release oxygen and has a small water load (up to 15 kg) to fight fires. It can stay in the air for about 45 minutes, but its limited capacity is a drawback.
2. Search and Rescue Drone (JOUAV CW-30E VTOL): Equipped with thermal cameras, this drone can locate hotspots. It has a flight time of up to 6 hours, can carry 8 kg, and operates in temperatures from 20°C to 50°C.

UAV Fighting Drone

Search and Rescue Drone

What are the limitations of these solutions?

Firefighting drones have benefits like reaching dangerous areas, reducing risks to people, providing real-time data, and improving efficiency. However, their limited carrying capacity and battery life need to be improved to help control wildfires better. Also, using water or foam isn't ideal because drones can only carry so much, it is not always easy to refill them with water in the field, and it weighs the drone down.

DRONE RANGER

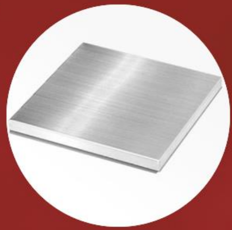
Home | Present Technology | Future Technology | APSA System | Breakthrough

Future Technology

DR Exterior and Components

Tantalum Halfnium Carbide

330 Stainless Steel



The drone is made of 330 stainless steel, which has a melting point of around 1,500 degrees Celsius, with tantalum hafnium carbide (THC) exterior coating, which has a melting point of 4,215 degrees Celsius. The purpose of using these two materials is to help resist the spread of flames and provide a fireproof coating against the intense heat produced by the fire. DR is equipped with many devices on its exterior. It is equipped with smoke detectors and infrared cameras to detect heat sources and help monitor remote areas. An AI-trained camera network is incorporated, which uses data from cameras, satellites, other drones and meteorologists to help monitor forest conditions and the fire itself. This information can also be used to predict fire behaviors based on the weather conditions and terrain, which can also improve firefighting strategies. DR is also equipped with a modern piece of equipment., the APSA system. This system uses elements in the air to help extinguish fires, eliminating the use of harmful fire retardants.

Thermoelectric and Hydrogen-Powered Drone for Extended Operation

Thermoelectric Generator

Hydrogen Generator for Drones

DR is powered by hydrogen and thermoelectricity, which are both environment friendly and energy efficient. A product of using these sources for energy is water vapor. This water vapor will also be sprayed at the fire to extinguish the fire faster. This setup also allows the drone to operate for extended periods of time, even in extreme heat. Hydrogen provides a high energy density which is crucial for the drone's performance and important on long missions. The two adsorbing agents, APA and Palladium, will be heated to release the two gasses that were adsorbed into a tank connected to the fuel cell where chemical processes will produce electrical energy to power DR. The thermoelectric generator (TEG) uses the Seebeck effect to turn heat into electricity by generating electric voltage using temperature differences. Using the heat produced by the wildfire, it can generate enough electricity to sustain its flight and operations. Components of the TEG include a silicon germanium and a heat sink. The silicon germanium will be placed on the outside where heat is most abundant whilst the heat sink will be placed within the drone to be cooled by liquid nitrogen.

The APSA system stands for Advanced Pressure Swing Adsorption system. Our APSA system is a groundbreaking piece of technology that will completely change the current scene of firefighting, which is heavily dependent on chemicals.

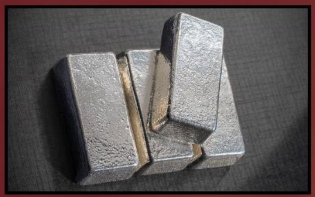
For more information about our APSA system, click here.

DRONE RANGER

Advanced PSA System (APSA)

The DroneRanger uses 3 materials to efficiently separate nitrogen to extinguish fires. This method is called Advanced Pressure Swing Adsorption

Palladium



Adsorb Hydrogen

Zeolite

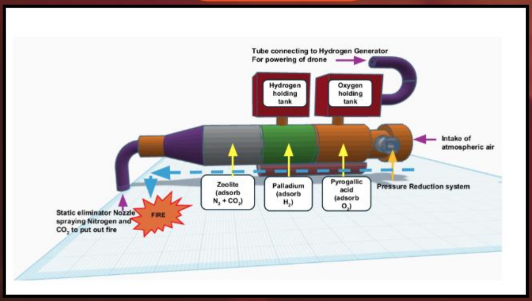
Adsorb Nitrogen and Carbon Dioxide

Pyrogallic Acid

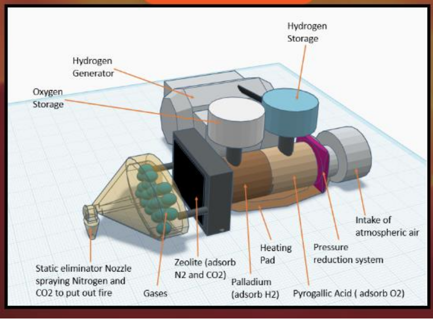
Adsorb Oxygen

DR has a special fire suppression system that uses nitrogen to for fires, because nitrogen does not breakdown or create toxic by-products when in the presence of flames. The system functions by extracting air from the surrounding environment and running it through various substrates under reduced pressure to adsorb particular gases. First, air passes through APA (alkaline pyrogallic acid), which adsorbs oxygen. It then passes through palladium, which adsorbs hydrogen. It then goes through zeolite, which captures nitrogen and carbon dioxide. The zeolite and Palladium are then heated to release Nitrogen and CO2 which are used to fight fires. The Hydrogen is further processed ton be used as fuel for the drone.

APSA Model 1



APSA Model 2



DRONE RANGER

Home | Present Technology | Future Technology | APSA System | Breakthrough

Breakthroughs

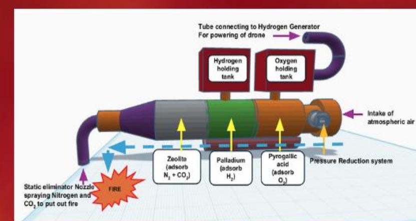
Maximizing a Small-Scale, High-Capacity, and High-Efficiency APSA System

For effective DR operation, it is crucial to integrate the APSA process, which uses adsorbent materials to capture gases essential for firefighting: nitrogen displaces oxygen, and carbon dioxide suffocates flames. Our advanced APSA system employs a 3-layer adsorbing matrix—alkaline pyrogallic acid, palladium, and zeolite—to absorb oxygen, hydrogen, and nitrogen/carbon dioxide. Current adsorbents lack the capacity and selectivity for efficient gas capture under rapid cycling conditions. Advancements in nano-engineered adsorbents with higher porosity and hybrid materials are needed. Additionally, low-energy desorption techniques will enable quick regeneration. Optimizing APSA for faster, eco-friendly wildfire suppression requires breakthroughs in real-time gas separation and the use of high-capacity compressors.

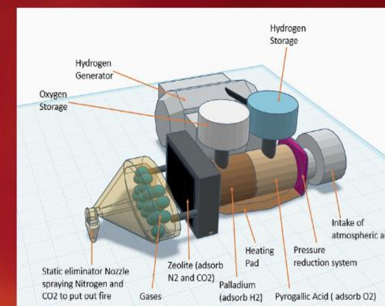
Thermoelectric and Hydrogen-Powered Drone for Extended Operation

A key challenge for DR is providing autonomous, sustainable power for longer flight times to suppress fires continuously. DR uses thermoelectricity and hydrogen fuel for extended operations. However, TEG efficiency is low compared to other power sources and relies on temperature differences and materials used. A large temperature difference is needed to generate enough electricity. A breakthrough is needed to improve TEG efficiency and enable easy, efficient electrochemical processing of hydrogen/oxygen inside a small drone to produce the necessary power.

DroneRanger's Revolutionary APSA System



APSA Model 1



APSA Model 2

Hydrogen Generator for Drones

Thermoelectric Generator for Drones