Standards Working Group Report

Wildfire Science & Technology Commons
October 2025

Executive Summary

The Standards Working Group is focused on establishing a comprehensive framework for the community catalog towards seamless registration, discovery and integration of data, AI AI models, code, code, tools, and services within the Wildfire Commons. Additionally, focusing on reuse of community catalog offerings through reproducible workflows. Meeting monthly from February through October 2025, this working group brings together data scientists, researchers, and technology specialists to define and implement standardized metadata schemas, tagging conventions, and vocabularies for the Wildfire Commons community catalog listings. The group ensures standards reflect the diverse needs of the wildfire community while facilitating interoperability across the Wildfire Commons. Key deliverables included reviewing the Wildfire Commons metadata requirements for the community catalog, sharing knowledge around existing repository practices to ensure compatibility, and recommending maintainable standards and trackable metrics that evolve with emerging technologies to support the long-term sustainability of the Wildfire Commons.

Working Group Members:

- Danielle Christianson, Lawrence Berkeley National Laboratory
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Working Group Analysis

<u>What gaps or unmet needs does the Wildfire Commons fill?</u>

The Wildfire Commons addresses several critical gaps identified through stakeholder interviews and community engagement:

- Centralized Discovery and Cataloging: The Commons serves as a unified meeting place for diverse wildfire repositories, solving the fragmentation problem where valuable data, models, and tools exist in isolation across different organizations. As an example, the Wildland Fire Science Initiative (WFSI) data portal supports Strategic Environmental Research and Development Program (SERDP) program data, but the broader community lacks a comprehensive catalog that spans all wildfire research domains.
- Model and Service Integration: Currently, the community operates in an ecosystem of interconnected models (fuel models, fire behavior models, climate models, weather models,

drought models) that currently lack standardized interfaces and metadata descriptions. The Commons can provide the infrastructure needed to describe, discover, and integrate these diverse modeling resources.
- Standards Harmonization: The wildfire community currently operates with few standardized practices around research and reproducible workflows. Key standardization gaps include keyword vocabularies at the dataset level, point cloud data naming conventions, and metadata describing data acquisition processes. The Wildfire Commons provides a framework to establish and promote community-validated standards.
- Enhanced Reproducibility and Open Science: While funding agencies increasingly require open science practices, researchers often lack adequate tools and incentives for reproducible workflows. The Wildfire Commons can bridge this gap by providing containerized environments, standardized workflows, and validation mechanisms that make reproducible science more accessible and transparent.

<u>What do other similar efforts to the Wildfire Commons do well that we could learn from?</u>

Several exemplary communities provide valuable lessons for the Wildfire Commons implementation:

- Biomedical Community Standards: The biomedical community's mature approach to standards adoption, where comprehensive metadata requirements and community validation processes have become standard practice. The Protein Data Bank's requirement for data submission before publication demonstrates how mandatory standards can drive community adoption.
- AmeriFlux Community Model: This community effectively utilizes carrots to promote standards adoption. By adopting the global Fluxnet Processing standards, research teams receive network-standardized data quality review and publication, leading to increased visibility of high-quality data. Furthermore their data can be easily synthesized across the network, which increases their utilization. This incentive structure could be adapted for wildfire research.
- DataOne Standards Framework: The WFSI data portal's adoption of DataONE standards for dataset-level metadata as well as file-level metadata standards including data dictionaries modeled after the DOE ESS-DIVE Community provides an interoperable foundation for data discoverability and usability. These established frameworks can be extended rather than recreated.
- NASA's Central Metadata Repository (CMR): CMR's ontologies and standardized workflows as potentially valuable resources. The CMR's approach to federated systems and knowledge graph interconnection offers a model for enabling interoperability between wildfire research systems.

<u>What partnerships or collaborations could the Wildfire Commons pursue to launch the Marketplace</u>

Strategic partnerships should focus on both technical infrastructure and community adoption:

Technical Infrastructure Partnerships:

- NASA Earth Science Data Systems: leverage CMR ontologies and federated system approaches for knowledge graph development
- DataOne Consortium: build upon existing metadata standards and repository practices already adopted by community members
- Container Orchestration Platforms: partner with cloud providers to enable exploratory containerized workflows for data around reproducible science

Community and Standards Partnerships:

- Professional Associations: engage through AGU, Gateways conferences, and wildfire-specific conferences to gather ethnographic and user research data
- Funding Agency Collaboration: work with NSF, NASA, DOE, and SERDP to align Wildfire Commons standards with open science requirements and create enforcement mechanisms
- Journal Publishers: large impact goal could be to develop relationships with journals to establish "data paper" publication pathways and ensure Wildfire Commons listings meet scholarly publication standards

Research Community Partnerships:

- Academic Institutions in Wildfire Prone States: ideally with departments focused on wildfire research
- National Laboratories: expand the successful WFSI data portal model to serve as a reference implementation for Wildfire Commons standards
- Regional Fire Research Networks: partner with established researcher networks to pilot badge systems and community validation processes

<u>What trends or changes could benefit the further development of the Wildfire Commons</u>

Several converging trends create favorable conditions for the Wildfire Commons development and adoption:

- Open Science Mandates: Increasing requirements from federal funding agencies for open science practices create both pressure and opportunity. Researchers require platforms that facilitate compliance while enhancing their science, thereby positioning the Wildfire Commons as an essential tool rather than an additional burden.
- AI and Machine Learning Integration: The rapid adoption of AI/ML in wildfire research creates demand for standardized model metadata, containerized workflows, and reproducible science practices.
- Cloud Computing and Containerization: The maturation of cloud-based research environments and container technologies makes it feasible to provide standardized, reproducible workflows that researchers can easily adopt and adapt.
- Knowledge Graph Technologies: Advances in federated knowledge graphs and semantic web technologies enable the kind of interconnected, discoverable research ecosystem that the wildfire community needs.
- Community-Driven Validation: The success of crowdsourced validation in other scientific communities (like AI model benchmarking) suggests that the wildfire community is ready for collaborative standards development and badge/recognition systems.
- Cross-Disciplinary Research Growth: Wildfire research increasingly draws from diverse fields (remote sensing, climate science, ecology, computer science), creating demand for standardized vocabularies and interoperability that the Wildfire Commons can provide.

Priorities for Next Phase of Working Group

Priority #1: Finalize and Implement Comprehensive Metadata Schema for Models and Services

Complete the development and deployment of standardized metadata schemas for code, AI models and services that were extensively discussed in the June 2025 meeting. This includes reviewing AI metadata schemas such as Croissant while incorporating stakeholder feedback on the need for more detailed specifications beyond high-level model descriptions. The schema should address the diverse model ecosystem identified by the group, including fuel models, fire behavior models, climate models, weather models, and drought models.

Key implementation steps include establishing automated assignment processes for metadata validation, developing community nomination mechanisms for model quality assessment, and creating feedback systems that ensure continuous improvement. The working group will also explore automation practices that the community would like to implement to keep metadata listings current and accurate.

Proposed working group actions:

1. Working group to provide guidance on interview guide to understand how the community is searching and discovering data/models in the Wildfire Commons today and for registering data/models - what is missing in the metadata
2. Working group recommends other community members not in the Wildfire Commons catalog today that should have their products listed
3. Working group to review outcomes from community interviews conducted by the Wildfire Commons team

Priority #2: Develop Wildfire-Specific Ontology and Controlled Vocabularies

Building upon the fire ontology through the National Wildfire Coordinating Group (NWCG) Glossary of WIldland Fire and incorporating insights from DataONE standards and NASA's CMR, develop comprehensive wildfire-specific controlled vocabularies and taxonomies. This priority addresses the critical gap identified regarding keyword standardization at the dataset level.

The approach will implement an AI-assisted vocabulary collection process that gathers information from the community and generates candidate vocabularies for community validation through review and voting. The system will include pre-, during-, and post-fire categorizations, spatial-temporal metadata standards, and integration with existing ontologies, such as ENVO. User-friendly interfaces with tooltips and type-ahead functionality will make these vocabularies accessible to researchers while maintaining scientific precision and accuracy.

The working group will also address point cloud data naming conventions and metadata describing data acquisition processes. In these areas, standardization can significantly improve data discovery and reuse across the wildfire research community.

Proposed working group actions:

1. Working group work on reviewing existing ontologies and creating a combined dataset
2. Working group recommend knowledge graph based interconnections between the ontology
3. Working group to advise on an interview guide for community validation or ontologies in the NWCG Glossary of Wildland Fire and curating queries where the onology would be used to discover products in the Wildfire Commons

4. Working group to collaborate with the Wildfire Commons team on an AI search engine (chat based interface for discovery, train an LLM on existing acronyms and community database)
5. Working group to explore a recommendation system that guides users
    a. Explore the registration process with this recommender - what metadata fields could a recommender be connected to registration process (i.e., recommend keywords)
6. Working group and dev team to think about maintenance of terms and flagging by the community in the interface for missing terms/errors

Priority #3: Badge System Identification & Implementation for Marketplace

Define a comprehensive badge system that addresses the community's need for quality recognition and standards compliance. Based on stakeholder feedback, this system should include badges for reproducibility (containerized workflows), open science compliance (data availability and documentation), community validation (peer review and testing), and adherence to standards (metadata completeness and vocabulary compliance).

The implementation will define specific criteria for each badge category, establish automated assignment processes where feasible, and create community nomination mechanisms that capitalize on the collaborative nature of wildfire research. The user experience design will enable easy filtering and recognition of high-quality, high-compliance listings while encouraging community participation in the badge assignment process.

Proposed working group actions:

1. Working group to collaborate with Wildfire Commons development team to provide first pass of community badges and award expectations
2. Working group to review first version badges and improve the qualifications
3. Working group to recommend additional badges beyond the initial set
4. Working group to discuss and recommend future community involvement in recommending badges

Appendix

Create a template example of what standardization for remote sensing workflows might look like (Provided by working group member, Nick LaHaye):

- Project Metadata and Goal Specification
    - Include fields for project name, objectives, area of interest, target variables, research questions, and intended outcomes.
- Data Acquisition and Selection
    - Platform type (Satellite, Aerial, UAV, Ground-based)
    - Sensor type (Optical, SAR, Lidar, Thermal, Multispectral, Hyperspectral)
    - Data level (Raw, L1A, L1B, Geo-corrected)
    - Data source (e.g., NASA EOSDIS, Copernicus, commercial provider)
    - Temporal range and spatial extent.
- Data Preprocessing Options
    - Calibration (radiometric, geometric/ L1,L2, etc.)
    - Atmospheric correction protocols
    - Cloud and noise masking
    - Spatial subsetting, re-projection
    - Data normalization and quality checks.
- Data Storage and Management
    - File formats (GeoTIFF, HDF5, NetCDF, etc.)
    - Provenance tracking
    - Metadata standards compliance (ISO 19115, OGC SensorML).
- Processing and Feature Extraction
    - Algorithms (classification, regression, segmentation, change detection)
    - Input parameter definition (model hyperparameters, threshold settings)
    - Ancillary data integration (DEM, weather, ground truth).
- Analysis and Modeling
    - Statistical methods
    - Inter-model connections
    - Multiple model options, validation strategies
    - Uncertainty quantification.
- Visualization and Output Generation
    - Maps, charts, and report formats
    - Visualization tool selection (GIS platforms, Python/R Notebooks, GEE)
    - Custom output file settings.
- Export, Sharing, and Archiving
    - Data export options (formats and destinations)
    - Workflow versioning
    - Repository/Archive registration options (e.g., Zenodo, PANGAEA).

Send links about CMR (Central Metadata Repository) and systems that use it:

https://www.earthdata.nasa.gov/engage/open-data-services-software/earthdata-developer-portal/cmr-api

Provide further information on standardization of validation and stratification

- Stratification
  - Defining Strata
    - Stratify datasets by land cover class, ecological zone, spectral signature, or administrative boundaries relevant to the study area.
      - Options include pre-stratification (before classification) or post-stratification (after classification or mapping).
    - Sample Allocation and Design
      - i.e. Employ stratified random sampling, proportional allocation, or double-sampling, with standardized protocols for reproducibility.
    - Document the sample design (number of samples per stratum, methods, randomization protocol).
  - Stratification Accuracy Reporting
    - Report user's accuracy, producer's accuracy, and overall accuracy for each stratum using an error (confusion) matrix.
- Validation
  - Validation Data Collection
    - Use independent data (field surveys, high-resolution imagery, reference datasets), ensuring representative coverage and appropriate spatial resolution.
  - Document site selection, sampling protocols, homogeneity criteria, and up-scaling strategies for coarse products.
  - Validation Metrics and Reporting
    - Employ a confusion matrix (error matrix) for classification products, reporting things like:
      - Producer's Accuracy
      - User's Accuracy
  - Validation Procedures
    - Specify the stage of validation (CEOS stages 1-4), referencing the Committee on Earth Observation Satellites standard.
    - Compare products with reference datasets or inter-product comparisons, document uncertainties, and traceability to SI standards for reference data where possible.

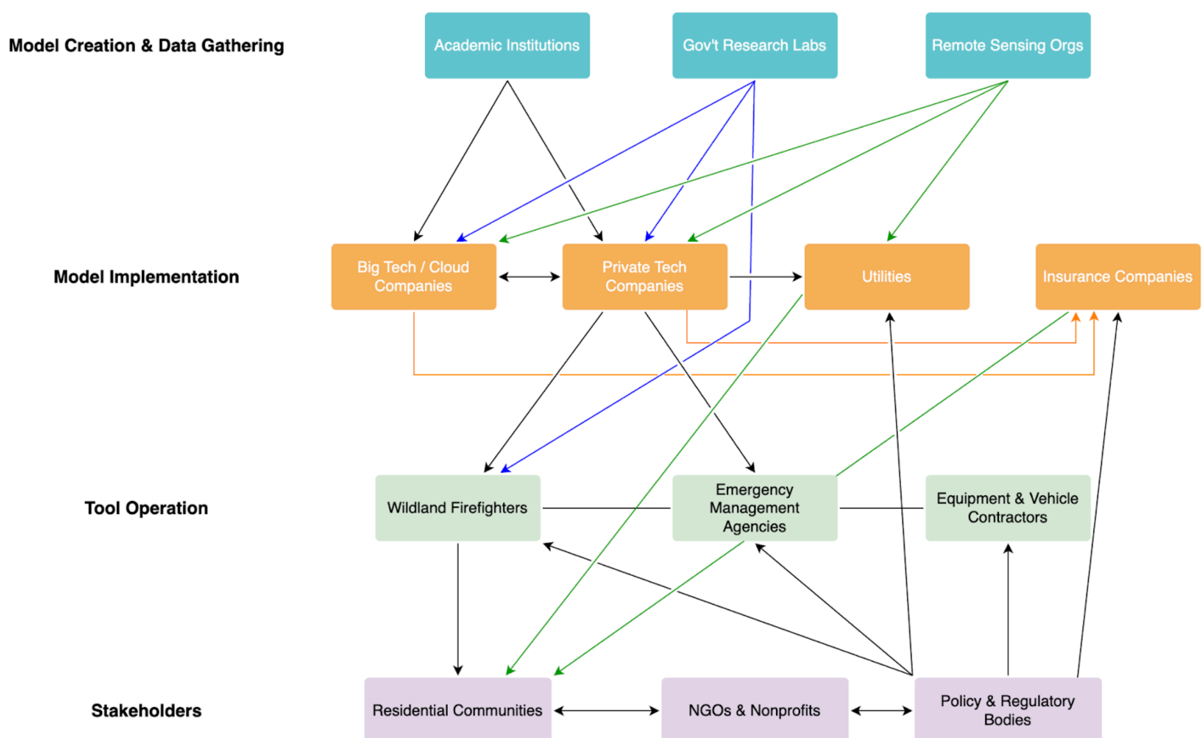
Share initial thoughts on ML/DL metadata improvements

- Making Metadata More Cohesive and Useful: Right now, metadata frameworks used for machine learning are somewhat fragmented and don't always talk to each other well, making research harder than it should be (FAIR, Schema.org, DCAT, Model Cards). Building common standards, or even lightweight tools that can bridge existing gaps, would help streamline collaboration and sharing.
- More Automation: A lot of metadata creation and management still relies on manual entry and upkeep, which can become tedious or error prone. Smarter tools using natural language processing and code tracing can automatically capture key information, like how and when a model was trained, what data it used, and which versions were deployed.
- Metadata on Ethics and Fairness: Most current metadata frameworks don't go far enough to make ethical safeguards and fairness visible and actionable. By adding clear fields that report

fairness scores, climate footprint of models + training, intended use, and audit trails, metadata can better inform users about whether a model is suitable, responsible, or free from bias.

- Enriching Data with Human Context: Going beyond technical specs to include source details (who created this dataset?), timing (when was it made?), and connections to other work (who cited or reused it?). With better context, researchers and users make more informed decisions and maximize model value over time.
- Versioning and model updates: Machine learning models and datasets change quickly and often. If metadata tools can automatically track these updates, record lineage, and roll back or compare versions, teams can keep up with today's rapid pace while maintaining reliability and reproducibility.

Market Landscape Understanding: Diagram



Market Landscape Understanding: Acronyms

Acronym	Definition	Notes
3DEP	3D Elevation Program	Provides high-quality topographic data (LiDAR), used for fire modeling and fuel assessments.

ABI	Advanced Baseline Imager	GOES-R instrument; visible/IR imagery for fire detection, smoke tracking.
ARD	Analysis Ready Data	Preprocessed satellite data ready for scientific analysis (e.g., Landsat ARD).
ASM	Aerial Supervision Module	Aircraft that supervises retardant drops and air operations.
ASOS	Automated Surface Observation System	Automated weather stations, sometimes used for fire weather inputs.
ATGS	Air Tactical Group Supervisor	Manages tactical aircraft during incidents.
AVL	Automatic Vehicle Location	Tracks firefighting resources in real time.
BI	Burning Index	NFDRS index, relates to flame length.
BIA	Bureau of Indian Affairs	Federal land agency, with fire management programs.
BPS	Biophysical Settings	Vegetation types used in LANDFIRE modeling.
CAL FIRE	California Department of Forestry and Fire Protection	State-level fire agency.
CBD	Canopy Bulk Density	Fuel parameter for crown fire modeling.
CBH	Canopy Base Height	Fuel parameter for crown fire initiation.
CC	Canopy Cover	Key LANDFIRE fuel characteristic.
CFFDRS	Canadian Forest Fire Danger Rating System	Canadian counterpart to NFDRS.
CFIS	Crown Fire Initiation and Spread System	Software to simulate crown fire behavior.
CH	Canopy Height	Fuel characteristic used in fire models.
CONUS	Contiguous United States	Term used in datasets like LANDFIRE.
CRWB	Crew Boss	Supervises a hand crew.
CRS	Coordinate Reference System	Used for spatial fire/fuel datasets.
CWPC	Catastrophic Wildfire Prevention Consortium	Research/coordination effort.

DBH	Diameter at Breast Height	Used in fire behavior/spotting calculations.
DEM	Digital Elevation Model	Foundational data for fire spread modeling.
DIVS	Division/Group Supervisor	Oversees resources in a division/group.
DOI	Department of the Interior	Oversees BLM, NPS, FWS — all fire management agencies.
DROTAM	Drone Notice to Airmen	NOTAM specific to wildfire incident UAS.
DZ	Dozer	Bulldozer used for fireline construction.
EGP	Enterprise Geospatial Portal	Wildfire incident geospatial data sharing.
ELCFIRE	Eulerian Level set Model of FIRE spread	Research wildfire spread model.
ENGB	Engine Boss	Supervises wildland fire engine crew.
ERC	Energy Release Component	NFDRS index for seasonal fire potential.
ESM	Ember Spread Model	Simulates ember transport/spotting.
EVC	Existing Vegetation Cover	LANDFIRE input.
EVH	Existing Vegetation Height	LANDFIRE input.
EVT	Existing Vegetation Type	LANDFIRE input.
FALA	Faller A	Advanced sawyer qualification.
FALB	Faller B	Intermediate sawyer qualification.
FALC	Faller C	Chainsaw operator, basic qualification.
FAR	False Alarm Ratio	Used in fire detection (e.g., satellite hot spots).
FARSITE	Fire Area Simulator	Widely used deterministic fire growth model.
FASMEE	Fire and Smoke Model Evaluation Experiment	Large-scale experiment to validate fire/smoke models.
FBFM	Fire Behavior Fuel Models	Standard set of fuel models (Anderson, Scott & Burgan).

FBFRG	Fire Behavior Field Reference Guide	NWCG reference guide.
FDist	Fuel Disturbance	LANDFIRE disturbance input layer.
FEAT	Fire Ecology Assessment Tool	Ecosystem monitoring software.
FEMO	Fire Effects Monitor	Tracks ecological effects of fire during incidents.
FFI	FEAT/FIREMON Integrated	Fire ecology monitoring software.
FFMC	Fine Fuel Moisture Code	Component of Canadian FWI system.
FFS	Fire, Fuel, and Smoke Science Program	USFS RMRS program (Missoula Fire Lab).
FFT2	Firefighter Type 2	Entry-level firefighter qualification.
FHAES	Fire History Analysis and Exploration System	Fire history analysis tool.
FIA	Forest Inventory and Analysis	USFS inventory program; fuels baseline data.
FIREMON	Fire Effects Monitoring and Inventory System	Field-based fire ecology monitoring.
FIRESEV	Fire Severity Mapping System	Fire effects mapping project.
FIRIS	Fire Integrated Real-time Intelligence System	California-based real-time fire mapping/modeling.
FIRMS	Fire Information for Resource Management System	NASA fire detection portal (MODIS/VIIRS).
FMAC	Fire Modeling and Analysis Committee	Alaska analyst network.
FMI	Fire Modeling Institute	USFS center for fire modeling expertise.
FMSF	Fire Modeling Services Framework	Analytical fire modeling system.
FOFEM	First Order Fire Effects Model	Predicts mortality, emissions, nutrient loss.
FPA	Fire Program Analysis	Fire planning system (risk, resources).
FRAMES	Fire Research And Management Exchange System	Fire science knowledge hub.
FRG	Fire Regime Group	Classification of fire return intervals and severities.

FRIA	FAA-Recognized Identification Areas	Drone operations near fire incidents.
FSC	Finance Section Chief	Manages incident costs/contracts.
FVC	Fuel Vegetation Cover	Input for fire models.
FVH	Fuel Vegetation Height	Input for fire models.
FVT	Fuel Vegetation Type	Input for fire models.
FWI	Fire Weather Index	Canadian fire danger rating metric.
FWS	Fish and Wildlife Service	DOI agency with fire responsibilities.
GACC	Geographic Area Coordination Center	Regional fire resource coordination hub.
GEDI	Global Ecosystem Dynamics Investigation	LiDAR-derived canopy structure (used for fuels).
GFS	Global Forecast System	NOAA forecast model, used for fire weather.
GIS	Geographic Information Systems	Critical for fire management mapping.
GMAC	Geographic Area Multi-Agency Coordinating Group	Regional coordination authority.
GOES	Geostationary Operational Environmental Satellite	Key fire detection satellites.
GSAN	Geospatial Analyst	Wildfire intel/IMT role.
Haines Index (HI)	Haines Index	Fire weather instability index.
HDist	Historical Disturbance	LANDFIRE input.
HEQB	Heavy Equipment Boss	Supervises dozers, tractor plows.
HIFLD	Homeland Infrastructure Foundation-Level Data	National geospatial data, including fire-relevant infrastructure.
HLS	Harmonized Landsat Sentinel-2	Remote sensing dataset useful for fuels/fire.
HROS	Head Rate of Spread	ROS at fire head.
HPWREN	High Performance Wireless Research and Education Network	Provides wildfire camera feeds (esp. California).

HRRR	High-Resolution Rapid Refresh	NOAA fire-weather forecast model.
IA	Initial Attack	First response to new wildfire.
IAFC	International Association of Fire Chiefs	Fire service professional group.
IHC	Interagency Hotshot Crew	Elite 20-person hand crew.
ICT1	Incident Commander Type 1	Manages highest complexity incidents.
ICT2	Incident Commander Type 2	Manages large/complex fires under IMT2.
ICT3	Incident Commander Type 3	Manages extended attack/complex IA fires.
ICT4	Incident Commander Type 4	Manages small fires or initial attack.
ICT5	Incident Commander Type 5	Entry-level IC for very small fires.
ICTP	Incident Commander Trainee	Training status for IC roles.
IFTDSS	Interagency Fuel Treatment Decision Support System	DOI fire planning tool.
IMET	Incident Meteorologist	Specially trained NWS fire-weather forecaster.
IMT	Incident Management Team	Interagency incident management structure.
IRPG	Incident Response Pocket Guide	Standard wildfire field reference.
IRWIN	Integrated Reporting of Wildland Fire Information	Federal interagency wildfire reporting system.
JFSP	Joint Fire Science Program	DOI/USFS-funded fire research program.
JPSS	Joint Polar Satellite System	Polar satellites (VIIRS fire detection).
KBDI	Keetch–Byram Drought Index	Soil/duff dryness and drought measure.
KML	Keyhole Markup Language	Geospatial format used in fire mapping.
LAL	Lightning Activity Level	Fire weather lightning scale.
LANCE	Land, Atmosphere Near real-time Capability for Earth Observations	NASA NRT data system, includes FIRMS.
LANDFIRE	Landscape Fire and Resource Management Planning Tools	Fuels/vegetation/fire datasets.

LAT	Large Air Tanker	Multi-engine retardant aircraft.
LCES	Lookout, Communication, Escape route, Safety zone	Safety system used by wildland firefighters.
LCP	Landscape file	Fuel/terrain input file for fire models.
LCG	Landscape GeoTIFF	Georeferenced LCP.
LFPS	LANDFIRE Product Service	LANDFIRE data distribution portal.
LFTFC	LANDFIRE Total Fuel Change Tool	LANDFIRE fuel update tool.
LiDAR	Light Detection and Ranging	Used for canopy/fuels measurement.
LSC	Logistics Section Chief	Manages incident logistics/supply.
LTAN	Long-Term Analyst	Provides long-range fire behavior forecasts.
MAFFS	Modular Airborne Firefighting System	C-130 aircraft with internal retardant tanks.
MACS	Multi-Agency Coordinating System	Framework for interagency fire coordination.
MFRI	Mean Fire Return Interval	Time between fires in a given ecosystem.
MOD	Wildland Fire Module	Self-sufficient crew for fire/monitoring.
MoD-FIS	Modeling Dynamic Fuels with an Index System	NDVI/WELD-based seasonal fuels modeling.
MODIS	Moderate Resolution Imaging Spectroradiometer	NASA fire detection sensor.
MSD	Maximum Spotting Distance	Longest distance an ember travels.
MTT	Minimum Travel Time	Fire growth algorithm (FlamMap/FARSITE).
NAM	North American Mesoscale Model	NOAA model used in fire weather.
NAIP	National Agriculture Imagery Program	High-res aerial imagery (fuels mapping).
NAFRI	National Advanced Fire & Resource Institute	Training center, Tucson AZ.
NASS	National Agricultural Statistics Survey	Crop/landcover datasets useful for fuels.
NBM	National Blend of Models	NOAA blended forecast guidance, incl. fire weather.

NCEP	National Centers for Environmental Prediction	Hosts GFS, NAM, HRRR — key for fire weather.
NDVI	Normalized Difference Vegetation Index	Vegetation greenness, fire fuels proxy.
NEPA	National Environmental Policy Act	Governs fire/fuel treatment planning.
NERIS	National Emergency Response Information System	Fire incident data system.
NFDRS	National Fire Danger Rating System	US fire danger rating system.
NFDSC	National Fire Decision Support Center	Fire science application hub.
NIFC	National Interagency Fire Center	Federal wildfire coordination hub.
NIMO	National Incident Management Organization	Specialized Type 1 IMTs for complex incidents.
NIROPS	National Infrared Operations	Nighttime fire mapping flights.
NMAC	National Multi-Agency Coordinating Group	Top-level national coordination for resources.
NLCD	National Land Cover Database	Land cover data used in fire modeling.
NOAA	National Oceanic and Atmospheric Administration	Weather/fire weather agency.
NOTAM	Notice to Airmen	Fire TFRs issued as NOTAMs.
NRCS	Natural Resources Conservation Service	Fuels/land management partner.
NRT	Near Real-Time	Satellite data delivery class (used in FIRMS).
NTFB	Near Term Fire Behavior	Fire growth modeling tool.
NWCG	National Wildfire Coordinating Group	Sets wildfire standards/training.
NWP	Numerical Weather Prediction	Underpins fire weather modeling.
NWS	National Weather Service	Provides fire weather forecasting.
OLI	Operational Land Imager	Landsat sensor used for vegetation/fuels.
OPS	Operations Section Chief	Leads operations section on IMTs.
PB-B	Prescribed Fire Burn Boss	Qualified prescribed fire manager (Types 1–3).

PIO	Public Information Officer	Manages external communications.
PLI	Position Location Information	Used in resource tracking on incidents.
POD	Probability of Detection	Fire detection performance metric.
POI	Probability of Ignition	Schroeder's ignition probability model.
ProWESS	Proactive Wildfire & Environmental Sustainability Solutions	Fire risk initiative.
PSC	Planning Section Chief	Oversees incident planning/intel.
PSPS	Public Safety Power Shutoff	Utility fire prevention practice.
RAP	Rappeller	Firefighter deployed by rope from helicopter.
RAWS	Remote Automatic Weather Station	Backbone of fire weather data.
RESL	Resource Unit Leader	Tracks resources/personnel on incidents.
RFM	Reference Fuel Moisture	Standardized fuel moisture input.
RID	Remote ID	Drone ID requirement on fire incidents.
RMRS	Rocky Mountain Research Station	USFS research branch; home to Missoula Fire Lab.
ROS	Rate of Spread	Fire spread speed metric.
RT	Real-Time	Satellite data latency class.
SAB	Strategic Analytics Branch	Fire data/analysis branch (DOI).
SC	Spread Component	NFDRS index for fire spread potential.
SEAT	Single Engine Air Tanker	Small, fast fixed-wing retardant aircraft.
SMKJ	Smokejumper	Firefighter parachuted into remote fires.
SOFR	Safety Officer (Fire)	IMT position for firefighter safety.
SP	Standard Processing	Satellite data latency class.
SRW	Short-Range Weather	Forecast model (UFS/EPIC).

STCR	Strike Team Leader (Crew)	Leads a group of crews.
STEN	Strike Team Leader (Engine)	Leads a group of engines.
STPL	Strike Team Leader (Plow/Dozer)	Leads heavy equipment strike teams.
STFB	Short Term Fire Behavior	Fire growth modeling tool.
SUADS	Small Unmanned Aircraft Detection Systems	Detects drones over fire airspace.
SWA	Southwest Area	One of 10 GACC regions.
TCDC	Total Cloud Cover	Weather parameter used in fire models.
TFLD	Task Force Leader	Leads mixed resource task forces.
TFR	Temporary Flight Restriction	Airspace restriction over incidents.
TIFF	Tagged Image File Format	Remote sensing imagery format.
TIRS	Thermal Infrared Sensor	Landsat sensor for fire/heat detection.
TOM	Treatment Optimization Model	Fire/fuel treatment planning tool.
UAS	Unmanned Aerial System	Fire drones.
UFS	Unified Forecast System	NOAA modeling system; includes fire weather.
URT	Ultra Real-Time	Satellite data latency class.
USFS	U.S. Forest Service	Major wildland fire agency.
USFS FAM-IM TnT	Fire and Aviation Mgmt – Info Mgmt Tools & Tech	Fire tech/tools program.
USS	UAS Service Supplier	FAA-authorized UAS data provider.
UTM	Universal Transverse Mercator	Common projection for fire data.
VCC	Vegetation Condition Class	LANDFIRE departure-from-natural-conditions metric.
VIIRS	Visible Infrared Imaging Radiometer Suite	High-res fire detection sensor (NPP/NOAA-20/21).

VIPR	Virtual Incident Procurement	USFS fire contracting platform.
VLAT	Very Large Air Tanker	High-capacity retardant aircraft (e.g., DC-10).
WCS	Wildfire Crisis Strategy	USFS fuels initiative.
WFAS	Wildland Fire Assessment System	National fire danger maps.
WFAIP	Wildland Fire Application Information Portal	Fire application hub.
WFDSS	Wildland Fire Decision Support System	Fire decision support tool.
WFIPS	Wildland Fire Investment Planning System	Risk-based fire planning tool.
WFIT	Wildland Fire Information & Technology	Wildfire IT/program unit.
WFM RD\&A	Wildland Fire Management Research, Development & Application	Interagency science-application program.
WFPI	Wildland Fire Potential Index	Fuels/fire potential index.
WFSI	Wildland Fire Science Initiative	DOI science initiative.
WFSP	WFPI-based Fire Spread Probability	WFPI-based probability metric.
WFSTAR	Wildland Fire Safety Training Annual Refresher	Annual safety training (RT-130).
WHP	Wildfire Hazard Potential	National wildfire hazard raster.
WIMS	Weather Information Management System	Central fire weather data system.
WLFP	WFPI-based Large Fire Probability	WFPI-based probability metric.
WoFS	Warn-on-Forecast System	Short-term severe weather/fire weather model.
WRF	Weather Research and Forecasting Model	NWP model used in fire weather.
WSTC	Wildfire Science & Technology Commons	Fire knowledge-sharing hub.
WT	Water Tender	Vehicle transporting large volumes of water.
WUI	Wildland-Urban Interface	Fire/human development boundary.

Market Landscape Understanding: Models

Market overview of wildland fire models provided by working group member, Jake Rose.

Fire Modeling Tool	Organization	Purpose and Description	Features	Resources	Software Platform and Accessibility	Notes
1-D Deep Learning NN High-Res Model	Missoula Fire Sciences Laboratory (MFSL)	A deep learning (DL) approach was employed to represent the behavior of a high-resolution physics-based wildland fire spread model.	* Fully connected Feed-Forward Neural Network.	* Interactive webpage for model, but it doesn't work yet, last I checked. * Related paper: LIHTFire: A high-resolution 1D physics-based wildfire spread model		
BEHAVE	* MFSL	The BEHAVE fire behavior prediction and fuel modeling system was a system of interactive computer programs for modelling fuel and fire behavior. It was developed in 1976 and released for in-the-field use in 1984. BEHAVE has been updated and expanded and is now called the BehavePlus fire modeling system to reflect its expanded scope.	* Designed for the practioner and available in both batch and interactive mode.	* Pat's paper on BehavePlus: Past, Present, and Future	* Consisted of 5 FORTRAN programs.	* The concept for BEHAVE came from Dick Rothermel after the 1976 S-590 'Fire Behavior Officer' course. He thought that a comoputer program could automate the nomograms (Albini 1976b) and tables taught in the course. * BEHAVE could do interactive runs in 1976 but only at night when the MFSL had access to the Lawrence Berkeley Lab computer in CA. * The first presentation of BEHAVE was given at the MFSL in September 1977. * In Aug 1984, BEHAVE was formally transferred

						from the fire behavior research work unit to the Forest Service Washington Office as a nationally supported system and tested in the field for the first time. * Required a 3-day BEHAVE course, taught by Andrews, Burgan, and Rothermel.
BehavePlus (B+) (NOTE: The old "BEHAVE" upgraded to BehavePlus, which is sometimes confusingly called "Behave")	Funded by: * USDA: - US Forest Service Fire and Aviation Management - US Forest Service Rocky Mountain Research Station MFSL * Systems for Environmental Management * Fire and Aviation Management (FAM) * Joint Fire Science Program (JFSP)	BehavePlus is a fire modeling system that can be used for any fire management application that needs to calculate fire behavior, fire effects, and the fire environment. Its models simulate: * surface fire rate of spread * crown fire rate of spread * intensity * probability of ignition * fire size * spotting distance (the only software in 2010 to calculate **max** spotting distance) * scorch height * tree mortality * fuel moisture * wind adjustment factor.	* Includes a robust GUI into which user adds inputs, usually as ranges of values. * Condition variation is **constant in time** and **uniform in space**. * User specifies a time duration over which to run the model. * It is a point system (vs. a spatial system, like FlamMap and FARSITE) that calculates fire behavior for an area (or point) with homogeneous fuels.	* Pat's paper on BehavePlus: Past, Present, and Future * Download BehavePlus 6.0.0 (Build 626). * BehavePlus 6.0 Tech Tips (28 pages) * BehavePlus Design and Features (120 pages) * Models used in BehavePlus. * Behave FAQ. * Known bugs. * For help with Behave: - Phone: (866) 224-7677 or (616) 323-1667 - Fax: (616) 323-1665 - E-mail: iia-helpdesk@usda.gov - Website: https://iiahelpdesk.nwcg.gov * Online	* Windows only. * Personal Computer	* It is only available via a GUI (instead of a CLI executable). * Each calculation assumes that conditions are uniform and constant for the projection period. * Behave v7 is coming out in spring of 2025: more intutive, new UI, updated containment equations, shares code with FlamMap. * The official version of BehavePlus is v6.0.0 (Build 626). * There are special download instructions for USFS employees. They should install the Fire Characteristics Chart from the Software Center. * The software is so sophisticated that 3 online training courses are

			Each calculation is separate and independent for each cell of a table or point on a graph. * Takes user inputs and produces many tables and graphs to predict different scenarios. For example, it shows the potential for a surface fire to transition to crown fire for various wind speeds. * A 'model' is a mathematical relationship describing a specific aspect of the fire. It is also a "representation of reality". * BehavePlus has **9 modules**, each of which has a specific fire modeling capability (e.g., SURFACE, SPOT). There	training for Surface Fire 2021. * Online training for Prescribed Fire 2021. * Online training for Crown Fire 2021. Papers: * Do you BEHAVE? — Application of the BehavePlus fire modeling system * BehavePlus, Variables (124 pages) * BehavePlus v4.0, User's Guide (123 pages) * Modeling Spot Fires—U.S. Modeling System Comparisons for Practitioners (October 2010 — Opperman)		available. In order to take them, you must make an account for the Wildland Fire Learning Portal. This can take up to 2 days to approve. - BehavePlus is complicatied: used by GIS Specialists, FBANs. * Has been formally integrated into FB and Rx fire courses in the NWCG fire curriculum. * BehavePlus functionality is incorporated into WFDSS. * Unlike nomograms, the spotting capability accounts for terrain and number of torching trees. Also the number of torching trees is used to calculate firebrand lofting height. "Higher firebrands travel further". - In mountainous terrain, ridge top winds are used if wind is blowing across valleys. - The shape of the valley is taken into account with parameters like the ridge-to-valley horizontal distance and elevation difference. * In this study, BehavePlus was used to assess the

			are 35 models that comprise the 9 modules, described in 42 publications. - SURFACE: surface fire rate of spread, fireline intensity and flame length, reaction intensity and heat per area, intermediate values (heat source, heat sink, characteristic dead fuel moisture, relative packing ratio, etc.), Standard, custom, and special case fuel models, wind adjustment factor. - CROWN: Transition from surface to crown fire, crown fire rate of spread, crown fire area and perimeter, fire type (surface, torching, conditional			spotting potential of the Chakina Fire, AK (2009). - They wanted to see what conditions were required for the fire to jump the 200–400 meter wide Chitina River. First they visually identified where spotting seemed most likely to occur. Then used BehavePlus to determine the wind speed required to produce such spotting at those locations. - **Interesting:** The author claims that, "there is no 'probability of ignition' considered in any of the geospatial models — you can only get it from BehavePlus or fireline handbook." - Author also says that BehavePlus underestimates wind speeds required to produce spotting vs. geospatial models.

			crown, crowning) - SAFETY: Safety zone size based on flame length, Area, perimeter separation distance. - SIZE: Elliptically shaped point source fire, Area, perimeter, shape - CONTAIN: Fire containment success, final area and perimeter, fire size at initial attack. - SPOT: Max spotting distance from torching trees (Albini and Baughman 1979; Chase 1981), burning piles (Albini 1981), or wind-driven surface fire (Albini 1983a; Albini 1983b; Chase 1984). Expected to add spotting from active crown fire in BehavePlus v6.0 (Albini			

			et al. 2012). - SCORCH: Crown scorch height from surface fire flame length. - MORTALITY: Probability of mortality from bark thickness and crown scorch. - IGNITE: **Probability of ignition by firebrands** (Schroeder 1969) or by lightning strikes (Latham and Schlieter 1989). * Spotting model in which you add a probability of ignition. Includes the same process provided by the NWCG nomograms but also includes number of torching trees, Ridge/Valley elevation difference and horizontal			

			distance, and spotting source location. * Unique features to Behave: the containment equations and 4 different models to calculate max spotting distance.			
BurnPro3D	WIFIRE	A Rx burn planning and management tool used by land managers and burn bosses. It simulates Rx burn fire behavior based on forecast weather data and user-defined ignition patterns. Helps determine the risk of a "slop-over". It is powered by the next generation WIFIRE Data and Model Commons.	* In Beta Testing. Log In window is protected behind UN/PW screen. * Cool, interactive 3D fuel map. * They have a UI (WIFIRE Edge Firemap) that shows map view of fire simulation: 3-hour advance predicted fire expansion. * Uses QUIC-Fire as the behind-the-scenes model.	* Feature Article: Edge Computing at the Wildfire's Edge * WIFIRE Lab * WIFIRE Lab Forms New Partnership with U.S. DHS		* They capture hyper-localized data in and around a fire, couple it with other data, and do all processing at the edge. They call this platform **WIFIRE Edge**. It seems like they are only doing it for Rx burns for now. * They have conducted "prescribed burn scenarios". The Kern County Fire Department would use the WIFIRE Edge platform for a planned brush fire. * Some sensors are worn by responders. Others (Gateway sensors) are mounted on a tripod or magnetically attached to a fire truck. * Another in-situ sensor they have is the COMMs Station. It's the largest they have and offers the

						best environmental sensing. * Sounds like some Burn Bosses are already using BurnPro3D. * Their team + advisory board comprises 59 people. * They deploy their own sensors on responders and fire trucks, collect local data, process data on LOCAL network. * They gather high-res info on the fire front, weather, and location. * Sensor units developed by Red Line Safety, Inc. * The San Diego Supercomputer Lab does the data processing. * The team is located in UC San Diego's WIFIRE Lab. * They've demonstrated in Kern County, CA.
CFAST		**Consolidated Fire And Smoke Transport (CFAST):** A two-zone fire model capable of predicting the environment in a multi-compartment structure subjected to a fire. It calculates the time-evolving distribution of smoke and gaseous combustion products as well as the temperature throughout a building during a		* GitHub.		

		user-prescribed fire.				
CFIS	FRAMES	**Crown Fire Initiation and Spread (CFIS) system:** CFIS is a software tool incorporating several recently developed models designed to simulate crown fire behavior. The main outputs of CFIS are: * the likelihood of crown fire initiation or occurrence; * the type of crown fire (active vs. passive) and its rate of spread; and * the minimum spotting distance required to increase a fire's overall forward rate of spread. The primary models incorporated into CFIS have been evaluated against experimental and wildfire observations. CFIS has applicability as a decision support aid in a wide variety of fire management activities ranging from near-real time prediction of fire behavior to analyzing the impacts of fuel treatments on potential crown fire behavior.	* Windows only.	* Download the exe file here.		

ELMFIRE		The Eulerian Level set Model of FIRE (ELMFIRE) spread is an open-source wildland fire spread model that can be used to: * Forecast the spread of fires in real time. * Reconstruct the spread of historical fires. * Quantify landscape-scale fire behavior potential. * Estimate annual burn probability and fire severity.	* "Note that the current spotting model is different from the spotting model described in the original ELMFIRE paper." * "Spotting distance is modeled as a lognormal distribution with the mean and stdev determined semi-empirically as a function of ambient wind speed and fireline intensity." * When ENABLE_SPOTTING = .TRUE., only pixels that burn as passive or active crown fire trigger the spotting algorithm. * User sets the POI ("PIGN") that an ember will ignite its destination pixel. * Interestingly, whereas	* Paper: Wildland fire modeling with an Eulerian level set method and automated calibration * GitHub		* Gives users exceptional control of spotting parameters.

			other FB models will only simulate embers from torching trees, ELMFIRE can generate embers from surface fire. RISK: * Quantifies impacts to three assets: 1. population (POPULATION_DENSITY) 2. real estate/structures (REAL_ESTATE) 3. land/timber (LAND_VALUE)			
FARSITE	Joint Fire Science Program RMRS Fire, Fuel, and Smoke Science Program USDI National Park Service USFS USFS Rocky Mountain Research Station USFS WFM RD&A Pacific Southwest Region U.S. Forest Service, Pacific Southwest Research Station Systems for Environmental	FARSITE4 is no longer supported or available for download. FlamMap6 now includes FARSITE. (As of June 3, 2021). **A fire area simulator that models fire growth under varying spatial and temporal conditions.**	* Spatial fire behavior system. Determines the fire behavior at each point (pixel) depending on the fire spreading from adjoining pixels and the conditions at the time it burned. *** Conditions vary diurnally, by**	* Modeling Spot Fires—U.S. Modeling System Comparisons for Practitioners (October 2010 — Opperman)	* Personal Computer	

	Management (SEM)		**day, and across the landscape.** * User specifies hours/days of (true) active burning and then, separately, number of days for simulation. * Predicts a fire perimeter location.				
FDS	NIST Fire Safety Research Institute	FDS is a large-eddy simulation (LES) code for low-speed flows, with an emphasis on smoke and heat transport from fires. These are typically small structural fires — not wildfires. In other words, it is a computational fluid dynamics (CFD) model of fire-driven fluid flow. The software solves numerically a form of the Navier-Stokes nist-equations appropriate for low-speed, thermally-driven flow, with an emphasis on smoke and heat transport from fires. FDS has been aimed at solving practical fire problems in fire protection engineering, while at the same time	* Windows only. * Requires * FDS is a program that reads input parameters from a text file, computes a numerical solution to the governing equations, and writes user-specified output data to files. Smokeview is a companion program that reads FDS output files and produces animations on the computer screen.	* GitHub. * Manuals: User's Guide (524 pages), Technical Reference Guide (233 pages), etc. * Download FDS * Tutorial * Download FDS: Windows, macOS, Linux			* Built mostly in Fortran. * As of Feb 2025, the repo has almost 48K commits!

		providing a tool to study fundamental fire dynamics and combustion.	* An FDS simulation requires a lot of computing power, and in the case of very large geometries or very long simulations, using your PC can be very limiting and not always the best solution. A possible solution is to run FDS on a VPS (Virtual Private Server): in other words, you rent a server with a certain computational power and run the FDS simulations on it.			
FIRE-CA						
FireCast	Heartland Software Solutions (acquired by Technosylva)	FireCast is a fully automated software service developed to provide real-time analysis of wildfire behaviour. Simulations presenting fire perimeters and a variety of statistics are completed within minutes. These quick results help support timely decision-making in	**Specified Features:** * Fuel models cover Canadian and New Zealand FBP fuel types. * Secured access available via web and mobile browsers, as	2022_F… * 2022 Fireline Magazine article	* Browser * Mobile device * REST API's for your existing IT infrastructure to consume results	* FireCast is powered by W.I.S.E. and thus is built upon validated software that implements the Canadian Fire Weather Index (FWI) and Fire Behaviour Prediction (FBP) standards. FireCast provides results via your desktop web browser or mobile

		response planning. Realtime automated wildfire predictive modelling. Deterministic and ensemble outputs from a suite of weather models. Implemented for the 2021 Canadian fire season, modelled all western Canadian wildfires in near real-time for 2022, and over 1000 simulations simultaneously.	well as REST API's. * Visualizations in 2D and 3D views, with a variety of options (streets to satellite imagery). * Perimeters and fire statistics displayed in the UI, and available via the API's. * Interactive playback of simulations for visualization of fire growth. * Agency and user-customization of the UI for FBAN's, Duty Officers, Meteorologists. * Agency and user-customization of a variety of simulation options. * Predictions based on GDPS, GEPS, RDPS, REPS, HRDPS, NAM, GPS, HRRR, SREF, ECMWF			device, as well as REST API's for your existing IT infrastructure to consume results. * In 2022, they advertise: - They analyzed 7000 fires in near real time across western Canada. - Performed 4.7M scenarios. - Simulated 675K fires. * Works off the Canadian Forest Fire Behaviour Prediction System.

			weather models. * Results automatically generated within minutes of new inputs. * A growing set of advanced outputs such as arrival times and critical fire paths to assets. * Archival of every fire ever modelled, for playback, post-fire analysis, and training.			
Firemap	WIFIRE	Firemap is an operational tool for real-time environmental data visualization, fire behavior modeling and forecasting, and "what-if?" analyses for potential fires. It shows the user active and historical wildfire perimeters, weather data, and live camera feeds. Firemap enables simple execution of fire models with options for running ensembles by taking the information uncertainty into account. The results are easily viewable sharable, repeatable,	*** Can view live and historical fires on the UI:** - CONUS: 2006–2024 - CA: 1878–2024 *** UI has easy-to-use drop-down menus to turn on VIIRS, MODIS, and GOES data. Loads instantly.** - Legend goes from red (last 12 hrs) to gray (2–7 days). *** Cameras:**	* Link to UI. * Firemap FAQ * Firemap UI Tutorial	* Browser based.	* Funded by NSF ($2.6M). * Partnered with: - Los Angeles Fire Department - Orange County Fire Authority - U.S. DHS Science and Technology Directorate - Sage AI (Cyberinfrastructure) * Last update was Dec 21, 2023.

		and can be animated as a time series.	- They integrate ALERTWildfire Pan-Tilt-Zoom (PTZ) Cameras and HPWREN Fixed Camera into the UI. - You can see the field of view (FOV) and the target of the cameras. Click the thumbnail to see exactly what the cameras sees. - There is a fancy feature in which you can drop a pin onto the map where multiple FOVs overlap. Then live feeds of ALL those cameras pops up. *** Weather (wx) data:** - You can toggle on/off wx stations to see their locations as well as their data: air temp, humidity, fuel moisture,			

			wind, gust - NOTE: The data shown on the UI is just a single point per wx station. **They don't interpolate between wx stations.** - View the forecast wind flow streamlines by going to the top right menu button > Weather > Weather Forecast. - Their wx stations are almost entirely located in CA and CO. *** Can log in with credentials (optional?).**			
FIREMOD	King's College London (KCL)	Designed for research application and ran in batch mode from card decks. I think there are two different FIREMODs: (1) An older one that ran in batch mode from card decks. (2) A physics-based wildfire modelling project created by a King's College London group. These *may* be the same...	* Spatial fire behavior system. * Looks like it's being developed by a university at the moment.	* Fire Science Show Podcast.		

FirePlus Ver 5.0						
FireRisk	Technosylva	Part of their Wildfire Analyst cloud-based platform.				
FIRESEV						
FireSight	Technosylva	Part of their Wildfire Analyst cloud-based platform. Interesting. This tech was likely acquired from Heartland Software Solutions.				
FireSim	Technosylva	Part of their Wildfire Analyst cloud-based platform.				
FlamMap6	Joint Fire Science Program RMRS Fire, Fuel, and Smoke Science Program USDI Bureau of Land Management US Forest Service US Forest Service Rocky Mountain Research Station US Forest Service Wildland Fire Management Research, Development & Applicatio	The FlamMap fire mapping and analysis system (Finney 2006) describes potential fire behavior for constant environmental conditions (weather and fuel moisture). Fire behavior is calculated for each pixel within the landscape file independently. Potential fire behavior calculations include: * surface fire spread * flame length * crown fire activity type * crown fire initiation * crown fire spread. **"Fuel is the only variable that changes":** Dead fuel moisture and conditioning of dead fuels in each pixel based on slope,	* Condition variation is **constant in time** but **variable across the landscape**. * User specifies total burning time (minutes). * Spatial fire behavior system that effectively does a BehavePlus run on each pixel. **Each calculation is separate and independent for each point (pixel) on the landscape.** * FlamMap MTT calculates	* Spotting technical documentation * FlamMap help website. * Video: How to use FlamMap6. * FlamMap software page. * Modeling Spot Fires—U.S. Modeling System Comparisons for Practitioners (October 2010 — Opperman)	* Desktop application that ONLY runs in a 64-bit Windows OS. * Personal Computer	* "As originally implemented in BEHAVE, the spotting component of FlamMap and FARSITE is **intended to compute the maximum spotting distance** from a given point on a fire front if torching occurs. It is **not intended to simulate the numbers of embers, exact locations embers would land, or locations of resulting spot fires**." * Tonja Opperman claims that FlamMap desktop doesn't include the spotting module (as of 2010). * Because environmental

		shading, elevation, aspect, and weather. With the inclusion of FARSITE, FlamMap can now compute wildfire growth and behavior with detailed sequences of weather conditions.	minimum travel times (MTT) of fire spread based on numerous fire spread pathways. - User can use a "drip torch" cursor to draw an ignition line polygon. - User can add a barrier file to impede fire growth. * Can run WindNinja on the fly and overlay wind vectors onto map during an MTT run. **Includes the following software:** - FARSITE (Finney 1998, 2004) - FlamMap BASIC (Finney 2006) - Minimum Travel Time (MTT, Finney 2002, 2006) - Treatment Optimization Model (TOM, Finney 2001, 2006, 2007) - Conditional Burn			conditions remain constant when using FlamMap, MTT, Burn Probability, and TOM it will not simulate temporal variations in fire behavior caused by weather and diurnal fluctuations as FARSITE does. Nor will it display spatial variations caused by backing or flanking fire behavior. These limitations need to be considered when viewing FlamMap output using these models in a relative sense rather than absolute sense. However, these outputs are well-suited for landscape level comparisons of fuel treatment effectiveness because fuel is the only variable that changes. Outputs and comparisons can be used to identify combinations of hazardous fuel and topography, aiding in prioritizing fuel treatments. * **FlamMap MTT is not a replacement for FARSITE**, nor is it a complete fire growth simulation model. Although you can run a simulation for many

			Probability (Finney 2005, 2006) **Includes the following FB Models:** - Rothermel's (1972) surface fire spread model, - Van Wagner's (1977) crown fire initiation model, - Rothermel's (1991) crown fire spread model, - Albini's (1979) spotting model, - Finney's (1998) or Scott and Reinhardt's (2001) crown fire calculation method, and - Nelson's (2000) dead fuel moisture model. This allows conditioning of dead fuels in each pixel based on slope, shading, elevation, aspect, and			hours, the wind and weather inputs remain constant for the duration of the simulation. FARSITE, however, can model fire spread and fire behavior using varying wind and weather inputs that allow dead fuel moisture conditions to change over time. MTT uses spatial information of topography and fuels to calculate fire behavior characteristics for the duration of the simulation using one set of wind and fuel moisture conditions. **Assumptions and Limitations:** * Assign a constant Foliar Moisture Content (%) to the entire canopy, even though you might analyze a massive, varying landscape.

			weather. **Spotting Procedure:** 1. FB calculated for each landscape node. 2. If node experiences passive/active crownfire, then 16 incrementally-sized embers are lofted and followed to determine max spotting distance and direction. 3. Crown Fraction Burned and Canopy Cover determine the num of torching trees (1–10), which determine firebrand lofting height. 4. Crown Fraction Burned, Canopy Cover, Elevation, Wind info then determine max spotting distance and azimuth.			
ForeFire						

FSim	Pyrologix	The Large-Fire Simulator. Quantitative wildfire risk analysis requires complete geospatial coverage of fire impact probabilities and sizes. Wildfire simulation is the primary means of estimating these, including the frequency distribution of large fire events. FSim simulates the growth and behavior of hundreds of thousands of fire events for risk analysis across large land areas using geospatial data on historical fire occurrence, weather, terrain, and fuel conditions. Effects of large fire suppression on fire duration and size are also simulated.		* FSim on Pyrologix website. * Guide to best practices.		
FSPro		Fire Spread Probability (FSPro) A fire spread and spotting probability system but does not show fire behavior or max spotting distance.	* Essentially uses hundreds of WFDSS NTFB runs to create a probability analysis for long-term fires. * Performs hundreds or thousands of separate fire growth simulations from weather sequences based on climatologic	* FSPro analysis in Alaska user's guide v1.1. * Modeling Spot Fires—U.S. Modeling System Comparisons for Practitioners (October 2010 — Opperman)	* High-performance computers * Requires Internet access. * Must be authorized	* Does not show where torching/crowning is likely to occur on the landscape. * "Cannot distinguish spotting without inclusions." — Tonja Opperman. I think she's saying that if spotting occurs, then the fire front will merge with these new spot fires to look like one single fire. * "Fire probability surface output that may or may not distinguish spot fire activity." — Tonja

			al probabilities. * Produces the probability of the fire reaching each point from the known fire perimeter during the specified simulation duration (typically 1–3 weeks). *** Conditions vary by day and across the landscape.** * User specifies hours/days of (true) active burning and then, separately, number of days for simulation. * Models the fuel moisture and wind sequences from climatology. **Spotting Process:** * Sets up vertices, each of which lofts 16 incrementally sized embers			* "Calibrate FSPro with STFB utilizes consistent spotting methods." — Tonja

			(source, slide 26). Number of vertices depends on perimeter and distance resolutions & timestep. * Distance and perimeter resolutions are determined from the LCP resolution; timestep is 60 minutes. Embers are randomly drawn based on user-def spotting probability. * Ember distances and azimuth are based on canopy cover, crown fraction burned, elevation, winds, and species/DBH. Embers are tracked until they burn out or land. * Ignores short-range spotting.			

Good Ol' Nomograms	* NWCG	A nomogram is a graph that helps you quickly read off values. For example, the NWCG has created nomograms to help wildland firefighters quickly read off the maximum spotting distance for embers based on parameters like torching tree height, species, DBH, wind speed, and target tree height.	* Rothermel published the nomograms (1983) which were based on the model published by Albini (1979).	* Modeling Spot Fires—U.S. Modeling System Comparisons for Practitioners (October 2010 — Opperman)	* Likely only paper-based!	* Assumptions and limitations: - Gives max distance only. - **Assumes level terrain and does not factor in terrain features.** - Considers only a single torching tree. - Looks at wind speed at only 20 ft above ground level. - Does not account for: likelihood of trees torching, firebrand material availability, number of spot fires, probability of ignition for that firebrand. * The species quick reference lookup tables assume that only 3 trees are torching, that they are 50 ft tall, have DBH = 10 in, and the downwind canopy cover has an open stand of 50 ft trees. These assumptions are generally crude and only give an estimate on the max spotting distance possible.
GridFire	Pyregence	GridFire is a raster-based fire behavior model that may be used to simulate the spread of wildland fires across a landscape, either individually or in monte carlo simulations over space and time. For				

		inputs, it requires a stack of co-registered raster maps for your area of interest as well as a text configuration file that specifies various parameters necessary for the simulation.				
HIGRAD-FIRETEC						
IFTDSS	Interagency Fuel Treatment Decision Support System (Pronounced: "IF-tee-diss")	**Interagency Fuel Treatment Decision Support System (IFTDSS):** A web-based application designed to make fuel treatment planning and analysis more efficient and effective.	* Windows only. * You can edit your fuels but then do a different run. * Their basemap is LANDFIRE data.			
NTFB	WFDSS (Pronounced: "WOOF-diss") * USFSP	WFDSS Near-Term Fire Behavior is a geospatial, two-dimensional fire growth model that is similar to FARSITE. NTFB incorporates existing models for surface fire, crown fire, spotting, post-frontal combustion, and fire acceleration.	* Environmental conditions do not need to be constant; the model reacts to changes in weather and wind inputs throughout the simulation. * Most applicable for modeling mid-term periods: 1–3 days (sometimes 7 days, but 15 days max) **under a variable weather**	* Instructions on how to use NTFB.	* Web-based app	* Assumptions and limitations. * "Requires quite a bit of setup, data acquisition, and calibration." — Tonja Opperman * "Without a lot of experience, users have little control over the number of opportunities for embers to be lofted. Spotting in FARSITE is more complex than what is occurring in a square grid with Minimum Travel Time methods. The moral of the story is that a much lower spotting probability is needed in NTFB/FARSITE than MTT-based models.

			forecast. * Creates deterministic simulated results, which you can relate directly back to your inputs. You will get the same outputs every time (except for spotting). Useful as a calibration tool for other models. * "Accurately represents fire growth and behavior, but fires must be “grown” to the area of concern at the right time." * Uses both crown fire methods (1. Finney, 2. Scott & Reinhardt). **Spotting Process:** * Sets up vertices, each of which lofts 16 incrementally sized embers			The level of spotting is based on these inputs, and the more finely they are set, the more spotting will occur. Vertices have 16 chances to beat the user-set "extinguishment rate," but in MTT, there is only one ember. FARSITE has a 1/16th chance of choosing the farthest ember, but MTT has a very, very small chance of choosing the farthest ember." — Tonja Opperman * Grand fir is used as the spotting tree species for the entire landscape. Distance resolution, perimeter resolution, and timestep are automated. * The minimum spotting distance (set to the landscape resolution) essentially skips the first cell. For example, on a 60-meter landscape, no spots occur in the first 60 meters from the perimeter, but any viable embers that land beyond 60 meters can produce spot fires. * NOTE: Users will probably want to set spotting

			(source, slide 26). Number of vertices depends on perimeter and distance resolutions & timestep. * Distance and perimeter resolutions are determined from the LCP resolution; timestep is 60 minutes. Embers are randomly drawn based on user-def spotting probability. * Ember distances and azimuth are based on canopy cover, crown fraction burned, elevation, winds, and species/DBH. Embers are tracked until they burn out or land. * Ignores short-range spotting. * Simulates lofting and downwind travel of individual embers of different			probability lower in NTFB than in systems using MTT (STFB, FSPro). * "NTFB is slowly becoming its own unique thing. It has evolved considerably from FARSITE." — Opperman

			sizes from each vertex that exhibits passive or active crown fire.			
Probability of Ignition Tables	* NWCG	Depends only on fuel moisture, temp, and shading (from canopy or clouds). Concepts developed by Schroeder (1969) and adapted by Andrews.				* "They describe only the likelihood that an ember will ignite a fire in receptive fuels"
Prometheus	Canadian Forest Service Northern Forestry Centre	the Canadian Wildland Fire Growth Simulation Model: A deterministic fire growth simulation model that was developed to help fire managers to understand the probable consequences of their decisions. It uses spatial input data on topography (slope, aspect, and elevation), fuel types, and weather to simulate fire growth by applying Huygens' principle of wave propagation to the rate-of-spread predictions from the Canadian Forest Fire Behavior Prediction System of the Canadian Forest Fire Danger Rating System.		* Workshop: Incorporating breaching and spotting considerations into PROMETHEUS		
PROPAGATOR						

[PyreCast](#)	Pyregence	An **open-source platform** for viewing active fires and forecasting likely spread. PyreCast is integrated into the Department of Energy’s (DOE) situation awareness North American Energy Resilience Model (NAERM) program as part of a partnership with the Lawrence Livermore National Laboratory (LLNL). Developed as part of the California Energy Commission EPIC program funded Pyregence Project (#EPC-18-026)	* 2D and 3D UI. * Integrates with ALERTCalifornia's cameras on PyreCast's UI. * Many, MANY different layers (fuel, weather, risk, active fires). Examples: - Transmission lines. - Structures. - Fuel models. - HRRR, GFS - Active Fires. - Firebrand Ignition Probability (%) but only for 3-km pixels.	[* Link to UI.](#) [* Fire Forecasting User's Guide.](#) [* PyreCast Webinar](#)		
QUIC-Fire		QUIC-Fire is a new physics-based cellular automata fire spread simulation tool that that offers advanced fire modeling capabilities without the demand for extraordinary computational resources. It rapidly solves these feedbacks by coupling the mature 3-D rapid wind solver QUIC-URB to a physics-based cellular automata fire		[* How to create a QUIC-Fire Export.](#)		

		spread model Fire-CA. QUIC-Fire uses 3-D fuels inputs similar to the CFD model FIRETEC, allowing this tool to simulate effects of fuel structure on local winds and fire behavior. Results comparing fire behavior metrics to the computational fluid dynamic model FIRETEC show strong agreement. QUIC-Fire is the first tool intended to provide an opportunity for prescribed fire planners to compare, evaluate, and design burn plans, including complex ignition patterns and coupled fire-atmospheric feedbacks. Kevin Hiers is involved				
RANDIG						
Simtable						
Smokeview		Smokeview is a companion program that reads FDS output files and produces animations on the computer screen.		* Download. * GitHub.		
Spark Operational	* The Commonwealth Scientific and Industrial Research Organisation (CSIRO). * National Council for Fire and Emergency Services (AFAC). * The Minderoo	Spark Operational has been developed to be utilised by **Australasian** fire and emergency service agencies. **Proprietary software.**		* Articles about Spark. * Article: Bushfire prediction tool can simulate dangerous ember showers and fire-generated thunderstorms		

	Foundation.			* Natural Hazards Research Australia: Fire ember transport * Ember transport for bushfire simulation - final report		
SRW	The Earth Prediction Innovation Center (EPIC) and the Unified Forecast System (UFS) community	Short-Range Weather (SRW) v3.0.0 is expected to be released in Spring 2025 to model smoke, dust, and fire.	Features: 1. Two-way Fire-Atmosphere Coupling: Integration of the Community Fire Behavior Model (CFBM) allows high-resolution wildfire simulations within the atmospheric model. 2. Smoke & Dust Forecasting: New capabilities to simulate smoke and dust transport, including test cases, a dedicated Conda environment, and platform-wide support. 3. Expanded Grids & Verification:	* All the code. * SRW App v3.0.0 Release Capabilities		

			Includes high-res Colorado grids and improved verification tools. 4. Workflow & CI/CD Improvements: Streamlined workflows, upgraded scripting, better container support, and continuous integration enhancements. 5. Documentation & Tutorials: Updated guides and new tutorials to help users adopt the new features. * Will allow for improved air quality and particulate dispersion predictions with new tests and optimized configurations. * Simulates fires on a very-high-res			

			olution fire modeling grid nested within the atmospheric domain, enhancing model accuracy in simulating wildfire spread, smoke emissions, and their subsequent meteorological impacts. * A new Conda environment ensures smooth execution across platforms, resolving conflicts and improving workflow efficiency for smoke, dust, and fire simulations. * Includes enhanced verification, automation, and data management. *** It offers a bunch of open source weather and fire modeling tools we could incorporate**			

			into WindTL.			
STFB	WFDSS (Pronounced: "WOOF-diss") * USFS	**Short-Term Fire Behavior:** Shows where torching of trees and spotting will occur on the landscape. "Quickly and spatially calculates fire behavior that produces embers, and can show spot fires, but may not give Max [spotting] Distance." — Tonja Opperman Often compared to FlamMap MTT.	* Best used for 1 or 2 burn periods to model a "snapshot in time" for a particular weather event. — not sure if this info is relevant for STFB or something else. * Useful for quickly showing where passive and active crown fires occur and where embers can be produced across the entire landscape. * Used to determine wind speed and dir thresholds required for spotting across a barrier. * Calculates fire behavior for each cell simultaneously for a single scenario. Nodes are on fixed grid equal to LCP spatial resolution.	* Comparing spotting models on the Chakina Fire. * Modeling Spot Fires—U.S. Modeling System Comparisons for Practitioners (October 2010 — Opperman)	* Web-based app?	* Probabilistic nature of spotting means that every run will be different and that max spotting distances are unreliable. Assumptions and Limitations: * Spotting only occurs when passive or active crown fire is modeled. Finney and Scott & Reinhardt methods are available for crown fire; each calculates crown fraction burned (CFB) differently. CFB and canopy cover are used to determine "number of torching trees" (1-10) used in firebrand lofting height. * More embers will be lofted at finer landscape resolutions. Faster ROS will encounter more nodes, but the absolute number of nodes is static. One ember per node; less chance than in NTFB/FARSITE that an ember will travel the maximum distance. * NOTE: Users will probably want to set spotting probability higher in STFB than for NTFB tools.

			* Uses MTT to calculate fastest fire travel paths. Embers produced only with passive and active crown fire. **Spotting Process:** * For every cell on the landscape where tree torching is predicted to occur, 16 "test" embers are lofted. Only the MAX spotting distance and angle of travel is recorded. * User-defined Spotting Probability (is this problematic?) randomly determines which torching cells produce a **single ember**. Those nodes generate a single ember with random distance from zero to the max for that node.			

			For cells predicted to have active or passive crown fires, 16 incrementally-sized embers are lofted. - Randomly lofts a single ember from a node if the predicted fire type is passive or active crown fire. - Embers are produced from a fixed grid — limited opportunities to loft an ember. * Max ember distance & azimuth are calculated using canopy cover, crown fraction burned, elevation, and all available wind information. * Embers that land on burnable fuels always ignite (Finney 2002), similar to spotting in			

			FlamMap 5.0 and FSPro.			
WFA Pocket	Technosylva	**Wildfire Analyst Pocket Edition:** An application that provides the wildland fire community with operational fire behavior tools for use in the field. WFA Pocket uses concepts and formulas developed by the US Forest Service Missoula Fire Sciences Lab to perform fire behavior calculations. It is a culmination of the wonderful science made possible by the work of applied wildfire scientists and wildland firefighters across the world. WFA Pocket compiles knowledge gained from the five plus decades of applied research on wildfire behavior, and is intended to serve as a companion to the Fire Behavior Field Reference Guide (PMS 437). It's free on the App Store.	* Version 1.3.3 added spotting calculations (Apr 2022).			
WFDS						

WildEST	Pyrologix	**Wildfire Exposure Simulation Tool (WildEST):** A **proprietary**, cloud-based software system that uses a command line application of the FlamMap fire behavior modeling system to produce continuously variable landscape scale spatial data representing fire weather, flame-front, and **ember characteristics** as well as integrated measures of risk to buildings, wildfire hazard, and suppression difficulty. WildEST includes an ember module that simulates ember production, transport, and load (accumulation). WildEST also tracks the sources of embers that land on a specified "target," such as buildings, which allows a fuel management planner to target these ember sources for treatment to mitigate hazard and risk.	* They create a Structure Exposure Score: a relative measure of the exposure of a structure — assuming one were present — to wildfire hazard.	* Download page. * Link to Documentation. * History of Documentation on OSF (shows updates).		

WindTL		WindTL is a specialized fire modeling tool designed to simulate and predict wildland fire behavior under varying wind conditions, providing real-time insights that help firefighting teams, utility companies, and emergency planners make informed decisions about risk mitigation and resource allocation. By integrating high-resolution meteorological data with terrain and fuel information, it estimates how fires propagate, identifies potential hotspots, and forecasts fire spread and intensity. Combining advanced physical modeling with user-friendly visualization, WindTL accounts for the complex interactions between wind patterns, topography, and fuel characteristics, allowing users to input real-time conditions and generate scenario-specific predictions displayed through maps, heat intensity overlays, and temporal projections. This makes WindTL an essential decision-support system for wildfire				

		management, enhancing situational awareness, guiding resource deployment, and improving safety for communities and infrastructure during wildfire events.				
WISE		**Wildfire Intelligence Simulation Engine (WISE):** **Owned by the Goverment of the Northwest Territories (Canada).**				
WoFS		Dr. Thomas Jones is "one of the developers of the Warn-on-Forecast System (WoFS), which is a regional data assimilation and forecast system designed to make short-term probabilistic forecasts (0-6 hour) of high impact weather events. Originally, the system focused in severe weather, but has been extended for fire weather applications. During the past couple of years, I have been very active in adding fire weather related tools and outputs to the system. The forecast model itself is based off of the HRRR-v4, but we generate output at 5 minute intervals for 18 ensemble members, which is something I think				

		would be very useful for your inputs."				
WRF						
WRF-Fire	Weather Research and Forecasting	WRF-Fire is a physics module within WRF ARW that allows users to model the growth of a wildland fire in response to environmental conditions of terrain slope, fuel characteristics, and atmospheric conditions, and the dynamic feedbacks with the atmosphere. It is implemented as a physics package with two-way coupling between the fire behavior and the atmospheric environment allowing the latent and sensible heat released by the fire to alter the atmosphere surrounding it, i.e. 'create its own weather'. It was first released in Version 3.2 (April 2010).		* Wiki on Open WFM. * Wiki page. * GitHub.		
WRF-Firetec		A novel coupled model that combines the physics-based wildland fire model HIGRAD/FIRETEC, with the mesoscale Weather Research and Forecasting (WRF) model. WRF-Firetec leverages the detailed fire behavior simulation capabilities of HIGRAD/FIRETEC and the sophisticated weather forecasting abilities of WRF. This				

		integration enables a comprehensive analysis of fire-weather interactions, offering valuable insights into how meteorological conditions influence fire behavior and vice versa. These folks were going to present at the FireWx1 AMS 2025 Conference but their oral presentation was withdrawn.				
WRF-SFIRE	Weather Research and Forecasting * Dept of Atmospheric Sciences, The University of Utah * The Abdus Salam International Centre for Theoretical Physics		* Uses Anderson's 13 fuel models (1982).	* WRF-SFIRE User Guide on Open WFM. * GitHub. * WRF-SFIRE Presentation. * AMS FireWx1 2025 presentation: Surface and Canopy Heat Fluxes Parameterization Improvements in WRF-SFIRE		
XyloPlan		XyloPlan creates a data-driven, shared view of wildfire risk, with actionable solutions that enable Fire Adapted Communities				

Market Landscape Understanding: Ecosystem Types

Group	**Examples**	**Function**
Academic	University of Montana Fire	Research into fire behavior, fuels, ecology, modeling, and

Institutions	Center, Colorado State University, UC Berkeley	social impacts. Develop algorithms, models, and decision-support tools.
Government Research Labs	U.S. Forest Service RMRS, LANL, NIST, NASA	Develop predictive fire models, remote sensing, climate-fire research. Provide authoritative science and technology.
Satellite Operators / Remote Sensing Orgs	NOAA (GOES), ESA (Copernicus), Planet Labs, Maxar	Provide earth observation data for fire detection, fuels mapping, and monitoring.
Wildland Firefighters	U.S. Forest Service hotshot crews, CAL FIRE firefighters	Frontline response: fire suppression, mitigation, controlled burns, incident management. Provide field data back to researchers and agencies.
Insurance Companies	State Farm, Allstate, Munich Re	Risk assessment, loss modeling, incentivize mitigation for property owners, demand better predictive tools.
Utilities	PG&E, SDG&E, Xcel Energy	Fire prevention (vegetation management, grid hardening), situational awareness, risk monitoring. Often early adopters of private wildfire risk tools.
Civilians / Communities	Homeowners, local residents, community fire safe councils	Implement defensible space, participate in community resilience, provide local observations.
Private Tech Companies	Technosylva, OroraTech, BurnBot, SkyTL	Commercialize wildfire modeling, detection, and monitoring systems. Deploy AI/ML, SaaS platforms, and satellite/drone tech.
Cloud / Big Tech	AWS, Google Cloud, Microsoft Azure	Provide scalable compute and storage for fire models, geospatial services, satellite imagery, and real-time data pipelines.
NGOs / Nonprofits	Fire Adapted Communities Network, The Nature Conservancy	Promote policy, community engagement, fuels reduction, prescribed fire, and bridge between science and practice.
Emergency Management Agencies	FEMA, state and county emergency operations centers	Coordinate disaster response, evacuation planning, and communication.
Policy & Regulatory Bodies	State legislatures, Congress, DOI, USFS, CAL FIRE leadership	Create wildfire policy, allocate funding, set safety standards.
Heavy Equipment / Aviation Contractors	Erickson (helitankers), Coulson Aviation, bulldozer contractors	Supply specialized suppression assets and operational support.