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Fire Ecology

BRIEF REPORT

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Developing a science strategy and science priorities for FireSat, an upcoming high spatial and temporal resolution fire monitoring system

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Abstract

In many regions, wildfires are increasing in frequency, extent, and intensity, with consequences for climate, human health, and ecosystem integrity. Addressing increasing wildfires requires timely, accurate, and management-relevant observations to detect fires, characterize their behavior, and quantify their impacts around the world. This meeting report synthesizes outcomes from three international science workshops held in 2025 that brought together approximately 100 participants from academia, government, non-governmental organizations, and the private sector to develop a coordinated science strategy for FireSat, an upcoming non-governmental satellite constellation dedicated to global fire monitoring. FireSat is designed to provide unprecedented spatial (~80 m) and temporal (sub-hourly at full deployment) resolution of active fires, enabling improved understanding of large and short-duration fires and detection of small, cool, short-duration, and understory fires that are poorly resolved by existing systems. The report outlines priority scientific opportunities spanning climate and carbon emissions, community health and safety, and ecosystem impacts. It presents a structured research timeline from 2026 to 2030 aligned with FireSat's phased deployment. Central themes include independent validation, uncertainty characterization, integration with legacy fire datasets, and translation of science advances into operational decision support. By articulating a shared roadmap from data to science to action, this paper aims to foster complementary researcher engagement, guide and encourage investments, foster community, and accelerate the effective use of FireSat to improve fire science, management, and societal outcomes worldwide.

Keywords Remote sensing, Fire, FireSat, Climate change, Community health, Ecosystem, Fire management, Active fire mapping, Fire radiative power

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Introduction

Wildfires are increasing in frequency and severity in many regions, with major consequences for climate, human health, and ecosystems (Burton et al. 2024; Jones et al. 2024). Fire occurrence reflects interactions between environmental and human drivers (Jones et al. 2022). Both are changing. In some regions, reduced human ignitions and fuel fragmentation have decreased burned area, but climate-change-driven fires are increasingly offsetting these declines (Burton et al. 2024). Extreme weather increases are attributed to human-caused climate change (Abatzoglou et al. 2019), changing fire intensity and severity worldwide (Pausas and Keeley 2021). The consequences are substantial: forest fire emissions have increased by ~60% over the past two decades (Jones et al. 2024; van der Werf et al. 2025), and annual premature deaths from smoke exposure could exceed 1.4 million people (0.66–2.25 million, 95% CI) by century's end (Zhao et al. 2025).

Addressing wildfire challenges requires trustworthy, systematically acquired, global coverage satellite data. Satellite-based fire remote sensing is rapidly evolving (Chen et al. 2024), with a long legacy of expertise and new platforms offering novel opportunities for fire quantification and management. However, current global satellite observations lack the resolution to capture small, fragmented fires or the temporal frequency to track them (Roy et al. 2024). This gap is notable because the unpredictable location, timing, and rapid evolution of fires requires constant, highly detailed monitoring.

Developing higher-resolution spatial and temporal data will improve understanding of fire drivers and impacts, thereby informing pre-fire planning and prescribed fire evaluation. Critically, the development and validation of scientifically robust fire products is a prerequisite for their adoption by operational users, who rely on trusted and well-characterized datasets. Rapid detection would support fire management and timely response during high-risk conditions once such products are proven reliable. This report highlights the environmental scientific strategy for FireSat, an upcoming satellite constellation for high-resolution fire monitoring, to advance fire science and management across climate, community health and safety, and ecosystem integrity.

Approximately 100 participants from Australia, Brazil, South Africa, various European nations, Canada, and the USA, representing academia, NGOs, government, and the private sector, came together over three workshops in 2025 to outline fruitful scientific workplans and timelines. The three workshops also identified scientific priorities in climate impact, community health and safety, and ecosystem integrity from 2026 to 2030. Participants were asked to identify how scientific understanding could be built alongside the growth of the FireSat mission (described below) to maximize impact at each stage. The teams co-created a communal document of key data needs and priorities, which was distilled into a general consensus on the common set of priorities and timelines below. All participants were invited to participate in and review this consolidation and manuscript.

Description

FireSat, a program of the non-governmental Earth Fire Alliance (EFA; https://www.earthfirealliance.org/), is a dedicated fire monitoring satellite constellation currently under development with the potential for rapid fire detection and tracking across the globe and to provide robust data across the fire life cycle. In addition to supporting the fire management community, the data collected by FireSat will also be used to support global fire and climate science. FireSat was specifically designed with improved spatial and temporal resolution and a specific suite of thermal infrared imaging bands specific to fire to address gaps in current operational global satellite systems for high sensitivity to cooler, smaller, and short-duration fires, while maintaining its ability to also detect, track, and measure with more detail large, long-duration, intense fires (Table 1).

The first FireSat satellite (called "protoflight") was launched in March 2025 for the purposes of testing and demonstration; the first three operational FireSats (termed Initial Operation Capability (IOC)), launched in 2026 and are expected to begin providing data in northern hemisphere fall/winter 2026. The intention is to continue to build and launch satellites until the system reaches Full Operational Capability (FOC). The FireSat constellation should reach an average hourly temporal resolution across the globe around 2029 with approximately twenty satellites and ultimately achieve a 20–30 min revisit (depending on latitude) in the early 2030s with approximately fifty satellites at FOC. The FireSat sensor is a multi-band imager that collects data in six spectral channels: red, near infrared, shortwave infrared, two mid-infrared (one attenuated band and one unattenuated band to reduce saturation effects over hot fires), and longwave infrared. All six spectral channels are collected simultaneously and at the same resolution. The sensor was designed to maximize fire information while minimizing false positive detection rates. The FireSat sensor is a scanning system with a 1500 km swath width with an average spatial resolution of 80 m. In addition to the image data, EFA will deliver derived data products including hotspot detections (with a goal of < 5% false positive rate), fire perimeters, fire progression time series (i.e., fire perimeters through time), and gridded fire radiative power (FRP)

Table 1 FireSat instrument specifications

Key performance parameter	Specification
Instrument type	Cross-track scanning multispectral imager
Spectral access Wavelengths and FWHM Bandwidth	5 unique bands, and one attenuated band Red through LWIR Red: 0.64 um, 0.08 um NIR: 0.87 um, 0.06 um SWIR: 1.6 um, 0.10um MWIR1: 3.75 um, 0.51 um MWIR1A: 3.75 um (attenuated), 0.44 um LWIR: 10.75 um, 0.33 um
Swath width	1500 km
GSD (from 600 km altitude)	~50 m (nadir), ~80 m (average), ~150 m (edge of swath)
Geolocation accuracy	100 m (CE90)
Frame rate	Up to 36 fps per camera
Data rate	~20 GB per minute of imaging
Detection sensitivity—hotspot	Targeting fires as small as 5 m × 5 m at 650 K
Dynamic range	Cool fires (650 K) to hot fires (1000 K+)

measurements. Downstream and derived data products, like estimated carbon emissions or fire radiative energy (FRE) will need to be developed by the scientific community.

EFA and FireSat grew out of a co-design effort among the Environmental Defense Fund, philanthropic funders, and technical collaborators including Google Research and Muon Space. EFA operates under a public–private–philanthropic partnership model, with the satellites built and operated by its technical partner, Muon Space. Funding to date has been primarily philanthropic, with long-term sustainment expected to rely on government funding, agency-level data agreements, and commercial licenses. Individual satellites have an expected lifetime of three to five years, and EFA's operations plan provides for replenishment to maintain continuity beyond FOC. EFA will archive all FireSat data and retain the ability to reprocess the archive as algorithms improve. Validation is led by EFA's Chief Science Office, supported by a science advisory council now being established and by more than 20 partner organizations on five continents, which span fire operations, land management, and research, and cover tropical to boreal regions and both fire-adapted and non-fire-adapted ecosystems. FireSat's potential to positively impact climate, community health/safety and loss avoidance, and ecosystem integrity will depend on the quality and reliability of its data. Developing the core science to develop and support those data will require robust testing and transparent sharing of results. It is our hope that the strategic framework and structured workplan (2026–2030+) developed below will aid the scientific community in testing and developing this emerging tool.

International cooperation and leverage are critical to the success of FireSat. Operational clarity on image collection distribution, data availability, and use permissions is important to deliver as soon as feasible. This will inform and undergird research proposals and funding applications that require substantial amounts of lead time. If data delivery can be anticipated, potential delays in applying for funding to leverage FireSat can be minimized. The activities in this strategic timeline will require funding. We intend this document to be leveraged by the scientific community to develop proposals and funding calls to demonstrate the strategic and efficient development of this resource.

FireSat will be only one part of the larger fire science and management system, which includes space agency satellites (e.g., NASA MODIS/NASA VIIRS/ESA Sentinel-3), airborne systems (e.g., AVIRIS, MASTER, NIROPS), ground-based platforms (e.g., fire alert ground cameras), and both public and private enterprises. It complements those systems by providing moderate spatial resolution (and high spatial resolution for hotspots) with high temporal resolution (Fig. 1). Success will depend on, and should be integrated into, both the publicly supported (e.g., NASA, ESA) and private/nonprofit ecosystem for maximal effectiveness. The opportunities here should be read with that integration in mind. Further, while focused on FireSat, conclusions also apply to other public (e.g., WildFireSat; Johnston et al. 2020; Thompson et al. 2025), private, and, to some extent, existing missions (e.g., VIIRS). The report aims to engage the research community in testing new platforms and strategically building knowledge to improve future fire management.

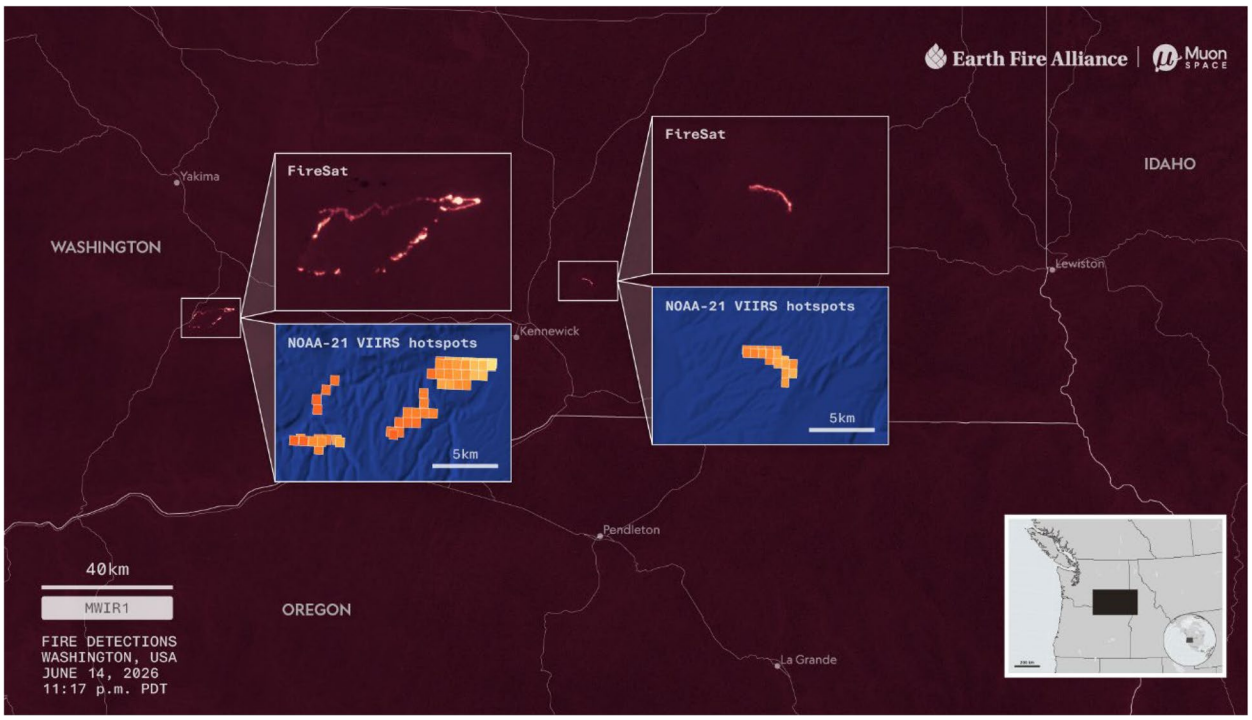


Fig. 1 Initial FireSat imagery example, MWIR1 band (see Table 1 for wavelengths) and coincident VIIRS imagery. Photo courtesy of Earth Fire Alliance

Strategic science timeline

As the satellite system develops, opportunities shift from basic data validation and integration to leveraging increasing temporal resolution for new insights and into new opportunities for wildfire science and management (Fig. 2). Several commonalities emerged (Table 2), including the need for independent validation, incorporation into existing fire products, and testing the limits of the core functionality of the FireSat data products. For example, fire detection limits need to be carefully calibrated for off-nadir observations, under canopies, and in a range of ambient environmental conditions. Given the

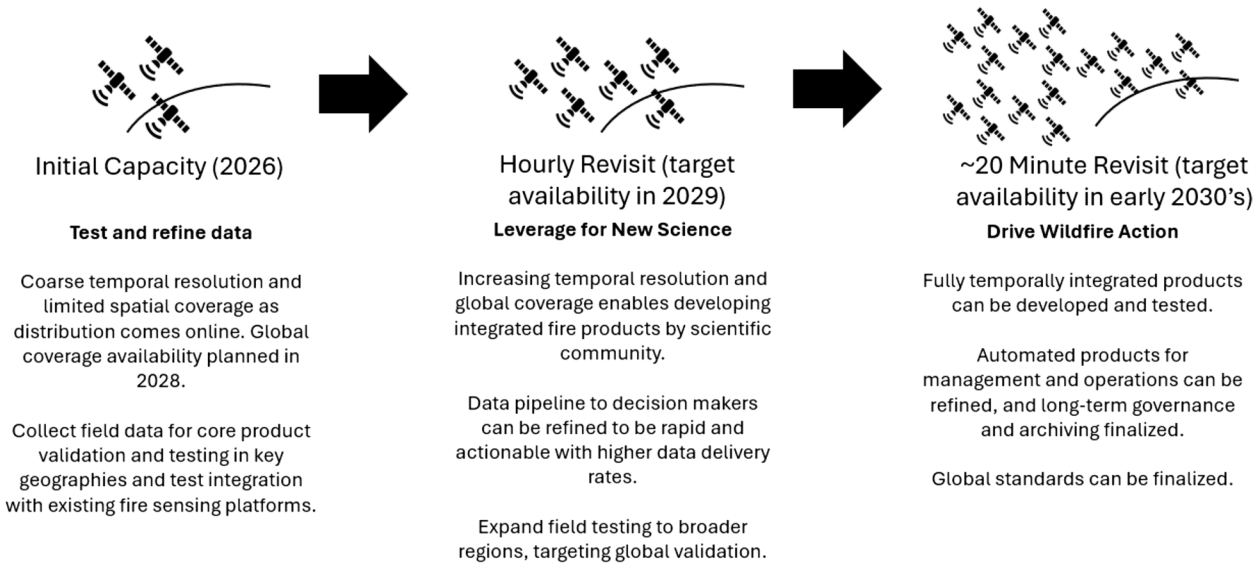


Fig. 2 Scientific and management themes change as the capacity of the system expands

Table 2 Key tests and data needs timeline for the scientific mission of FireSat

Theme	End 2026	End 2028	End 2030
Building confidence	Independent evaluation of core FireSat products from level L0, test alignment with existing fire records (e.g., MODIS)	Test temporal consistency within fire events, optimize data availability framework	Final tests of temporally integrated products (e.g., FRE), full integration into and across existing fire satellite ecosystem; evaluate distribution
Fire detection and carbon emissions	Evaluate fire detection capability across test landscapes, test FRP with ground or airborne measures	Generate regional estimates of emissions and test against existing estimates, develop integrated FRP/FRE emissions estimation methods	Global estimates of emissions and climate impact available and operationalized for emission goals
Fuels	Build fuels maps, including in Rx burn environments, understand different signatures of burn type (smoldering vs flaming)	Tie FireSat to fuel consumption and emissions. Burn type product development and deployment under testing	Generate automated emissions profiles for operational prioritization
Ecological impacts	Compile and define linkages between burn and ecosystem response and test locations	Develop diagnostics and identify temporal thresholds necessary for decisions	Operationalize predictive conditions; prioritize understudied regions
Enabling management	Identify vulnerable locations for key management goals to connect to operational teams when data are available	Regional assessment of gaps in climate, AQ, ecosystem goals and use of FireSat for evaluating effectiveness	Rapid data availability and a policy framework to support fire management for goals
Scaling	Construct relevant scaling metrics in advance; connect with drone and airborne data; begin community algorithm iteration	Expand scaling data to new regions, test temporal resolution requirements, develop plan for integration into global platforms	Maintain global calibration standards and versioned science-quality data products

unprecedented resolution of FireSat, a clear understanding of omission and commission errors across all contexts will be required to interpret the new dataset. As the constellation matures, this requirement will extend into new biomes and landscapes. Importantly, community engagement and potentially user capacity-building efforts must begin early so that the impact of these data can be translated into real world action (e.g., enforcement, management plans). Building the baseline understanding of uncertainty and confidence in the data products is a first step that can begin immediately, as the first operational satellites have been launched in 2026.

Climate opportunities

Wildfire emissions are a significant part of the global carbon cycle, averaging ~2 gigatons C year^{-1}. Wildfires start from a combination of natural and human ignitions (both intentional and accidental). In the past, much of those wildfire emissions would be balanced by re-uptake of recovering vegetation; however, climate change is increasingly driving increases in emissions due to longer fire seasons (Jones et al. 2024), higher emission intensities, and combustion of old carbon (Walker et al. 2025). Stronger quantification of fire-induced carbon emissions is necessary to manage this increasing climate driver.

Quantification

Short-duration, small ground fires (Chuvieco et al. 2022; Fernández-García et al. 2025) and sub-canopy smoldering (Johnston et al. 2018) fires are not well-characterized with existing sensors due to infrequent observation or coarse spatial resolution (Hall et al. 2016; Roy et al. 2024). It has been estimated for small fires in Africa that coarse resolution fire products underestimate net carbon emissions by 31–101% (Ramo et al. 2021). As such, FireSat could fill a critical gap in global emissions accounting. Characterizing fires at higher temporal and spatial resolutions could also provide improved fire radiative energy (FRE) data (Wooster et al. 2005; Ichoku et al. 2008; Chatzopoulos-Vouzoglanis et al. 2023), valuable for estimating emissions. High-resolution FRE and cumulative radiative energy estimates, especially at night, could then support more accurate greenhouse gas emission inventories and enable real-time tracking of fire progression and severity (Chen et al. 2024). Ultimately, this can also be used to strengthen fire emission models, reduce uncertainty in global fire emissions budgets, quantify legacy carbon loss in peatlands and other settings, develop post-fire recovery predictions based on burn intensity, and enable burn residency time analyses that are not currently feasible. Benchmarking against existing and legacy datasets will be critical.

Management

Fire management targeting climate goals could also benefit from strategic research to develop FireSat. For pre-fire planning, there is a significant opportunity noted to evaluate prescribed burns or natural fires to gauge fuel consumption (e.g., Turney et al. 2023). Research that connected FRE or fuel consumption products enabled by FireSat could also inform carbon projects and evaluate their effectiveness. Higher temporal resolution on spread rates was noted as an opportunity to refine fire modeling for management planning and risk assessments. Once a fire occurs, early detection can provide the opportunity to actively manage ignitions before they grow too large to proactively control (for a review of boreal region temporal requirements, see Table 3 in Johnston et al. 2020; for a review of platforms, see Barmpoutis et al. 2020). Improved data on emissions, plus the early detection capacity, offers opportunities for strategic management of fires, such as suppression of fires in key carbon stores (e.g., boreal forests peatlands; Turetsky et al. 2015) or active management of fires to minimize their climate impact.

An important first step will be a rigorous validation of the fire detection product against existing datasets and field observations, including characterization of detection performance against high-resolution burn products through intercomparisons, error matrices, and assessment of potential saturation effects before proceeding to the calibration and evaluation of FRP products. FireSat products should be integrated with well-characterized MODIS/VIIRS active fire detection and FRP products (Giglio et al. 2016) as well as burned area products (Giglio et al. 2025) for long-term climate consistency and to help quantify emissions for national reporting and carbon markets. See Table 3 for key opportunities from 2026 to 2030.

Community health and safety opportunities

Wildfires impose substantial health burdens through direct effects of burns, trauma, infrastructure damage causing evacuation and displacement, smoke exposure and via mental health impacts (Gould et al. 2024; Qiu et al. 2025). Addressing these health burdens requires accurate quantification of exposure, which depends on fire location, intensity, and emissions across combustion phases. Mitigation can be supported and advanced via higher-resolution data on fire spread and burn characteristics that can inform fire management decisions.

Quantification

Although FireSat is not designed to quantify air pollution directly, its potential for improved characterization of

Table 3 Climate science and management opportunities from 2026 to 2030, by broad focus area

Focus area (research opportunity)	2026—initial capacity (early FireSat data, pilots, validation)	2028—expanded capacity (higher revisit, more validation, early integration)	2030—full capacity (global coverage, multiple years of data)
Small and cool fires	Detect and quantify small/cool fires missed by MODIS/VIIRS; validate with field campaigns	Estimate emissions at regional scale; refine detection thresholds and omission/commission rates	Global quantification of small fire emissions and their contribution to carbon cycle models
Smoldering fires	Compare image retrievals between flaming and smoldering combustion areas, Build emission factors for low severity burns	Develop and validate smoldering fire emissions algorithms; estimate FRP-to-emissions relationships	Create global climatology of smoldering fire persistence and emissions
Fire progression and spread	Limited opportunity for validation due to relatively few satellites. Identify opportunity space with first three satellites by matching overpass time to prescribed burns or other known events	Test and refine spread and reburn models; support real-time operational and post-event analysis, test burn duration impacts	Scale models globally; integrate into early-warning and fire risk platforms
Strategic management	Develop carbon vulnerability mapping to inform climate-as-management goal for fires	Integrate under-canopy testing for forest detection capacity	Policy incorporation of climate risk mapping to identify priority management areas
Emissions for inventories	Test early emissions estimates from active fires; link with pilot partners	Support integration into national inventories and carbon credit risk tools; evaluate avoided emissions	Formal adoption in national planning processes and third-party GHG verification frameworks
Post-fire effects (mortality, albedo, recovery)	Begin mapping tree mortality and regrowth signatures in early adopter sites	Develop post-fire forest change models; track albedo and surface recovery metrics, test for delayed mortality and other effects like landslide occurrence	Global mapping of post-fire ecosystem transitions and carbon impacts
Agricultural burning and air quality	Test detection ability of small/cool ag fires with well instrumented regions as initial tests	Expand to Africa, India, Brazil, test for short duration burn prevalence, separate ag burns from kilns/landfills/etc.	Link emissions to air quality and policy enforcement platforms globally
Management and fuel treatments	Setup fuel consumption tests on example Rx landscapes; build database of historical Rx burns for future comparison if burned	Track treatment longevity, reburn, and ecosystem transitions with different ages of Rx treatments	Quantify climate mitigation effectiveness of management strategies
Science infrastructure and community	Validate base products with field, drone, and airborne data; begin community algorithm iteration; test detection capacity/FRE products at different viewing angles, through smoke (for cool fires); build formal feedback loop science community experts	Standardize validation pipelines; cross-calibrate with MODIS/VIIRS for long-timespan	Maintain global calibration standards and versioned science-quality data products

FRP, rate of spread, and combustion phase could reduce the upstream uncertainty that currently limits air quality (AQ) predictions and smoke dispersion models. Estimating population smoke exposures currently relies on chemical transport models that take fire location, size, and emissions as inputs and simulate smoke transport and PM2.5 concentrations downwind. Satellite data are central to this data integration and estimation pipeline: they provide fire detections, FRP, and aerosol optical depth that, combined with ground-based monitors and plume data, enable the spatial and temporal coverage the health impacts research requires (Childs et al. 2022; Li et al. 2022). However, uncertainty in upstream fire characterization, especially for FRP, rate of spread, and changes during flaming and smoldering combustion, propagates through the modeling chain and affects estimated health impacts (Qiu et al. 2024). FireSat data that resolves energy release and combustion characteristics could therefore support more accurate estimation of smoke-attributable health outcomes, including pharmacy use, emergency visits, hospitalizations, and premature mortality. We specifically note the importance of refining and improving emissions factors for the new spatial and temporal resolutions being considered, as direct translation of emissions factors from other platforms may not be appropriate to finer scales. To translate FireSat fire characterization into useful health insights, its products must be integrated with smoke chemistry, optical depth, fuels, vertical plume structure, and boundary-layer dynamics to further refine and develop smoke exposure products (e.g., Xue et al. 2025). This will require systematic benchmarking against legacy fire datasets, standardized uncertainty quantification, and scaling tests across diverse ecosystems.

FireSat could also better quantify tradeoffs associated with prescribed fire, which can present a challenge: burns can reduce risks of very large fires while generating PM2.5 exposures in the short term (Kiely et al. 2024; Higuera-Mendieta and Burke 2026). This tradeoff has not been well explored. Paired with field validation of smoke chemistry and toxicity, FireSat could refine understanding of how fuels and combustion phases influence health risks across regions and seasons. Near-real-time FireSat monitoring could enable adaptive management of prescribed fire timing and intensity to tilt this tradeoff towards net benefits even under short time horizons.

Management

Improved fire detection could also support early-warning forecasts of smoke impacts and inform actionable exposure thresholds for advisories or school closures. Identifying populations bearing disproportionate burdens through integration with demographic and infrastructure datasets in near-real-time is important: evidence suggests that low-income communities are less able to protect themselves during smoke events (Burke et al. 2022), and Indigenous communities in California face roughly 1.7× the average wildfire PM2.5 burden (Casey et al. 2024), with less capacity to respond quickly. Co-development of data products, alert systems, and decision-support tools with public health agencies and frontline communities, and clear data access via familiar platforms will be essential to ensure that these datastreams reach the decision-makers and populations that need them most. Ethical handling of health data in this context will be essential.

See Table 4 for key opportunities in the community health space from 2026 to 2030.

Ecosystem opportunities

Wildfires play a key role in natural and human-dominated ecosystems. Higher spatial and temporal resolution fire data will inform our understanding of, and management for, biodiversity outcomes, resilience trajectories, and resource dynamics (e.g., Huerta et al. 2022; Mahood et al. 2023).

Quantification

Higher spatial and temporal resolution can help in fire identification, attribution, and impact assessment. Many small, cool, understory, agricultural, and tropical ground fires remain poorly detected by current systems, particularly in peatlands and cloud- and canopy-obscured regions and remain a challenge to understanding net fire impacts at global scales (e.g., Johnston et al. 2018; East et al. 2023; Hall et al. 2024). Attribution is challenging, especially in fine-scale ecosystem mosaics. For example, in areas where remnant forests are surrounded by agricultural land, it can be challenging to determine if fires are deforestation fires, agricultural clearing fires, or both (Roy and Kumar 2017; Tyukavina et al. 2022). Within a burn, impacts of fires are closely related to fire intensity and heterogeneity of intensity. By capturing fine-scale variation in FRP, cumulative FRE, fire residence time, and spread rate, FireSat could quantify patterns of burn heterogeneity, vegetation loss, and potentially soil impacts (indirectly, through burn times or FRP, or directly through color change) needed to predict species abundance, habitat fragmentation, and post-fire recovery (e.g., Fallon et al. 2024). This improved detection capacity would be particularly important in data-poor tropical and understory systems, where fire impacts on biodiversity and ecosystem function are less well described.

Table 4 Community health science and management opportunities from 2026 to 2030, by broad focus area

Focus area (research opportunity)	2026—initial capacity (early FireSat data, pilots, validation)	2028—expanded capacity (higher revisit, more validation, early integration)	2030—full capacity (global coverage, multiple years of data)
Air quality exposure metrics lack spatial/temporal resolution	Pilot in early adopter regions: compare FireSat detections with ground AQ sensors and health data; validate the additional value of FireSat re: $PM_{2.5}$ improvements over existing hourly products	Global integration with chemical transport models; hourly-scale exposure assessments	Continuous global fire-smoke-health exposure mapping; real-time public alerts
Smoke toxicity differences by fire type (wildfire, Rx, urban interface, agriculture)	Proof-of-concept fire type classification; link to limited toxicity data from Rx burns	Large-scale studies on toxicological differences; evaluate trade-offs (Rx vs wildfire smoke)	Automated global fire type classification with toxicity profiles to guide policy
Limited understanding of health impacts from fire proximity and evacuation timing	Develop evacuation trigger models for pilot regions; test with past fires	Integrate real-time FireSat detection with live evacuation decision tools	Global adaptive evacuation and shelter-in-place decision support systems
Unknown cumulative and chronic health effects of repeated smoke events	Identify high-exposure communities; launch chronic exposure pilot studies	Expand to multi-country longitudinal studies with health cohorts	Global database linking fire event history to long-term health metrics
Fuel and combustion phase data insufficient for accurate emissions modeling	Field validation of flaming vs smoldering detection in early adopter regions	Integrate combustion phase data into emissions models for improved AQ forecasts	Near-real-time emissions forecasting incorporating fire type, fuels, and weather
Rx fire benefits vs wildfire avoidance not well quantified	Compare smoke/health outcomes from Rx vs no Rx in pilot regions	Regional and national-scale avoided cost and avoided health impact studies	Global Rx policy evaluation based on quantified health and safety outcomes
Poor detection and tracking of high-smoke risk fires (mass fires, night burns)	Detect and characterize nighttime and persistent burns in early adopter regions	Global characterization of high-smoke risk fire conditions and triggers	Operational suppression prioritization for smoke-intensive events
Weak integration between fire detection and public communication	Prototype public fire/smoke alert tools with simple risk language. Link with Watch Duty?	Test message types in randomized trials; refine thresholds	Fully operational, culturally adapted global fire/smoke communication system
Policy effectiveness on fire and smoke impacts hard to measure	Identify policy-relevant boundaries; test before/after fire outcomes	Multi-region evaluations of agricultural burning bans, defensible space mandates	Global fire policy impact platform combining FireSat, health, and economic data

Management

Ultimately, key fire metrics such as fire duration, intensity, and heterogeneity could help distinguish when fire supports ecosystem functioning (i.e., stabilizing fires) from when it drives degradation or catastrophic climate or human health impacts (i.e., destabilizing fires) in near-real-time and at global scales. Management in these cases may be primarily tied to informing response—for example, derived FireSat metrics such as cumulative energy release, burn duration, and patchiness, combined with baseline ecological data, may indicate whether systems are likely to recover within historical regimes or shift toward invasive-dominated or highly flammable alternative states. By refining the heterogeneity of fire intensity and burn durations, FireSat could improve understanding of resilience thresholds under climate change and help define conditions associated with stabilizing or destabilizing fires. Burn intensity and spatial heterogeneity strongly influence erosion, flooding, nutrient export, hydrophobic soil formation, and downstream water quality impacts. Higher-resolution fire data, when combined with precipitation and soil data, could enable near-real-time watershed-scale early-warning systems for postfire impacts, improve estimates of postfire evapotranspiration and snowmelt shifts, and help identify intensity thresholds associated with irreversible water quality degradation. These advances would support predictive models of postfire ecosystem trajectories, including risks of long-term compositional change (e.g., Coop et al. 2020).

If successful and well developed, FireSat—along with other satellite fire observation systems, ground networks, and other tools—could support ecosystem impact mitigation by providing actionable information on the effectiveness of targeted prescribed fire, managed natural fire (e.g., Barros et al. 2018), thinning, firebreaks, and suppression strategies in promoting biodiversity and resilience while minimizing hydrological risk. Near-real-time monitoring of treatment intensity and spread could help evaluate whether ecological objectives are being met and reduce escape risk, while also clarifying tradeoffs between short-term disturbance and long-term ecosystem health.

Integration with existing ecological and hydrological datasets, alongside careful benchmarking against legacy fire products, will be essential for scaling findings across ecosystems and operationalizing FireSat data within adaptive management frameworks. See Table 5 for key opportunities in the ecosystem impact space from 2026 to 2030.

Data to science to action

Efficiently establishing the strong scientific data foundation for the new FireSat platform will benefit from a coordinated progression from fire detection to characterization (e.g., FRP and energy), to emissions estimation, and ultimately to impacts on climate, air quality, and ecosystems. Because a fire can move or extinguish in minutes, active fire detection validation conventionally involves multi-resolution satellite comparison, treating the higher-resolution data as the "reference" for the coarser product. For example, the MODIS 1 km active fire detection product was validated by comparison with active fires detected from higher spatial resolution but coincident ASTER data sensed from the same satellite platform (Morisette et al. 2005a,b; Csiszar et al 2006). Similar approaches for FireSat active fire detection validation can be undertaken by comparison with judiciously selected near-contemporaneous satellite and airborne data over both large/hot fires and small/cool fires.

Field campaigns to calibrate and validate space-borne measurements enabling characterization of uncertainties in detection, retrieval, and estimation of active fires and their properties are a critical step (Wooster et al. 2021; Thompson et al. 2025). In the early stages, this will be single image testing—e.g., fire perimeters or detection capacity under canopies. As the constellation develops, temporally integrated metrics like FRE will become a uniquely valuable resource from this system due to the concurrent fine spatial scale. Anticipating that need, with early studies on FRP uncertainties, is critical to speed overall value. The Land Product Validation (LPV) subgroup of the Committee on Earth Observing Satellites' Working Group on Calibration and Validation (Boschetti et al. 2009; Giglio et al 2016) is a valuable resource in the field, with recognition that a "uniform protocol to validate spaceborne FRP retrievals is required" (Wooster et al. 2021).

There is a long history of this work which can inform the roadmap. The data provided from FireSat (hotspots, perimeters, active fire and FRP) will need to be translated into the metrics described here with rigorous science. Validation of derived fuel combustion rates from spaceborne FRP against ground data highlighted the utility of FRP as a physically observed variable related to combustion rather than fuel characteristics (Roberts et al. 2005) and supported work demonstrating agreement with spaceborne sensors (Smith and Wooster 2005). Similar small-scale fire experiments confirmed FRE and fuel mass combustion rates for additional fuels in both laboratory and field settings (Freeborn et al. 2008; Kremens et al. 2012). Assessment and validation for active fires and FRP continues with active field experiments using coincident measurements over

Table 5 Ecosystem science and management opportunities from 2026 to 2030, by broad focus area

Focus area (research opportunity)	2026—initial capacity (early FireSat data, pilots, validation)	2028—expanded capacity (higher revisit, more validation, early integration)	2030—full capacity (global coverage, multiple years of data)
Biodiversity—quantification	Test FireSat's capacity to quantify canopy loss, regreening rates, and burn patchiness. Pilot detection of understory, tropical, and agricultural fires with strong preexisting networks	Develop landscape biodiversity indicators (heterogeneity, fragmentation) that map onto FireSat. Integrate FireSat data with biodiversity monitoring networks (camera traps, UAVs, acoustic sensors)—workflow	Build predictive models of biodiversity resilience vs. collapse using FireSat time series to inform, and embed FireSat into global biodiversity monitoring programs and rapid response frameworks
Biodiversity—mitigation	Test relationships between FRP/FRE and biodiversity impacts, validate Rx burn effectiveness for biodiversity targets in field	Test FireSat utility in estimating Rx effectiveness and scaling on broader scales, operationally distinguish "good fire" vs. damaging fire for biodiversity and tie to observed FRE/FRP or other product	Develop biodiversity-informed fire management guidelines, integrate FireSat biodiversity layers into restoration and conservation planning
Resilience—quantification	Identify fire intensity/duration thresholds linked to transformation vs. recovery, pilot assessment of FireSat metrics vs. invasive species presence/absence	Link FireSat FRP, residence time, and spread speed with ecosystem recovery outcomes, model resilience trajectories (multi-fire exposure, invasive risk)	Establish global benchmarks for typical heterogeneity and intensity metrics, incorporate FireSat into long-term resilience forecasting and planning
Resilience—mitigation	Assess effectiveness of treatments (thinning, Rx fire, backfires) using FireSat before/during/after fires, build early case studies linking treatments to resilience	Integrate FireSat into burn window projections under climate change, use FireSat for ecosystem triage (prioritizing low-resilience areas)	Provide adaptive restoration guidance (species/strategies resilient to climate + fire), deliver global resilience indices to guide policy
Water—quantification	Pair FireSat intensity/severity with watershed water quality measurements, map overlaps of precipitation and high-severity burns for risk hotspots	Evaluate importance of high temporal resolution FRP to less frequent measures for hydro impacts, use FireSat to constrain evapotranspiration, snowmelt timing, and soil hydrophobicity, landslide potential	Develop global fire–hydrology models for forecasting water supply and quality risks
Water—mitigation	Develop strategy for FireSat-enabled early warning systems for water utilities, define intervention thresholds for watershed management	Test early warning platforms for water managers based on burn severity, create cross-agency data pipelines linking fire and water management	Test operational response plans for rapid watershed response to fires with characteristics likely to cause water issues

experimental burns (e.g., Roberts et al. 2025). Requirements for simultaneous and unsaturated FRP data collection for validation pose challenges, given the variability of FRP that can occur during a fire (Roberts et al. 2025). Uncertainty in energy release directly affects emissions estimates, which in turn influence atmospheric composition models, smoke exposure assessments, and evaluations of ecosystem response. Improving validation across fire regimes, fuel types, and temporal scales is therefore essential not only for product development but for enabling reliable application of FireSat data across disciplines.

Numerous multidisciplinary field campaigns have explored simultaneous measurement of fire characteristics with many utilizing prescribed or agricultural burning to capture relevant data such as those for FRP, micrometeorological aspects of fire spread, air chemistry and fire behavior (e.g., RxCADRE, Dickinson et al. 2016 and 2021; O'Brien et al. 2016; Hudak et al. 2016; FireFlux I and II Clements et al. 2019; FASMEE Liu et al. 2019; Prichard et al. 2019; FIREX-AQ Warneke et al. 2023). Field validation methods have utilized helicopter-mounted thermal cameras (Roberts et al. 2025), tower-mounted spectroradiometers, cameras, and thermocouples (Wooster et al. 2005; O'Brien et al. 2016; Clements et al. 2019) as well as unmanned aerial vehicle (UAV) cameras (Eames et al. 2023; Batchelor et al. 2024).

Community engagement is a necessary and key enabler for scaling these efforts into operational use. Groups like NASA FireSense provide infrastructure and logistics for coordinated, cross-platform calibration and could be key partners for rapid scaling and community engagement with the FireSat platform. Other groups developing similar efforts, such as WildFireSat, have relevant expertise and can provide significant collaborative opportunities, especially for tests which would inform both platforms. Lastly, the broader fire community already supporting MODIS/VIIRS and other legacy fire observation platforms (many of which participated in this exercise) will be critical in building continuity, trust, and interoperability across datasets. They will also be instrumental in determining the best research efforts to leverage FireSat data in the larger instrumental context, both now and in the future.

Several opportunities for advancing fire and climate science via this new platform do not require FireSat products to proceed through the initial stages. This creates a powerful parallel-processing approach to integrated science as the constellation grows. These include developing lower-threshold emission factors for carbon and air quality metrics, carbon vulnerability to fire maps, lab or field-based FRE testing to inform anticipated high-temporal resolution data, and quantifying relationships between FRP/FRE and ecosystem response metrics in anticipation of FireSat's full 2030 capacity.

Ultimately, advancing from data to science to action requires not only improved, validated observations that are trusted by the wider scientific community, but also integration into operational decision-support systems. When supported by robust uncertainty characterization, FireSat data products can inform fire management strategies, improve smoke forecasting and public health exposures, and strengthen emissions inventories used in national reporting and international assessments such as the IPCC.

Conclusion

FireSat is a fire-focused remote sensing constellation being built for high spatial and temporal resolutions, targeting ~80 m resolution (with ~5 × 5 m minimum fire hotspots detection) and ~30-min return intervals depending on latitude by 2030. New insights from these higher resolutions should support substantial scientific advances, such as ignitions, small and short-duration fire quantification, progression maps, event-scale FRE estimation, and others. Those new insights, coupled with management, could drive a new way to manage the climate, human, and environmental effects of fire.

Building that capacity efficiently will require strategic research to be conducted alongside the constellation as it grows from 2026 to 2030. Early in the process, independent and transparent verification of single products and algorithms can be done, as these do not require high temporal resolution coverage. Similarly, integration into the existing fire remote sensing ecosystem can begin, an important consideration to grow the fire record. As the constellation develops, and higher frequency imagery becomes available, temporally integrated products at fine-grained spatial resolution—not commonly available today—will need to be tested. Throughout, there is a need for independent, transparent verification of the FireSat product algorithms as a baseline for understanding the data and properly characterizing it (e.g., uncertainty descriptions) within research frameworks.

Recognizing the value of strategic planning, the priorities and timelines identified here, from transparent validation to field testing to ancillary dataset development, are intended to accelerate and streamline the development of data for positive impact.

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Authors' contributions
BB coordinated the workshops. BB led the manuscript generation, which was highly collaborative. EA, KB, NRB, BP, NJD, AD, TD, MJF, CG, JVH, WDH, RH, CH, HH, MLK, AGK, MCM, HM, TM, DO, SP, WJR, BMR, EAGS, KS, WT, SV, PH, DR attended the workshop and contributed to the draft. JKB, KT, DBS, LM-M, GR, RK, YJ, IG, AK, CS, BP, TL, LZ attended the workshop. JS, DS contributed to the draft.

Data availability
No datasets were generated or analysed during the current study.

Declarations

Competing interests
The authors declare no competing interests.

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