Wildfire Intelligence Capability Gap Analysis

FFRDC/UARC/Independent Lab Wildfire Working Group

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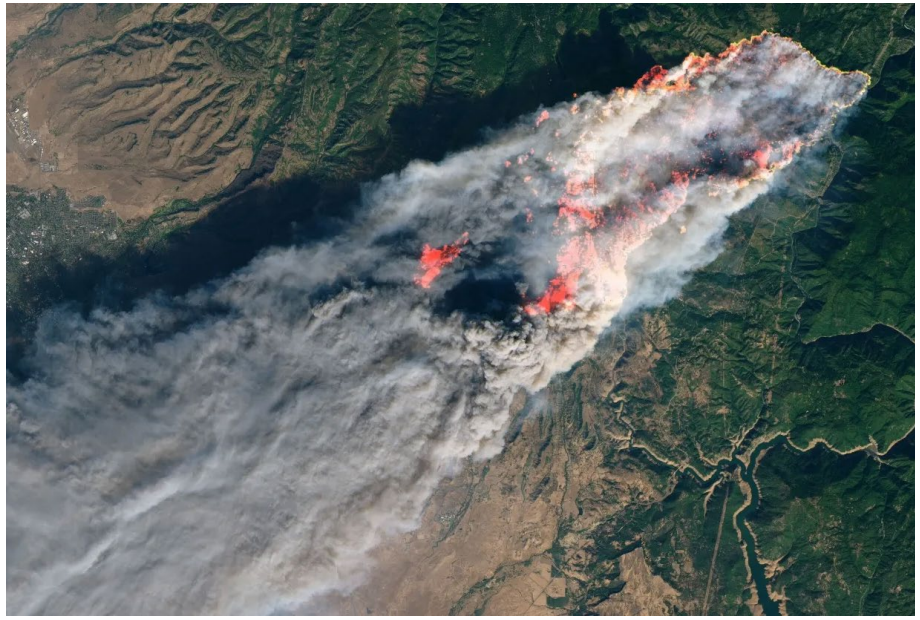
Project Objective and Scope

TECHNICAL OBJECTIVE

Apply the collective expertise of Working Group participants to accelerate the Federal government's ability to address critical wildfire intelligence capability gaps at scale from a whole-of-government, systems perspective.



SCOPE

- Mature technology/capabilities (2024 baseline)
- Relevant, emerging technology/capabilities projected to mature in the next 5-10 years (i.e., forward look to 2034)

Why has wildfire become an urgent national challenge?

Wildland-Urban Interface (WUI) Encroachment

Accumulation of Fuels

Regional Heat and Drought

~44M RESIDENCES ACROSS **60,000+** COMMUNITIES

ARE VULNERABLE TO WUI WILDFIRES

(USFS, 2023)

Seven Critical Gaps

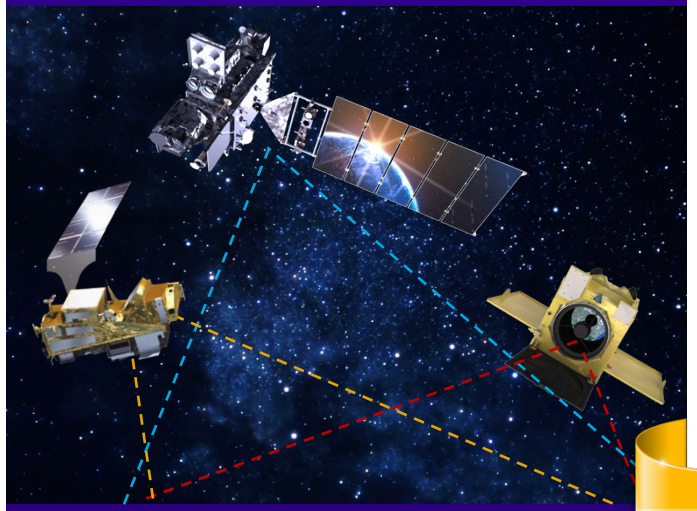
Pre and Active Wildfire Intelligence

- Last Mile Communications
- Common Operating Picture
- Rapid Detection
- Unmounted Firefighter Tracking
- Persistent Surveillance
- Fuels Intelligence
- Weather Intelligence

Study team identified seven critical gaps based on stakeholder engagement and conducted deep dives to identify existing and emerging solutions.

Wildfire Intelligence Value Chain

ALL-SOURCE TASKING & COLLECTION



DATA TRANSPORT & PROCESSING

EXPLOITATION

DISSEMINATION

Limiting Factors

No centralized Federal function with budget authority to procure remotely sensed data at scale, on-demand in support of wildfire management activities

Constraints on data transport throughput and processing capacity

Lack of compute capacity to run state-of-the-art models at scale (hundreds of fires) in operationally relevant timeframes; no centralized Federal wildfire intelligence function; humans-in-the-loop for data quality and product production

Tendency for low user trust, confidence in products and tools based on “new” technology

Mapping of Capability Gaps to Stakeholder Mission Threads

	SEVEN CRITICAL GAPS						
Mission Threads	Last Mile Communications	Common Operating Picture	Rapid Detection	Unmounted Firefighter Tracking	Persistent Surveillance	Fuels Intelligence	Weather Intelligence
Fire Planning	X	X	X		X	X	X
Incident Command & Control	X	X	X	X	X	X	X
Fuels Management					X	X	X
Fire Weather & Smoke Forecasting	X	X	X		X	X	X
Fire Behavior Analysis		X	X			X	X
Fire Danger Risk Analysis & Warnings (pre-fire)						X	X

Summary Insights

- The wildfire (WF) community is highly segmented between federal, state, tribal and local entities
- Federal government's capacity to augment state and local resources to fight wildfire in the WUI is critically important – capabilities such as space-based monitoring solutions are feasible to procure at national scale through federal funding
- Federal agency technologists are overwhelmed by the avalanche of ideas from private industry, academia and government labs – exacerbated by lack of consolidated, prioritized technology needs
- Policy-related structural and organizational challenges at the federal level create barriers to implementing solutions
- **No technology miracles are required to make significant progress towards narrowing of all seven critical gaps**

The U.S. Federal government needs a roadmap reflecting an objective systems approach to cost-effectively invest limited resources in suitable wildfire intelligence capabilities that will deliver value at a national scale

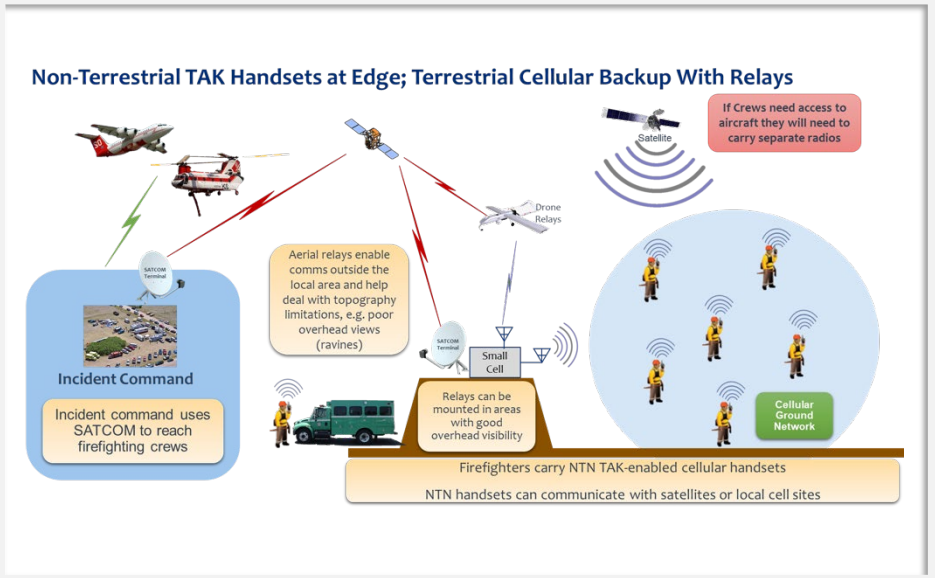
Last Mile Communications

PROBLEM STATEMENT

- Reliable and resilient voice/data/video communications, at all levels from the incident commander (IC) to individual firefighting teams, are essential for the effective and safe management of wildfires.
- Many wildfires occur in austere locations with no existing communications infrastructure to support firefighters, e.g. no commercial cellular service. Wildfire locations can also have topographical features (ravines, etc.) that limit the range of conventional land mobile radio (LMR).
- Must support incremental upgrade of existing capabilities (i.e. no “forklift upgrades”) preferably with backward compatibility during the transition, given multi-organization involvement and funding constraints. The lack of a Common Operating Picture (COP) from the IC to individual crews negatively impacts real-time understanding and awareness of an incident.

RECOMMENDATIONS

- Leverage Team Awareness Kit (TAK) technology
  - Used in many civilian applications and is gaining traction in the community.
  - DHS/CBP model can be leveraged.
  - IT and Training are needed for successful deployment.
  - TAK provides a COP to monitor ground vehicles and personnel, but not aircraft
- TAK will require both line-of-sight (LOS) and beyond-line-of-sight (BLOS) comms
  - Tactical radios or local cellular (existing or bring-your-own cell site) can provide LOS comms within crews and between nearby crews
  - SATCOM (e.g. Starlink) will be required for BLOS comms to incident command or other remote locations
  - Total cost depends on the quantity of devices/users and traffic requirements (data rates)
- Bring Your Own Device (BYOD) is not recommended due to integration issues
- Approaches to consider:
  - Cellular handsets with SATCOM access (e.g. AST) - near-term, requires ground cell infrastructure
  - Non-Terrestrial Network (NTN) and Device-to-Device (D2D) Handsets do not require ground infrastructure – longer-term; 3GPP standards and products still being developed



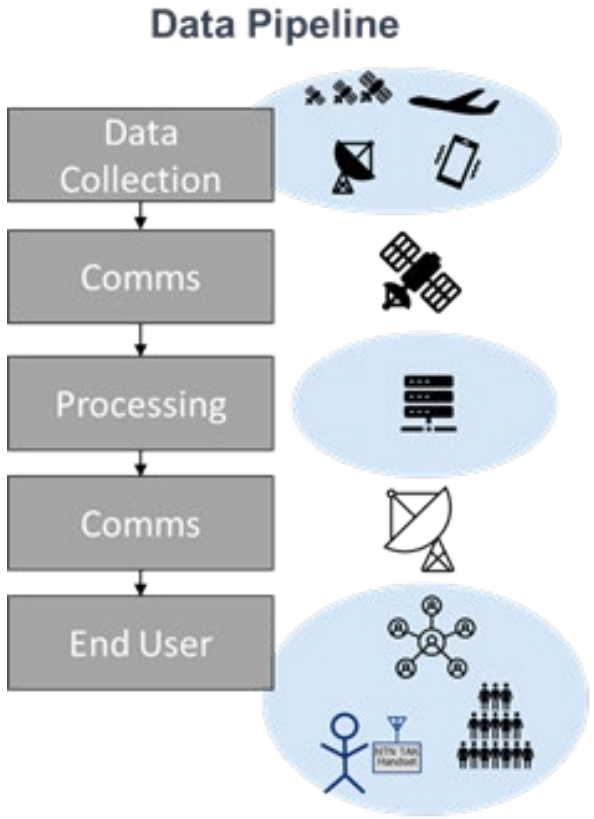
Common Operating Picture (COP)

PROBLEM STATEMENT

- Wildfire incidents lack a Common Operating Picture (COP) across local, state, tribal and federal entities
- Lack of effective data integration and system interoperability are key limiting factors to establishing a COP for any incident

RECOMMENDATIONS

- Secure a civil stakeholder community seat at the table with the Team Awareness Kit (TAK) Product Center to establish standards and strengthen wildfire utility
  - In parallel, invest in the development of a dedicated civil application TAK platform as a variant of the military-focused GOTS TAK product including applications/plug-ins to integrate wildfire data feeds
- Partner with commercial companies to develop wildfire TAK applications (i.e., plug-ins)
- Plan for integration of NTN-enabled TAK handsets as a COP enabler once it is field tested and commercially available in the next 3-5 years
- TAK is not a full COP solution. More research needs to be done with the stakeholders to understand what an overall COP looks like for the U.S. Forest Service (USFS) keeping in mind that the overall COP would need to interface with TAK



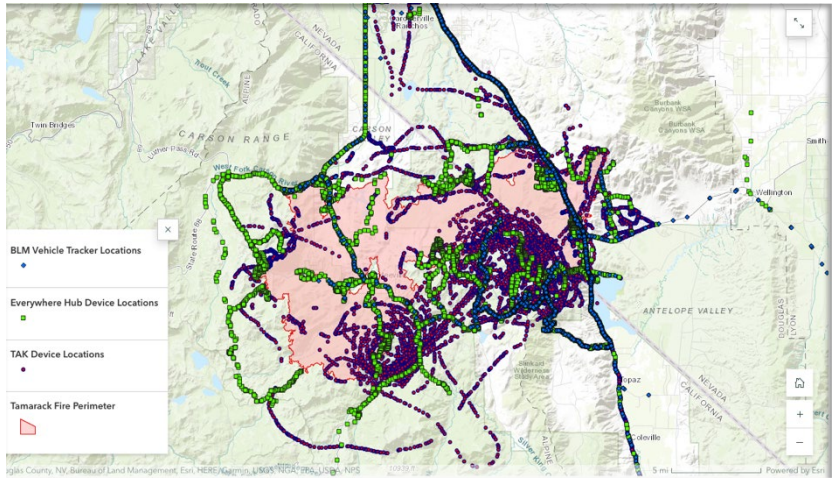
Unmounted Firefighter Tracking

PROBLEM STATEMENT

- Unmounted frontline firefighters are not tracked in real-time across all incidents
- Currently, location information is primarily reported via line-of-sight radio which has coverage gaps in austere conditions, especially in complex terrain
- Personnel are challenged to accurately describe their location is relation to landmarks
- An inordinate amount of radio airtime is consumed by location sharing messages

RECOMMENDATIONS

- Resource National Interagency Fire Center (NIFC) or other appropriate agency with sustained, additional funding above current budget baseline to procure devices at scale for federal wildfire assets
- ROM Cost (based on Garmin InReach solution as an example):
  - Total number of units needed to be operation at any time is CONOPS dependent – costs at scale for this study estimated per 10,000 units
  - Cost per unit: ~$400 with total up-front procurement cost (10,000 units): ~$4 million
  - Annual replacement costs for loss/damage (assuming 5% per year): ~$200,000
  - Total 3-yr lifecycle cost for 10,000 units: ~$4.6 million
- Initiate dialogue to achieve tracker interoperability and establish standards to achieve COP integration with agencies in states that are prone to large-complex wildfires (e.g., Western U.S.) and the extend initiative nationally



Rapid Detection & Persistent Surveillance

PROBLEM STATEMENT

- **Detection:** The capability to quickly detect wildfire ignition is lacking in most U.S. geographic areas – rapid initial attack provides the best opportunity to halt wildfire in its tracks which is critical in the wildland-urban interface (WUI)
- **Persistent Surveillance:** Lack of persistent (24/7, all condition) monitoring capability for Level 1 & 2 wildfire incidents undercuts situational awareness needed for optimal decision-making and assurance of firefighter and public safety

RECOMMENDATIONS

- Expand deployment of ground-based, AI-enabled fixed wildfire cameras across the WUI in high-risk, fire adapted regions (i.e., Western U.S.)
  - Authorize and fund a lead federal agency to partner with state and local agencies across the Western U.S. to deploy fixed cameras across the WUI
  - ROM Cost: $185 million (initial investment + 10 years sustainment)
- Initiate partnerships with commercial offerors to accelerate deployment of commercial wildfire satellite constellations
  - ROM Cost: ~$50 - $100 million/year (assuming all U.S. data licensing for open/free real-time data sharing across U.S. federal and state government entities)
- Create a National Combined Wildfire Forecast and Threat Intelligence Center to pool compute, accelerate research transition to ops, and provide timely, authoritative wildfire intelligence equitably across the nation
  - ROM Cost: $50 million/year (labor, high-performance compute, capital expenses)

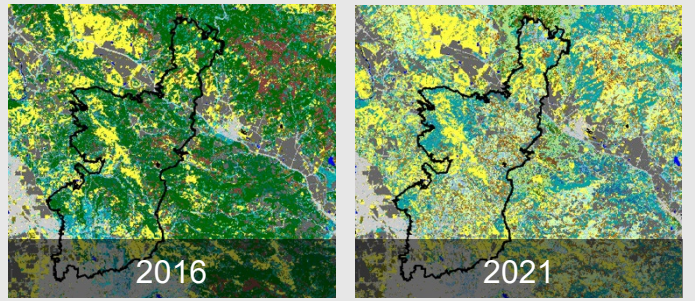
Fuels Intelligence

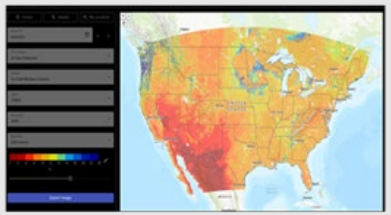
PROBLEM STATEMENT

- **Fuels Intelligence Active Fire:** Inaccurate fire spread modelling from fire behavior models drawing on outdated curated vegetation/fuels database from Landsat observations does not support decision-making
- **Fuels Intelligence Pre-Fire:** Challenges in planning both controlled burns to reduce wildfire risk and asset pre-positioning when using fire behavior models using out of date information
- **Fuels Intelligence Post-Fire:** Potential for insufficient landslides warnings due to lack of current surface conditions

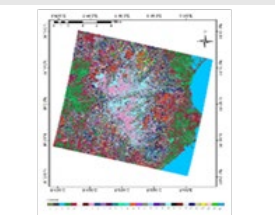
KEY FINDINGS AND RECOMMENDATIONS

- New merged products drawing on existing data with improved algorithms (e.g. NCAR's Fuel Moisture Content) hold near-term potential for users
- Using international hyperspectral assets (e.g., EnMap, PRISMA, GHOSt) could yield better products, although hyperspectral algorithms need development (TRL 2-4)
- Recommend continuing to develop/refine hyperspectral algorithms for land types
- Recommend pursuing combined products with available data today / near- term to provide additional benefit for users
  - New products generated in a new wildfire fuels system could provide value
- Recommend developing a common center for processing hyperspectral data into new fuel products for Landfire (source of curated data) to provide curated plus non-curated products
- Recommend considering commercial / industry / private entities that may be willing to fund development with commercialization of products for various industries, since single agency budget may not support all agency interface needs
- ROM for recommendations above: $25+ million/year for 10 years for significant progress

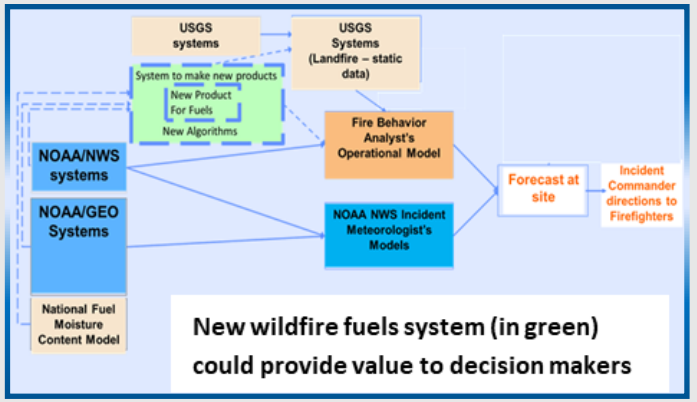




NCAR's Machine Learning Fuel Moisture Content



Fire Fuel Classes from PRISMA HSI



Weather Intelligence

PROBLEM STATEMENT

- Many fire-adapted landscapes are undersampled in terms of surface weather observations from operationally maintained sensors calibrated to national standards
- The boundary layer is under-observed in all areas, degrading forecast model performance
- Coupled wildfire-weather modeling, relative to other analogous applications such as hurricane forecasting, is slow, fragmented, and crude
- Compute capacity is inadequate for 24x7 fire weather forecast modeling operations

RECOMMENDATIONS

- Expand partnering with commercial companies to develop and deploy UAS technology to observe the boundary layer
- Grow NOAA's wildfire weather modeling capacity to enable 24x7 modeling operations to produce probabilistic forecast products
- Expand the ability to ingest and assimilate relevant observations from all sources including private networks such as those operated by power companies
- Double the number of fixed, Remote Automatic Weather Stations (RAWS)
- Increase incident (i.e., deployable) RAWS to better observe areas of complex terrain in fire adapted ecosystems (especially where wildfire would threaten the WUI)
- Add personnel to incident response teams whose primary responsibility is deploying sensors and taking observations

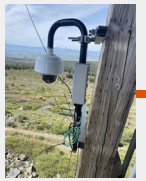
Image credit: International Met Systems

Joint (Interagency Federal-State Combined) Wildfire Weather and Intelligence Center Concept

Government Data (U.S. and International)

Commercial Satellite Data

Federal Aircraft/UAVs



Commercial Cameras

Joint Wildfire Weather and Intelligence Center

- Wildfire SA Decision Aids
- Unmounted FF Tracking
- Wildfire Risk Products
- Fire Behavior Models
- Wildfire Fuel Intel Products
- Wildfire Weather Models

Regional/Strategic Emergency Centers

Incident Command

- Incident Commander
- Incident Meteorologist
- Fire Behavior Analyst
- Fire Planner

State Wildfire Intelligence Centers

(examples)

Aircraft/UAVs

Private cameras and weather data

Commercial Wildfire Crisis Center

Appendix: Interviews with Stakeholders and Experts

- **Sean Triplett**, Director, National Interagency Fire Center (NIFC) Technology Branch
- **Chief Michael Morgan**, Director, Colorado Division of Fire Prevention and Control (incident commander, state official)
- **Everett Hinkley**, USFS National Remote Sensing Program Manager (Chair, TFRSAC)
- **Ann Kapusta**, Environmental Defense Fund (consultant for capability needs assessment)
- **Chief Tim Chavez**, Assistant Chief, Wildfire Forecast and Threat Intelligence Center, CALFIRE (fire behavior analyst)
- **Scott Brewer**, Fire Planner, Central Oregon Fire Management Service
- **Ann Bartuska**, Chair of Science, Data and Technology Working Group, National Wildland Fire Mitigation and Management Commission
- **Tyson Bertone-Riggs**, Data and Technology Working Group, National Wildland Fire Mitigation and Management Commission
- **Branko Kosovic**, Director of the Weather Systems and Assessment Program, Research Applications Laboratory (RAL), (now at Johns Hopkins Applied Physics Laboratory)
- **Jason Knievel**, Deputy Director for Science in the National Security Applications Program (NCAR), Research Applications Laboratory (RAL)
- **Marva Willey**, R5 Fire and Fuels Coordinator for Wildfire Crisis Strategy Landscapes, U.S. Forest Service, Fire and Aviation Management, Pacific Southwest Region, Regional Office (fuels management SME)
- **Matt Ahearn**, Assistant Director, Fire & Aviation Management, U.S. Forest Service, Pacific Southwest Region, Southern California Operations (Ops Chief, burn boss, 30 years experience)
- **Lara Campbell**, Executive Director, EOP/OSTP/PCAST
- **Kathy Sullivan** and **John Dabiri**, OSTP PCAST Wildfire Study Co-Leads
- **Jeff Rupert**, Director, Office of Wildland Fire, Department of Interior (Wildfire Commission member)
- **Chief Tonya Hoover**, U.S. Deputy Fire Administrator + staff members Faith Berry, Jose Budaburu, and Nicole Larosa
- **Clint Cross**, Assistant Director, Landscapes and Partnerships, USFS
- **Dr. Heather Heward**, Professor at University of Idaho (prescribed burn SME)
- **Chris Markle**, Wildland Fire Enterprise Systems Business Analyst, Dept of Interior
- **Mark Goeller**, State Forester/Director, Oklahoma Department of Agriculture, Food and Forestry
- **Todd Lindley**, NWS Science and Operations Officer, National Fire Weather Services Senior Advisor
- **Drew Daily**, Deputy Fire Management Chief, Oklahoma Department of Agriculture, Fire and Forestry
- **Dave Celino**, Fire Warden for Massachusetts, Department of Conservation and Recreation, Bureau of Forest and Fire and Forestry
- **Genny Biggs**, Moore Foundation
- **Ryan Walbrun**, NWS IMET, Weather Forecaster at Monterey WFO
- **Kari Fleegel**, NWS IMET, Weather Forecaster at Aberdeen WFO
- **Lisa Kriederman**, Consulting Fire Weather Meteorologist, Portland General Electric (Oregon), also former NWS IMET
- **Kate Dargan**, Nationally renounced wildfire expert
- **Tim Yurkiewicz**, Program Manager, Interagency Fuels Academy