The Wicked Wildfire Problem and Solution Space for Detecting and Tracking the Fires that Matter

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Teaser: Leading change agents with expertise and authority across organizations, industries, and disciplines converge on a set of recommendations to address the growing costs of wildfire.

The Wicked Wildfire Problem

In the last decade, record-breaking fires, unprecedented losses, and escalating suppression costs have raised concern over the onset of a new era of megafires, which 'have joined the forlorn polar bear as an emblem of a climate crisis' (Pyne, 2020). This is a critical moment to redefine our nation's relationship with fire and build resilience in fire-prone social-environmental systems. Our biggest challenge is the wicked nature of the problem with many organizations working on different "solutions", all slightly different, but with similar challenges.

Furthermore, many organizations misconstrue the nature of the problem. The problem is not fire, as fire has been characteristic of the North American west for millennia (Marlon et al., 2012); rather, the problem exists around megafires. Megafire is a sociopolitical term to describe "the fires that matter" (Figure 1). Big fires matter for smoke, proximal fires matter for infrastructure, and fast fires matter for lives.

Figure 1. Detecting and tracking the fires that matter focuses tactical fire management on fires that produce toxic levels of smoke, burn homes, and jeopardize lives. Figure by Chuck Carter at KISS.

There are three key ingredients for megafires: climate, fuels, and ignitions. Climate alone is expected to increase the likelihood of very large wildfires (Stavros et al., 2014). Meanwhile, a century of fire exclusion results in fuel abundance and flammable invasive species, both of

which affect fire behavior. Additionally, the built environment encroaches on vegetated wildlands putting more homes in harm's way (Mietkiewicz et al., 2020). Lastly, humans are extending the fire season and starting over 90 percent of the fires that threaten homes (Balch et al., 2017). Together these ingredients increase our chances of million-acre fires (Joseph et al., 2019), and increase fire risk leaving vulnerable communities exposed in fire-prone areas.

The Solution Space

The wicked nature of the problem requires systemic change across sectors and industries (Figure 2). It will require resolving conflicting policies (e.g., Endangered Species Act and Clean Air Act) that can be barriers to prescribed burning. We need to redefine how we think about fire to include traditional ecological practices that account for feedbacks between humans and the natural system. We need to remove barriers of siloed funding that inhibit innovation. Lastly, we need to provide sustainable, accessible, operational, viable products with the information of value on the fires that matter in the decision-making contexts.

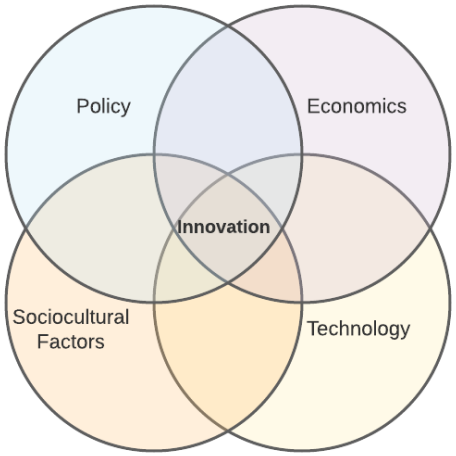


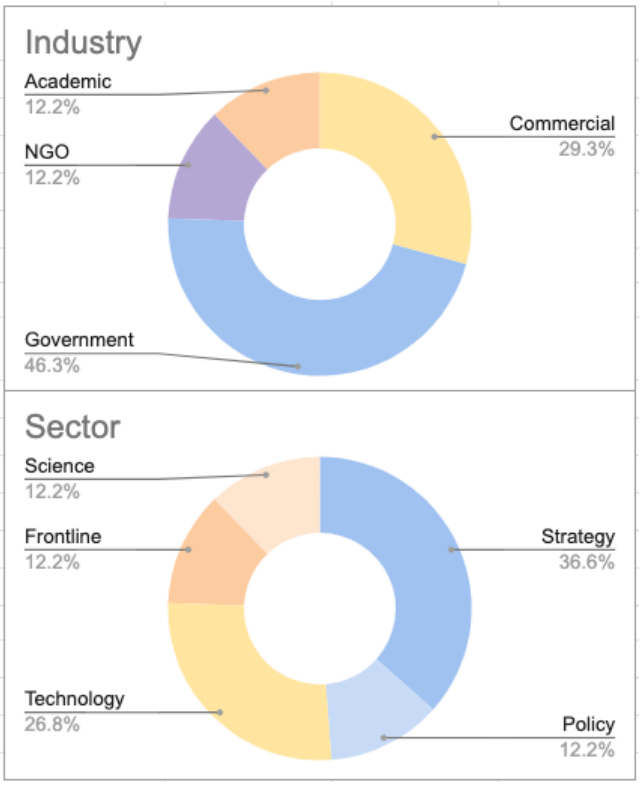
Figure 2. Innovation defined as a change in methods, ideas, or products, occurs at the intersection of policy, economics, sociocultural factors, and technology (Aguilar, 1967).

We cannot implement this solution without enabling sovereign stewardship through cultural fire, expanding health and safety policy around building codes and zoning, and incorporating climate policies to shift to green, decentralized energy. It will require raising public awareness of fire resilience, not active fire exclusion, and differentiating funds for proactive vs. reactive measures. Lastly, it will require a shift to incentivising equitable home hardening not only for houses in the wildlands, but in cities exposed to smoke.

Keck Institute for Space Science (KISS) Think Tank Study

While the scope of the problem spans pre-/post-fire resilience planning and active tactical management, the decisions related to these different time periods for managing fire are quite different. As such, these phases face slightly nuanced challenges. In 2019, the Moore Foundation hosted a workshop to map the current state of the art in the United States for tactical fire management (suppression, evacuation, etc.) . Building on that work, the Keck Institute of Space Sciences (KISS) hosted a workshop focusing specifically on detecting and tracking the fires that matter in the wildland urban interfaces of the western United States. Notably, the fires that matter include context from pre- and post-fire. However, the scope for this workshop focused on the question: When, where, and how is a fire we care about going to

move? **Figure 3.** Industry and sector representation of participants attending the KISS Workshop.



The workshop design included two half-day, invite-only virtual meetings with one day for problem definition and another for solution definition with key change agents across sectors and industries (Figure 3). Each day consisted of one hour of framing, one hour lightning talks, one hour discussion in working groups, andone hour group discussion to reach consensus. Key change agents participated represented: NASA/USFS TFRSAC; NASA CFIRES; USFS GTAC; CEOS Fire pilot project, NOAA NWS Fire Weather, NOAA Fire and Smoke Hazard Mapping, CSA WildfireSat, CALFIRE/Tecnosylva/SDA FireGuard, Intterra, FireSat, California Forest Observatory, Fireball International, XPRIZE Fire Challenge, Minderoo Foundation Fire Shield, as well as California Natural Resources, EDF, Moore Foundation, Planet, ESRI, Google, L3 Harris, OMB, CALFIRE, Moraga-Orinda Fire Protection District, AXA XL, CU Boulder, UMD, Caltech, Australian Space Agency, JPL, and Virgin Galactic.

The intent was to co-produce recommendations for change to tactical fire management of the fires that matter. The workshop had three objectives: 1) define the problem, 2) outline a solution, and 3) develop a community that can work together and identify mechanisms to support that work.

Detection and Tracking the Fires that Matter

The workshop discussions converged on four key themes: organization, data and observations, research and development, and financing and business. Table 1 provides the problems, solutions, and recommended actions.

Table 1. Key findings from the workshop.

	Problem Definition	Solution	Action
Organization	Need for single vision unified interagency leadership	A single Interagency Body for operations on pre-, during, and post-fire management that has the authority to set a vision and driving objectives, coordinate roles/responsibilities, and deliverables as well as manage dependencies across agencies.	Establish an Federal Organizing body with longevity that has authority to coordinate across agencies (Fire Service, NASA, NOAA, SDA, NIST, NGA, USGS, NSF, USDA, DOI, DOD, DHS, others)
	Siloed efforts that are not coordinated	A single plan for the nation (e.g., cancer cure map)	Assign responsibilities and develop mechanisms for cross-sector collaboration between NGOs, Federal, State, Philanthropists, and Industry
Data and Observations	Need for sustained access to free, open-access, unclassified data in a stable format that is bandwidth friendly, low latency (< 5 min), and reliable (many false alarms and poor geolocation accuracy)	An interconnected system of systems linking ground sensors (cameras, people - e.g., social media), drone, airborne, and space-based data	Conduct a thorough mission architecture study leveraging a constellation of nascent systems, new systems to fill gaps, and commercial sector
		Technology development for integrated communications networks in low reception areas	
		Technology development of missions designed for fire: multi-spectral (not just 4 um to drive down False Positives), precise geolocation (i.e., high accuracy), high spatial resolution, high temporal resolution, and longevity of the mission	
	Need for data from different sources to be universally program accessible to display on different operating platforms	A single data clearinghouse with APIs on all data	Assign a single point lead agency
	Need for data standards: format, quality, and metadata	National protocols for data collection and archive	Assign a single point lead agency
Research and Development	Need for appropriate intel	Co-production with decision makers to define the Information products and establish benchmarks for thresholds of utility of the intel created	Establish a Community of Practice to facilitate federal to local level communication, cooperation, and intelligence and guide data search, discovery, and access, intel definition, software development, trainings, and table-top exercises
	Need for intel that matches the human experience	Testbed for agile solution development and implementation	
	Need for context to detect 100% of ***fires that matter*** in real time	Dynamic pre-fire assessments that identify high fire risk as defined by fire hazard potential as well as social exposure and vulnerability	Enable cross-disciplinary, cross-program sponsored research to address wildfires in a holistic way, from preparedness and mitigation, to response, monitoring, and rehabilitation.
		An end-to-end modeling framework for a human-earth system for fire to improve predictability of a fire that will matter	
Financing and Business	Current funding mechanisms do not support innovation by private industry	Clear communication of relevant requests for information, contracts,etc in the broader context of strategy and easy to find despite the sponsor	Remove barriers to siloed funding motivated by different agency motivations
	Need to support localized, custom solutions for building community resilience and preparedness	A single data clearinghouse with APIs on all data	Assign a single point lead agency
	Poorly defined operating costs compared to benefits	Estimates of the true, holistic economic costs of fires to inform business as usual vs. cost of what is required	Shift incentives, taxes, and regulations accordingly
	Need for public awareness of efforts underway and funded	Media engagement and public relations	Include a communications specialist in the Federal Organizing body

Problem Definition

Organizational challenges were related to siloed efforts that are not coordinated, generally due to absence of a single interagency vision. Each agency has their own working group dedicated to different aspects of the problem: tactical fire operations, satellite and airborne assets, research and development, health and safety, etc., yet each effort seems slightly tangential to the other making it very difficult to bridge findings and develop holistic solutions.

Further contributing to these challenges are the lack of free, open-access, sustained, and accurate data on the ground to where and how fires are moving as well as lack of common standards for data collected from ground to aircraft to satellite.

These challenges in turn affect the efficacy of research and development to inform real-world decision making. Research and development needs to incorporate human-centered design to define the intel (i.e., actionable information) needed and assess its utility in the context of the

human experience. Specifically, research needs to incorporate contextual information and pre-fire assessments to distinguish fire detections from the fires that matter.

Lastly, financing and business challenges include the lack of funding mechanisms for innovative business models, and general lack of support for localized solutions to build resilient communities, as well as lack of publicity on current efforts and funding across agencies. Many innovative start-ups do not have a clear idea of what's truly needed and the state of the art.

Solution

To address organizational challenges, workshop participants recommended a single organizing interagency body with the authority to set a coherent vision for fire management and a plan with discrete objectives, roles, and responsibilities across agencies.

That vision would include an integrated system of systems linking ground, air, and satellite data. Such a system would require data standards, a single data clearinghouse across agencies, and program-accessible interfaces such that tools could be localized to community-specific needs. It would also include technology development for sensors/mission architectures specific to sustaining, accurate observations for fire.

Research and development would be informed by a detailed user needs assessment to define intel needs and thresholds for acceptance, a testbed for agile solution development and implementation, and an end-to-end human-earth system model to predict fires that matter.

Lastly, such a vision would address business and financing challenges by providing clear communication of relevant mechanisms for public-private partnerships independent of agency, estimates of the true economic costs to inform sustainable business model development, and more public awareness.

Recommended Next Steps

The workshop participants recommend using these findings as a coordinated voice across industries and sectors to inform policy and support at state and national levels. This request is synergistic with other calls to action from universities and government representatives. This workshop reached consensus despite each organization's self-interests and embodied co-production, a practice of working together across agencies and organizations to identify public services of value.

We recommend follow-on workshops to continue deep dive studies to scope the megafire problem more holistically thinking about the pre-/post- resilience planning. It is worth noting the limitations of the findings from this workshop. Specifically, we focused on pre/post fire to contextualize the fires that matter for tactical fire management, which centers the problem around current authority systems. We recommend that future workshops include collaborations with broader, more diverse communities and perspectives that build on millennia of traditional ecological knowledge from the Tribal Nations to find fire resilient solutions in the context of our modern world.

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References

Aguilar, F. J. (1967). *Scanning the Business Environment*. Macmillan Publishers Limited.

Balch, J. K., Bradley, B. A., Abatzoglou, J. T., Nagy, R. C., Fusco, E. J., & Mahood, A. L. (2017). Human-started wildfires expand the fire niche across the United States. *Proceedings of the National Academy of Sciences*, *114*(11), 2946–2951. https://doi.org/10.1073/pnas.1617394114

Joseph, M. B., Rossi, M. W., Mietkiewicz, N. P., Mahood, A. L., Cattau, M. E., St. Denis, L. A., et al. (2019). Spatiotemporal prediction of wildfire size extremes with Bayesian finite sample maxima. *Ecological Applications*, *29*(6). https://doi.org/10.1002/eap.1898

Marlon, J. R., Bartlein, P. J., Gavin, D. G., Long, C. J., Anderson, R. S., Briles, C. E., et al. (2012). Long-term perspective on wildfires in the western USA. *Proceedings of the National Academy of Sciences*, *109*(9), E535–E543. https://doi.org/10.1073/pnas.1112839109

Mietkiewicz, N., Balch, J. K., Schoennagel, T., Leyk, S., St. Denis, L. A., & Bradley, B. A. (2020). In the Line of Fire: Consequences of Human-Ignited Wildfires to Homes in the U.S. (1992–2015). *Fire*, *3*(3), 50. https://doi.org/10.3390/fire3030050

Pyne, S. J. (2020). From Pleistocene to Pyrocene: Fire Replaces Ice. *Earth's Future*, *8*(11). https://doi.org/10.1029/2020EF001722

Stavros, E. N., Abatzoglou, J. T., McKenzie, D., & Larkin, N. K. (2014). Regional projections of the likelihood of very large wildland fires under a changing climate in the contiguous Western United States. *Climatic Change*, *126*(3–4), 455–468. https://doi.org/10.1007/s10584-014-1229-6