XPRIZE WILDFIRE | PG&E | GORDON AND BETTY MOORE FOUNDATION

STATE OF PRIZE REPORT

The grand challenge and rationale behind XPRIZE Wildfire

WE ARE XPRIZE

A global future-positive movement of over 1M people and rising. A trusted, proven platform for impact that leverages the power of competition to catalyze innovation and accelerate a more hopeful future by incentivizing radical breakthroughs for the benefit of humanity.

At XPRIZE, our mission is to inspire and empower a global community of problem-solvers to positively impact our world. We believe the solutions to the world's problems can come from anyone, anywhere.

Our role is to define the problems, set the targets, and crowdsource solutions through global competitions to incentivize the development of technological breakthroughs that accelerate humanity toward a future of equitable abundance. We provide the opportunity and the platform for people to take risks that ultimately lead to solutions that seemed out of reach or impossible. We celebrate great ideas and reward those who dare to follow through on their vision and create tangible solutions that are validated through extensive testing and judging.

The first-ever XPRIZE competition, the $10 million Ansari XPRIZE for sub-orbital spaceflight, captured the world's imagination and catalyzed a multi-billion-dollar commercial space industry, representing a massively leveraged initial philanthropic investment. Since then, we have launched competitions in the areas stretching from energy and mobility, through education and health, to conservation and automation.

WHY XPRIZE WILDFIRE?

WILDFIRE LANDSCAPE

Around the world, wildfires increasingly grow more dangerous and destructive. Fast exhausting firefighting resources, these extreme wildfires unleash devastating consequences—from a growing economic burden and the loss of life and assets, to the destruction of ecosystems.

EXTREME WILDFIRES ARE ON THE RISE

A Wildfire, in its most basic definition, is an uncontrolled fire. Wildfire has been a process central to our planet's cycles for some 350 million years and is an important part of certain ecosystems.[1] A "good fire," a low-intensity surface fire that burns at a controllable rate, is integral to the health and sustainability of forests as it clears dead fuel and encourages new growth, and it is essential for the survival of certain plant species, including the Sequoia and Eucalyptus.[2]

However, more and more do we see fires that burn bigger, at a higher intensity, uncontained, and faster to sprawl out of control. These large and destructive wildfires, also known as Extreme Wildfire Events (EWEs), are only around 3% of all wildfires, but drive over 80% of total associated fire-damages.[3]

In light of global trends, including a changing climate, the risk of conflagrations will continue to heighten, increasingly becoming the new norm. This norm increasingly outpaces present-day wildfire management, a practice that has not changed in a century. It is time to rethink paradigms and end destructive wildfires.

UNCONTROLLED, NEAR COMMUNITIES

Wildfires increasingly start in unsafe places. Nowadays, globally, 50-90% of wildfires are started by human activity and often near communities, where humans and assets are most exposed to fire risk.[4]

The Wildland-Urban Interface (WUI) is where a community meets or mixes with the wildland; it is where the risk to life and assets is most heightened.[5] As will be discussed later, it is also where wildfires are the hardest to fight. This risk can be particularly devastating in developing countries due to the frequent use of fire for daily activities, combined with informal structures and limited availability of firefighting resources.[6] In such high-risk areas, what makes the difference between a friendly and a deadly fire is control.

The goal of controlling fire, or fire management, may be as old as humanity.[7] Controlled fires are used for a variety of purposes, including cooking, heating, agricultural clearing, and forest management, but all, even if planned carefully, carry the risk of escaping.

ENGULFING MORE LAND

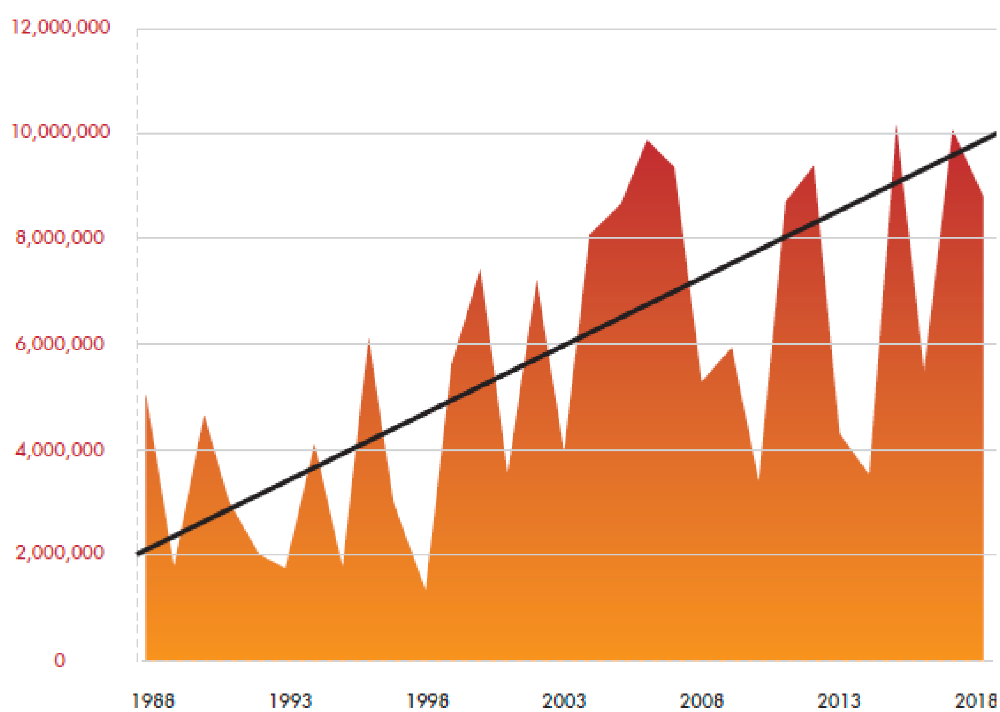
Globally, wildfires burn a total area of over 350 million hectares (865 million acres) every year—an area equivalent to the size of India, or over five times the size of Texas. It is double the annual area burned just 40 years ago.[8] 70% of all wildfires burn in Africa, and while the risk is global, it is fast-growing in the world's most fire-prone landscapes as well as ecosystems vulnerable to fires, including Southern Australia, Southern California, Southern Europe, Southern Kalimantan, Indonesia, and the Brazilian Amazon.[9]

In Australia, the early 2000s saw an eightfold increase in the average area burned over 20 years. In Southwestern Australia, the area burned over the following decade represented over 50% of hectares burned in the previous 40 years.[10] Since 2010, the frequency of destructive fires has risen 40%.[11] The Black Summer fires of 2019-2020 ravaged the Australian landscape, with over 18 million hectares of land burnt, creating devastating losses for biodiversity.[12] In the United States (U.S.), since 2000, an average of nearly 3 million hectares (7 million acres) are burned annually—double the average in the 1990s.[13] In Western U.S., over the past 50 years, wildfire frequency has increased by 400%, whereas wildfires burn over six times the land and last nearly five times longer.[14] 18 of California's 20 largest (by acre) fires took place since 2000.[15] Similarly to other phenomena affected by Climate Change, these fires are unprecedented.

FIGURE 1.1 US ANNUAL WILDFIRES AND ACRES BURNED

Wildfires increasingly burn more land

Source: National Interagency Fire Center[16]

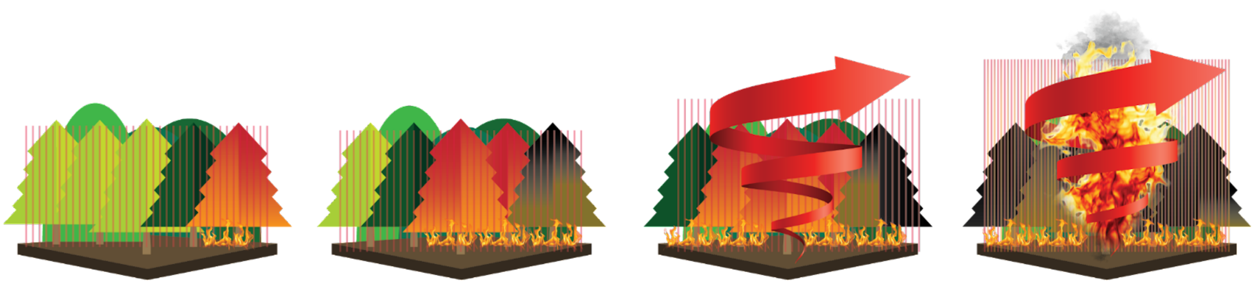


The key trend we see is a rise in frequency of magnitude—more frequently, we see wildfires that burn more land, last longer, and present Extreme Fire Behavior (EFB). Wildfires burn around the globe at any given moment, but most are safe. On an average day, the National Aeronautics and Space Administration's (NASA) satellites will detect 10,000 active fires globally.[17] They usually do not pose a great risk as firefighters are incredibly good at their job. Around 97% of fires are suppressed successfully before an escalation into a large fire event that exceeds capabilities.[18] In wildland firefighting, a fire successfully suppressed is considered one that did not exceed 40 hectares (100 acres) of forest or 120 hectares (300 acres) of grass and bush.[19] Increasingly, however, wildfires outperform present-day suppression capabilities. These wildfires are known as extreme fires and as Mega Fires when they exceed 40,000 hectares (100,000 acres).[20]

HIGH INTENSITY, FAST MOVING, "OUT OF CONTROL" FIRES

Fire behavior is a set of characteristics used to observe a burning fire. These characteristics range from the manner in which fuel ignites to how the flame develops and spreads and other factors as they are affected by the interaction with environmental conditions, including fuel type, weather, and topography.[21] For firefighters responding to an incident, how the fire behaves informs the course of action. EFB is used to describe an evolving extreme wildfire when the fire presents characteristics such as a high Rate of Spread, prolific Crowning and/or Spotting, Fire Whirls, or a strong Convection Column.[22]

FIGURE 1.2 EXTREME FIRE BEHAVIOR
Source: Swain, D. (UCLA), PAI/Bay Area News Group[23]



The concept of EWEs has emerged in recent years to describe the growing phenomenon of destructive wildfires, which are often described as "fast-moving," "high-intensity," or by their size (of area burned). In an effort to bring further clarity to the phenomenon, a group of U.S.-based researchers embarked on defining fire events and their behavior.[24] As shown in Figure 1.3, those categorized as EWEs demonstrate conditions that move between “virtually impossible” to “impossible” to control and suppress.

FIGURE 1.3 WILDFIRE EVENTS CLASSIFICATION

Source: Tedim et al., 2018[25]

	FIRE CATEGORY	FLI (KWM-1)	ROS (M/MIN)	FL (M)	PYROCB (SMOKE-INFUSED THUNDERSTORMS)	DOWNDRAFTS	SPOTTING ACTIVITY	SPOTTING DISTANCE (M)	TYPE OF FIRE AND CAPACITY OF CONTROL
Normal Fires	1	<500	<5 a <15 b	<1.5	Absent	Absent	Absent	0	Surface fire; Fairly easy
	2	500–2000	<15 a <30 b	<2.5	Absent	Absent	Low	<100	Surface fire; Moderately difficult
	3	2000–4000	<20 c <50 d	2.5-3.5	Absent	Absent	High	≥100	Surface fire, torching possible; Very difficult
	4	4000–10,000	<50 c <100 d	3.5-10	Unlikely	In some localized cases	Prolific	500-1000	Surface fire, crowning likely depending on vegetation type and stand structure; Extremely difficult
Extreme Wildfire Events	5	10,000–30,000	<150 c <250 d	10-50	Possible	Present	Prolific	>1000	Crown fire, either wind- or plume-driven; Spotting plays a relevant role in fire growth; Possible fire breaching across an extended obstacle to local spread; Chaotic and unpredictable fire spread; Virtually impossible
	6	30,000–100,000	<300	50-100	Proable	Present	Massive	>2000	Plume-driven, highly turbulent fire; Chaotic and unpredictable fire spread; Spotting, including long distance, plays a relevant role in fire growth; Possible fire breaching across an extended obstacle to local spread; Impossible
	7	>100,000	>300	>100	Present	Present	Massive	>5000	"Plume-driven, highly turbulent fire; Area-wide ignition and firestorm development non-organized flame spotting; Impossible"

Note: a Forest and shrubland; b grassland; c forest; d shrubland and grassland

As informative as these metrics are in determining the course of action and resource mobilization, they cannot yet be accurately measured in real time. Instead, experienced wildland firefighters interpret the fire behavior on-site and estimate variables such as the fire intensity, forward rate of spread, and flame length.[26]

“Out of Control” is a term used by firefighters to indicate the need for a change of strategy. Put simply, the fire’s behavior is too dangerous to fight and the firefighting capabilities and suppression resources become ineffective.[27] At that point, resources are mobilized to focus on saving lives and property. EWEs spread and grow extremely fast, thus shrinking the time available for effective control and suppression activities.

THE DEVASTATING CONSEQUENCES

Conflagrations (extreme fires) may be a small portion of wildfires, but they account for about 97% of total firefighting costs and area burned and the vast majority of total fire damages (over 80%).[28] The tragic consequences range from immediate to long-term and include a broad array of problems, such as loss of life and livelihood, destruction of homes and habitats, and drive other natural disasters.

FATALITIES AND HEALTH

Fatalities are the tragic and undiscriminating toll of the raging flames. The 2018 Camp Fire, U.S.'s deadliest in a century, killed 86[29], the 2018 Attica Wildfires in Greece killed 102[30], the 2017 June and October wildfires in Portugal, killed over 100[31], and the 2009 Black Saturday bushfires, Australia's deadliest, killed 173[32].

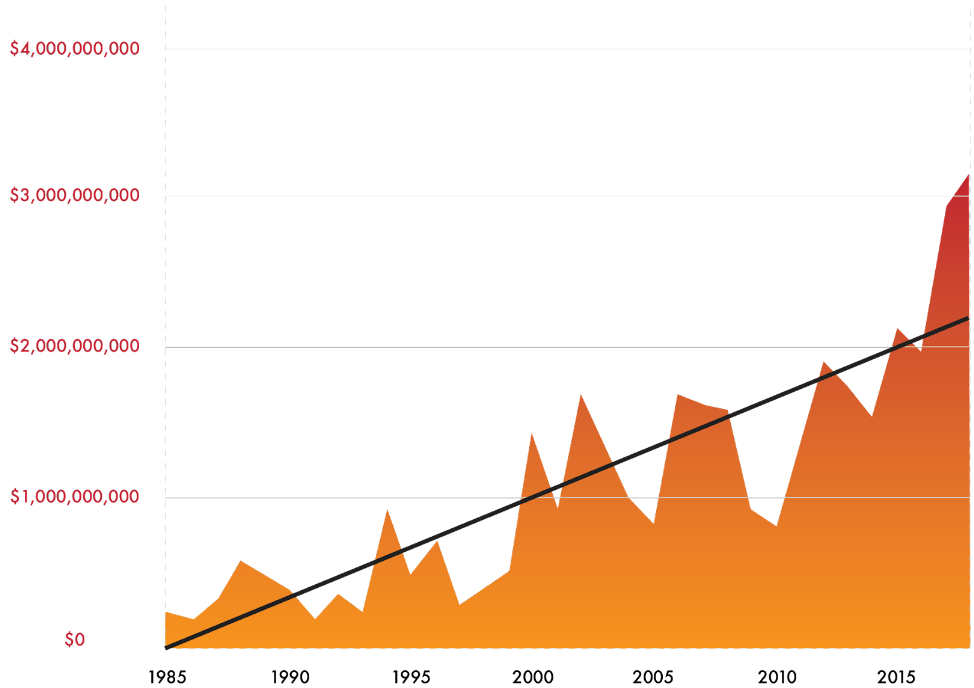
But it does not end with direct fatalities. Intense wildfires' effects last long after the flame is out, and may linger for a lifetime as they degrade air quality. Global estimates suggest that every year, around 340,000 people die prematurely from fire-related particulate matter, which can be carried long distances.[33] During the fire, the increased duration of exposure to smoke bears acute and chronic health effects, including respiratory disease and cardiovascular disease.[34] In the Western U.S., fire seasons of 2017-2018 saw record breaking particulate levels, with over 10 million people exposed to high levels of $PM_{2.5}$ (fine particulate matter).[35] Smoke from Australia's 2019-2020 Black Summer is said to be responsible for 450 deaths.[36] Fine particles are strongly linked to premature death and linger longer in the air, thus increasing the risk of inhalation.

The young and elderly are especially at risk. The aftermath of wildfires shows a short-term spike in elderly hospital visits, including a 42% increase in heart attacks and a 22% increase in stroke-related issues.[37] Wildfires can increase mercury levels in the air by 30%, threatening especially infants, increasing the risk of a wide host of developmental effects, including on cognitive and fine motor skills.[38] Moreover, research has found changes to children's genetic code following exposure to wildfire smoke, potentially leading to a weakened immune system.[39]

RISING COSTS

As wildfires expand their reach, they give rise to another challenging trend: a growing economic burden. Big fires are incredibly expensive to fight, as they require more resources. And as the fire season extends year-round, costs of firefighting are breaking records.[40] In the U.S., the federal cost of firefighting is rising, with 2017 being the most expensive fire season yet, with $2.7 billion in costs. It surpassed the previous record set just two years before.[41] In 1995, fire costs were 16% of the United States Forest Service (USFS) budget (which accounts for 70% of national firefighting costs); now, they are over 50%.[42] In California's 2018 fire season, the state's fire agency exhausted its annual budget of $442.8 million by September, two months before the state's deadliest wildfire - the Camp Fire. California's firefighting costs more than tripled between 2013 and 2018.[43] And in 2021, California's Dixie Fire became the most expensive to fight in U.S. history, with a total price tag of $637.4 million.[44]

FIGURE 1.4 US FEDERAL FIRE SUPPRESSION COSTS
Source: National Interagency Fire Center[45]



The economic losses inflicted by wildfires are staggering. In the EU, annual economic losses amount to over $3.3 billion and are expected to rise to $5 billion by the end of the century.[46] In Indonesia, the devastating 2015 fire season cost nearly 2% of the country's GDP.[47] Beyond devastating direct losses, disruptions to communities and businesses drive further costs. The estimated total economic burden of all wildfires in the U.S. ranges between $125 billion and nearly $350 billion annually; according to another study, in Australia, it is around $12.3 billion.[48, 49] Over two-thirds of the world's land burned is in Africa, setting a major setback for economic development.[50] Globally, extreme wildfires alone are projected to inflict potential damages of up to $300 billion annually by 2050.[51]

BIODIVERSITY AND ECOSYSTEMS

Low-intensity wildfires help maintain forest health and are central to a variety of ecosystems. However, as high-intensity wildfires increase, they are becoming a major factor causing habitat loss, deforestation, and land degradation. Extreme fires are now the leading cause of animal habitat loss on U.S. federal lands and can destroy entire ecosystems.[52] In California, the 2007 Moonlight and Antelope fires converted the historically conifer tree-dominated landscape, where low-intensity fires used to burn regularly, into a shrubland dominated by chaparral, a highly flammable fuel that drives fast-moving, intense fires.[53] The northern boreal and taiga ecosystems are adapted to regular low-intensity fires, but in 2019 faced unprecedented levels of extreme fires.[54] High-intensity fires that reach the tree canopy kill most of overstory trees (over 75% in an area), and in turn, the dead fuel increases the likelihood of subsequent intense fires.[55]

Other ecosystems are never meant to burn. The 2019 devastating fires in the Amazon had the rainforest burning at a record rate. The Amazon is one of the most biodiverse places on Earth, but this forest did not evolve to burn.[56] Fire does not naturally burn in the Amazon, but fires have been used there for centuries to clear space for agricultural crops. Nowadays, it is practiced on an industrial scale for industries such as mass agriculture, logging, and mining, heightening the risk for fires to escape. [57] Thus, when high-intensity, fast-moving fires broke out in the summer of 2019, they brought the forest near a tipping point, threatening an irreversible collapse of the entire networked ecosystem.[58]

NATURAL RESOURCES AND GLOBAL WARMING

The effects of extreme wildfires on ecosystems unleash chain reactions affecting natural resources, such as soil and water, and potentially fuel disasters. Forests are important providers of clean water, in some places providing over 50% of the water supply. When a wildfire rages through, rivers get contaminated with sediments, dissolved organic carbon, and other chemicals released by the fire, and in the long-term, watersheds are altered.[59] After the fire, in the absence of ground cover, burned areas grow more vulnerable to flooding, and wildfire-driven soil erosion can lead to land degradation, reduced crop yield, and desertification.[60]

One of the key reasons for the increase in extreme wildfires, as will be discussed next, is Climate Change, and, more specifically, global warming, which, in turn, extreme wildfires help worsen. Globally, wildfires release into the atmosphere more CO_2 than global road, rail, shipping, and air transport combined.[61] It is estimated that wildfires emit around 8 billion tons of CO_2 a year.[62] When fires grow extreme, they release significant amounts in a short time: California's October 2017 Wine Country fires emitted in one week as much CO_2 as California's vehicles emit in a year.[63] According to some estimates, wildfires drive up to 20% of total global greenhouse emissions.[64]

In addition, wildfires burn large portions of forests, which play a key role in the fight against Climate Change as a significant source of carbon storage. 2019 saw massive wildfires raging in icy and tropical rainforests, and boreal forest, areas that store large amounts of carbon and historically rarely burn. These include the Amazon, which absorbs about 2.2 billion tons of CO_2, as well as over 2.4 million hectares of scorched Siberian Taiga and boreal forest and over 1 million hectares of Tundra and boreal forest in Alaska.[65]

ENTERING AN ERA OF MEGA FIRES

Wildfire risk is generally determined by the potential fire behavior and proximity to population centers. What ultimately determines the behavior are environmental conditions: the interaction between factors such as fuel, weather, and terrain. The risk continues to heighten due to the effects of three key factors: the changing climate, fuel build, and the expanding WUI.

The common denominator of the 3% extreme wildfires is EFB driven by respective extreme fire conditions. Favorable wildfire conditions that support the fire growth and spread include steep terrain, where fire can gain speed upslope, unstable atmosphere, hot temperatures, low humidity, an abundance of dry fuels, and high windspeed: above 25 km/h (15 mph). The specifications of these conditions vary on the basis of a location and its characteristics, as well as their interaction with one another and where the fire started. When these align at their extremes, fire risk is at its highest, and Red Flag weather warnings are issued.[66]

CLIMATE CHANGE

The changing climate is helping fuel more extreme wildfires, more frequently. In California, where fire risk is one of the world's fastest-growing and fire weather is extreme, Red Flag weather criteria include fuel moisture of ≤50%, relative humidity of ≤15%, sustained winds of ≥32 km/h (20 mph), or gusts ≥56 km/h (35 mph), unstable atmosphere and high temperatures. Wind is one of the most concerning factors during fire activity, as a gust can swiftly spread a wildfire, carry burning embers miles away, or dangerously change direction.[67] In Southern California, the Santa Ana winds infamously fuel intense fires with up to 156 km/h (97 mph) of sustained winds and 269 km/h (167 mph) gusts.[68]

With global warming advancing, we are experiencing more extreme weather conditions and changing climates. Drier conditions and higher temperatures increase the likelihood, duration, and severity of wildfires.[69] California and Australia used to have a fire season in their respective late summers. These seasons now last virtually year-round and quickly exhaust firefighting resources.[70] Places susceptible to naturally-caused wildfires, like Australia, will see a growing ignition risk as lightning incidences are likely to increase in a warming climate. At the same time, wetter places that are less accustomed to wildfires begin to see more of them.[71]

The 3% of wildfires considered extreme were 2% just a decade ago, and 1% the decade before.[72] According to the United Nations' Intergovernmental Panel on Climate Change (IPCC), with global surface temperatures continuing to rise, in as early as 2030, we will see a 14% increase in extreme heat days, further exacerbating extreme wildfire conditions.[73] By 2050, climate-induced wildfires are projected to burn 100% more land in the U.S., and fire risk days will increase 300% in Southern Australia, driving the devastating consequence to new extremes.[74] According to a 2022 UN Environment Programme report, the risk of extreme wildfires will rise by up to 50% by the end of the century.[75]

FUEL BUILD

The build of fuel (dead leaves and trees) on the forest floor powers extreme fires, and it increasingly accumulates in higher numbers due to the changing climate. Longer, warmer rainy seasons lead to an explosion of growth, and when followed by long, hot, and dry seasons, more fuel dies faster and is exposed longer to hazardous fire conditions.[76] Higher temperatures also weaken trees and attract pests, killing Californian trees in unprecedented numbers and generating more fuel.[77] Years of prolonged droughts set the scene for the record-breaking fire seasons of 2017-2018 in California and 2019 in Southeastern Australia.[78] As temperatures continue to go up, wet and dry extremes will worsen worldwide; by the end of the century, California will see up to 200% more very wet "rainy seasons" and up to 150% more very dry "rainy seasons."[79]

Historically, low-intensity fires regularly cleared the forest floor from dead vegetation. In light of increasingly high-intensity fires, more efforts are given to forest management tools such as Thinning and Prescribed Fires. Prescribed Fires, otherwise known as Prescribed/Controlled Burns, are seen as the most cost-effective tool to manage forests. They are prescribed for a specific purpose and are carefully planned to ensure safety.[80]

However, Prescribed Fires can also escape and turn catastrophic, and that has been affecting the use of these important tools. In the U.S., examples include the 2000 Cerro Grande Fire in New Mexico, 2012 Lower North Fork Fire in Colorado, and in 2023 in the Willamette National Forest in Oregon. Although only 1% of Prescribed Fires escape, fire and forest managers are reluctant to use them due to the high risk involved.[81]

EXPANDING WILDLAND-URBAN INTERFACE

The heightened risk of wildfires in the WUI translates to multiple levels. Human proximity to flammable vegetation in the WUI increases both the risk of ignition, as humans start most fires, and of a fast fire growth that drives extreme wildfires.[82] The WUI is where "wildfire problems are most pronounced," according to the U.S. Federal Emergency Management Agency (FEMA).[83] Control and suppression activities are significantly costly and challenged when fighting wildfires amidst burning structures. With a priority to ensure the safety of people and assets, firefighters divert up to 90% of their resources to protecting houses. Houses frequently re-ignite and quickly consume suppression resources.[84]

At least 25% of California's population, over 11 million people, live in the WUI and are highly exposed to fire risk. The state's 2017 fire season resulted in over 45,000 insurance claims, totaling more than $11.8 billion.[85] Across the U.S., on average, 3,000 homes are lost annually to Wildland Fires (fires burning in the WUI). The WUI challenge is global: homes and lives are lost from France to Chile, from Canada to Greece and Indonesia. The 2016 Fort McMurray wildland fire in Canada displaced over 80,000 people for a month and consumed over 2000 structures.[86] As the global population continues to grow and move into cities in record numbers, cities expand into the wildland, further expanding the exposure to fire risk. Due to the high risk involved, a fire burning in the WUI cannot be left to burn and demands immediate suppression and protection actions to save lives and property.[87]

When combining these three key factors of Climate Change, fuel build, and expanding WUI, we will increasingly see more high-intensity, extreme fires more frequently. More people will be exposed to the heightened risk of fire ignition, fast spread, and growth. More wildfires will surpass firefighting resources and unleash devastating consequences, risking lives, assets, and the environment.

PREFERRED FUTURE STATE

What might an alternative future look like?

This is a vision, a target for our prize competition to calibrate towards, not its end state. XPRIZE competitions are designed to unlock innovation that, if properly nurtured, sets humanity on a path toward the Preferred Future State.

> **IMAGINE A WORLD WHERE HUMANITY AND FIRE CAN SUSTAINABLY AND SAFELY CO-EXIST.** WHERE WILDFIRES ARE DETECTED RAPIDLY, ACCURATELY, AND PRECISELY; ALLOWING FOR THE SAFE MANAGEMENT OF BENEFICIAL FIRES AND SWIFT SUPPRESSION OF HIGH-RISK FIRES.

TOWARDS A PREFERRED FUTURE STATE

To identify the core problems in the present day of affairs that keep us from realizing the preferred future state, we have harnessed the power of collective minds, drawing insights from expert practitioners, including fire incident chiefs, wildland smokejumpers, fire investigators, forest specialists, testing specialists, and researchers across a wide array of relevant fields.

IN NUMBERS

90+

Experts Interviewed

75+

Consulted Members of XPRIZE Wildfire Online Community

02

Expert Workshops

PRESENT-DAY INDUSTRY STATE

The control and suppression of raging wildfires is a multifold process divided across three general areas of work: detection and monitoring (including risk assessment), response (arrival at the scene and resource mobilization), and suppression (initiation of suppression activities and delivery of suppression materials).[88] We have spoken with experts across all areas to draw a picture of the process, a general overview of which follows.

To unpack the response to a high-risk wildfire, we examine the case of the US Wildland Firefighting for its experience in some of the world's most fire-prone regions. Nonetheless, the process shares great similarities globally, assessed throughout the research.

High-risk, destructive wildfire suppression begins with detection, a field that has progressed greatly since the time of lookout towers. Detection begins with the weather forecast and risk assessment. Data derived from a wide variety of sources, including notably satellites, help inform fire weather conditions and the likelihood of a wildfire. The geostationary satellites orbiting Earth (e.g., GOES 16-18 and the upcoming GOES-U) are a prime tool to detect wildfires by identifying hot-spots, while the high-resolution Low-Earth orbit satellites (e.g., MODIS on board the Aqua and Terra satellites, which are due to retire in 2023) are used for strategy and monitoring due to revisit time limitations. A hot-spot is then monitored for confirmation; if the perimeter in the imagery is growing, it calls for action.[89] Ground detection tools include cameras and sensors on planes or towers, mainly detecting heat signatures with greater accuracy.[90] Nevertheless, experts tell us that the most common detection tool remains citizens calling in to report a fire when flames are shown.[91]

The response and suppression aspects depend on where the fire is. When it comes to a wildland fire, one that burns in the high-risk WUI, the first responders are the local (municipal) firefighting agency. There is no common initial response, and it could range from a single fire engine to multiple engines, chiefs, and crews.[92] After confirmation and assessment of the fire event, wildland firefighters will be called in, and additional resources will be mobilized. Depending on the accessibility to the fire site, these may include large Air Tankers (of 3000-18,000 gallons), Smokejumpers (firefighters that parachute into wildfires), Helirappellers (firefighters that rappelle down to the fire from a helicopter), and Hotshots and Handcrews will fly in or hike to the fire site to construct fire lines.[93]

The process can be cumbersome. Firefighting organizations range from disadvantaged volunteer fire departments, often staffed by retired firefighters, to municipal and national specialized fire agencies. Firefighting is a complex field encompassing many disciplines, and similarly, agencies tasked with firefighting, as will be discussed later, are numerous and challenging to coordinate.[94]

The core practice of wildland firefighting is said to have not changed in a century.[95] Once at the scene, firefighters begin the initial attack phase with control and containment activities. Using tools such as chainsaws, brush hooks, Pulaskis (a double-headed axe with an adze), McLeod (a large rake), and shovels, Interagency Hotshot Crews (IHC) and others move in to clear fuel and create fire lines to stop the spread of the fire's flaming edge. They are known as "hotshot" as they face the hottest part of wildfires. At the same time, water and retardants are used to battle flames.[96] Response vehicles include fire engines, helicopters, and planes, and all face accessibility challenges that will be discussed next.

In wildfires, the main suppression materials are mineral soil and water. These are effective retardants when available, but the main focus is not to introduce dangerous chemicals to the environment. As such, only class A foam and retardants are allowed.[97] Once a wildfire is declared (100%) contained, Mop-Up activities begin—a process that may take months. Firefighters walk around to ensure all surface fuels (i.e., leaves and branches) no longer burn. Only then can firefighters declare 'Fire Out,' and the wildfire is officially suppressed.[98]

The initial attack is an invaluable timeframe for suppression activities before a high-risk wildfire sprawls out of control.[99] 30 minutes is an approximate target used by firefighters to indicate that timeframe, but the actual time varies as it depends on the evolving fire behavior characteristics.[100] Increasingly, firefighters face fast-growing EWEs that are impossible to apply suppression activities to. The reality of present-day capabilities is that for a flame of 1.2m (4 ft.) in height, ground operations of direct attack (control and suppression activities) cannot continue with hand tools alone. At 2.4m (8 ft.) in height, flames are too high and intense for an aerial attack.[101]

CORE PROBLEMS

Against increasingly devastating fires, present-day firefighting capabilities grow increasingly ineffective and insufficient. In this section, we identify the core problems that currently inhibit progress and will likely continue to do so without innovation.

01 SHRINKING RESPONSE TIME

With extreme conditions aligned to drive EWEs, time is more crucial than ever. Time is a challenge across every aspect of the firefighting process, including detection, response, and suppression activities, and delays in each phase affect the next. In fact, all interviewees unanimously confirmed that the timeframe to effectively suppress a dangerous fire is the biggest challenge, and it is shrinking as more fires grow more rapidly.[102]

The present-day best-case average time is 60 minutes, with estimated targets being 15 minutes to detect, 15 minutes to arrive at the scene, and 30 minutes (from detection) to perform suppression activities. The new reality is that wildfires reach their out-of-control phase much faster than that.[103]

The smaller the fire is, the easier and less costly it is to suppress. As all fires start small, the crucial difference-maker is the time to detect the fire source accurately.[104] However, given Climate Change and other trends mentioned earlier, the time window in which the fire is small is shrinking.

02 ACCURATE AND PRECISE DETECTION

Early detection is a game changer for firefighting, allowing valuable time for suppression activities, yet current capabilities still lag behind, driving delays in strategy and response. Citizens calling the emergency line provide the fastest detection, but it is possible that hours of combustion had already passed before a fire was noticed.[105]

Key detection tools in the U.S. include satellites and planes mounted with infrared sensors. The National Oceanic and Atmospheric Administration's (NOAA) Geostationary Operational Environmental Satellites (GOES) are favored by responders as they update every 15 minutes. However, a hot pixel, indicating a possible wildfire, represents 1 km^2 (0.38 square miles): an area large enough to challenge pinpointing the fire location.[106] Closer to the ground, monitoring offers greater accuracy. From an altitude of about 3 km (~10,000 ft.), planes can detect a hotspot of 15 cm (~6 in.) across and place it within 4m (~13 ft.) on a map.[107] But planes cannot roam the sky continuously, and detection is challenged in the presence of thick forest canopy and smoke. All detection methods, ground or aerial, are challenged by certain environmental conditions.[108]

Another challenge is False Positives, i.e., safe hotspots mistaken to be high-risk fires. These may be safely contained large fires or hot reflective surfaces like solar panels and water glares, or water vapor mistaken for smoke. When resources are mobilized to the wrong location, valuable time is lost.[109] Moreover, as noted above, live fire behavior intelligence is unavailable to emergency forces at large, hindering the ability to effectively strategize and mobilize resources.[110]

03 CHALLENGED ACCESSIBILITY

Wildfires can start in hard-to-reach areas that exceed present-day capabilities to access. This problem is present across all firefighting stages and is particularly challenging around response and suppression, in both ground and airborne capabilities. Fire engines are limited to a 40% slope; beyond that, losing control over the vehicle is imminent.[111] This was the case in the 2018 Camp Fire. Firefighters were at the scene within 15 minutes of reported detection, but they had no way of reaching the wildfire burning in the canyon on a slope.[112]

Up in the air, low-flying planes, used for detection, monitoring, and suppression delivery, are limited by weather conditions, time of day, and environmental and fire conditions. In the U.S., they cannot fly below ~150m (500 ft.), which affects monitoring and suppression capabilities. Planes also cannot fly before daylight, directly above ~2m (6 ft.) flames, if the wind is strong, or if visibility is impaired.[113]

Reliable connectivity is another major issue in managing fire operations. Wildfires are not always near cell towers, sometimes they ignite in GPS-challenged locations or the network is overwhelmed, and there have even been incidents of data throttled by providers.[114]

04 OPERABILITY IN EXTREME CONDITIONS

Climate-change-induced weather leads to more extreme fires that spread faster and are harder to fight, making the current way of detecting, responding to fires, and delivering suppression materials or other fire attack maneuvers more challenging and increasingly obsolete. As one example illustrates, high winds and dense smoke ground planes, which are vital for fire suppression. That was frequently the case during the 2018 Camp Fire.[115]

We see more fires burning in winds of 100 km/h (60 mph) and up.[116] Present-day capabilities, even if they can withstand such strong winds, cannot effectively deliver suppression material to the fire, especially when extreme fires begin generating their own weather.[117,118] In the aftermath of Camp Fire, officials reported that the aerial fleet, the most costly firefighting option, was able to slow the spread of the fire, put out spot fires, and clear routes, but it was no match to the wind-induced firestorm.[119]

05 A SILOED, FRAGMENTED INDUSTRY

As widely discussed thus far, the firefighting process is a complex operation involving many moving parts that interact and influence one another. However, our research found that this industry is highly siloed. Nine key U.S. federal agencies engage in firefighting and are supported by others, such as NASA and FEMA. Each focuses on firefighting from a different angle. For example, NOAA notably detects, monitors, and informs fire weather, whereas the bulk of wildfire suppression activities are carried out by the USFS. But there is also some overlap; both USFS and the Bureau of Land Management (BLM) perform airborne firefighting.[120] The picture is further muddled by local and state fire agencies. There is no central dispatching system, and the multi-layered levels of data and authority often cause conflicts driven by funding, policy, and agency priorities. The challenges range from coordination through resource mobilization to knowledge exchange, and they ultimately drive delays in a highly time-sensitive operation.[121]

The case of the wildland fire (a wildfire in the WUI) highlights the siloed challenge of firefighting. To begin with, not all agencies are resourced equally, as was the case in the 2018 Woolsey Fire in California, when the response was delayed due to resource shortages.[122] Secondly, in the WUI, the first responders are the local agencies. Yet, they are usually not equipped for wildfire firefighting but rather to fight structural urban fires. The fire will burn over 20,000 m^2 (~5 acres) before federal wildfire firefighters are likely called in. This means that in the precious early moments of a high-risk fire, time is lost over trying to suppress a fire with inadequate equipment.[123]

This siloed nature also translates into innovations in the field and how, if at all, these are introduced into the practice of firefighting.

06 GLOBAL AVAILABILITY

Even when the technology does exist, it can be costly and out of reach for many countries and communities, as is the case with supertanker planes, satellite-based remote sensing, and even having a local firefighting unit.[124]

> **EXTREME AND DEVASTATING WILDFIRES ARE ON A RISING TRAJECTORY, EXPOSING MANY TO ACUTE RISKS AND DESTRUCTIVE CONSEQUENCES THAT RANGE FROM THE IMMEDIATE TO THE LONG-TERM.** AGAINST THE GROWING RISK, FIREFIGHTING RESPONSE WAS IDENTIFIED AS INCREASINGLY OUTPERFORMED BY FREQUENT EXTREME FIRES. SPECIFICALLY, THE CAPABILITIES TO RAPIDLY, ACCURATELY, AND PRECISELY DETECT WILDFIRES AND TO FACILITATE THEIR SAFE MANAGEMENT OR SWIFT SUPPRESSION IN CASE OF HIGH-RISK FIRES WERE IDENTIFIED AS AN AREA THAT COULD BENEFIT FROM THE FOCUS OF AN XPRIZE.

XPRIZE WILDFIRE

Destructive wildfires are on the rise with increasingly catastrophic effects: billions of dollars of damages, hundreds of thousands of lives prematurely ended, and irreversible environmental damage.

Unfortunately, current solutions are not up to the task. We have heard from nearly everyone we interviewed that wildland firefighting is an industry that has not changed in a hundred years. We are still fighting fires with hand tools and containment lines. It is no wonder then that a fundamental hopelessness seems to have permeated the global consciousness on this issue. It seems there is nothing we can do to match the increasing demand.

But we at XPRIZE believe we do not have to accept this reality. We believe that all over the planet there are brilliant, audacious minds that can crack this challenge. XPRIZE Wildfire is set to drive innovation across all aspects of firefighting response. Across two tracks, supporting near and long-term impact goals, we believe this competition will yield moonshot breakthroughs to unlock a future where we co-exists safely and sustainably with fire.

THIS FUTURE IS POSSIBLE. IT STARTS WITH XPRIZE WILDFIRE.

XPRIZE Wildfire is a 4-year, $11M competition that will incentivize teams to innovate firefighting technologies that will transform the practices of a crucial industry that have not changed in a century, and end destructive wildfire events.

- **Competition Track A:** Space-Based Wildfire Detection and Intelligence
- **Competition Track B:** Autonomous Wildfire Response

To learn more about the competition, visit our website at www.xprize.org/wildfire.

XPRIZE Wildfire is offered in partnership with Co-Title Sponsors Gordon and Betty Moore Foundation and Pacific Gas & Electric, Presenting Sponsor Minderoo Foundation, Bonus Prize Sponsor Lockheed Martin and Supporting Sponsor Conrad N. Hilton Foundation, and individual benefactors.

APPENDIX
A: COMPETITION DESIGN

XPRIZE WILDFIRE DESIGN SPONSORS

The research and design of this competition was made possible through generous contributions by Dr. Richard Merkin, CEO of Heritage Group and a longtime XPRIZE benefactor and Vision Circle member, and by The Minderoo Foundation.

AUTONOMOUS WILDFIRE RESPONSE TRACK (2019, UPDATE 2023)

Dan Selz - Senior Project Manager, Research & Design, XPRIZE
Eti Shechtman - Research Lead, Research & Design, XPRIZE
David Poli - Senior Associate, Research & Design, XPRIZE
Nick Azer - Community Manager, Research & Design, XPRIZE

A special thank you goes to the expert council that met with us regularly to ensure rigor and audacity:

Alex Maranghides - Fire Protection Engineer, National Institute of Standards and Technology (NIST)
William (Ruddy) E. Mel, PhD - Research Combustion Engineer, US Forest Service (USFS)
Dave Zader - Wildland firefighter and Wildland Fire Policy Committee Member at International Association of Fire Chiefs (IAFC)
Mark A. Finney, PhD - Research Scientist, Rocky Mountain Fire Sciences Laboratory in Missoula, US Forest Service (USFS)

SPACE-BASED WILDFIRE DETECTION & INTELLIGENCE TRACK (2022)

Eti Shechtman - Research Lead, Research & Design, XPRIZE

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Karen O'Conner - Missions Architect & Fire Shield Mission Lead - Fire & Flood Resilience, Minderoo Foundation
Rania Poullos - Project Manager, Fire Shield Mission - Fire & Flood Resilience, Minderoo Foundation

B: CONSULTED EXPERTS

We extend a big thank you to all experts engaging in the design process. Thank you for inspiring us, for stress-testing assumptions and challenging conventions. These experts, each a leader in their field, sharing their knowledge and time, greatly contributed to the development of a transformative XPRIZE Wildfire. **Disclaimer: expert interviews were held under Chatham House rule and expert workshops in confidence. No information may be attributed to any experts without their explicit permission.**

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