TRILLIUM AUSTRALIA

Bushfire Situational Awareness & Systems

A USER-LED CONCURRENT DESIGN STUDY OF BUSHFIRE MANAGEMENT SYSTEMS IN AUSTRALIA

NOVEMBER 2021

Contents

Many of the images from used in this report come from the work of ACT RFS photographer Gary Hooker.

We are deeply grateful for permission to use them.

The images form part of a new book illustrating the catastrophic fires in Australia during 2019 and 2020.

Ablaze.The Long, Hot Summer 2019-20
actvolunteerbrigadesassociation.com/shop

Introduction

The bushfires experienced during the 2019/2020 Australian summer were bigger and more intense than any in fires in living memory. Blazes like the Gospers Mountain Fire burned for months, destroying homes and livelihoods, reducing pristine wilderness to ash and submerging vast areas under thick smoke clouds. The task of fighting these 'megafires' fell to the rural fire and emergency services - most of whom are volunteers from local communities. These courageous men and women battled exhaustion, choking air and dangerous conditions to control the fires, saving people, property and environment. We are deeply grateful for their efforts and want to make their work easier in the future by building modern tools for situational awareness and decision support.

We strongly believe that the first step in developing any system is to listen to the end-users. This report stems from a user-led concurrent design workshop on bushfire systems organised by Trillium Technologies in February 2021. The workshop brought together active firefighters with data and technology experts to define current best practices, and to identify strategic opportunities for applying new technology with maximum impact.

In this report, we present a system-level overview of bushfire management in Australia, with a particular focus on fireground operations. We identify challenges and significant pain points experienced by active firefighters, and show how technology might solve issues in the near future.

We are releasing this work as an open resource in the hope it proves useful to a broad range of stakeholders - organisations seeking to understand fire management processes and the needs of ground crew, companies developing technical solutions, government departments who want to understand possible applications of technology, firefighters at different levels, and the general public who want a broad overview of the firefighting effort.

A REPORT FOR THE COMMUNITY

This document remains a work in progress. We are keenly aware that procedures and capabilities differ significantly between states, and that these differences may not yet be captured here.

Please get involved to make this report more useful - send a correction, clarify a point or make an edit. We would be delighted to hear from you!

Workshop participants at the Australian National Concurrent Design Facility. This was the first use of the UNSW facility for a purpose other than designing satellite missions. Left to right: Garry Hooker (ACT RFS), Jan-Christian Meyer (UNSW), Rob Gore (ACT RFS), Cormac Purcell (Trillium Technologies) and Sheida Hadavi (ARDC). Other attendees participated via videoconference links. Image Credit: Rob Gore.

DISCLAIMER:
The contents of this report should not be construed as an endorsement of any particular product or service. The authors have reached out to public and private organisations to capture the views of a broad range of bushfire stakeholders. We welcome feedback and further engagement – please contact team@trillium.tech

Context of this Report

WHO IS THIS REPORT FOR?

We hope this report is generally useful for a wide range of groups and organisations:

- **Technology developers** seeking to understand current firefighting practices in Australia and New Zealand.
- **Emergency management** personnel from other jurisdictions seeking a 'systems level' overview of how fires are fought and managed in Australia.
- **Firefighters** who would like to understand how increasingly connected sensors and remote-sensing data could benefit firefighting operations.
- **Organisations seeking insight** into the major 'pain points' experienced by firefighters occupying different roles on the rural fireground.
- **Academics** undertaking technology or fire related research, who want to understand how their results might have practical impact.
- **The general public** who are interested in the positive use of artificial intelligence in a 'cyber-infrastructure' for disaster response.
- The **broad emergency response ecosystem**: insurance and risk experts, land management agencies, infrastructure, logistics and utility companies, heritage custodians, local government departments, and data management agencies.

WHAT IS THE PURPOSE OF THIS REPORT?

This report seeks to help shape the future development of bushfire management systems by capturing a common perspective of current practices and identifying opportunities to enhance capabilities by employing new and emergent technologies.

- Record the current systems and operating procedures employed by the personnel and agencies that play an essential role in combating bushfires.
- Identify the needs and challenges of:
  - Firefighters at tactical (crew) and strategic (management) levels;
  - Data and technology specialists who service firefighters;
  - Broader emergency management organisations surrounding the firefighting cohort.
- Identify and describe potential technology, systems, or components that address these needs.

This report has been prepared using a 'fireground up' approach by first listening to the experiences of active firefighters, before considering and discussing technological possibilities. This iterative approach has the advantage of validating ideas against field-users, while building community consensus on potential future strategic directions. The report aim to complement recent reports and initiatives in Australia:

Reports:
- Bushfire Earth Observation Taskforce Report
- Royal Commission into Natural Disaster Arrangements
- The NSW Bushfire Inquiry
- The CSIRO Report on Climate and Disaster Resilience

Initiatives:
- The ARDC Bushfire Data Challenges
- The Minderoo Foundation Fire Shield Mission
- Resilience NSW executive agency
- Natural Hazards Research Australia
- Bushfire & Natural Hazards CRC

Authors and Reviewers

This work would not have been possible without the contributions of our authors and reviewers from the organisations below. Special thanks go to the Rural Fire Service in the Australian Capital Territory (ACT RFS) and the AFAC Predictive Services group, who went beyond the call of duty to provide insight into the processes and technology used to fight fires in Australia.

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About Trillium Technologies

Trillium Technologies is a research and development company with a focus on intelligent systems and collaborative communities for planetary stewardship, disaster response and space exploration.

We are an international team of designers, scientists, developers and AI specialists motivated by ‘impact for human good’ through the application of technology.

Our work is driven by the scientific method and we strongly believe in open development, transparent processes and the ability to explain outcomes.

We don’t offer unscruitable ‘black boxes’ – instead we work with our partners to develop systems that explain the ‘how’ and ‘why’ of a result. We are keen on ‘explainable artificial intelligence’ as a building block of trusted tools that can be validated and audited for decision making.

Our ‘sprint’ programs accelerate academic and practical research, with the end-user in mind. Work is guided by NASA’s technology readiness level (TRL) system and we conduct regular reviews with expert users during the development cycle.

All of our programs are built on a large and diverse community of experts – we specialise in curating and managing highly effective interdisciplinary teams. We believe in open, reproducible science and most outcomes are released under open licences. Academics are free to build on the results, which have been proven to be state-of-the-art.

We sincerely believe in the moto ‘better together’ – that collaboration and cooperation builds healthy knowledge ecosystems, creating opportunities for all.

Come and join us on this journey!

The mission of Trillium is to accelerate the adoption of intelligent technologies in planetary stewardship, space exploration and human health.

LOW TRL | HIGH TRL

Idea or principle | Proof of Concept | Component Validation | Prototype in field | Final system

0 1 2 3 4 5 6 7 8 9

PROGRAMS

DATA QUEST | FDL | SPACE ML | XRL

PARTNERSHIPS

RESEARCH AND DEVELOPMENT | OPEN SCIENCE | TECHNOLOGY TRANSLATION

ACTIVITIES

Challenge Identification Data/Algorithm Discovery	Systemic Problems Interdisciplinary Research	Community Building Reproducible & Open Science	Concurrent Design Explainable AI

PART 1

Current Practise

An overview of current firefighting practise – from the fireground to the Incident Management Team.

Photo Credit: *Gary Hooker, ACT RFS.*


MOLONGLO

Overview of Rural Firefighting

Fighting fires in rural Australia is uniquely challenging for a number of reasons:

- Fires are often ignited in **remote locations**, most commonly because of lightning strikes.
- **Wild terrain** can make fireground access difficult.
- **Water** is often a scarce or contested resource, especially during times of drought.
- **Eucalypt forests** are highly flammable and shed combustible bark that is easily ignited.
- **Airborne firebrands** are a common feature of Australian bushfires and can ignite new fires up to 30 km away.

Each Australian state maintains fire and emergency services whose remit is to fight fires in rural areas. Most fire services rely on a large contingent of volunteers in addition to career firefighters, especially during the annual fire season in the southern hemisphere summer. As our climate warms, fire seasons are predicted to span more time each year and catastrophic fire seasons become more common.

Tasmania Fire Service

ORGANISATION	MEMBERSHIP
Tasmania Fire Service fire.tas.gov.au	Mix of volunteer and career firefighters.
ACT Rural Fire Service esa.act.gov.au/rural-fire-service	Volunteer firefighting service covering rural areas.
NSW Rural Fire Service rfs.nsw.gov.au	Largest volunteer firefighting organisation in the world, with professional senior roles.
Victorian Country Fire Authority (VIC) cfa.vic.gov.au	Volunteer fire service covering rural areas in Victoria alongside the FFMV.
Forest Fire Management Victoria ffm.vic.gov.au	The FFMV manages fire risk and hazard reduction burns on Victorian public land.
NT Fire and Rescue Service fes.nt.gov.au/fire-and-rescue-service	Mix of career of volunteer firefighters, with some fire stations staffed entirely by volunteers.
Queensland Rural Fire Service ruralfire.qld.gov.au	Volunteer firefighting arm of the Queensland Fire and Emergency Services.
Queensland Fire and Rescue Services qfes.qld.gov.au	Professional firefighting arm of the Queensland Fire and Emergency Services.
South Australia Country Fire Service cfs.sa.gov.au	Volunteer firefighting service covering rural and occasionally urban areas.
Western Australian Department of Fire and Emergency Services (DFES) dfes.wa.gov.au	The WA Department of Fire and Emergency Services coordinates emergency services for a range of natural disasters and incidents.
AFAC afac.com.au	Peak body of fire-related organisations in Australia and New Zealand.

The Australasian Fire and Emergencies Authorities Council (AFAC) is the peak body that supports collaboration between fire, emergency and land management agencies in Australia and New Zealand. It promotes knowledge transfer and development of common best-practice techniques, and operational standards.

There are also many other organisations, like the State Emergency Services (SES), who support operational firefighting. We map these out later in this report [TODO: REF PAGE].

LAND MANAGEMENT AGENCIES AND GOVERNMENT DEPARTMENTS

In every state, land management agencies deploy firefighters and firefighting equipment as part of their normal duties. In most states, land managers, rather than rural fire services, are responsible for managing the majority of fires on the land under their control. The exception is the Australian Capital Territory, where the RFS is responsible for fire suppression, irrespective of land tenure.

ORGANISATION	MEMBERSHIP
NSW Parks and Wildlife Services nationalparks.nsw.gov.au	Part of the NSW Department of Planning, Industry and Environment. Maintains fire history data at data.nsw.gov.au
Resilience NSW nsw.gov.au/resilience-nsw	Resilience NSW leads disaster and emergency efforts from prevention to recovery. Part of the Department of Premier and Cabinet.
Bushfires NT nt.gov.au/emergency/emergencies/about-emergency-services/bush	Division of the NT Department of Environment and Natural Resources (DNER). Chartered to reduce the risk of wildfires in rural and remote communities. Fire data can be found at firenorth.org.au/nafi3
NT Department of Environment, Parks and Water Security (DEPWS) depws.nt.gov.au	DEPWS includes the key functions that foster and protect the environment and natural resources in the Northern Territory, including hosting environmental and geospatial data layers at nrmaps.nt.gov.au
SA Department for Environment and Water (DEW) environment.sa.gov.au/Home	The SA Department for Environment and Water helps South Australians manage and conserve environmental and cultural resources, including performing prescribed burns. Geospatial maps can be accessed at data.sa.gov.au, naturemaps.sa.gov.au and naturemaps.sa.gov.au
Tas Department of Primary Industries, Parks, Water and Environment (DPIPWE) dpipwe.tas.gov.au	DPIPWE is Tasmania's lead natural resources agency. Open data, including fire history, can be accessed at thelist.tas.gov.au/app/content/data/index.
Vic Department of Environment, Land, Water and Planning (DELWP) delwp.vic.gov.au	The Victorian Department of Environment, Land, Water and Planning contains Forest Fire Management Victoria, which includes staff from Parks Victoria, VicForests and Melbourne Water. DEWLP manages bushfire risk and prescribed burns. Fire data is available from data.vic.gov.au
Department of Biodiversity, Conservation and Attractions dbca.wa.gov.au	Promote biodiversity and conservation through sustainable management of Western Australia's species, ecosystems, lands and attractions. Data available at data.wa.gov.au

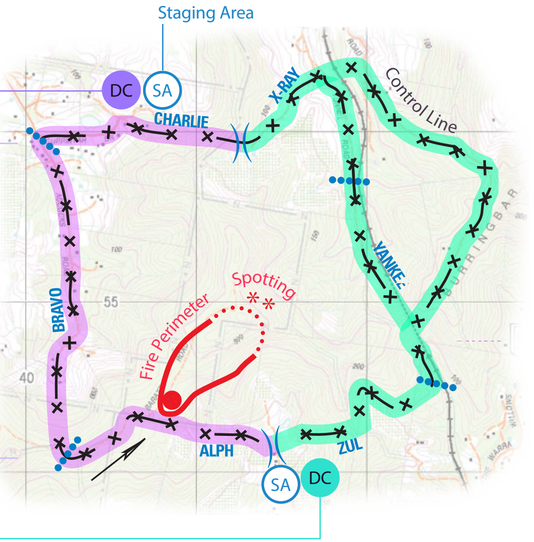
Organisation of the Fireground

This report covers firefighting practices and systems at scales that span individual firefighters to the incident management team (IMT) responsible for managing large fires. Command and control structures at higher levels (e.g., regional and state levels) replicate and expand on the fireground IMT using the AIIMS paradigm (see page REF). The figure below illustrates the command structure on the fireground, showing the staging area where the IMT is usually located and how the perimeter control lines are broken into divisions and sectors.

Small fires are managed locally by the first crews on the scene (level 1 incident – L1). Larger fires (L2+) require a more coordinated response: the proposed control lines for the fire are broken into divisions and sectors and an incident management team is created at the staging area. The divisional commander (DivCom) is a key liaison between the IMT and fire crews, while the sector commanders coordinate crew shift changes every 12 hours.

FIREGROUND OPERATIONS

- OPERATIONS OFFICER (IMT)
  - DIVISION COMMANDER 1
    - SECTOR COMMANDER A
      - STRIKE TEAM (5x trucks/crews)
      - APPLIANCE
    - SECTOR COMMANDER B
      - TASK FORCE (Truck/Crews)
  - DIVISION COMMANDER 2
    - SECTOR COMMANDER Z
      - ...



INCIDENT MANAGEMENT TEAM

- INCIDENT CONTROLLER
  - PLANNING OFFICER
    - INTELLIGENCE / MAPPING
  - OPERATIONS OFFICER
    - AIR OPERATIONS
  - LOGISTICS OFFICER
    - STAGING AREAS
  - PUBLIC INFORMATION OFFICER

Credit: *Adapted from a figure created by the NSW Rural Fire Service.*

USER STORIES

Ground Crew

Fire Detected

INITIAL DISPATCH AND TRAVEL

On-call firefighters notified of:

- Incident location.
- Incident type (e.g., bushfire, flood).

Pager, BART App.
15 minutes to gather

Situation update en-route:

- Fire extent
- Weather currently
- Weather forecast
- Resources available.

Route-planning to access a fire can be a big issue.
Radio Voice, MDT, Mobile apps.

MDT (when available):

- Navigation to fireground.
- Road maps.
- Registered crew.
- Truck status (proceeding, responding, ...).

Crew 'attached' to job using firefighter ID numbers (manual entry).

ARRIVAL AND FIRST ASSESSMENT

Assess situation by driving and observing.

ITASC:

- Incident
- Threat
- Access
- Safety
- Comms

Personal observations, Notebook

Identify or create access points (gate, fence to cut):

- Map fireground
- Point of origin
- Boundary
- Landscape features
- Key assets
- Dangers

First crew on the ground fends for themselves and establishes a local command structure using the AIIMS principles:

- Work out plan-of-attack
- Which trucks where?
- Communications channels on radios.

In this section we provide a general overview of the fire fighting process from the perspective of crew on the fireground. Australian fire crews commonly deploy in trucks and are typically comprised of a Crew Leader and 3-4 Firefighters. They are first on scene an provide support as part of a rotational shift pattern which endures until the fire has been extinguished..

Fire Extinguished

COMPLEX FIRE INCIDENT (≥ 1 DAY) FORMAL IMT ESTABLISHED

Fires that take more than 12 hours (1 shift) to deal with will require a formal IMT to be established (L2):

- Command structure on fireground changes.
- Initial IC becomes a division commander (DivCom).
- Staging ground established.
- IMT usually based out of an Incident Control Centre,
  chosen for good comms.

Information handover:

- Assessment from 1st crew to formal IMT.
- Incident Action Plan (IAP) document created and distributed.
- Crews tasked and receive a printed IAP (or link/QR-code). One per vehicle or person.
- IAP includes maps with features of interest, fire extent and in limited instances fire spread predictions.

Information flowing down:

- Crews are briefed by DivCom at staging area.
- Crews tasked and deployed from staging area, and return to staging area when done.

Information flowing up:

- Hourly situation report from crew leader to DivCom.
- Crews report safety issues to DivCom (can include photos and GPS coords).
- Crews annotate IAP maps with changes.
- Annotated IAP facilitates handover to new shift and updates to IMT (12 hours),

USER STORIES

Ground Crew Pain Points

MAPPING

PRIOR ACCESS

Gaining access to maps ahead of time can be difficult – need to pre-load the files.

ANNOTATION LAG

There is often no mechanism for the annotations made on IAP maps by fire fighters to transfer to the IAP map for the next shift. Where this is possible these annotations are often passed to the incoming shift of fire fighters which results in fire fighters and the IMT having a different versions of the truth. This shift change typically takes 12 hours which means the map the IMT has access to is often 12 hours behind reality. Sharing KML or pdfs is manual and time consuming and slows the tempo of operations.

INFORMATION SHARING

There is currently no simple way to share mapping and other information; i.e. dangerous trees, fire perimeter. Fire fighters can share KML /annotated PDFs etc. using Avenza however this only works on apple devices and depends on the availability of 4G network.

SITUATIONAL AWARENESS

FEATURE IDENTIFICATION

Fire fighters do not know anything about the features in the fire location (e.g. hazards, assets, completed prevention activities that do not appear on standard maps) until they see them with their own eyes – they may not be able to see them due to smoke/darkness. The existence of such features, which are spatial, must be shared by radio – it is extremely difficult to describe spatial dynamic features by radio.

STRAW TUBE PERSPECTIVE

Each fire fighter can only see a small part of the fire – the person initially in charge of the fire must mentally piece together a number of unique verbal descriptions to create a map of the fire in their head. Developing this mental image is extremely challenging and cannot be shared with others.

INFORMATION FLOW

VOICE COMMUNICATION

Radio voice communication is the main technology in use (GRN/TRN). Information is passed by radio from one hierarchical level to the next and from that level to the next and so on. This results in a 'Chinese Whispers' scenario.

HANDOVER BETWEEN SHIFTS

Poor information flow from previous crew to next crew. Debrief currently happens at the staging area, but better done on the fire ground.

REASONING AND DOCUMENTATION OF DECISIONS

Need to record damage to property (e.g cut fence) and amount of water extracted and reasons for decision in consistent way. All decisions need to be documented (e.g. decided asset was undefendable, locals warned of danger but decided not to evacuate).

Photo Credit: Cory Hooker, ACT RFS.

Firefighting Timeline & Tactics

INITIAL RESPONSE TO AN INCIDENT

When first dispatched to a fire, the first arriving crew leader will assume command of the incident and provide a briefing to the relevant Fire Command or Communications Centre. This will include;

- Assessment of the size and ferocity of the fire.
- List of threatened assets nearby.
- The resources at hand, actions to be taken by the crew and the firefighting strategy to be adopted.
- Whether further support will likely be needed (e.g., a request for a divisional commander and further strike teams).
- The basic command and communications structure on-site.
- Assessment of relevant access routes and water points.

The first responding resources will then proceed with the elected firefighting strategy.

Photo Credit: *Gary Hooker, ACT RFS.*

Photo Credit: *Gary Hooker, ACT RFS.*

MAIN FIREFIGHTING RESPONSE

When resources are deployed to an ongoing incident, most often firefighters are organised into shifts. In NSW, generally the day is divided into three twelve-hour shifts. These are the morning shift (0900-2100), swing shift (1200-0000), and night shift (2100-0900).

Start of a Shift - Briefings

Crews starting a firefighting shift will often receive a briefing, generally held at a designated staging area. The briefing will be conducted in a SMEACS format and accompanied by the incident action plan. Personell will be briefed in a stepwise manner down the chain of command, with the IMT briefing divisional commanders, who then brief sector commanders, followed by sector/crew leaders, and then crew leaders brief crew members.

However, this briefing process is not always available – for example, early on when the command structure has not yet been fully established, or if the situation is changing rapidly. In such instances, briefings may not be conducted at all, or done in a highly condensed manner.

During the Shift

A shift can entail a variety of firefighting activities. These can be broadly categorised into the firefighting strategy to be employed – offensive or defensive.

Within an offensive firefighting strategy, there are three predominant tactics which may be used depending on the fire's intensity: direct attack, parallel attack, and indirect attack.

Direct attack: Firefighters directly attack the fire's edge with either heavy plant or water/wetting agents. Used for low intensity fires.

Parallel Attack: Firefighters create a control line (a fire-break) using hand tools or heavy plant along the sides the fire, and clear the fuels between the control line and the fire by igniting them, or simply patrolling the lines to put out spot-over fires. Eventually the two flanks join to 'pinch off' the fire. This strategy is used for low-moderate intensity fires. Variations of this strategy can seek to use pre-identified control lines and attempt to 'hold' them by prevent spot-overs from crossing those points.

Indirect Attack: Firefighters use control lines away from the fire's edge (e.g., existing roads) to ignite fuels and `back-burn' the intervening fuels. This is used for high-intensity fires, however care must be taken to maintain control over the back-burn and not 'lose it'.

When offensive strategies are infeasible due to resource limitations, or the intensity, location, or size of the fire, then defensive strategies are implemented. These include property protection, backstop defence, and patrolling a fire.

Aside: Out-Of-Fire-Seasons Tasks

Firefighters conduct a variety of out-of-season fire management work. Most pertinently, this includes hazard reduction burns, ecological burns, and indigenous burns. As with most planned firefighting operations, these are conducted in accordance with a prepared IAP. Taskings generally involve a number of resources, generally ranging between 5-20 trucks, creating a perimeter when necessary and then igniting fuels in accordance with a burn plan.

Photo Credit: *Gary Hooker, ACT RFS.*


Photo Credit: Gary Hooker, ACT RFS

Property Protection: Firefighters protect individual assets by employing direct attack methods, extinguishing spot-fires that are generated by embers, and applying backburning tactics around the asset, whilst letting the fire burn past.

Backstop Defence: Firefighters prepare endangered assets as best as possible before the fire front arrives by removing inflammable materials around the asset, applying foam, or other risk-reducing activities. Consequently, firefighters will retreat to a safety-zone until the firefront passes. As soon as the front passes, firefighters return to assets and extinguish any fires that have started. This tactic is used for exceptionally high intensity fires.

Patrol: Firefighters observe and monitor a fire. Used when a fire is inaccessible, or does not need to be suppressed.

After a Fire has Passed: Mop Up

After a fire has passed, firefighters 'mop-up' the burnt area. This involves extinguishing any smouldering material, extinguishing hot spots, and ensuring that there is no possibility of further embers being generated that could be blown over control lines to ignite new fires.

After a Shift

Firefighters will seldom debrief with oncoming crews. If a debrief does occur, firefighters will do so with their sector leader, passing information up the command chain. They are then released from the fireground to return back to their home station or camp.

FIREFIGHTING ACTIVITIES

Firefighting Operations can generally be classed into 'wet' and 'dry' firefighting.

Wet Firefighting: Firefighters employ various hoses and pumps, or coordinate with aerial assets, to deliver wetting agents onto the fire, or to establish control lines.

Coordinating with aerial assets will often involve directing a helicopter to deliver water onto identified targets – for example a large burning tree or a fire flare-up. Fixed wing aircraft may also be directed to deploy their water on specific 'hot-spots' or to lay down control lines.

Dry Firefighting: Firefighters use hand tools or heavy plant to remove fuel in a specific area, creating control lines as required by the IAP. In inaccessible terrain this is often done by 'hand-crews' using various hand-tools.

Firefighters may also conduct back-burning to remove fuel before the firefront approaches. Generally, the back-burn is initiated from a control-line (pre-existing or newly created) using drip-torches where a crew will be tasked to ignite a length of one side of a control line. However, incendiaries may also be deployed from helicopters if appropriate.

During mop-up or blacking out firefighters employ a variety of hand-tools and hoses to systemically extinguish and cool any material that is still hot. Following a fire-front's passing, many large logs are not fully consumed and still remain alight. Similarly, seemingly innocuous patches of ground may actually have a temperature in excess of 500 C. If these hot-spots and fires are not extinguished they can oftentimes remain alight for weeks, or even months. Subsequently, any material that comes in contact with them may ignite and be carried over control lines, igniting new fires. Therefore, mopping up and blacking out is essential.

Relevant hot-spots and areas that require mopping up may be marked on the IAP. This activity represents the largest portion of

Photo Credit: *Gary Hooker, ACT RFS.*

PERSPECTIVE

A Shift on a Truck

Tony Xu, ACT Rural Fire Service

BACKGROUND

Following an unseasonably dry winter, a fire has started in a heavily forested area of Northern NSW, in October, following a bout of dry lightning. Dubbed the ‘Thimble Point Fire’, it has burnt for eight days fanned by strong winds, low humidity and temperatures in the high 30’s. The fire has burnt 70,000 hectares and is 8 km away from a town - Ashburg - which is currently under a watch-and-act warning.

The NSW RFS commissioner has declared the incident as a ‘Section 44 fire’ and has requested interstate resources from the ACT. In response, the ACT RFS has deployed a strike team composing of 5 heavy tankers and their crews, a command vehicle with an officer (acting as sector leader) and a scribe, an ambulance, a liaison officer, and mechanical support. The strike team spend a day travelling to the camp, located in Ashburg, where they will be deployed for three days. They will need to travel for a day to return to the

Photo Credit: *Gary Hooker, ACT RFS.*

FIREFIGHTING OPERATIONS: **DAY 1**

At 0700, the IMT begins briefing the Divisional Commander on the day-shift's taskings. The ACT Strike Team arrive at the staging area at 0730 to be briefed on the activities they will be conducting during the day. Owing to printing delays and miscommunications, the IAP arrives late, at 0900, and the briefing concludes at 0945.

The ACT Strike Team has been assigned Sector Bravo, part of Southern Division. They are the only units in this sector. Everyone is cognizant of the oncoming weather system, expected to pass through on the third day and bringing dry, hot and gusty northerly winds. At this time the Fire Danger Rating (FDR) is predicted to be Severe to Extreme and the Fire Danger Index (FDI) will be 70-80. However, the conditions today are comparatively mild with an FDI of only 25 and a FDR of High.

In an effort to strengthen containment lines before the third day, the strike team is tasked with finishing a back-burn from the prior shift. Subsequently, the Strike Team is to familiarise themselves with threatened assets and – as best possible – protect properties in preparation for the oncoming weather.

The ACT Strike Team arrives at 1030 and commences operations. After a successful test burn, the Sector Commander seeks permission from the Divisional Commander to commence back-burning. The Divisional Commander wishes to have a look at the sector before granting permission and so drives from Sector Delta. It is 1130 before ACT Strike Team begins backburning. Crews

Photo Credit: *Gary Hooker, ACT RFS.*

use drip-torches to ignite 150m stretches at a time, with one appliance patrolling behind them to ensure they mop up each patch, ten metres from the fire-trail they are working off. By 1600 they have completed the last 1.5km of the backburn.

The sector commander updates the divisional commander with the progress by radio. Crews then are assigned threatened assets to familiarise themselves with. Within the sector there are 15 properties to protect, with roughly 25 assets altogether. Crews visit each property, taking note of the defensibility of the assets, the property owner's intentions to stay or leave, property priorities, safety hazards on the property (asbestos, fuel storage etc.), access to water tanks and whether they have the appropriate fittings, and other useful information. Crew members write these things down in each of their notebooks and tie pink flagging tape on the letterboxes of those properties deemed to be indefensible. Unbeknownst to them, the previous strike team had already conducted this work, but have tied orange flagging tape for those properties where the occupiers have decided to leave early.

At 1900, the shift concludes and ACT strike team heads back to home base, leaving the

Photo Credit: *Gary Hooker, ACT RFS.*

swing shift and the oncoming night shift to further prepare.

FIREFIGHTING OPERATIONS: **DAY 2**

Again at 0700, the Divisional Commander begins a briefing with the IMT on the tasks for the day shift. The strike team arrive at the staging area at 0730 and meet with the Divisional Commander. The briefing goes smoothly and concludes at 0800.

The hot, dry weather has begun to pick up ahead of the anticipated weather system. The day is forecast to have an FDI of 30–40, FDR of Very High, wth NE winds blowing at a sustained 25kph. Peak fire weather is expected from 1430 onwards. The next day's forecast remains at a FDI of 70–80 and FDR of Severe to Extreme.

In view of the weather, the strike team have again been attached to Sector Bravo, Southern Division, and have been tasked with extending the back-burn from the previous day by another 500m, and then turning to defend containment lines as the weather picks up. This is also the containment line that provides access to neighbouring Sector Charlie.

The strike team arrives at Sector Bravo at 0830, however, the weather is not currently conducive to conducting the burn, so they wait. The Sector Commander discovers that the mountainside the back-burn is to be conducted across has no GRN signal. Moreover, owing to a bend in the trail, line-of-sight radio communications are not possible without a relay too. The Sector Commander makes note of the communications issues and passes the information on to the Divisional Commander.

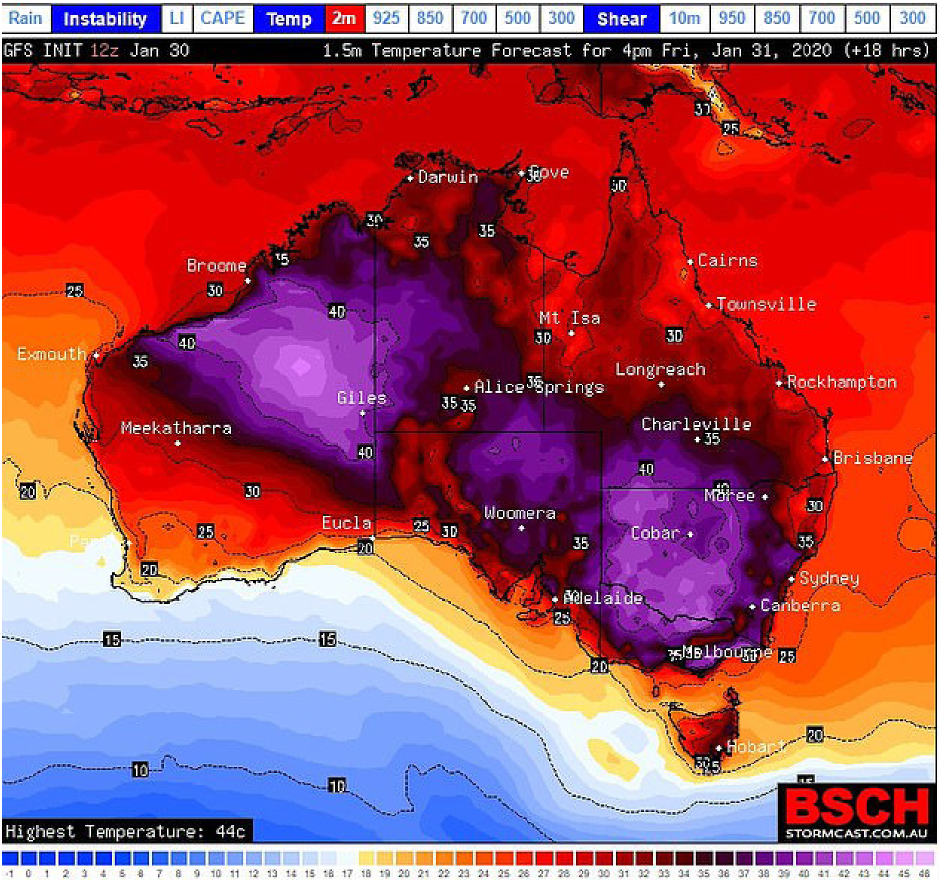
Whilst waiting for appropriate weather to continue the back-burn, the ACT strike team blacks out the previous days backburning. At 0930, a successful test burn is conducted, and the team begins operations burning. The Sector Commander stays put at the trail-bend, acting as a radio relay for the trucks between the two sides. Otherwise, operations progress smoothly, with crews mopping up the burn by 1330. Just in time too – the weather is beginning to deteriorate and the fire activity on the mountain has markedly increased.

At 1430 a crew member notices a small column of smoke about 150m into the unburnt side of the fire trail. They pass the information onto the crew leader who relays it on to the Sector leader. The crew leader is only able to give an approximate location of the smoke. This is communicated by providing a six-figure grid reference, which outlines a 100m x 100m square location. Consequently, the location of the smoker is difficult to convey accurately.

Photo Credit: *Gary Hooker, ACT RFS.*

Simultaneously, a 000 call reporting a fire approaching at 1085 Jones Street, within Sector Bravo, is passed onto the Sector Leader. The Sector leader tasks two trucks to attend the fire call, and goes to inspect the smoker themselves. However, in doing so, the relay communications link between the trucks are now severed. The two trucks navigate using Google Maps as best they can, however without further instructions on how to access the property, they promptly become lost. At this time, they realise that they can no longer contact the Strike Team Leader, and are out of range of the GRN. After 20 minutes of searching, the trucks eventually find the caller who reported the fire. Thankfully, it is a false alarm, the caller simply being concerned about the growing smoke column. However, they are not able to inform the Sector Leader or the divisional commander, and thus head back to the Sector leader to relay that information.

Upon returning to the Sector Leader, the situation has deteriorated with the spotover fire rapidly growing in size. Aviation assets are deployed to support operations, in conjunction with crews dragging hose all the way from the fire trail. Crews coordinate with the aviation assets by directing them with hand signals and via the radio channel listed in the IAP. Seeing that the resources are not enough, the Sector Leader requests additional assets from the Divisional Commander, and is allocated another three tanker trucks. These tankers are CFA trucks, and consequently do not have interoperable radio communications with the ACT personnel. The strike team gives the CFA tankers spare hand-held radios to allow for communication. The sector leader requires heavy plant to assist in the extinguishing of the fire, and coordinates their arrival. At this point, the Sector leader is communicating on 4 different radio channels: the tactical channel, the operations channel, the aviation channel, and the heavy plant



channel. Nevertheless, the spotfire is eventually contained, and soon the swing shift arrives to take over.

FIREFIGHTING OPERATIONS: **DAY 3**

On the final rostered day of the deployment, the ACT strike team is once again briefed at 0700. The fire weather forecast has remained at a predicted FDI of 70–80 and FDR of Severe to Extreme. The Haines Index is at is 12, indicating a very unstable atmosphere. It is on this basis that the IAP warns of possible pyrocumulonimbus formation. The fire behaviour has not eased throughout the night, with new spot fires breaching containment lines and growing quickly. Unfortunately there has not been time for a line-scan to be conducted on the fireline overnight. Accordingly, crews are provided with maps showing only rough estimates of where spot-fires are likely located. Finally, the increased fire weather and new spot-fires mean resources are very stretched. The strike team has been assigned to Sector Alpha and is responsible for defending twenty assets.

Given the fire danger and scarcity of assets, a property protection strategy is employed. Upon arriving on the fireground at 0800, the crews begin area familiarisation. It is unclear what the pink ribbons tied to the front letterboxes are, and crews once again need to identify who is staying, what structures are defendable, and where the local water sources are. The smoke column can be seen growing steadily, and now is a bronze-copper colour. Already, the weather is deteriorating, with winds sustained at 40km/h and a temperature of 34C.

At 1100 a radio warning sounds on the operations channel that a pyroculultonimbus has formed. Weather conditions on one side vary greatly from the other; different wind directions, lightning, and hailstones present. However, at the fire front, none of this is visible as the whole area is clouded in smoke and haze. The only situational awareness afforded is the already obsolete map, and information the sector leader passes on. The fire is moving quickly now, with no defined front, but rather a large area that is ablaze as spot fires are ignited ahead and coalesce. Moreover, because of the lack of situational awareness, no one knows clearly where the fire has progressed to, and owing to the weather, there is no aviation support for firefighting or line scans.

Photo Credit: *Gary Hooker, ACT RFS.*

The ACT strike team has classified the properties and positioned themselves at vulnerable exposure sites. A number of homeowners have decided to stay and defend too. However, there is no way to communicate more broadly which of the houses these are.

Upon receiving information of a 000 call, one fire truck, Ashburg 10, is dispatched to assist. Whilst driving there, crews drive along a road lined with fire damaged trees. Suddenly, a tree falls onto the road in front of the truck. Ashburg 10 is unable to stop in time and collides with the tree, injuring the crew leader and driver. The two crew in the back begin to administer first aid within the cabin and radio in a 'Red Emergency' call (the highest priority radio code). They give their grid reference, a brief summation of what has happened and the required support. Due to the lack of GRN connection, they are only able to use the local simplex radio, which thankfully reaches the Sector Leader.

Following this the Sector leader seeks further medical assistance, and paramedics in a four-wheel-drive ambulance are dispatched. Additional fire-trucks are sent scene to provide another driver so that the crew can be relocated to a safer environment. However, the closest are the CFA crews, who have incompatible radios. All messages between these two crews (until radios are exchanged) need to be relayed through the Divisional Commander – further filling the radio space. Despite these difficulties, the CFA crew arrives and helps evacuate Ashburg 10 and its crew. Paramedics begin treating the injured crew members at the nearest safe area.

Unknown to the treating professionals, the unconscious Crew Leader is on a wide range of medications already, potentially complicating what treatment should be applied. Only through good fortune do no further medical complications arise during their treatment and subsequent transport to the hospital.

Photo Credit: *Gary Hooker, ACT RFS.*

Photo Credit: Gary Hooker, ACT RFS.

Data Flow
Observations and Requests from the Fireground

Observations by people on the fireground and in the local community are incredibly valuable. They serve to:

- Validate assumptions made up the chain-of-command.
- Provide first-hand intelligence on the location of fire, local weather conditions, sources of water, difficulty of terrain and access routes, locals staying to defend property, location of vehicles (including private vehicles, for instance, bulldozers operating on farms to clear firebreaks).
- Provide information on changes as they happen (e.g., a fallen tree blocks a route, or makes it impassable in one direction).
- Report on current fire behaviour and predict spread (assessed by experienced crew), taking into account local wind patterns.
- Give timely warnings of threats to safety, such as fuel stores or dangerous trees.
- Identify threatened assets and whether they should be prioritized for protection (e.g., if they are of significant cultural value, or are essential to security, or to someone's livelihood).
- Provide ground-truth data to mapping, fire and smoke modelling teams so they can make more accurate predictions.

Information flowing from the fireground can also be operational in nature as systems are created to manage the firefighting effort:

- Rules to manage traffic flow, e.g., one-way systems on tracks.
- Locations of staging points and services like refueling depots, food stations, accommodation and equipment drops.
- Reports of 4G mobile network coverage and radio dead zones.
- Requests for assistance and resources.

Photo Credit: *Gary Hooker, ACT RFS.*

Possibility:

Devices capable of recording geo-tagged pictures and videos can provide valuable information on all of the above. Intelligent algorithms are capable of automatically extracting actionable information, such as fire extent, flame-height and fuel load, or landscape features can be detected and de-projected onto a map.

USER STORIES

The Incident Management Team

Monitoring Mode

Fire Detected

MONITORING MODE

Pre-fire situational awareness: duty officer monitoring local area or skeleton IMT active:

- Current weather in region.
- Weather forecast for 3 days
- Fuel condition: load and moisture maps.

These drive fire risk maps (fire danger index). Also monitor resources and adjacent fires.

- Active fires in adjacent regions.
- Available resources locally and in-use at active incidents, or seconded elsewhere.

Note: BoM are the only agency permitted to provide an official WARNING of fire weather.

FIRE DETECTED

Fire detected:

- Fire-tower(s) report smoke.
- Public 000 emergency phone call reporting smoke.
- Hotspots must be confirmed by aerial or space assets.

Initial assessment by duty officer:

- Local duty officer has unique information and ability to assess risk due to fire.
- Remit to use whatever resources necessary and available.
- First-pass fire spread model: 'gut feeling' assessment from experience or McArthur prediction.
- If enough information available, run modelling tools like Aurora .
- Assess access routes and initial deployment capabilities.
- Decide on how big an effort is needed to fight the fire.

Reports from fireground / crew:

- Crews report flame-height, size of fire, direction and confirm location.
- Crew suggest suppression strategy and relay what resources are needed.
- Everyone using radio voice comms.

Further actions:

- Officer requests detailed site weather forecast from BoM.
- May deploy an aircraft for monitoring.

THE COP

The Common Picture:

- Real-time situ awareness ma at the IMT.
- Positions of tr bulldozers, air (automated).
- Breadcrumb tr history (for so
- Sometimes de deployed pers skills.
- Multiple base topography, ve flammability i
- Weather infor

The incident management team (IMT) is responsible for planning the response to a fire that requires sustained action to fight (more than one day). During a fire season, a local IMT may be ‘spun up’ in monitoring mode, waiting for a report of fire.

Operating

uational
pping software

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rcraft

ails – position
me vehicles).
eper data on
onnel and

layers for map:
egetation type,
ndex,
mation.

SUSTAINED ACTION

Transition to IMT-controlled effort:

- Decisions move from fireground to the IMT (initial crew advise on actions).
- Formal Incident Action Plan created.
- Full AIIMS team convened, including intelligence / mapping role.

Longer-term planning:

- Detailed risk analysis.
- Understand overall probability of success better. ‘Can we fight this (part of) the fire successfully’?
- Strategic planning on timescale of a week, depending on weather forecast and available resources.
- Monitoring upwards & sideways – what is happening at the regional level and in adjacent firegrounds?

Adjacent services:

- Work with stakeholders from other organizations: police, medical, defence, utility providers, state emergency service, cultural organisations.
- Representatives in the room next door to IMT (called Emergency Management Team in Victoria and Emergency Control Centre in ACT).
- Provides an interface to requirements – understanding risks to important threatened assets (e.g., critical telecoms infrastructure).
- A briefing officer from some services can also be

SHIFT CHANGE

Information refresh cycle and hand-over:

- Situation reports hourly from fireground via the division commanders.
- The IMT is where all the information comes together – critical node.
- Hand-over between teams changing shift is critical. This is planned at the IMT level for the crews on the fireground.
- Sector-commanders coordinate handovers between shifts on the fireground.
- Fire crews change shift at a different time to IMT personnel to preserve continuity of information during the handover process (ensures overlap)

USER STORIES

The Incident Management Team Pain Points

SITUATIONAL AWARENESS

DISPERSED INFORMATION SOURCES

The use of multiple, different systems which often contain conflicting information or information from different times ensures that there is no single version of truth within the IMT. Every room will have a map on the wall with someone drawing critical information on it, resulting in a different map in every room.

MANUAL DEVELOPMENT OF THE FIRE GROUND PICTURE

Having to piece together descriptions from different parts of the fire (Sectors, Divisions) to get an overall picture of the fire is extremely difficult owing due to the difficulty of creating a visual picture based on verbal descriptions.

ANNOTATION LAG

Because of the delay in features annotated on maps by fire fighters getting onto maps in the IMT, the maps available in the IMT are not the same as those being used by fire fighters, there is a consistent lack of shared situational awareness.

INFORMATION FLOW

HANDOVER

Handover and communications of detailed information from the fireground.

RESOURCE MANAGEMENT

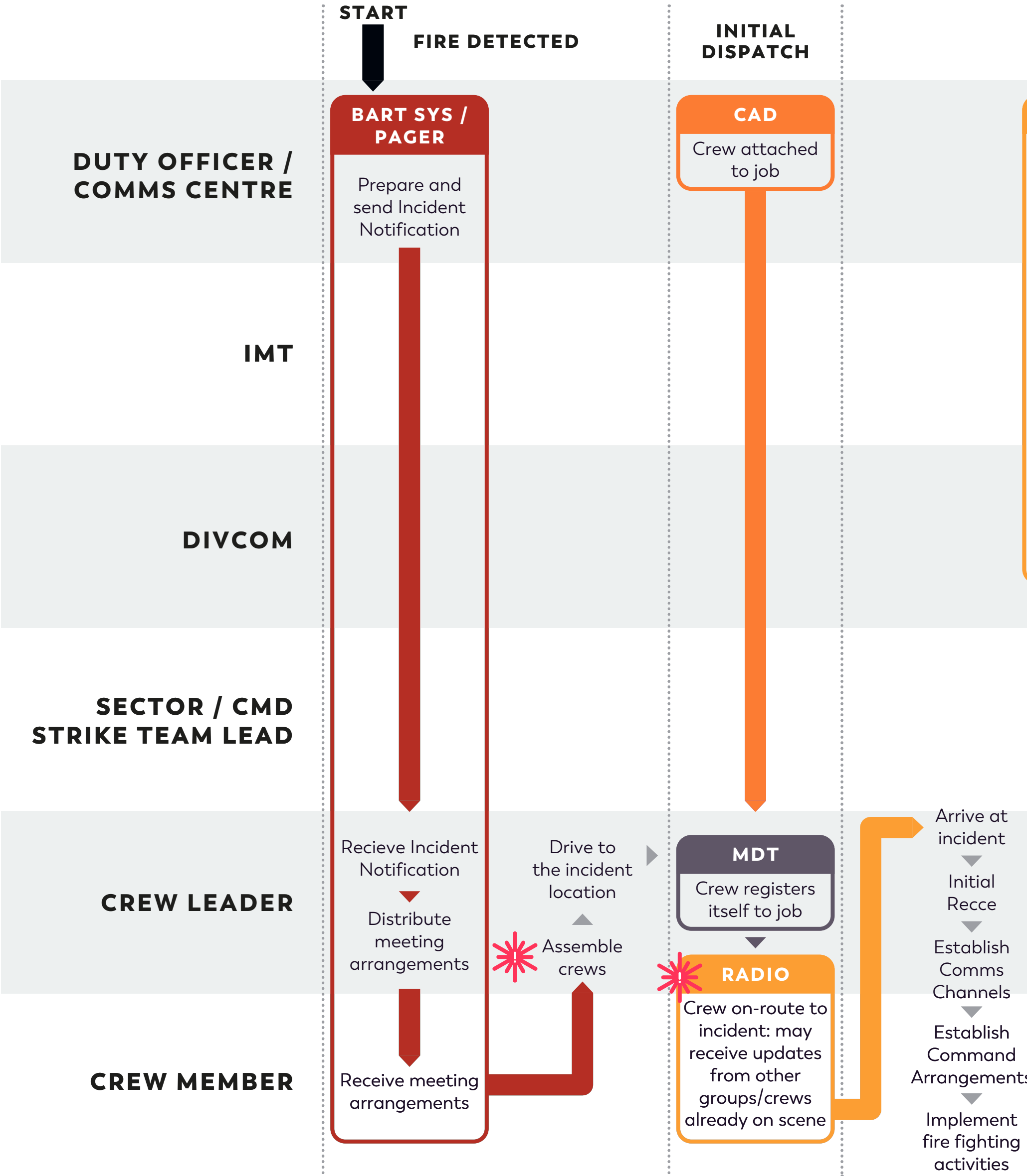
DECISION MAKING.

Making decisions about where to position resources and managing fire fighter availability, food, water deployment etc.

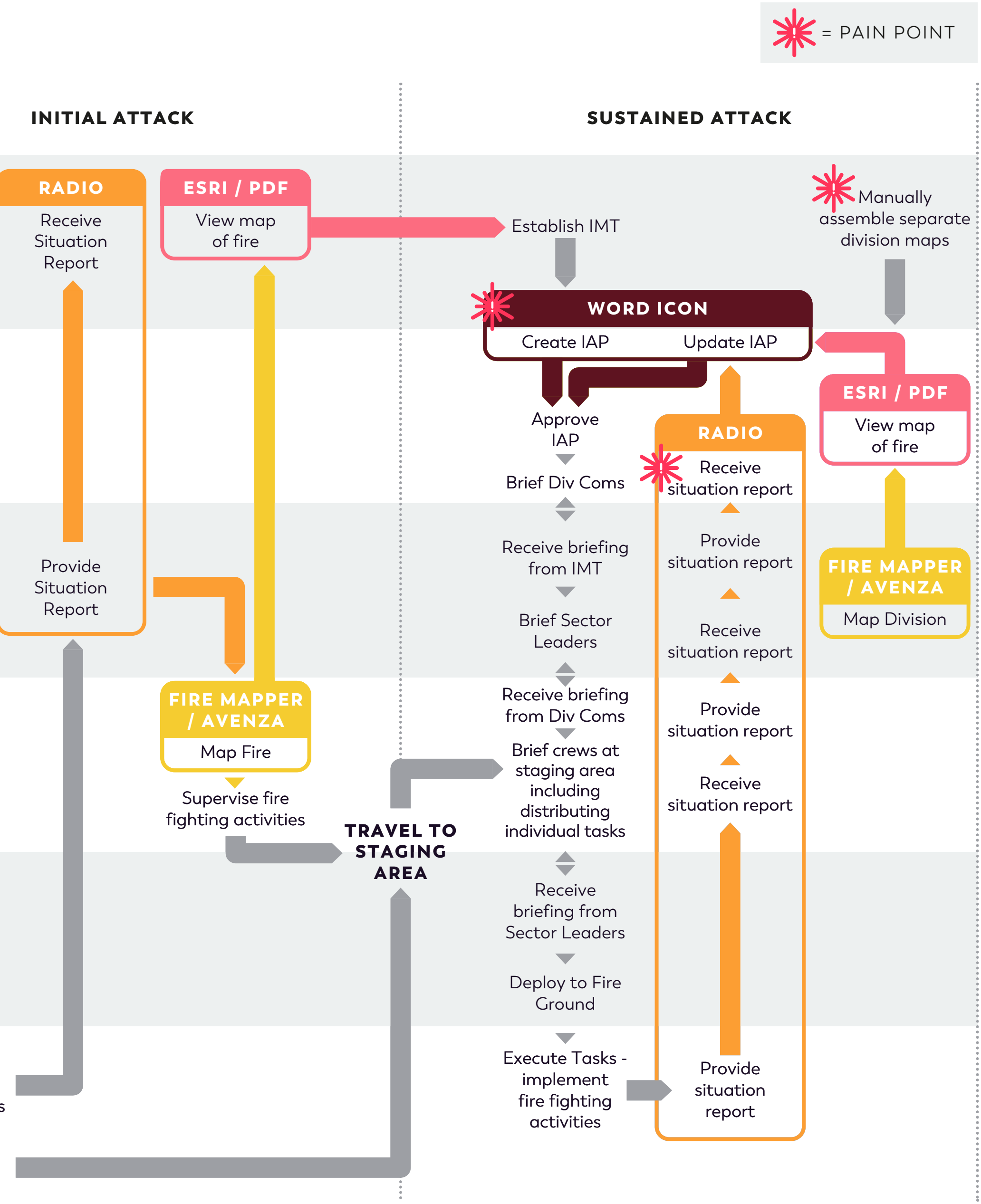
Photo Credit: *Gary Hooker, ACT RFS.*

INFORMATION FLOW ANALYSIS OF CURRENT PRACTICE:

The Incident Management Team / Ground Crew



Credit: Thanks to Dylan Kendal of Zirkarta for help and insight preparing this diagram.



= PAIN POINT
INITIAL ATTACK
SUSTAINED ATTACK
RADIO
Receive Situation Report
Provide Situation Report
ESRI / PDF
View map of fire
FIRE MAPPER / AVENZA
Map Fire
Supervise fire fighting activities
TRAVEL TO STAGING AREA
Establish IMT
WORD ICON
Create IAP
Update IAP
Approve IAP
Brief Div Coms
Receive briefing from IMT
Brief Sector Leaders
Receive briefing from Div Coms
Brief crews at staging area including distributing individual tasks
Receive briefing from Sector Leaders
Deploy to Fire Ground
Execute Tasks - implement fire fighting activities
RADIO
Receive situation report
Provide situation report
Receive situation report
Provide situation report
Receive situation report
Provide situation report
Manually assemble separate division maps
ESRI / PDF
View map of fire
FIRE MAPPER / AVENZA
Map Division

The Incident Action Plan

The Incident Action Plan (IAP) is a formal static document drawn up by the Incident Management Team in response to a significant event - a fire that will require more resources than the first responding team. Typically, this is put together within 12 hours of a fire igniting.

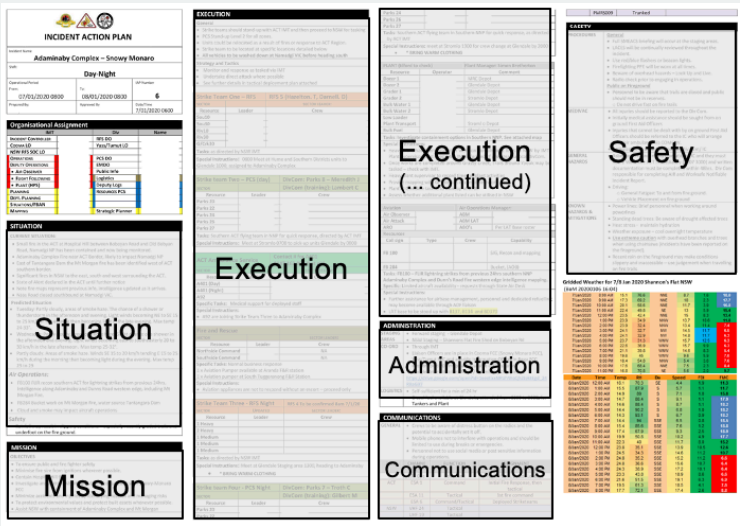
The IAP is given to each crew chief at the fireground and handed over at every shift change. It represents:

- an agreed plan on how to manage the fire,
- a record of responsibilities and personnel,
- a lookup table of communication frequencies and the best intelligence on the situation.

Photo Credit: *Gary Hooker, ACT RFS.*

SMEACS layout of the IAP:
Situation, Mission, Execution, Administration Communications and Safety.

Example of an anonymised Incident Action Plan (IAP) showing the SMEACS system of information. Static maps of the fireground may also be attached to the IAP, presenting critical information and location of assets. This example was kindly provided by the ACT RFS.



The front page of the IAP is laid out in blocks according to the SMEACS system: **Situation**, **Mission**, **Execution**, **Administration**, **Communications** and **Safety**. Subsequent pages may present maps of the fireground, annotated with fire extent, fire spread predictions, weather forecast, location of assets and other important information.

As the situation on the ground changes, the fireground copy of the IAP is updated with new information. Updates can include annotations on the map (new fire edge, spot-fires, dangerous trees, assets of different type, control lines, etc.), weather observations, changes in personnel, redeployment information and records of tasks completed.

IAPs are often printed for distribution (e.g., on A5 paper), but increasingly are being distributed as PDF files electronically. Firefighting personnel rely on personal devices to download and view the IAP, often triggered by scanning a QR-code.

The Incident Action Plan Challenges

MOBILE DATA COVERAGE

Electronic IAPs can be difficult for fireground personnel to obtain if mobile data coverage is poor.

SHIFT CHANGE

Changes at the fireground must propagate to the IMT before shift change to included on the next version.

HAND-HELD RADIOS & VOICE REPORTS

Communication of information from the fireground usually relies on hand-held radios and voice reports, which are prone to distortion and miscommunication.

SPEED OF CHANGES TO IAP

Changes to the IAP require approval by a senior officer and maps must be validated. This can take up to four hours, meaning that the information on the IAP may be significantly out of date for large, fast-moving fires.

UPDATING THE IAP

The official IAP is updated at every shift change (i.e., every 12 hours) and must incorporate the latest annotations from the fireground. This is a large task, incorporating changes reported by the crew through the sector and division commanders.

Photo Credit: *Gary Hooker, ACT RFS.*

The Incident Action Plan Example

INCIDENT ACTION PLAN

Incident Name: Adaminaby Complex – Snowy Monaro		
Shift: Day-Night		
Operational Period From: 07/01/2020 0800	To: 08/01/2020 0800	IAP Number: 6
Prepared By:	Approved By	Date/Time: 7/01/2020 0600

Organisational Assignment

IMT		Div	Name
Incident Controller		RFS DO	
Cooma LO		Yass/Tumut LO	
NSW RFS SOC LO			
Operations		PCS DO	
Deputy Operations		EMDO	
• Air Observer		Public Info	
• Flight Following		Logistics	
• Plant (HPS)		Deputy Logs	
Planning		Resources PCS	
Dept. Planning			
Situations/FBAN			
Mapping		Strategic Planner	

SITUATION

CURRENT SITUATION:

- Small fire in the ACT at Hospital Hill between Boboyan Road and Old Bobyan Road, Namadgi NP has been contained and now being monitored.
- Adaminaby Complex Fire near ACT Border, likely to impact Namadgi NP
- East of Tantangara Dam the Mt Morgan fire has been identified west of ACT southern border.
- Significant fires in NSW to the east, south and west surrounding the ACT.
- State of Alert declared in the ACT until further notice
- Note fire maps represent previous info, intelligence updated as it arrives.
- Naas Road closed southbound at Namadgi VIC.

Predicted Situation

- Tuesday: Partly cloudy, areas of smoke haze. The chance of a shower or thunderstorm in the afternoon and evening. Light winds becoming NE to SE 15 to 25 km/h in the evening then becoming light in the late evening. Max temp 24-33°.
- Wednesday: Partly cloudy, areas of smoke haze. Slight chance of a shower in the afternoon and evening. Light winds becoming east to southeasterly 20 to 30 km/h in the late afternoon. Max temp 25-32°.
- Partly cloudy. Areas of smoke haze. Winds SE 15 to 20 km/h tending E 15 to 25 km/h during the morning then becoming light during the evening. Max temp 23 to 29

Air Operations:

- FB100 FLIR recon southern ACT for lightning strikes from previous 24hrs. Intelligence along Adaminaby and Dunns Road western edge, including Mt Morgan Fire.
- FB284 Bucket work on Mt Morgan fire, water source Tantangara Dam
- Cloud and smoke may impact aircraft operations

Safety

- Rainfall may result in slippery conditions – especially recently graded trails and underfoot on the fire ground.

MISSION

OBJECTIVES

- To ensure public and fire fighter safety
- Minimise fire size from ignitions wherever possible.
- Contain Hospital Hill fire.
- Investigate and address Mt Morgan Fire in conjunction with Snowy-Monaro FCC
- Minimize accidents and injuries by identifying hazards and managing risks
- To protect environmental values and protect built assets whenever possible.
- Assist NSW with containment of Adaminaby Complex and Mt Morgan

EXECUTION

General

- Strike teams should stand-up with ACT IMT and then proceed to NSW for tasking
- PCS Stand-up Level 2 for all zones.
- Units could be relocated as a result of fires or response to ACT Region.
- Strike team to be located at specific locations detailed below
- **All vehicles to be washed down at Namadgi VIC before heading south**

Strategy and Tactics

- Monitor and response as tasked via IMT
- Undertake direct attack where possible
- See further details in tactical deployment plan attached

Strike Team One – RFS		RFS 5 (Hazelton. T, Darnell. D)
SECTOR		SECTOR LEADER:
Resource	Leader	Crew
Sou10		
Sou30		
Riv10		
Riv30		
G/Crk30		

Tasks: as directed by NSW IMT

Special Instructions: 0800 Meet at Hume and Southern Districts units to Glendale 1000, assigned to Adaminaby Complex

Strike team Two – PCS (day)		DivCom: Parks 8 – Meredith J
SECTOR		DivCom (training): Lambert C
Resource	Leader	Crew
Parks 20		
Parks 22		
Parks 24		
Parks 26		
Parks 27		

Tasks: Southern ACT flying team in NNP for quick response, directed by ACT IMT

Special Instructions: Meet at Stromlo 0700 to pick-up units Glendale by 0800

ACT Ambulance Service		Contact # for A401 0147 162 098 (Sat ph)
SECTOR		SECTOR LEADER:
Resource	Leader	Crew
A401 (Day)		
A401 (Night)		
A92		

Specific Tasks: Medical support for deployed staff

Special Instructions:

- A92 are Joining Strike Team Three to Adaminaby Complex

Fire and Rescue		
SECTOR		SECTOR LEADER:
Resource	Leader	Crew
Northside Command		NA
Southside Command		NA

Specific Tasks: Normal business response

1 x Aviation Pumper available at Aranda F&R station

1 x Aviation pumper at South Tuggeranong F&R Station

Special Instructions:

- Aviation appliances are not to respond without an escort – proceed only

Strike Team Three - RFS Night		RFS 4 To be confirmed 8am 7/1/20
SECTOR	Updated	SECTOR LEADER:
Resource	Leader	Crew
1 Heavy		
2 Heavy		
1 Medium		
1 Medium		
1 Medium		

Tasks: as directed by NSW IMT

Special Instructions: Meet at Glendale Staging area 1300, heading to Adaminaby

- *** BRING WARM CLOTHING**

Strike team Four - PCS Night		DivCom: Parks 7 – Troth C
SECTOR		DivCom (training): Gilbert M
Resource	Leader	Crew
Parks 20		
Parks 22		
Parks 24		
Parks 26		
Parks 27		

Tasks: Southern ACT flying team in So
by ACT IMT

Special Instructions: meet at Stromlo

- *** BRING WARM CLOTHIN**

PLANT (Elford to check)	
Resource	Operator
Dozer 1	
Dozer 2	
Grader 1	
Grader 2	
Bulk Water 1	
Bulk Water 2	
Low Loader Plant Transport	
Bulk Fuel	

Tasks: Investigate containment optio

Special Instructions:

- Heavy plant has been cleared to v
Plant Supervisor must keep NSW IN
- Once works are completed around
tasked – check with IMT.
- Heavy plant supervisor to record ti
- Provide mapping with GPS details c
- Plant at Glendale tasked to standu
- Assess whether additional plant list

Aviation	
Air Observer	
Air Attack	
ARO	
Resources	
Call sign	Type
FB 100	
FB 284	

Tasks: FB100 – FLIR lightning strikes f
Adaminaby Complex and Dunn's Roa
Specific: Limited aircraft availability -

Special Instructions:

- Further assistance for airbase mana
may become available through ADF
- LAT base to be stood up with B137,

ADMINISTRATION

STAGING AREAS	• Forward staging - Glenc • NSW Staging – Shannon
CO-ORD	• Through IMT • Liaison Officers are in pl Yass/Tumut FCC and a F • Geo-enabled PDF maps Google Drive / Incident https://drive.google.com/ RBaG97
LOGISTICS	• Self-sufficient for a min • Diesel fuel available at Tankers and Plant

COMMUNICATIONS

GENERAL	• Crews to be aware of di potential to accidentally • Mobile phones not to in limited to use during br • Personnel not to use so during operations.	
ZONE	CHANNEL	FUNCTI
	RFS Ops	Comma
ACT	ESA 1	Comma
	ESA 11	Tactica
	ESA 6	Command/T
NSW	VHF 24	Tactica
	UHF 19	Tactica

Example of an Incident Action Plan, courtesy of the ACT RFS.

uthern NNP for quick response, as directed

1900 for crew change at Glendale by 2000

Plant Manager: Simon Bretherton
Comment
MRC Depot
Glendale Depot
Glendale Depot
Stromlo Depot
Glendale Depot
Stromlo Depot
Stroml o Depot
Glendale Depot

ns in Southern NNP. See attached map

vork on containment lines in NSW by IMT.
MT informed of progress via local DivCom.
Grassy Creek, Trails around Yaouk may be

mes of plant activities
f completed work
at 0900
ed can be utilised in NSW

Air Operations Manager:	
ABM	
ABM LAT	
ABO's	Per LAT Base roster

Crew	Capability
	SIG, Recon and mapping
	Bucket, (AOB)

rom previous 24hrs southern NNP
d fire western edge intelligence mapping.
requests through State Air Desk

agement, personnel and dedicated refuelling
liaison
B134 and BD370

dale Depot
s Flat Fire Shed on Boboyan Rd

ace in Cooma FCC (Snowy Monaro FCC),
Public Information Officer in Bega FCC
are available in the shared
Maps / Adaminaby Complex
open?id=1eeelixxNRUhWoQh2JektEgd_24

of 24 hr
Glendale, attended from 0600 to 2000, for

stress button on the radios and the
set it off.
nterfere with operations and should be
eaks or emergencies.
cial media or post sensitive information

ON	ASSIGNMENT
nd	IC, Div Com, Sector Leaders
nd	Initial Fire Response, then tactical
l	1st fire command
actical	Deployed Striketeams
l	
l	

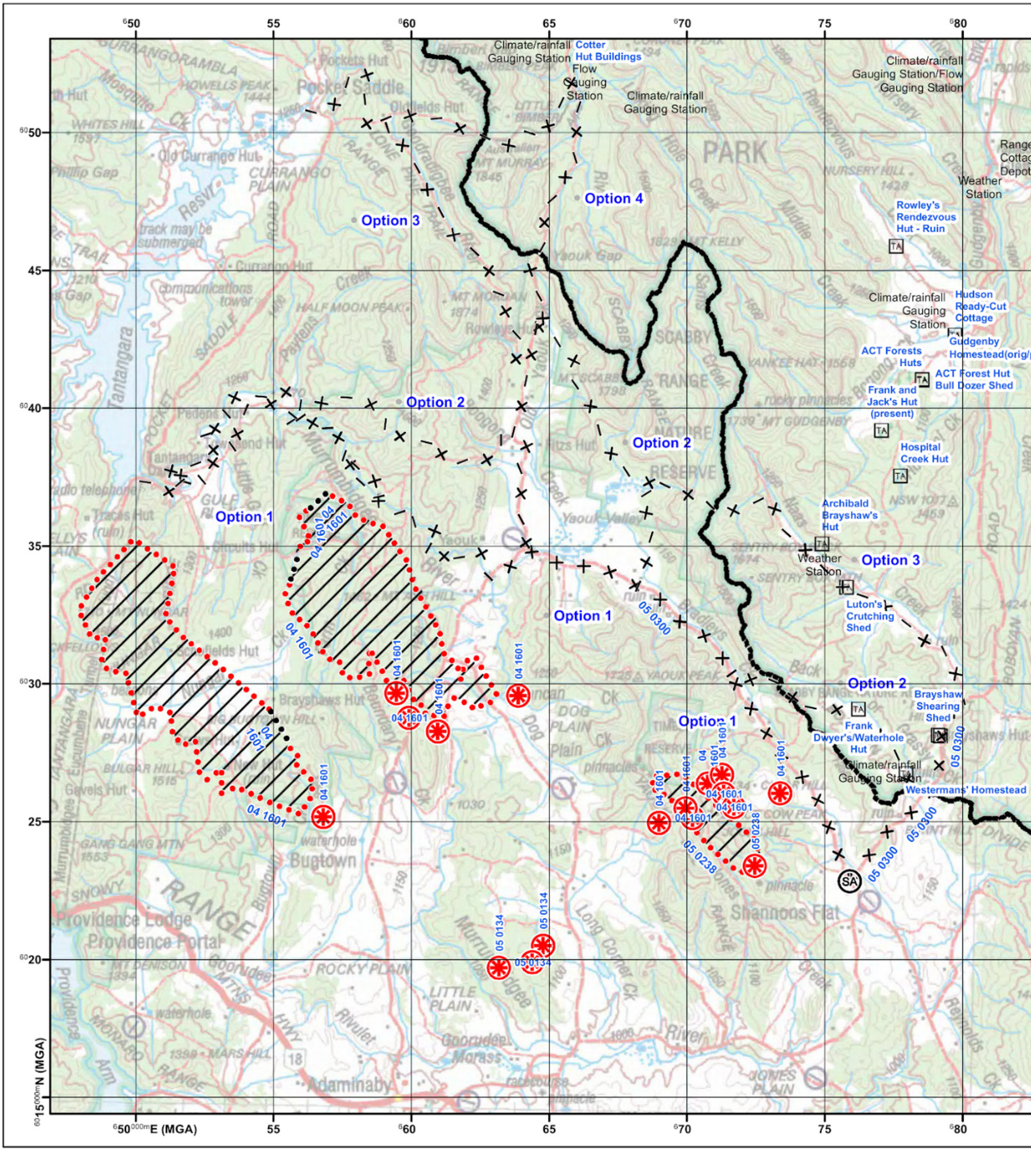
	PMRS009	Trunked	

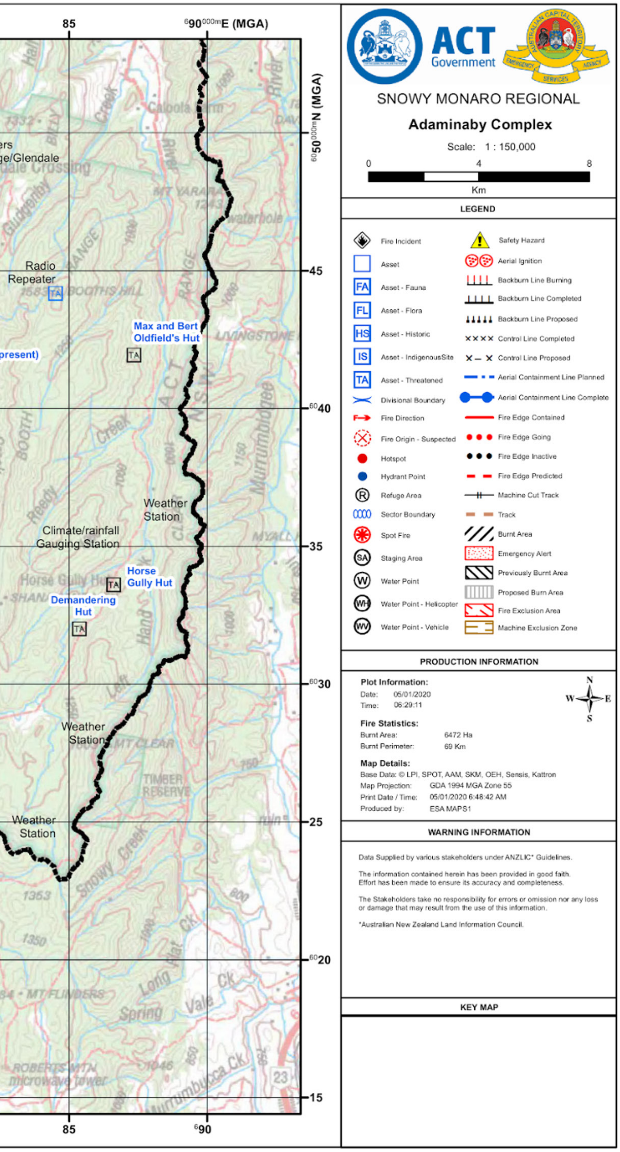
SAFETY	
PROCEDURES	**General** • Full SMEACS briefing will occur at the staging areas. • LACES will be continually reviewed throughout the incident. • Use red/blue flashers or beacon lights. • Firefighting PPE will be worn at all times. • Beware of overhead hazards – Look Up and Live. • Radio check prior to engaging in operations. **Public on Fireground** • Personnel to be aware that trails are closed and public should not be in reserves. ○ Do not drive fast on fire trails
MEDIVAC	• All injuries should be reported to the Div Com. • Initially medical assistance should be sought from on ground First Aid Officers • Injuries that cannot be dealt with by on ground First Aid Officers should be referred to the IC who will arrange road/air ambulance via COMCEN. • Ambulance: To be determined by Div Com/ IC
GENERAL HAZARDS	• Asbestos: If found, notify Operations/ IC and they must notify Worksafe ACT immediately (6207 3000) and written documentation must be completed within 48hrs. Div Com responsible for completing AIR and Worksafe Notifiable Incident Report. • Driving: ○ General Fatigue: To and from fire ground. ○ Vehicle Placement on fire ground
KNOWN HAZARDS & MITIGATIONS	• Power lines: Brief personnel when working around powerlines • Standing dead trees: Be aware of drought affected trees • Heat stress - maintain hydration • Weather exposure – cool overnight temperature • **Use extreme caution** with overhead branches and trees when using chainsaws (incidents have been reported on the fireground). • Recent rain on the fireground may make conditions slippery and inaccessible – use judgement when travelling on fire trails

Gridded Weather for 7/8 Jan 2020 Shannon's Flat NSW
(BoM 20200106 16:04)

Date	Time	Temp	RH	Dir	Speed	FDI	FMC
7/Jan/2020	8:00 AM	15.1	76.6	NNE	8.7	1.6	18.0
7/Jan/2020	9:00 AM	17.3	69.2	NNE	10	2.3	17.7
7/Jan/2020	10:00 AM	20.1	58.6	NNE	11.7	3.9	16.8
7/Jan/2020	11:00 AM	22.4	49.8	NE	13	5.9	15.4
7/Jan/2020	12:00 PM	23.5	42.4	NNE	15	8.3	13.4
7/Jan/2020	1:00 PM	23.9	34.9	NNW	13.7	10.6	11.8
7/Jan/2020	2:00 PM	23.9	32.4	NNW	13.4	11.4	7.4
7/Jan/2020	3:00 PM	24.1	32.7	NW	14.5	11.7	6.5
7/Jan/2020	4:00 PM	24.1	32.9	NW	14.8	11.7	6.3
7/Jan/2020	5:00 PM	23.7	31.3	WNW	15.7	12.5	6.3
7/Jan/2020	6:00 PM	22.6	36.9	WNW	15.7	9.9	6.3
7/Jan/2020	7:00 PM	21.1	39.8	WNW	14.6	8.3	5.4
7/Jan/2020	8:00 PM	19.6	45	WNW	9.6	5.9	7.0
7/Jan/2020	9:00 PM	18.4	54.8	NNW	5.4	3.6	7.6
7/Jan/2020	10:00 PM	17.6	68.4	NNE	7.5	2.3	8.4
7/Jan/2020	11:00 PM	16.8	70.8	NE	5.6	2.0	9.7
8/Jan/2020	12:00 AM	16.1	70.3	SE	4.4	1.9	11.3
8/Jan/2020	1:00 AM	15.5	87.9	S	5.7	1.1	11.7
8/Jan/2020	2:00 AM	14.9	89	S	7.1	1.0	15.8
8/Jan/2020	3:00 AM	14.7	88.4	S	9.1	1.1	17.9
8/Jan/2020	4:00 AM	14.6	88.4	S	8.7	1.1	18.2
8/Jan/2020	5:00 AM	14.4	90.2	S	6.8	1.0	18.2
8/Jan/2020	6:00 AM	14.3	93.1	S	6.7	0.9	18.2
8/Jan/2020	7:00 AM	14.4	94	SSE	6.5	0.8	18.5
8/Jan/2020	8:00 AM	15.4	85.6	SSE	7.6	1.2	18.8
8/Jan/2020	9:00 AM	17.4	67.9	SSE	9.3	2.5	18.9
8/Jan/2020	10:00 AM	19.9	50.8	SSE	10.2	4.9	17.7
8/Jan/2020	11:00 AM	22.3	40	SSE	11.7	8.0	15.2
8/Jan/2020	12:00 PM	23.8	35.1	SSE	13.9	10.5	12.6
8/Jan/2020	1:00 PM	24.5	34.3	SSE	14.6	11.2	10.7
8/Jan/2020	2:00 PM	24.8	35.2	SSE	15.2	11.2	6.6
8/Jan/2020	3:00 PM	24.8	36.6	SSE	15.6	10.7	6.4
8/Jan/2020	4:00 PM	24.3	38.9	SSE	17.2	10.1	6.4
8/Jan/2020	5:00 PM	23.3	43.8	SSE	18.9	8.6	6.6
8/Jan/2020	6:00 PM	21.6	51.5	SSE	19.1	6.3	6.9
8/Jan/2020	7:00 PM	19.5	61.3	SSE	18.5	4.1	7.6
8/Jan/2020	8:00 PM	17.7	72.1	SSE	17.4	2.6	8.8

The Incident Action Plan
Example map





Typical map attached to an Incident Action Plan, courtesy of the ACT RFS.

Scaling Command in the IMT: The AIIMS System

The Australian Inter-Service Incident Management System (AIIMS) is a set of organisational principles and team structures used across emergency agencies in Australia and New Zealand.

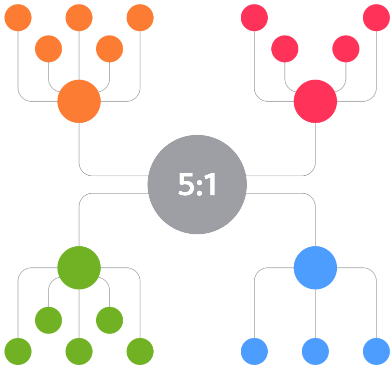
The system is designed to facilitate easy cooperation between different agencies, presenting familiar management roles across all organisations. It establishes a common terminology, clearly defined lines of communication, uses risk-aware planning methods and is adaptable to a wide variety of situations beyond fires.

AIIMS is based on five key principles:

PRINCIPLE	EFFECT
Management by objective	Agreed objectives set out in the Incident Action Plan. Objectives should be Specific, Measurable, Achievable, Relevant and Time-framed (SMART). Good objectives specify what, when and where.
Functional Management	Five to eight functional areas within a management team, depending on size of incident (see table at right).
Span of control	One supervisor should ideally control only up to five groups or individuals. The span of control may exceed this 5:1 ratio for very complex incidents, but should be continually reviewed and scaled down when appropriate.
Flexibility	Flexibility to scale the reporting structure across multiple agencies and for different types of incident spanning a wide range of duration.
Unit of Command	Each individual reports to only one supervisor. There is only one incident controller, one set of objectives and one incident action plan.

The Span of Control principle means that the branches of the command tree should not grow beyond five people at each level and that there are clear lines of responsibility. However, the size of the IMT should be reviewed and always reflect the scale of the incident and the stage of the response cycle.

The functional areas within the incident management team are colour-coded as in the table below. Managers wear appropriately coloured vests to be readily identifiable and easily found.

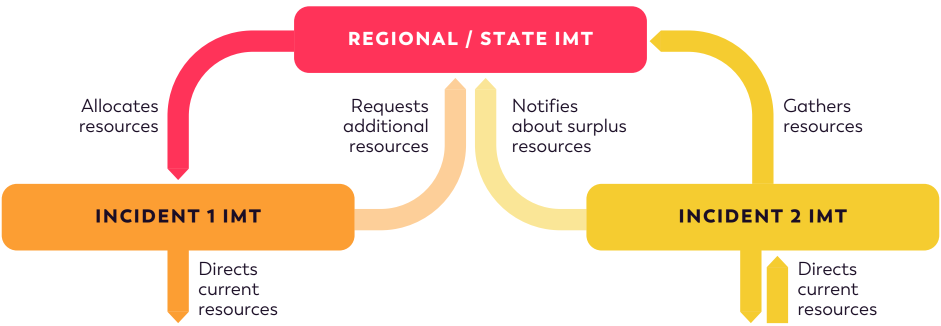


FUNCTIONAL AREA	DESCRIPTION
Control	Management and oversight of the firefighting process.
Planning	Develop objectives, strategies and plans for resolving the incident. Evidence-based.
Intelligence	Subset of planning dedicated to analysing data in support of decision making. Includes predictive modelling.
Public Information	Provide warnings and advice to community, liaise with media.
Operations	Tasking of teams and application of resources.
Logistics	Acquire and provide resources of all kinds: human, material, facilities and services.
Finance	Manage accounts: purchases, insurance, compensation and cost-estimates for incident.

AIIMS Beyond the Fireground

AIIMS is primarily designed to facilitate control at a local or incident level, however, higher levels of government also maintain an overview of ongoing incidents, especially with regard to directing resources.

Regional and state level IMTs are responsible for allocating resources like air-support, large vehicle appliances and fire crews seconded from other regions. They need to have a view of what resources are available across multiple jurisdictions so they can respond to requests for help from local IMTs. Timescales for managing these resources are longer, so higher level IMTs have the challenging job of predicting need and matching available resources, days or weeks in advance.



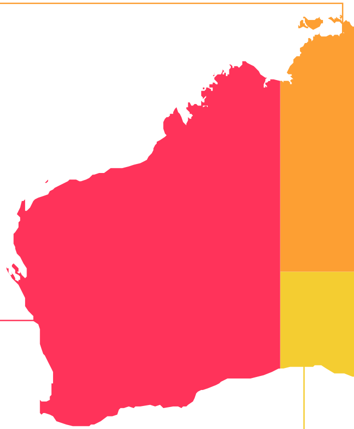
Aircraft and heavy plant equipment from state, national or even international sources can be requested during a catastrophic bushfire season. Credit: Garry Hooker, ACT RFS.

Supporting & Surrounding Agencies

Fire services need to coordinate with a broad range of other agencies that provide complementary services, hold relevant information, manage critical threatened assets in the landscape, or should be consulted during the decision-making process. Representatives from other agencies are often found in a room next to the IMT (called the Emergency Management Team in Victoria and Emergency Control Centre in ACT).

NORTHERN TERRITORY

NT Police Force	Dept. of Industry, Tourism and Trade
NT Emergency Service	Telstra
ST. John Ambulance	NT Power and Water Corporation
NT Transport Group (Dept. of Infrastructure, Planning and Logistics)	Western Power, Synergy and Horizon Power
Dept. of Environment, Parks and Water Security	



WESTERN AUSTRALIA

WA Police Force	WA Parks and Wildlife Service
Dept. of FIre and Emergency Services (DFES)	Water Corporation WA
DFES State Emergency Service	Western Power, Synergy and Horizon Power
St. John Ambulance	Telstra
Dept. of Primary Industries and Regional Development	Mainroads WA
Dept. of Water and Environmental Regulation	

SOUTH AUSTRALIA

South Australia Police	SA Water
Dept. for Environment and Water	SA Power Networks
Dept. of Primary Industries and Regions	Telstra
SA Ambulance Service	Dept. for Infrastructure and Transport
SA State Emergency Service	ForestrySA
National Parks and Wildlife SA	

TASMANIA

Tasmania Police
Dept. of Primary Industries, Parks, Water and Environment
Dept. of State Growth
Transport Tasmania
Ambulance Tasmania

QUEENSLAND

Queensland Police Service	Queensland department of Transport and Main Roads
State Emergency Service QLD	Energy Queensland
Queensland Ambulance Service	Telstra
Dept. of Environment and Science (Parks, Forest, and Wildlife Service)	Dept. of Resources (Water Authorities, land maps)

NEW SOUTH WALES

NSW Police Force	National Parks and Wildlife Service
Dept. of Planning, Industry and Environment	Water NSW
Dept. of Primary Industries	Ausgrid, Essential Energy, Endeavour Energy
Forestry Corporation	Telstra
NSW Ambulance	Roads and Maritime Services
NSW State Emergency Service	

AUSTRALIAN CAPITAL TERRITORY

ACT Police	Icon Water
ACT Government: Environment Directorate, Emergency Services Agency, Transport Canberra	Evoenergy
	Telstra
ACT Ambulance Service	ACT State Emergency Service

Tasmania State Emergency Service
TasWater
TasNetworks
Tas Gas Newworks
Telstra

VICTORIA

Victoria Police	Parks and Wildlife
Dept. of Environment, Land, Water and Planning	Water Corporations (19)
Agriculture Victoria	Electricity (5) and Gas (3) Distributers (See Australian Energy Regulator)
VicForests	Telstra
Ambulance Victoria	VicRoads
Victoria State Emergency Service	

IMT Situational Intelligence: The Common Operating Picture

A single Common Operating Picture (COP) providing a detailed overview of the fireground is a key AIIMS principle. In practise, this is implemented as mapping software that provides real-time situational awareness of the fireground for the IMT.

It plots critical asset locations over base mapping layers, overlaid with the latest weather information. Whilst referred to as the Common Operating Picture, it is important to recognize that this is only shared within the IMT as it does not provide shared situational awareness between firefighters on the fire ground and the IMT.

Different COP software is used by each fire service, however, they have the same purpose and many features in common:

- Live vehicle and aircraft locations – if GPS trackers are fitted.
- Breadcrumb trails for vehicles and aircraft.
- Critical weather data and warnings.
- A wide range of base mapping layers, including topography, trails and roads, vegetation type, fuel moisture and historic burn scars.
- Dynamic layers, including current fire perimeter, spot fires, fire spread predictions, wind vector fields and weather fronts.

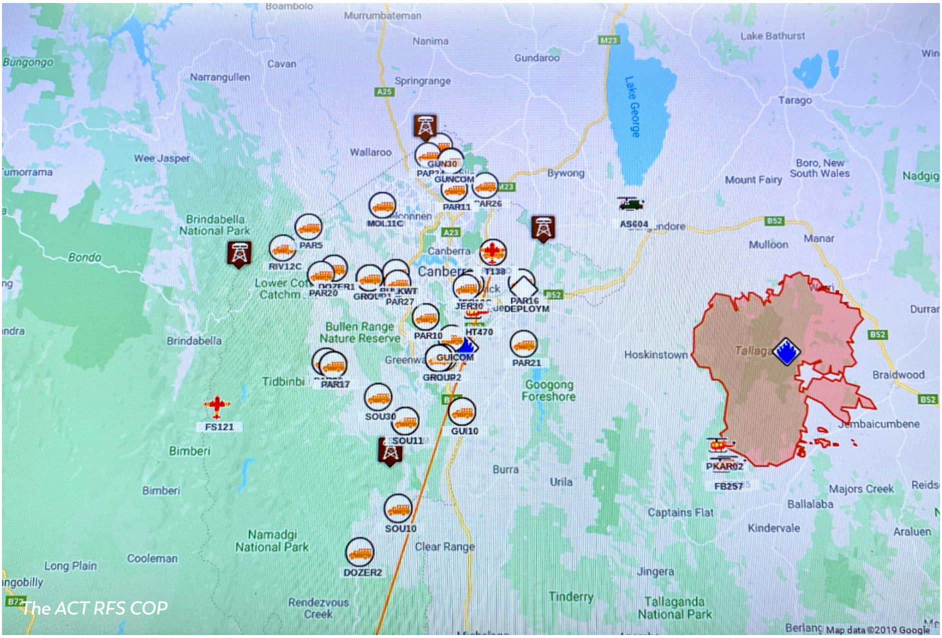
CHALLENGES

The capabilities of the COP software vary between organisations and opportunities exist for integrating fireground data in a much more seamless fashion:

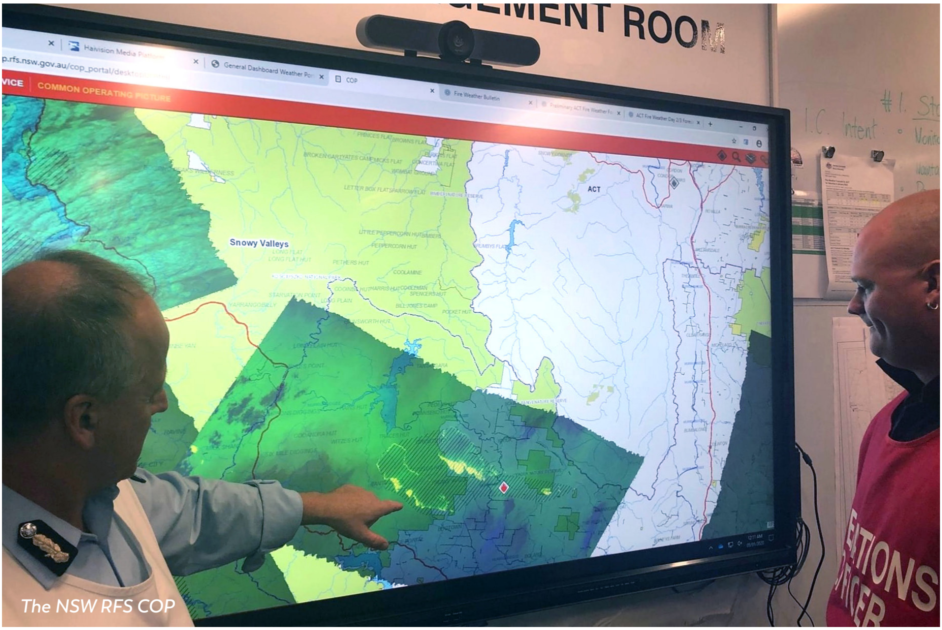
- The live IAP and up-to-date fireground maps could be much better integrated into the COP and automated:
  - Annotations and data flowing up from the fireground.
  - Automated information to replace radio updates.

- Some instances of the COP interface could be improved:
  - Better display of small-scale deployments (clustered symbols can obscure crew and truck deployments).

The manual processes involved in adding new information to the COP means the COP does not keep pace with incident development. As a result individual officers in the IMT annotate their own paper maps resulting in there being no single source of truth



The ACT RFS COP



The NSW RFS COP

Two examples of COP software running on a screen at the IMT. The maps are interactive: the zoom factor can be changed, maps panned and layers hidden. On some implementations drill-down information is available on deployed assets. Credit: Garry Hooker, ACT RFS.

The Logistics of Fighting Fires

Fighting large fires is a logistically challenging operation - not unlike a military campaign. Significant planning goes into keeping the flow of resources moving in order to ensure that the firefighting effort can continue without interruption until the fire has been successfully contained and suppressed.

The bill of resources required by those at the front line of the firefighting operations is extensive and includes everything from the fuel required to keep vehicles mobile, to the food and water needed to keep firefighters active, well equipped and able to fulfill their duties.

Significant geographic separation often exists between firefighting command-and-control entities - easily span 1000's of km. This introduces information barriers and time-lags between decision makers and decision executors, and demands that a successful firefighting operation identifies resource needs and potential shortfalls well in advance of supplies being exhausted. The impact of a lack of resource could be catastrophic.

In order to maintain a healthy supply of essential resources the firefighting crews provide periodic reports on their supply status throughout their shift to the IMT. This accounts for fuel, water, food, medical supplies and all other items which are deemed essential to mission success. The IMT will in turn work to coordinate a constant re-supply effort to ensure that stocks are quickly replenished to safe minimum levels, whilst also working to overcome immediate real-world factors which threaten the supply chain during a bushfire event; e.g., routes to firefighters being blocked by fire, shortages in equipment due to increased or prioritized demand in other areas, or breaks in the communication grid due to fire damage.

Photo Credit: Cory Hooker, ACT RFS

Temporary accommodation for personnel fighting a large fire campaign. The tents are owned by the NSW RFS and are fully equipped with air conditioning and purifiers.

Photo Credit: Gary Hooker, ACT RFS.

The Logistics of Fighting Fires
Challenges

HANDOVER BETWEEN SHIFTS

Currently the process of reporting what is needed and planning a re-supply effort is heavily dependent upon conventional voice comms and the T-Card system. Whilst this is functional, it presents inherent risks as the availability of the comms network can be unreliable and/or intermittent and equally the availability of dynamic data to support the detailed planning required to coordinate the resupply effort is often limited; i.e. problems in delivering equipment or kit will only be identified and reported when they are encountered on the ground.

SHARING INFORMATION

Managing resources for fighting a large bushfire is a wicked problem, requiring the incident commander to juggle competing priorities and make decisions based on imperfect knowledge and a limited view of the future. Incident commanders need integrated decision-support tools that melt knowledge of many areas:

- Availability of skilled personnel and their expertise.
- Knowledge of deployment locations and access routes.
- Real-time monitoring of fatigue levels, adjusted for difficulty.
- Accurate predictions of fire spread based on accurate weather and fuel information. Decision support for firefighting strategy.
- Agile resource management tools that adjust for dynamic data.

Photo Credit: *Gary Hooker, ACT RFS.*

Tracking Personnel and Equipment – The T-Card System

Incident controllers track the assignment of personnel, equipment, appliances, vehicles and aircraft via the paper-based T-Card system.

When RFS personnel respond to an incident each crew manually fills out a T-card detailing who is on the fire truck, their rank, what skills they possess, where they are deploying to and the crew leader's contact details (phone & radio information). Trucks and appliances often operate in groups (e.g., in NSW, typically a 5-truck strike team, or a more diverse task force containing appliances) and a similar T-Card is used to track which trucks and appliances are members of each group. The T-cards are passed to a fireground supervisor and collated at the IMT. Often the necessary information is communicated over the radio or via phone, which can take a lengthy period of time.

Below are two examples of T-cards from the NSW RFS:

Agency: RFS
Strike Team / Task Force Name: NORTH 12A
H H H L L
☐ REQ ☑ ORG ☐ SB
DURATION OF DEPLOYMENT INSTANT RESPONSE ☐
2 DAY (WEEKEND) ☐ 3 DAY ☑ 5 DAY ☐
COMMS IN TRANSIT CHANNEL NO: 10
AT ACCIDENT CHANNEL NO: 50
RESPONSE TEAM COORDINATOR: BRIAN DAY
MOBILE NO: 0499 219 093
Strike Team Leader: FRANK ZAMBELLI
Mobile No. 0499 623 517

Resource Name	Vehicle Type (see below)
STL/TF Leader	Command
MAIN ARM 1A	CAT 1
BURRINGBAH 1A	CAT 1
MURWILLUMBAH 1A	CAT 1
UKI 7A	CAT 7
KUNGHUR 7A	CAT 7

DTG Arrived: 24 1200 DTG Released:
TASK Location / DTG: 24 1400 DEC 02
BURRINYAH DRIVE
STATUS: STAGING AREA
E/R S/D
AVL 24 1200 U/S
ALC

Vehicle Type			
Cat 1	AWD	Heavy	3001-4000 litre
Cat 2	AWD	Medium	1601-3000 litre
Cat 7	AWD	Light	801-1600 litre
Cat 9	AWD	Mop Up	350-800 litre
PC	AWD	Personel Transport	

AUG 2005

RFS Agency
Name: MAIN ARM 1A
H
Vehicle Category/Type: ISUZU CAT 1
CABA Sets: 0
☐ REQ ☑ ORG ☐ SB
STRIKE TEAM/TASK FORCE ID: NORTH 12A
DURATION OF DEPLOYMENT INSTANT RESPONSE ☐
2 DAY (WEEKEND) ☐ 3 DAY ☑ 5 DAY ☐
PMR ☑ GRN ☑ UHFCB ☑ FIREGROUND ☐
OTHER:
MOBILE NO: 0499 655 668 ROOF ID No. 7812

Rank	Name	Skills
OIC CAPT Contact No. 0499	BOB GRAHAM 655 668	GL/VF
DC	TODD FROST	CL/VF
FF	KEVIN DAY	CSO
FF	STEPHANIE LITTLE	SFA
FF	PETER SMITH	BF
FF	RACHEL JONES	BF

DTG Arrived: 24 1200 DTG Released:
TASK Location / DTG: 24 1400 DEC 02
BURRINYAH DRIVE
STATUS: STAGING AREA
E/R S/D
AVL 24 1200 U/S
ALC

SKILLS			
Basic Firefighter	BF	Senior first Aider	SFA
Advanced Firefighter	AF	Rural Fire Driver	RFD
Village Firefighter	VF	Chain Saw Operator	CSO
Crew Leader	CL	Breathing Apparatus Operator	BAO
Group Leader	GL	Remote Area Firefighter	RAF

AUG 2005

Crew T-Card showing details of personnel deployed to a truck. Credit: NSW RFS.

Strike Team T-Card showing which trucks are deployed to a Strike Team. Credit: NSW RFS.

At the IMT staging area, the T-Cards are organised into slotted folders, grouped by categories such as deployment location and shift status. For ease of access folders are often mounted vertically on an incident command board, as shown below.

T-Cards on a portable incident command board.
Credit: bigredtruck.com.au

Tracking Personnel and Equipment – The T-Card System Challenges

HAND-WRITTEN INFORMATION

Hand-written information is often incomplete, garbled or prone to errors – doubly so if communicated over radio link.

MISSING INFORMATION

Vital information (such as medical advice) is omitted altogether and available information on skills and experience is very sparse.

SEARCHING

Searches are hard! Physical cards cannot easily be re-ordered to search for people matching a profile (e.g., skill, time-deployed).

REVIEWING CARDS

Reviewing cards to monitoring for fatigue is highly laborious.

POST-FIRE AUDITS

Post-fire audits are prone to errors and take significant time.

Photo Credit: *Gary Hooker, ACT RFS.*

Data to Support Firefighting: National & State Providers

The national providers of data to support firefighting include:

- **Geoscience Australia (GA).**
- **The Bureau of Meteorology (BoM).**
- **State environment, land and water management agencies.**
- **Private companies.**

Data organisations provide access to multiple types of data at different levels of processing. Raw data need to be corrected for systematic effects (e.g., atmospheric or diurnal effects) and packaged into a usable format in easily digestible chunks. Raster image data needs to be co-registered and reprojected onto a common grid. Time-series data may be updated at varying cadences. For all data types, quality, resolution and uncertainty can vary with both space and time, meaning significant effort is needed to prepare these for analysis and create insight for users.

Most data can be accessed or queried programmatically through application programming interfaces (APIs) or dedicated web portals. However, some high-quality data are restricted to accredited organisations, or require paid subscriptions (e.g., lightning strike data currently). The challenge is how to map each data source to the appropriate user, and how to visualise just enough information without causing cognitive overload.

Fire services deploy dedicated mapping teams at the IMT to support firefighting. During a campaign fire they operate at full capacity to synthesize a overview of the fireground daily. They integrate data from aircraft, local sources and the big data providers. However, the next few years will bring a tenfold increase in available information, meaning smart new tools will be essential to make sense of the available intelligence.

Key point
Care is needed to distil data to a sparse representation tuned for firefighting crews on the ground. Information overload is a real danger on the fireground.

DATA AGENCIES AND TOOL PROVIDERS

ORGANISATION	DESCRIPTION
Geoscience Australia (GA) ga.gov.au	National provider of remote sensing data from satellites and ground-based sensor networks. Risk management for natural disasters (fire, flood, earthquake, tsunami) and intelligence for land management.
Bureau of Meteorology (BoM) bom.gov.au	Australia's national weather, climate and water agency. Provides regular weather forecasts, climate and weather data, hydrological and oceanography services.
Landgate landgate.wa.gov.au	Landgate is the business name for the Western Australia Land Information Authority, the government authority responsible for property and land information in WA. See landgate.wa.gov.au/about-us Landgate Satellite Remote Sensing Service (SRSS) offer remote sensing data products and services for managing fires, floods, agriculture and environment. For bushfires they provide the following tools: • **FireWatch (& Pro):** Satellite hotspot mapping service. • **Aurora:** National fire monitoring and spread simulation.
Federal Government Open Data Portal data.gov.au	Central source of Australian open government data. Anyone can access the anonymised public data published by federal, state and local government agencies.
State and Territory Government Data Portals	Individual Australian states maintain open-access portals that serve a wide range of interesting data – for example, burn scars and fire history. data.nsw.gov.au firenorth.org.au/nafi3 nrmaps.nt.gov.au data.sa.gov.au naturemaps.sa.gov.au thelist.tas.gov.au data.vic.gov.au data.wa.gov.au

PROFILE

Geoscience Australia

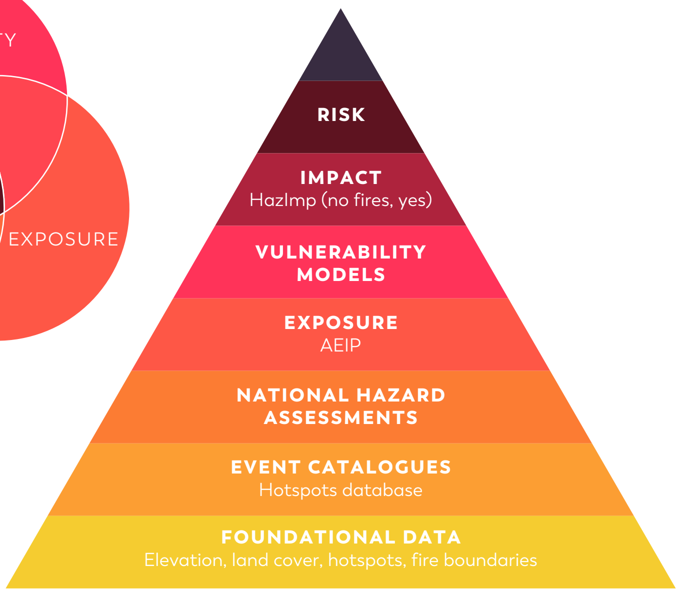
Geoscience Australia (GA) takes an all-hazards approach to providing trusted and actionable information to support decision-making around bushfires and other natural hazards.

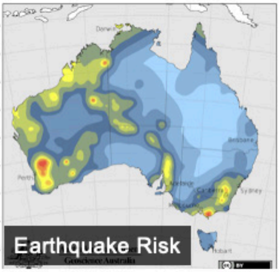
Fundamentally, GA provides end-to-end risk analysis for different types of event, including: Tropical Cylcones, Earthquakes, Tsunami. To do this requires a deep understanding of the processing steps between foundational data and risk maps.

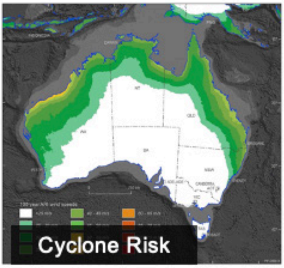
The process of creating a risk map for a natural hazard can be visualised as pyramid, with each layer having its own tools.

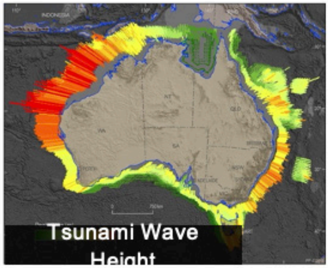
In the specific case of fires, tools for most layers are still

> *When disaster strikes, access to information is equally important as access to food and water"*
>
> **THE RED CROSS (2005)**









IMPORTANT TOOLS DEVELOPED OR SUPPORTED BY GA INCLUDE:

Australian Information Exposure Platform (AIEP):
This is a web tool is used to create exposure risk reports for assets (e.g., buildings) and populations (e.g., senior citizens, children) in a chosen geographic area.
portal.aeip.ga.gov.au

Digital Earth Australia (DEA):
This is a mapping platform delivering information useful for assessing, responding to and recovering from natural hazards.
ga.gov.au/dea/products

Elvis:
One-stop mapping platform serving topology and elevation data globally. These are fundamental data necessary for most risk models.
elevation.fsdf.org.au

HazImp:
Natural hazard impact assessment tool. Combines hazard map (e.g., flooding map) and asset or infrastructure maps (e.g., buildings) with damage models for types of construction materials to arrive at an impact map. Currently does not support fires.
github.com/GeoscienceAustralia/hazimp

EM-Link:
Online catalogue of emergency management services collating 145 web services and used by 60 organisations (restricted).
emlink.net.au

CASE STUDY

DEA Hotspots

Digital Earth Australia (DEA) Hotspots is a national bushfire monitoring system provided as a service by Geoscience Australia in partnership with the Bureau of Meteorology. It collates and processes satellite data to produce a map of possible fire locations, detected through their high levels of infrared radiation. The diagram on the right illustrates how the system works.

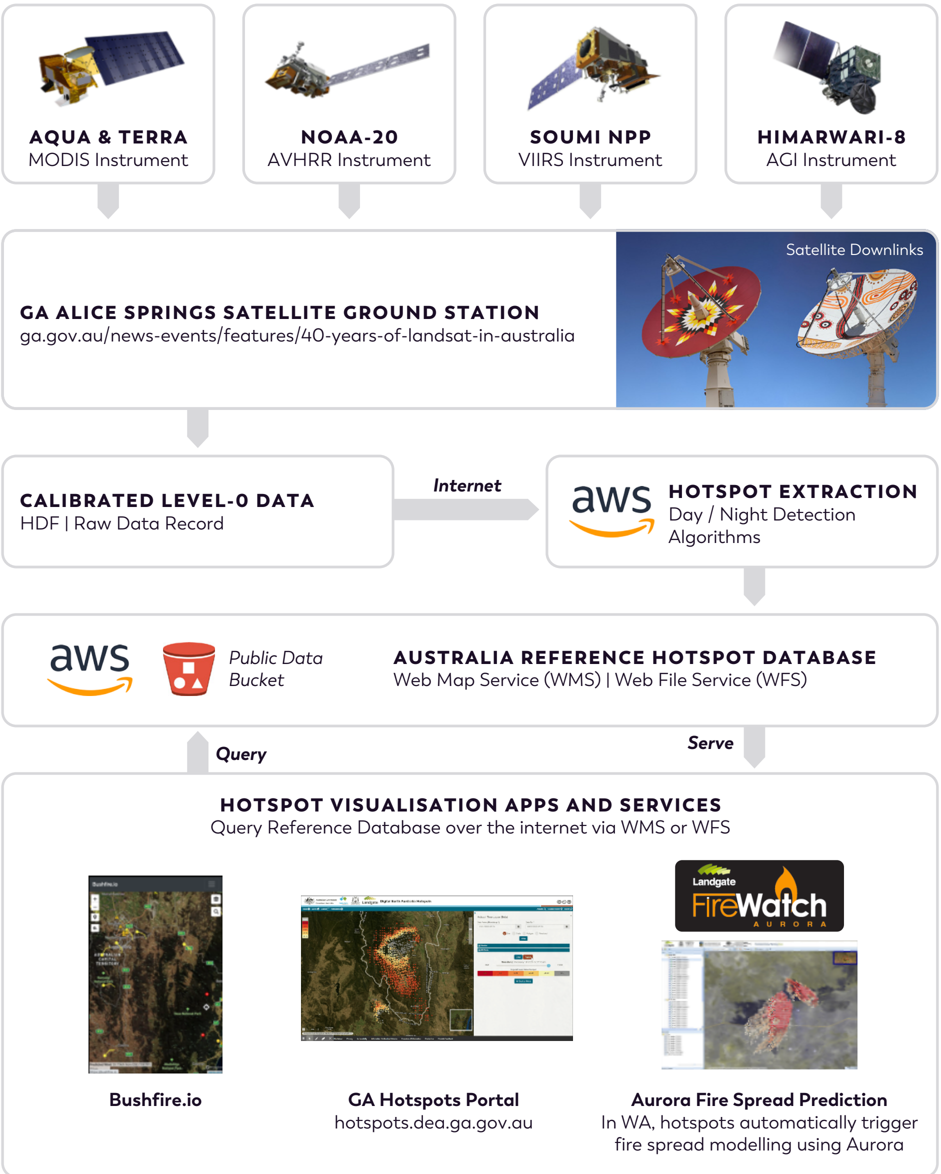
Input data is provided by satellites that pass overhead several times per day, or in the case of Himawari-8 are stationary over Australia and transmit images every ten minutes. Multi-band images from instruments on the satellites arrive via a ground station at Alice Springs, where they are processed into analysis-ready data.

The hotspot extraction algorithms are different for each instrument and optimised for the different sensors used. These sensors cover the visible and near-infrared bands, meaning that separate algorithms must be used during the night – when optical data is poor quality or noisy.

Conflicts in the data are resolved and detected hotspots are written to the Australia Reference Hotspot Database on Amazon Web Services, where they are available for collection by apps and services. Public hotspot information is updated every few hours, while the internal catalogue is updated in near real time – up to 140 times per day.

More Information:
DEA Hotspots Product Description PDF.

Variable Usage Across Territories:
DEA Hotspots are used as a decision support tool in populous states where ignitions are likely to be first reported by other methods (e.g., 000 calls). In NSW the satellite hotspot data is used to confirm geolocation within 1-2 km. However, WA and NT rely on the hotspots service as a first detection tool. Victoria also uses aircraft for spotting fires.


AQUA & TERRA
MODIS Instrument
NOAA-20
AVHRR Instrument
SOUMI NPP
VIIRS Instrument
HIMARWARI-8
AGI Instrument
GA ALICE SPRINGS SATELLITE GROUND STATION
ga.gov.au/news-events/features/40-years-of-landsat-in-australia
Satellite Downlinks
CALIBRATED LEVEL-0 DATA
HDF | Raw Data Record
Internet
aws
HOTSPOT EXTRACTION
Day / Night Detection Algorithms
aws
Public Data Bucket
AUSTRALIA REFERENCE HOTSPOT DATABASE
Web Map Service (WMS) | Web File Service (WFS)
Query
Serve
HOTSPOT VISUALISATION APPS AND SERVICES
Query Reference Database over the internet via WMS or WFS
Landgate
FireWatch
AURORA
Bushfire.io
GA Hotspots Portal
hotspots.dea.ga.gov.au
Aurora Fire Spread Prediction
In WA, hotspots automatically trigger fire spread modelling using Aurora

International Satellite Imagery Support

Groups of satellite operators have agreements to provide assistance during natural disasters.

The International Charter for Space and Major Disasters is a worldwide collaboration involving 17 space agencies and commercial satellite companies. It provides free access to data from expensive satellites in the event of a disaster (e.g., high resolution optical and synthetic aperture radar instruments).
disasterscharter.org

The Copernicus Emergency Management Service provides early warning and monitoring services and on-demand mapping to support selected emergencies. Examples are impact-maps and extent-maps created using the European Space Agency (ESA) Copernicus satellite resources.
emergency.copernicus.eu

ESA Sentinel 2, Credit: European Space Agency.

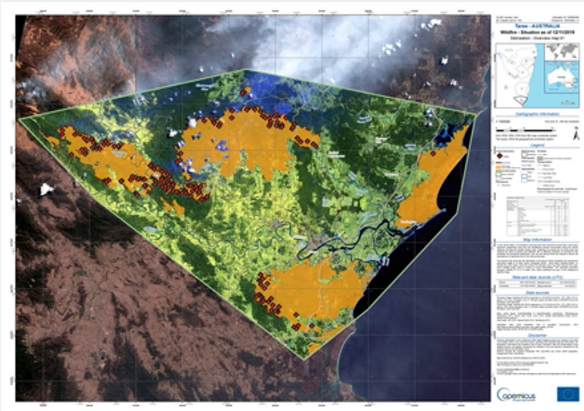
CASE: INTERNATIONAL SATELLITE SUPPORT ACTIVATION 631

EMSR408: Wildfires in New South Wales, Australia
Activated: 2019-11-13, 06:55 UTC
emergency.copernicus.eu/mapping/list-of-components/EMSR408

10 COUNTRIES FROM 13 CONTRIBUTING ORGANISATIONS

22 SATELLITES USED, 18 OF WHICH WERE SPECIFICALLY TASKED

2073 IMAGES SUPPLIED AND 28 DETAILED MAPS GENERATED



Example of Copernicus EMS map provided by David Hudson, Geoscience Australia

> *"This activation [...] represents one of the most important ones in terms of the analysis produced. [...]. [It] helps first responders on the field in order to make decisions, it's not only showing the burnt area."*
>
> **JUAN ESCALANTE, AT THE EU'S EMERGENCY RESPONSE COORDINATION CENTRE IN BRUSSELS SPEAKING TO 7-NEWS AUSTRALIA.**

PROFILE

The Bureau of Meteorology

The Australian Bureau of Meteorology (BoM) is responsible for providing accurate and timely weather information, and forecasts to assist in fighting fires.

PRODUCT	DESCRIPTION
ACCESS NWP **bom.gov.au/nwp/doc/access/NWPData.shtml**	The Australian Community Climate and Earth-System Simulator (ACCESS) Numerical Weather Prediction (NWP) service offers detailed gridded weather forecasts. The 'regional' ACCESS-R model covers all of Australia at a ~12km resolution and offers predictions to a 72-hour time horizon, updated at 6-hourly intervals (0, 6, 12, 18 hours UTC). See also: bom.gov.au/australia/charts/about/about_access.shtml
Graphical Forecast Editor (GRF)	Weather forecasts generated by the Numerical Weather Prediction (NWP) services are written to the Australian Digital Forecast Database. These are validated by human experts using the Graphical Forecast Editor, which produces gridded data products, symbolic forecast maps and traditional text forecasts. See also: bom.gov.au/weather-services/about/forecasts/NexGenBrochure.pdf

ACCESS-FIRE

AUSTRALIA'S COUPLED FIRE-ATMOSPHERE MODEL

bushfire&natural HAZARDSCRC

Mika Peace[1], Jeffrey D Kepert[1], Harvey Ye[1]

[1] Bureau of Meteorology and Bushfire and Natural Hazards CRC

END USER STATEMENT

Some bushfires exhibit extreme behaviour that exceeds the bounds of existing predictive guides. Coupling between the fire and the atmosphere has been invoked as a cause of such unexpected behaviour. Events of this type are uncommon and cannot be investigated by conventional field experiments. This modelling project allows complex interactions between a fire and the atmosphere to be studied, potentially providing physically-based explanations that will lead to more reliable predictions and reduced risk to firefighters and the community.

Dr Lachie McCaw
Parks and Wildlife WA

ACCESS

ACCESS is the Australian Community Climate and Earth-System Simulator - Australia's premier NWP model. ACCESS is based on the UK Met Office's system, one of the best three meteorological models in the world.

ACCESS is Australia's national operational weather forecasting model. It is run every 6 hours on supercomputers at the Bureau of Meteorology.

ACCESS can also be run in research mode for a range of purposes including climate research and examining case studies of extreme events in high resolution.

ACCESS can be initialised from a range of meteorological observations in operational mode, or by using archived global analysis fields for case studies.

Simulations of fire case studies are typically run using a series of nests, down to resolutions of a few hundred metres.

COUPLED FIRE-ATMOSPHERE (CFA) MODELS

CFA models have an empirical fire model coupled to a Numerical Weather Prediction (NWP) model. They capture the interactions between a fire and the atmosphere in three dimensions as well as topographical processes.

At each time step, the fire model runs and from the amount of fuel burnt, heat and moisture fluxes are inserted into the atmospheric model. This energy release changes the winds in the vicinity of the fire – known as 'fire-modified winds'. The feedback processes can change the direction and speed of fire spread. Coupled modelling also provides information about the structure of the fire plume above the surface and the potential for pyro-convective cloud to develop. ACCESS-Fire has been developed at Melbourne and Monash Universities.

JULES

JULES (the Joint UK Land Environment Simulator) is the land surface model in ACCESS.

The land surface scheme models process such as surface energy balances, hydrological cycle, carbon cycle and vegetation.

JULES provides the interface between the fire model and the atmospheric model.

At each time step the fire code runs it feeds heat and moisture fluxes through JULES to the atmospheric model and also passes the atmospheric conditions back to the fire model.

ROSE-CYLC

Rose-Cylc is the framework for interacting with and running the ACCESS model.

Rose is the Graphical User Interface for the ACCESS model. It is used to control settings (including the complex nested options) and to monitor the running of jobs.

Cylc is the scheduler component of the Rose-Cylc interface. It partitions the numerous individual jobs required for the ACCESS run and submits them to the supercomputer so as to minimise running time and maximise supercomputer utilisation.

Simulations for the project are run on NCI computing facilities.

PLANNED CASE STUDIES

The Coupled Fire-Atmosphere project will deliver a series of case studies including the Waroona fire in WA and the Sir Ivan fire in NSW.

WAROONA FIRE

The Waroona fire was ignited by lightning in January 2016. It burnt over 69,000 ha and more than 160 homes. There were two fatalities. Four episodes of extreme fire behaviour occurred. There were two pyrocumulonimbus events and two destructive evening ember storms associated with downslope winds.

SIR IVAN FIRE

The Sir Ivan fire, on 12 February 2017, burnt more than 55,000 ha, 32 homes a church, a community hall and the historic "Tongy Homestead". The hot, dry, windy conditions were described as the worst seen in NSW. The afternoon passage of a frontal wind change triggered development of pyrocumulonimbus cloud.

Australian Government Department of Industry, Innovation and Science | Business Cooperative Research Centres Programme

Contact person: Dr Mika Peace
mika.peace@bom.gov.au

bnhcrc.com.au

Intelligence Layers for Firefighting

Intelligence layers are geo-located data products that offer insight into the current and future situation on the fireground. They consist of calibrated primary data and derived products, such as fire risk maps.

MAPS AND GEO-LOCATED DATA

National provider State provider Private provider Local provider

FUEL TYPES & FUEL CHARACTERISTICS (FIRE RISK)	WATER RESOURCE MAPS	CIVIL INFRASTRUCTURE MAPS	FIRE PROPERTY MAPS
WEATHER MAPS	ELEVATION & TOPOGRAPHY	WATERCOURSE MAPS	WEATHER PREDICTION MAPS
FIRE & BURN HISTORY	POPULATION DEMOGRAPHIC MAPS	BUILDING USE MAPS (NEXUS)	AGRICULTURAL VALUE MAPS
COMMUNICATION COVERAGE & TOWER MAPS	UTILITIES STATUS MAPS	ROAD CLOSURE STATUS	RESOURCE LOCATION & HISTORY
LIGHTNING STRIKES			

Maps showing real-time information on the active fires are critical for safety and planning daily fireground operations. Modern simulations can predict the spread of the fire in response to fuel and weather conditions, informing strategic decisions over several days. However, the accuracy of these models depends closely on the uncertainty associated with weather forecasts and measured fuel properties. Fire spread prediction is covered in more detail in the following pages.

FIRE PROPERTY MAPS

ACTIVE FIRE HOTSPOTS	CURRENT FIRE AREA	FIRE SPREAD PREDICTION	SMOKE MODELLING & PREDICTION

All of these primary and tertiary data products feed into the difficult decision-making process around how to fight the fire. At a fundamental level this involves acquiring and directing resources in a highly uncertain and dynamic environment. Most processes have a lag of at least a day (e.g., transporting personnel or fuel), meaning that predicting spikes in demand for resources is a very desirable capability. In the following pages we cover important intelligence layers in detail.

STRATEGIC DECISION SUPPORT

FIRE SUPRESSION MODELLING	RESOURCE DEPLOYMENT SUGGESTIONS	EVACUATION MODELLING
RESOURCE ALLOCATION SUPPORT	RESOUCE ROUTING (TRUCKS, PLANT)	CONSUMABLES PREDICTIONS (FOOD, FUEL, WATER ETC.)

> *"Only 20% of firefighting personnel will be available for deployment at any one time."*
>
> **ACT RFS**

Fire Spread Prediction

FIRE SIMULATORS AND PREDICTION SYSTEMS

Fire prediction systems are user-focused tools that create maps of fire risk, or predict the direction, intensity and rate of spread of a fire as it evolves.

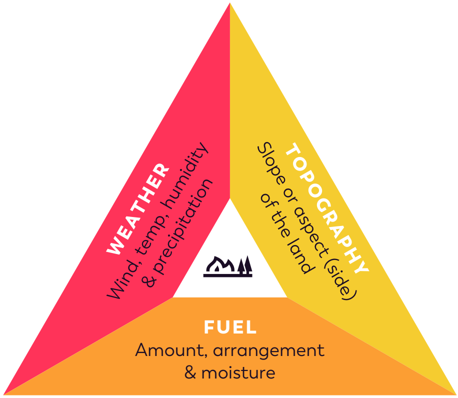
They ingest the latest information on environmental conditions and apply suitable fire modelling algorithms to make predictions, presenting the results to the user as an easily digestible visualisation. These tools are built around a core set of fire simulators – the algorithms that perform the fire behaviour calculations. Fire simulators come in different flavours:

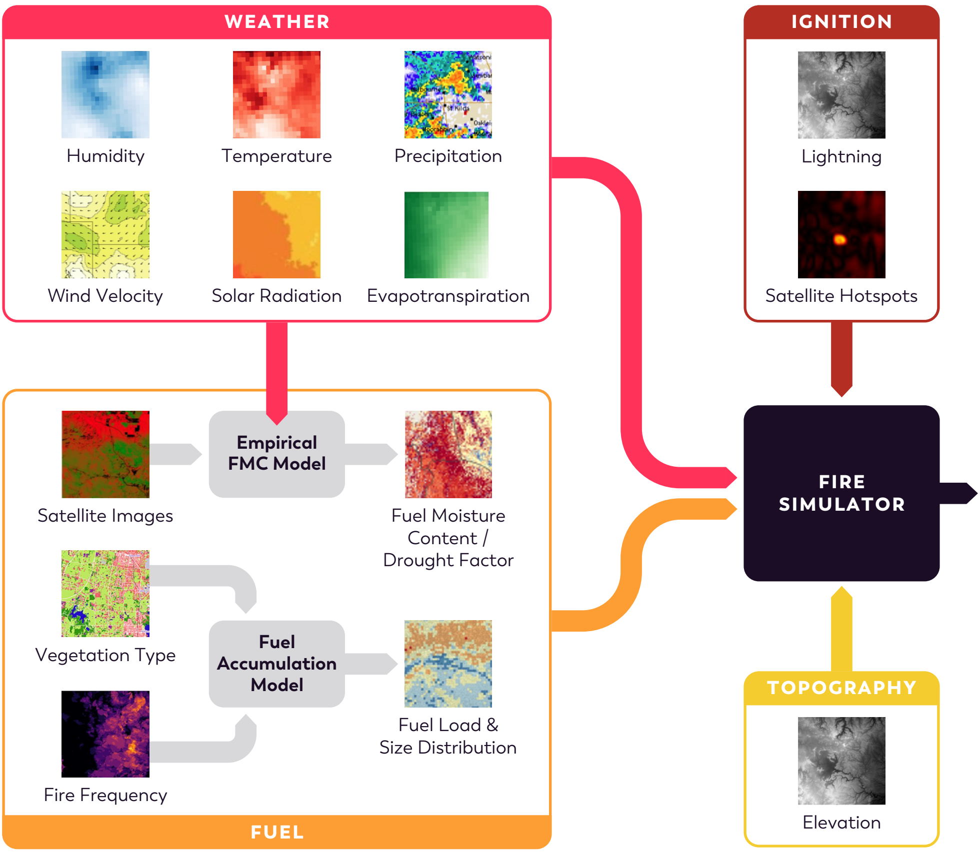
- **Empirical models** that encode fire behaviour for a limited set of circumstances (e.g., fires in cured grass). These have been developed from field measurements of real fires and are implemented as equations that map environmental conditions to fire properties, such as rate of spread, intensity and flame height.
- **Physics-based models** that calculate fire properties from fundamental physical parameters. Fire can be treated as a fluid in hydrodynamical simulations, which must take into account many complex interrelated processes such as radiative transfer, convection, turbulence and pyrolysis.
- **Hybrid models** that meld physics-based and empirical simulations.
- **Machine learning models** that learn features of input data to make predictions of fire behaviour or risk. These are currently experimental technology, but have great potential to take advantage of large archives of modern remote sensing data.

In general, physics-based modelling is still considered a research tool for understanding details of fire behaviour and is not directly used on the fireground. All currently deployed fire prediction systems employ empirical or hybrid fire simulators under the hood, choosing the appropriate one to apply for a particular situation. The prediction system feeds the simulator the latest input data and presents the results in a user-friendly format.

MODEL INPUTS

The fire behaviour triangle dictates that similar inputs are needed for all predictive models: information on weather, fuel, topography and ignition sources. Ideally, inputs should be sampled on a grid so that the predictive models produce useful maps for fireground use.





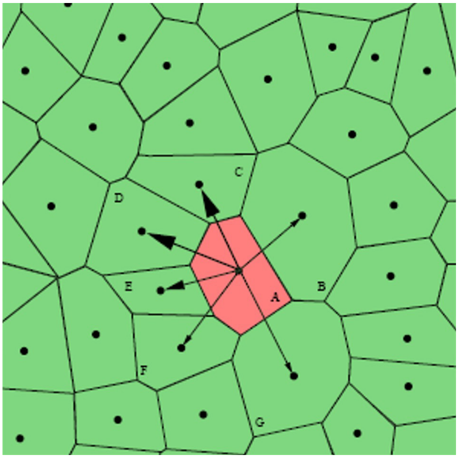
MODEL OUTPUTS

The outputs of fire simulators include estimates of intensity at the fire front, flame height, ember density and rate of spread.

Basic fire simulators produce one-dimensional outputs, however, simulators like Australis (Johnston et al. 2008, UWA) also model the spread of fire by propagating it on an irregular grid. Such cell-based spread simulators have proven to be effective when fed with accurate and timely data – a significant challenge in itself. Fire prediction systems further process these outputs into a variety of maps that address different needs, depending on the task at hand. These can be broadly sorted into two categories:

Managing Active Fires

- Predicting the path and intensity of an active bushfire as a function of time, taking into account the weather forecast.
- Planning 'backburning' to control an existing fire. This is where a new fire is lit between an active bushfire and an established control line to remove fuel and halt the spread.
- Planning the firefighting strategy during a campaign fire.



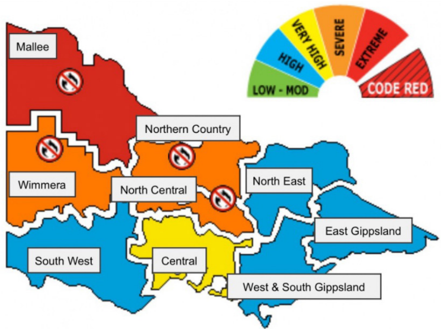
The irregular grid used by the Australis model (Johnston et al. 2008)

Managing Fire Risk

Assessing the predicted impact of fire on infrastructure, assets, communities and populations.

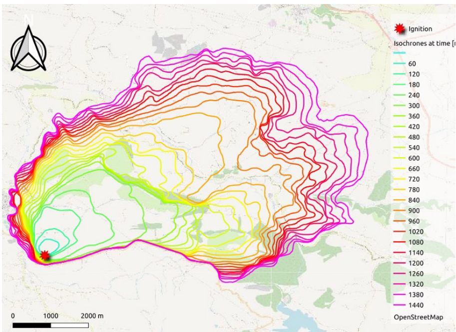
- Planning hazard reduction burns to remove fuel from the landscape (also called prescribed burns).
- Creating and updating fire risks maps, including calculating the fire danger rating for a region.

Computational fire modelling is a large field of study and also includes fuel property models, fire ignition models and models of fire effects. The outputs of fire prediction systems include maps of fire risk and fire danger index, temporal maps of fire spread, damage estimates to property and ecosystems, and ensemble simulations of fire suppression scenarios. Covering these in detail is beyond the scope of this report, but we show examples of commonly used tools on the following pages.

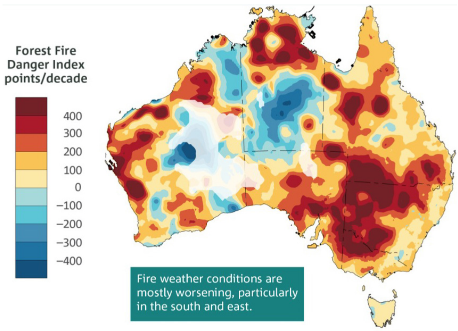


A map of fire danger index for the state of Victoria on a particular day.

A fire spread prediction map showing showing isochrones - contours outlining the burnt area at equal time intervals. The ignition point is marked by a red dot. Credit: Jackson Parker, DFES (WA).



Isochrones of a wildfire in Ittri, Sardinia, Italy as modelled by Trucchia et al. 2020.



Increase in annual sum of Forest Fire Danger Index 1978-2017. Source: BoM.

Fire Risk Assessment

The current Fire Danger Index (FDI) system has six levels that describe the potential level of danger should a fire start in vegetated areas.

Low Moderate	High	Very High	Severe	Extreme	Catastrophic

These are posted on the familiar roadside signs, shown at right. The Fire Danger Index is evaluated in two fuel types – grassland and eucalypt forests – using the McArthur empirical fire behaviour models (e.g., the circular slide-rule MK4 and MK5 fire danger meters). There are well known problems with the models, including over-sensitivity to input values and poor performance at higher danger ratings

The FDI system is being replaced (rollout 2022) by the Australian Fire Danger Rating System (AFDRS), which as been developed in a project led by the NSW RFS working with AFAC and the Bureau of Meteorology. The new system will be more accurate and spatially granular, and is evaluated in eight different fuel types: grassland, woodland, spinifex, buttongrass, forest, mallee, heath, shrubland and pine. It is designed to be calculated on a grid resolution of 1.5 kilometers and updated hourly (daily updates to public) as new weather information is received. The

For emergency services, the AFDRS will provide high-resolution maps of fire risk via a web portal. An editor interface will be available to change fuel types, as these data can be inaccurate or out-of-date.

Further in information can be found on the following links:

https://www.aidr.org.au/news/understanding-the-australian-fire-danger-rating-system/

https://www.afac.com.au/initiative/afdrs/afdrs-publications-and-reports

https://www.afac.com.au/initiative/afdrs

A roadside Fire Danger Index sign. Source: WikiMedia Commons.

CURRENT 'WORKHORSE' PREDICTION TOOLS

Aurora and PHOENIX Rapidfire are the workhorse tools of prediction efforts during normal operations. The new CSIRO Spark framework is destined to replace both tools, however, the operational version is still being developed, with support by The Minderoo Foundation.

FIREWATCH AURORA

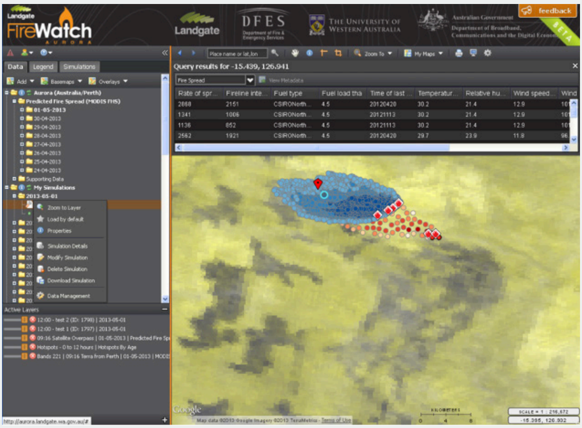
Online fire prediction tool and ArcGIS plugin

aurora.landgate.wa.gov.au

Developed by Landgate with University of WA.

Use:

- ⊠Simulate bushfires in real time and offline.
- ⊠Test fire suppression strategies.



The main interface of Firewatch Aurora showing hotspots (points) and predicted fire spread (grey shaded isochrones). Source: Landgate / DFES.

Aurora leverages the Australis fire simulator developed by the University of Western Australia. It offers the following capabilities:

- ⊠Predict and map the spread of active fires in real time from ignition sources, using latest weather forecasts.
- ⊠Run custom fire spread scenarios with user-defined ignition sources and alternative weather conditions.
- ⊠Test the effect of fire suppression actions, such as creating firebreaks in the

PHOENIX RAPIDFIRE

Stand-alone prediction tool for MS Windows

firepredictionservices.com.au

Use:

- ⊠Simulate bushfires in real time and offline.
- ⊠Test fire suppression strategies.
- ⊠Create risk maps.

Stand-alone fire spread prediction software incorporating multiple empirical models internally. Outputs include spatial maps of flame height, intensity, size, and ember density, and also projected impact on assets.

Suppression scenarios can also be tested, such as firebreaks and water bombing.

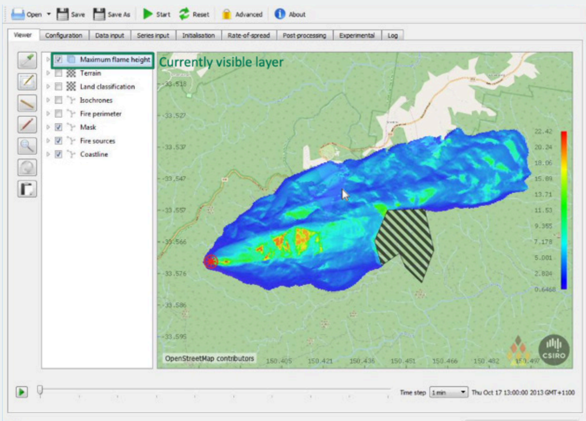
CSIRO SPARK

Flexible Web- and Cloud-Based Prediction tool

research.csiro.au/spark

Use:

- ⊠Simulate bushfires in real time and offline.
- ⊠Test fire suppression strategies.
- ⊠Create risk maps.



The CSIRO Spark interface presenting a map of predicted flame height. Source: Spark Applications User Guide.

Latest-generation fire modelling tool that wraps up many fire simulation models. Spark aims to supersede Phoenix and Aurora, offering a highly customisable user interface for adding new gridded data inputs, integrating new models as scripts and specifying time-series variables. Runs on CPUs and GPU (faster).

Model uncertainties can be explored by performing multiple runs (ensemble modelling) and some highly experimental models are offered for testing, such as spot fires from firebrands, or disruptions to fire spread from barriers (roads, firebreaks). Highly customizable and can integrate live data feeds (e.g., satellite hotspots).

Back-end service and API for integration with other tools.

OTHER FIRE INTELLIGENCE TOOLS AND SYSTEMS

A number of other tools exist (or are in development) to query, visualise, or otherwise process information relevant to bushfires:

FORESIGHT (VIC)

An online bushfire risk visualisation tool.
foresight.help.ffm.vic.gov.au/introduction

FORESIGHT

Developed by Victoria Predictive Services Victoria with DELWP.

Use:
- Assessing fire risk risk based on latest weather data.
- Victoria Only.

- Interactive map of key bushfire risk variables across Victoria.
- Selectable layers and time-series data from spatial cells (meteograms).
- Forecast 1 week in advance.
- Designed for bushfire managers to assess fire risk in the landscape (not for predicting path of a bushfire in progress).

Data & Models:
- BoM Gridded Weather product, produced by the Graphic Forecast Editor (GFE) system @ 3km res.
- FireMod System by DEWLP for fire behaviour and risk predictions.
- FireCast system, running Phoenix fire simulator under the hood. 1km grid across entire state.
- Weather information updates twice per day.
- FireCast predictions are created after morning weather update. Based on ~288K test ignitions.

NAFI (NT, QLD)

Online bushfire risk visualisation and active fire monitoring tool.
firenorth.org.au/nafi3/views/help/Info_hub.htm

Developed by the Darwin Centre for Bushfire Research.

Use:
- Tracking active fires.
- Visualising burnt areas.
- Reporting on historic burn patterns and gas emissions.
- Aggregating data (WMS).
- NT and QLD focused.

- Display active fires using hotspots, including visualisation of hotspot timings and spread.
- Display historical fire scars, including how recently areas were burnt (proxy for fuel load).
- Display latest satellite images & lightning strikes.
- Create formal reports on polygon-selected area: 1) Fire History, 2) Fire Scar By Year, 3) Species Booklet (threatened species and pests in NT only).
- Set otspot email alerts for custom area.
- Capabilities offered as a web map service (WMS)

Data:
- Firescars: Darwin Centre for Bushfire Research (NT), Cape York Sustainable Futures (QLD).
- Hotspots: Geoscience Australia and Landgate.

CSIRO AMICUS

Interactive map of Western Australia showing warnings for fires, floods, tsunami, earthquakes, storms, cyclones and hazardous materials. Also shows the current fire danger rating map.
emergency.wa.gov.au

EMERGENCY WA

Older fire simulation software that wraps empirical models. Outputs are 1D time-dependent graphs.

USE OF FIRE SPREAD PREDICTIONS IN PRACTISE

Initial Attack

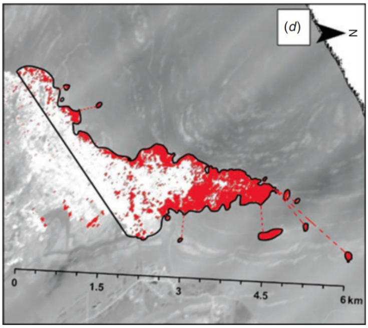
If available immediately, fire spread predictions can aid the first responding crew in planning initial attack on fire. These crews have limited access to technology and so tend to use low-tech solutions, such as the MacArthur Forest Fire Danger Meter or rules-of-thumb.

Ongoing Operations

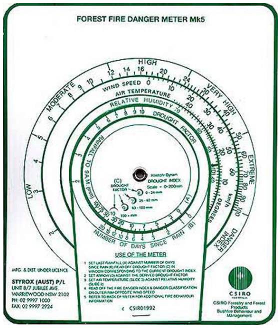
During ongoing operations of a campaign , fire spread predictions are created by the dedicated mapping team embedded within the IMT, or attached to a regional hub of a fire service. These teams collate the static map layers, recent fuel and weather information, and dynamic fireground data as inputs to the models. They run the simulations and produce fire spread maps to include with the incident action plan. These are updated as new information becomes available (e.g., from the fireground as manual fuel moisture content measurements, hand-held weather measurements, or from the upstream providers like GA and BoM).

Australian bushfires in eucalyptus forests can propagate through 'spotting'. This is where bark or other burning fuel is lofted into the air and deposited on an unburnt site in font of the main fire front. These secondary fires pose a significant danger, often starting up to 30 km away and merging into significant fires in their own right.

CHALLENGES AND LIMITATIONS



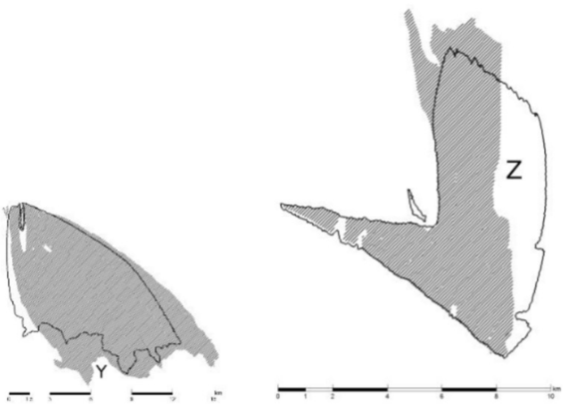
Spotting during a fire in Victoria. Source Storey et al., 2020 & DEWLP



The McArthur Mk5 Forest Fire Danger Meter

The current technology models could be improved by:

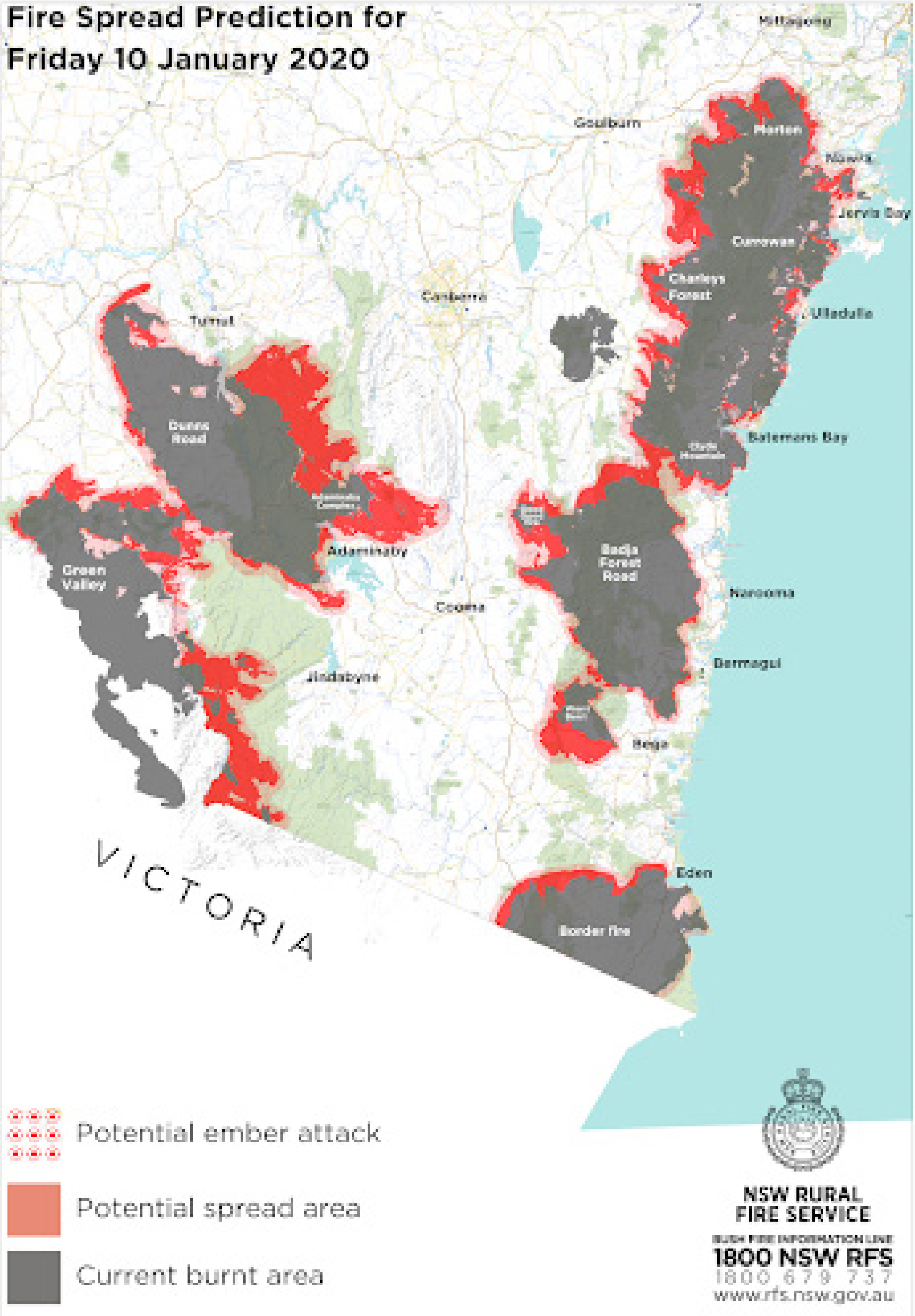
- Relying on very uncertain data as inputs.
- Input data on fuel conditions coarse and sparse for Aurora & Phoenix Rapidfire.
- Results can be inaccurate because uncertainties in input data and empirical models compound each other.
- Note that computational power not a limit (was for smoke modelling in 2020?).
- Australian fires are unique in ability to propagate via spotting – lofting of firebrands to start fires up to 30km away.



Phase 3a: 1900
kappa = 0.33

Phase 3b : 2359
kappa = 0.42

At left: Figure from Milne et al. 2014 comparing final fire perimeters estimated by Australis (black line) and the ground truth fire scar (shaded area). The region marked 'Y' on the leftmost plot was under-predicted due to vegetation mapping inaccuracies, while the region marked 'Z' on the rightmost plot was over-predicted due to inaccurate weather data. Accurate input data is a key requirement of predictive models.



Fire spread prediction map from the NSW Rural Fire Service.

Photo Credit: *Gary Hooker, ACT RFS.*

Water Resource & Point Maps

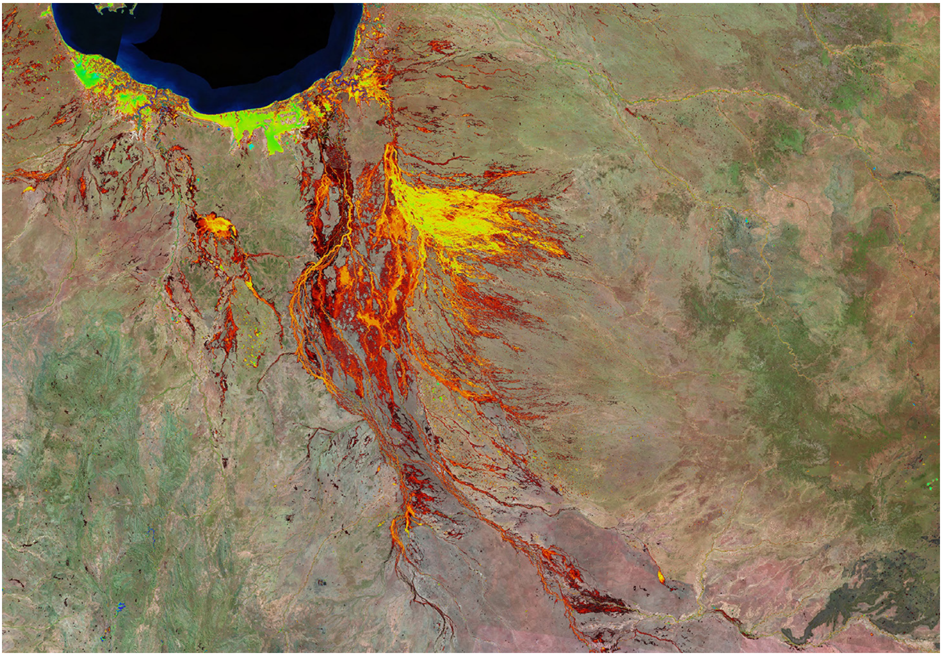
Up-to-date hydrology and water resource maps provide essential information for fighting fires. Water is used to suppress fires directly by spraying the active fire front: from the ground using trucks and hoses, and from the air using helicopters and aerial water-bombers.

Trucks and helicopters remain at the fireground after deployment, and refill locally by dipping into nearby water sources, such as ponds and dams. They need to know which sources are clean, available for use, have sufficient depth, and are accessible by ground or air.

Aside from natural water sources, firefighters may be able to draw from standpipes and water tanks if permission is granted by the owners. Water is a precious resource in rural areas and the fire services undertake to replace water used to fight fires. This means that crews who take water from a farm or community resource must estimate the volume extracted so it can be replaced later.

The intelligence layers below show where water is available and suitable (blue background) and what factors influence access (yellow background).

Water availability map (surface area + history)	Water occupancy (near real-time)	Water depth	Suitability / use / pollution	Stand-pipes, Tanks & Hydrants
Elevation & DEM Maps	Power line locations	LIDAR derived canopy maps	Roads & tracks	Obstructions & access routes



The image shows the percentage of time since 1987 that water was observed by the Landsat satellites on the floodplain around Burketown and Normanton in northern Queensland. The water frequency is shown in a colour scale from red to blue, with areas of persistent water observations shown in blue colouring, and areas of very infrequent water observation shown in red colouring. The image is part of the Water Observations from Space product, available for all of Australia. Source: Geoscience Australia

Examples of suitable and unsuitable sources are below.

CHALLENGES:

- Not easy to assess access routes in advance, so this information needs to be communicated from the fireground.
- Access to water for helicopters is assessed by ground crew and pilots together, including landing sites.
- Remote sensing from satellites and drones can help show where water lies, but can lag current conditions by up to a week. Also difficult to determine water occupancy and depth accurately.

SUITABLE	Rivers, creeks	Private reservoirs (permitted)	Pool at staging ground	Bulk water tanker
UNSUITABLE	Sewage ponds	Private reservoirs (denied permission)	Runoff ponds	

Communications: The System Backbone

The communications layer is the backbone of fireground operations. Every operation relies on the ability to reliably pass information around the fireground, between all levels of the emergency management apparatus.

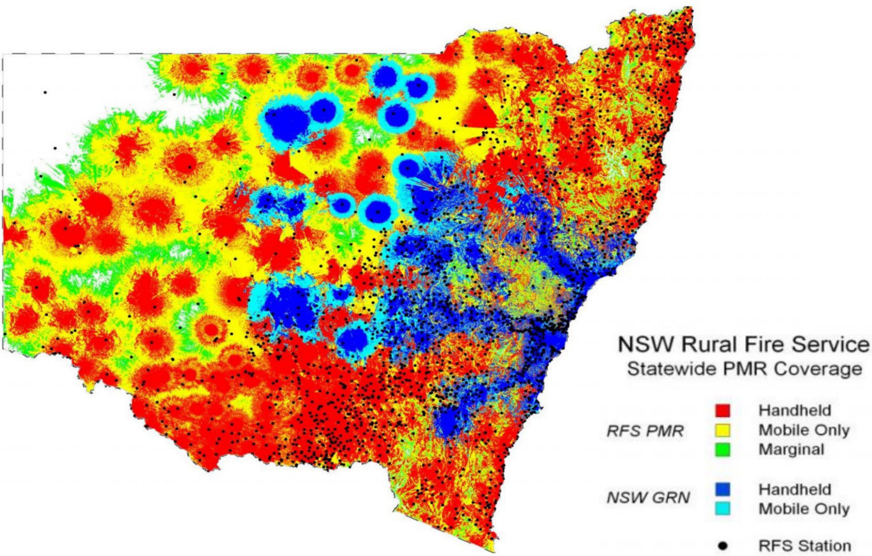
Firefighters currently rely on the following systems in order of reliability:

Government Radio Networks (GRN, TRN, NTESTN, GWN, SAGRN, RMR, TasGRN)	Voice communications to appliances, between IMT and division commanders. Limited data traffic to mobile data terminals.	Covers a high percentage of each state (> 90% typically), but also has poor coverage in some areas. Can link to the telephone/4G network and be enhanced by mobile repeaters on, or adjacent to, the fireground.
CB Radio	Voice comms between crew on the fireground and to crew leaders.	Used generally for local comms within teams – most carry a CB in addition to a GRN-capable radio.
4G Mobile Network	Voice communications. Almost all high-capacity digital data services for downloading maps and documents.	Poor coverage in rural areas and drops out rapidly away from urban areas.
Satellite Phones (Iridium)	Voice communications. Limited and slow data rate.	Worldwide coverage, but very expensive and so reserved for areas with no other communication options.

The deeply integrated data-rich system advocated by this report is reliant on a reliable wide-bandwidth communications system. The data-rate is only met by the current 4G mobile network, which is highly unreliable in the rugged rural areas where fires are fought.

CHALLENGES/SHORTFALLS:

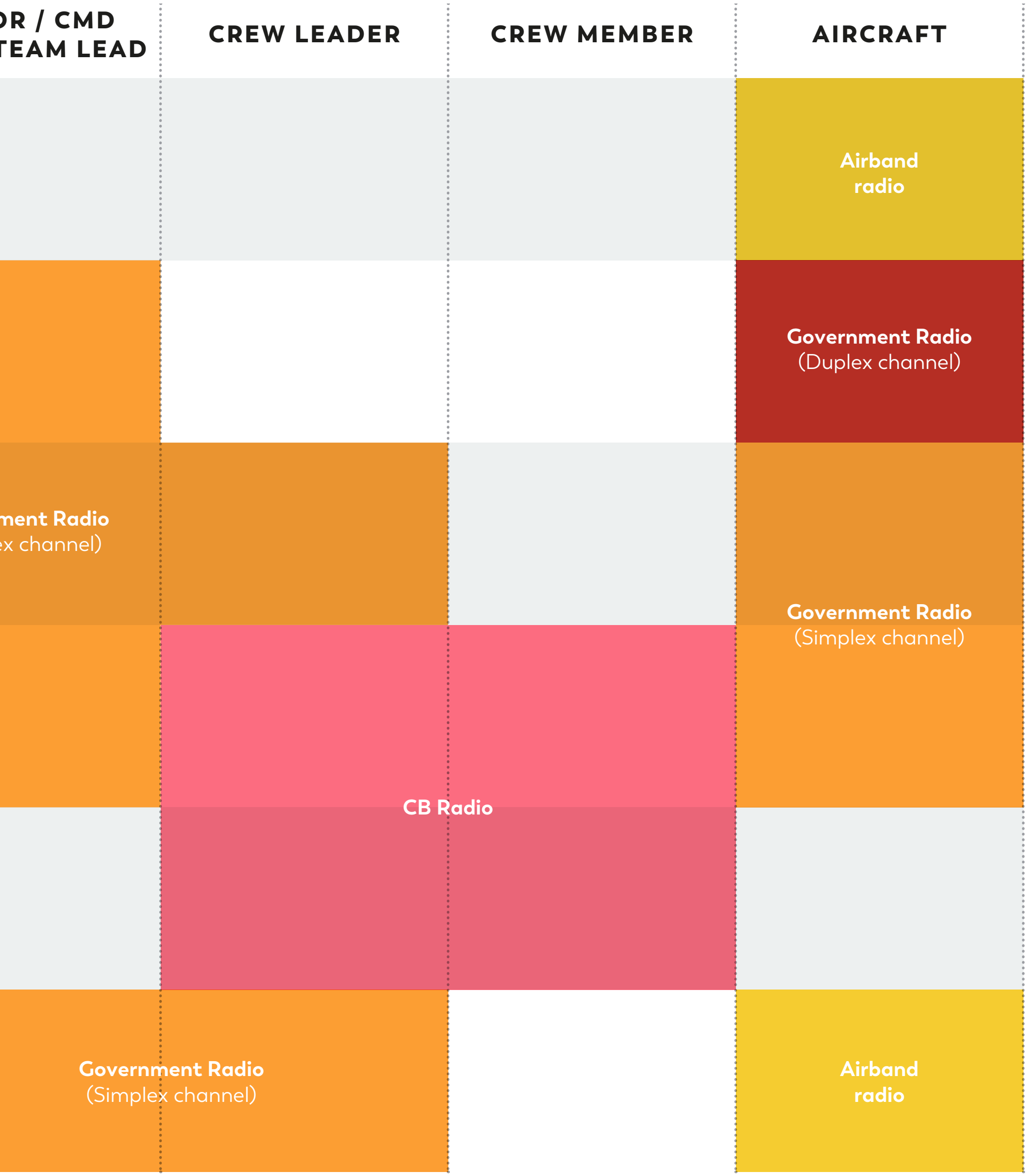
- Ad-hoc/organic system design and development, driven by what is available as opposed to what is needed.
- Staggered degradation, whilst a multi layered system provides levels of redundancy failure is not seamless and requires operator input/effort to coordinate transition between primary to fallback comms..
- Low data rate/throughput creates high reliance on voice comms demands significant operator input and engagement to report on routine activity – detracts from core duties?
- Reliance on systems designed for terrestrial environments to be employed in remote settings, poor connectivity increases risk to life of operators and reduces fire fighting effectiveness.



Source: http://arcia.org.au/wp-content/uploads/2019/03/economic-_report_-on_-the_-value_-of_-lmr_-services_-in_-australia.pdf

COMMUNICATIONS NETWORK: CURRENT SYSTEM PRACTICE AND INTEROPERABILITY

	IMT	DIVCOM	SECTO STRIKE T
IMT	**Government Radio** (Duplex channel), **4G Cell or Satellite Phone**		
DIVCOM			
SECTOR / CMD STRIKE TEAM LEAD			**Governn** (Simple
CREW LEADER			
CREW MEMBER			
AIRCRAFT	**Airband radio**	**Government Radio** (Duplex channel)	


OR / CMD
TEAM LEAD
CREW LEADER
CREW MEMBER
AIRCRAFT
Airband
radio
Government Radio
(Duplex channel)
ment Radio
ex channel)
Government Radio
(Simplex channel)
CB Radio
Government Radio
(Simplex channel)
Airband
radio

Government Response to the 2019 Fires

The unprecedented megafires in eastern Australia during summer 2019/2020 proved to be a significant test of fire management policy and procedures. In many ways the response by fire agencies was excellent, having especially benefited from the recommendations of the 2009 Victorian Bushfires Royal Commission.

However, the sheer size of individual fires, number of fires and extreme fire behaviour took even experienced firefighters by surprise. The scale of the operation needed to fight these blazes severely stretched the capacity of fire and emergency services. Fire authorities were often operating without information and only reaching remote fires well after ignition, making the task of quenching or containing the fires much more difficult.

Follow-up reports, such as the Royal Commission into Natural Disaster Arrangements, the NSW Bushfire Enquiry and the Bushfire Earth Observation Taskforce Report, all conclude that technology and data will have an increasingly important role in preparing for and responding to bushfires. All these reports recommended that barriers between government agencies should be lowered, and that data and technology should be shared more readily between and within states. The private sector also has a role to play by rapidly driving innovation and boosting research efforts. This will enhance all capabilities and really push the boundaries of what is possible, increasing resilience to all natural disasters.

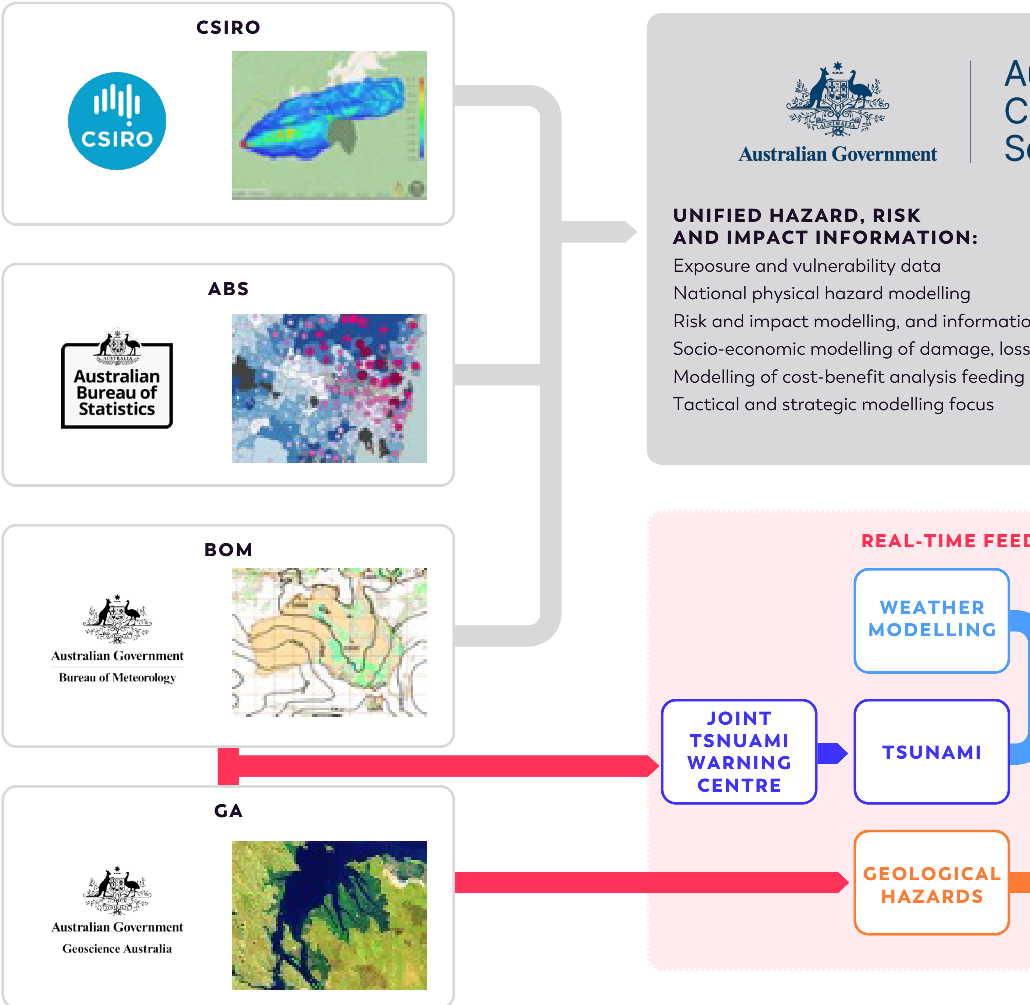
The following pages detail some of these efforts.

Photo Credit: *Gary Hooker, ACT RFS.*

AUSTRALIAN CLIMATE SERVICES (ACS)

acs.gov.au

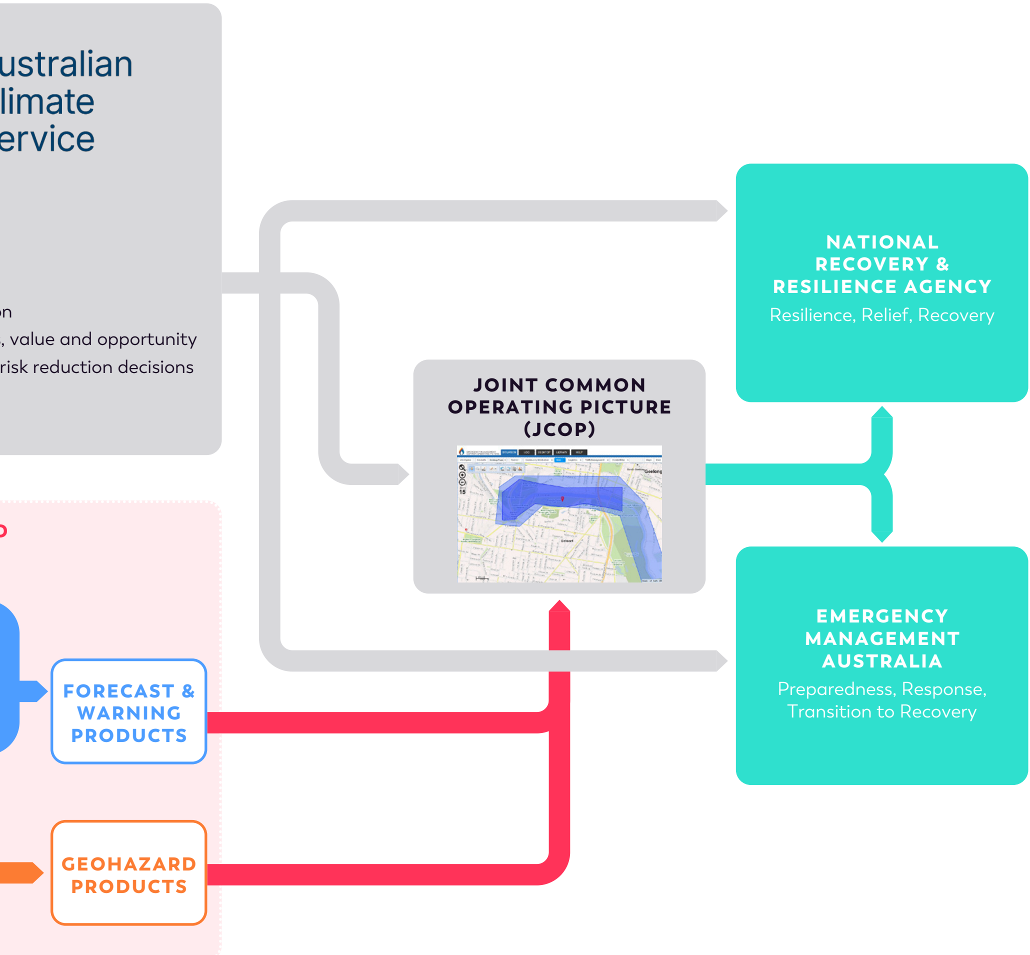
The ACS (initially called CaRSA) was established in 2020 in response to recommendations made by the Royal Commission into Natural Disaster Arrangements as a 'virtual agency' with the mission of integrating "Australia's extensive climate and disaster risk information into a new single national view to meet the significant information challenges in managing natural disasters". It presents information from four major government agencies, as in the diagram below.



Initial work is happening in federal government, with two agencies as internal clients of ACS: Emergency Management Australia lead the federal government disaster and emergency management response.

The new National Recovery and Resilience Agency incorporates the National Drought and North Queensland Flood Response and Recovery Agency and the National Bushfire Recovery Agency.

Tools and services are offered through a new Natural Hazards Information Hub web page, similar to the existing EM-Link page.



Credit: Based on a diagram presented by Brian Foo at the EMSINA Capability Meeting 2021

Australian Government
Department of Home Affairs

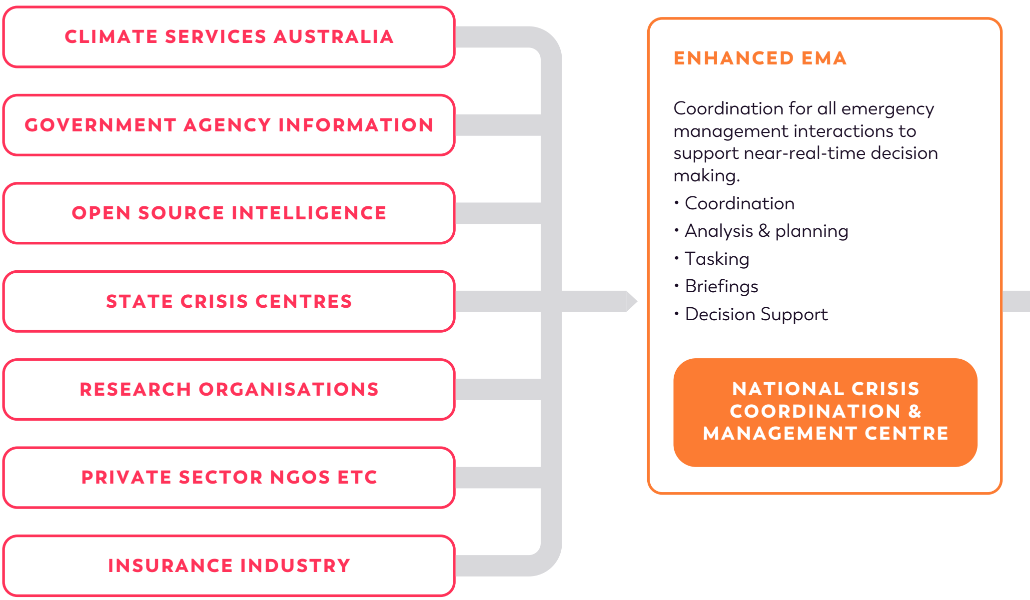
EMERGENCY MANAGEMENT AUSTRALIA (EMA)

Emergency Management Australia (EMA) is an agency that sits within the Department of Home Affairs and is the central coordinator for disaster response. It works to prevent, prepare and respond to disasters and emergencies.

Australian Government
National Recovery and Resilience Agency

THE NATIONAL RECOVERY AND RESILIENCE AGENCY (NRRA)

The National Recovery and Resilience Agency (NRRA) supports resilience, relief and recovery efforts in the community. It has a strong focus on locally-led programs to support communities affected by disasters, and also delivers initiatives to reduce risk and lessen impact of future events.

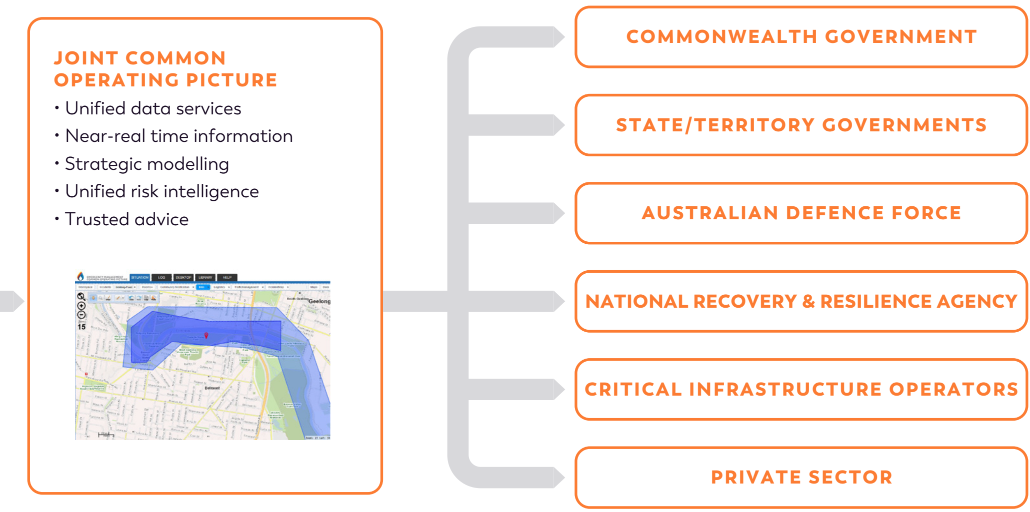


Priorities for both agencies include:

- Creating a Joint Common Operating Picture (JCOP) at the federal level.
- Looking at how to better use automation to draw data from CSA, states and territories.
- Integrating civilian and military operating pictures; the military are involved with disaster response in a 'search and rescue' role.
- Conducting national exercises for training and preparation.
- Engagement with private sector via the Australian Government Crisis Management Framework.

Key questions for the Joint Common Operating Picture (JCOP):

- What is the current situation, short term forecast and likely impacts?
- What are the broader community and strategic consequences?
- What actions are being taken by the commonwealth government?
- What is the response capacity at State and Territory levels.
- What is the projected effort needed for the next 3, 7, 14 or 21 days?
- What assistance or support might be required on those timescales?



Credit: Based on a diagram presented by Brian Foo at the EMSINA Capability Meeting 2021

PART 2

Data, Technology & Opportunities for the Future

The data and technology revolution in firefighting and where investment will have the greatest impact

Photo Credit: *Gary Hooker, ACT RFS.*

Map of the Opportunity Space

Space

REMOTE-SENSING, WEATHER & GIS DATA	FIRE IGNITION DETECTION
FUEL TYPE AND STATE MAPPING	FIRE RISK PREDICTION
INTELLIGENT WARNINGS FOR FIREGROUND PERSONNEL	EDGE DEVICE COMPUTING
FIREGROUND DATA FEEDS & SENSORS	REAL-TIME SITUATIONAL AWARENESS
STRUCTURED & BESPOKE FIREGROUND INFORMATION	DEPLOYMENT AND CREW HEALTH TRACKING

Ground

Fireground

Crew /

Over the next decade, technology, machine learning and data services will have an enormous impact on how fires – and other disasters – are managed. Intelligent tools and data–systems will inform risk assessment, preparation for fire seasons, firefighting activities and recovery. We call this 'cyber–infrastructure' for disaster management.

- **CHANGE TRACKING: FIRE & SMOKE SPREAD**
- **IMPACT & RECOVERY MAPPING**
- **ML & PHYSICS-INFORMED FIRE SPREAD MODELS**
- **FIREFIGHTING RESOURCE MANAGEMENT & PREDICTION**
- **PROBABILISTIC FIRE SUPPRESSION MODELLING**
- **AUTOMATED REPORT GENERATION**
- **LOCAL UPDATE OF MAPS AND MODELS**
- **COMMUNICATIONS ROUTING & INTEROPERABILITY**
- **FAST INTEGRATION OF NEW DATA TO PRACTICAL MAPS**

Opportunities detailed here

FUTURE COMMUNICATIONS

The provision of robust data services reaching down to individual crew on remote fairgrounds will enable a paradigm change in firefighting. Here we explore the design thinking around future communications.

A 'MINI-COP' ON THE FIREGROUND

Intelligent, connected devices with mapping capabilities are already in use on the fireground. We imagine the capabilities and benefits of a next-generation integrated device, informed by the challenges reported by firefighters.

FIRE SUPPRESSION MODELLING

Probabilistic fire spread modelling will not only make accurate predictions based on real-time data, but also be capable of recommending the best firefighting tactics to deploy in particular situations

INTELLIGENCE ON THE EDGE

Complex modelling and data-processing can increasingly be done on compute-constrained devices. Moving intelligent capabilities to 'edge devices' – mobile devices on the fireground or satellites in orbit – insulates against comms dropouts and greatly accelerates time-to-action.

DIGITAL TWINS FOR FIREGROUND MANAGEMENT

Comprehensive near-real-time data feeds and robust ensemble modelling capabilities will enable the creation of true digital twins firegrounds. This system will support high-level strategic decision making, helping manage resources across multiple fires over long timescales.

OPPORTUNITY

Future Communications

The need to ensure a seamless flow of information between management levels spanning operational firefighters and the IMT undoubtedly remains as prevalent today as it will be tomorrow.

> Break down cultural communications barriers by regularly sharing staff between organisations, outside of the stressful fire seasons.

The communication systems that are currently in use are predominantly based on single network, standalone voice comms systems with limited ability to distribute data dynamically, this technology is rapidly becoming outdated and is subject to significant bandwidth and coverage restrictions. These limitations collectively restrict the effectiveness and efficiency of current systems and therefore present a critical risk to the lives and safety of the firefighting community.

The rapid development of high-speed wireless communications networks ensures that the future firefighting architecture has the potential to integrate and exploit a range of highly capable technologies that have previously existed as standalone entities. These developments present the opportunity to deliver a range of benefits that could significantly enhance the speed and effectiveness of current processes whilst also greatly increasing resilience in the communications layer, and therefore the safety afforded to those who are placed in harms way.

A future communications architecture that can deliver these benefits will require a range of core attributes: Capacity, Coverage, Concurrency, Control, Availability, Resilience, Mobility, Interoperability and Security (C4ARMIS).

Capacity
Significant order of magnitude increases in the useable bandwidth available across user networks is required to allow rapid distribution of data (both static and real time) between firefighters and the IMT.

Coverage
Access to the network across all geographic areas of operation is needed. Current and legacy solutions are prone to 'black spots, i.e. intermittent areas of connectivity due to physical obstacles and working outside of

the range of network access points.

Concurrency

An expectation for an increased number of users on the network implies a need for a proportional increase in the concurrent number of active network connections.

Control

Enhanced network capability inherently gives rise to greater network complexity which could offer management trade-offs depending upon the needs of the operational situation at a given time. I.e. the coverage spot beam of a SATCOM network could be traded for bandwidth in the event that users are operating within a smaller footprint. The extent to which end users wish to actively manage the network must be considered.

Availability

The seasonal nature of bushfire activity could give rise to a network architecture that has variable performance attributes throughout the year. A higher likelihood of requiring greater bandwidth during the bushfire season could present an opportunity to tailor network access with suppliers accordingly.

Resilience

Overarching network resilience can be considered to be a product of:

a. Redundancy. The number of discrete links available in the event that primary bearers fail

b. Reliability. The likelihood of a single link failing and the need for redundant links to be employed.

c. Robustness. The effective power or signal strength above the noise floor utilized in wireless signal transmission. Greater transmission power increases the ability to communicate in environments where the network could be degraded due to electromagnetic interference.

d. Reconstitution. The ability to actively switch between network links in the event that bearers fail due to poor reliability attributed to poor robustness.

Mobility

Different wireless network access technologies; i.e. 5G, SATCOM have variable thresholds for network connectivity to be maintained whilst a user is mobile. The extent to which users require on the move connectivity will influence network design and the employment and integration of land and space-based networks.

Interoperability

Employment of open protocols to maximize user interoperability between firefighting communities which may otherwise be separated by differing technologies and standards. This will also provide a foundation for future system coherence and expansion through providing a growth path for network scalability.

Security

The extent to which access to the network is protected must be considered in order to prevent network distribution and data breaches which may be caused either deliberately or accidentally.

ENABLING TECHNOLOGIES

The implementation of a future communications architecture that is capable of meeting the needs of the firefighting community is achievable through adopting and integrating a range of existing technologies that are already in use across Space, Air and Ground domains.

AIR AND SPACE DOMAIN

Satellite Communications (SATCOM)
SATCOM technology has developed significantly over the past decade and is expected to continue to grow at pace in order to meet the predicted demand for broadband network connectivity across the globe, both in established and remote locations.

Strong industrial competition between SATCOM service providers has ensured that network performance has increased at pace whilst the cost/bit has reduced dramatically owing to strong market demand and decreasing satellite launch costs. A range of service providers exist to meet market demand, these include established service providers, operators and manufacturers such as ViaSat, IntelSat, EutelSat, Avanti and Airbus and also includes new entrants to the market such as Starlink and OneWeb.

High Altitude Pseudo Satellites (HAPS)
Whereas conventional SATCOM systems operate in space, the opportunity to employ lower cost alternatives pseudo satellites employing high altitude balloons or unmanned drones as airborne communications nodes is being explored across industry and a number of governments. HAPS broadly operate between 20,000ft and the stratopause (~50Km) and can establish high bandwidth spot beams over an area of operations to act as either a primary or secondary network to augment user traffic needs alongside conventional SATCOM systems. Whilst still in comparatively early stages of development, programmes such as the Airbus Zephyr initiative are underway to support the development of this technology.

GROUND DOMAIN

Terrestrial Networks

The ability to rely upon conventional terrestrial telecoms networks that offer 3g – 5g performance is greatly dependent upon availability in the area of operations. Whilst investment in satellite-based solutions can reduce the reliance on conventional telecoms, the low cost of cell phones ensures that they offer a cost effective backup or complementary solution in the event that access to a satellite network is degraded.

Portable 4G / GRN Repeaters

Ground Radio Network Repeaters enable ad-hoc hot-spots to be established, enabling point-to-point communications between users operating either in the same coverage area or through utilizing terrestrial networks to link separate user bubbles that are geographically separated. Repeaters are available in a range of sizes and configurations offering wide area coverage in open areas (~1 km radius) and/or the ability to 'bread crumb' repeaters in confined areas; i.e. caves and valleys.

Key Point

Data communications must be robust and systems designed to rely on data should degrade gracefully. Different technology is likely appropriate for different regions, but modules or system components should be agnostic to which technology is in use (self-governing). Security and cost also a concern at all levels.

CONCEPTUAL FUTURE COMMS ARCHITECTURE

The Future Bushfire Communications Architecture integrates a range of low-cost network bearers to achieve throughput performance that is orders of magnitude beyond current capabilities with unprecedented levels of end to end resilience.

AIR/SPAC

As the cost of access to space reduces the opportunity to utilis
for communications nodes within a network grows. HTS and H
resilient, high performance network conn

HIGH ALTITUDE PSEUDO SATELLITES (HAPS).

The use of high altitude balloons or unmanned drones as airborne communications nodes can create the ability to establish areas of high throughput, assured network coverage at short notice.

GROUND

Comms layer network interconnectivity between fire crews
internet and assured connectivity delivered as an end to end
remote locations would reach back to the IMT via a ve

SATCOM/HAPS G

TERRESTRIAL WID

USER N

DIRECT USER

Users operating outside of range of the fire truck hotspot would connect to the network directly either via HAPS or HTS bearers depending upon coverage, network availability and mobile handset functionality.

HOTSPOT USE

Fire trucks would
allowing a crews
one another and
the IMT via the H

FIREGROUND

E DOMAIN

se both the air and space domain as an operating environment HAPS represent two major capabilities that offer cost effective, nectivity between fixed and remote users.

HIGH THROUGHPUT SATELLITES (HTS) (SATCOM OVERLAY)

A new generation of LEO satellite constellations providing end user data throughput in the region of hundreds of Mb/s up/down link speeds are under development by companies such as OneWeb and Starlink. Network access is provided via a subscription service that is expected to be extremely low cost in comparison to conventional legacy SATCOM service providers

) DOMAIN

operating remotely of the IMT is achieved via the terrestrial service by SATCOM/HAPS providers. Fire crews operating in hicle mounted antenna incorporated into the fire truck.

ROUND STATIONS

DE AREA NETWORK

WAN

ETWORK

ER

provide a local wireless hotspot within range to communicate with send and receive data to and from TS link .

Network connectivity between the IMT and terrestrial WAN is achieved via standard commercial internet bearers. If this are not available the IMT would be equipped with a dedicated HTS/HAPS terminal and Local Area Network (LAN).

IMT

Fireground Intelligence Communications Concepts

Through the contribution provided by the participants of the Concurrent Design Workshop, it has been possible to clearly document how today's processes and practices of fighting bushfires are shaped by the availability of information that is exchanged between fire crews and the IMT.

The ability of fire fighters and the IMT to combat bushfires today is deemed to be greatly restricted by a reliance on outdated and legacy stove piped technologies which offer limited information flow and prevent accurate, timely and informed decision making. These inefficiencies present a critical and unnecessary risk to the lives of communities affected by bushfires and to the lives of those people who work to combat them.

The overall efficiency of the user processes that are underpinned by this information exchange is greatly determined by the available functionality of the supporting technology. Whilst today's heavy reliance on voice comms systems (either stand-alone radio or mobile phones) and static mapping technologies provides a basic form of direct communication and situational awareness between users, these systems are not equipped to enable future technologies which could greatly enhance the information flow through providing high fidelity, resilient, real time communications systems to enable advanced decision support tools.

Future development and investment in tool sets and underpinning technologies used to counter bushfires must seek to achieve the maximum possible benefit for a given level of investment. The relationship between a level of financial outlay in future systems and the benefits delivered to the fire fighting community is complex, in order to begin to bound this relationship a series of high-level future concept architectures are proposed with a preliminary assessment of the relative value of each. In this context 'Value' is defined as the cost of realizing a benefit and hence the cost benefit matrix seeks to consider which concept could deliver the greatest relative benefit for lowest possible cost.

The Communications Concepts that have been considered are:

1. Enhanced Current State (Voice Only)

A basic uplift of current voice systems to offer a marginal benefit against current ways of working, i.e. greater coverage and network availability.

2. Enhanced Integrated Data (Voice and Data)

An uplift of voice and data systems enabled by advanced performance low-cost satellite and terrestrial networks. This would offer significant improvements in the availability and reliability of voice and data products.

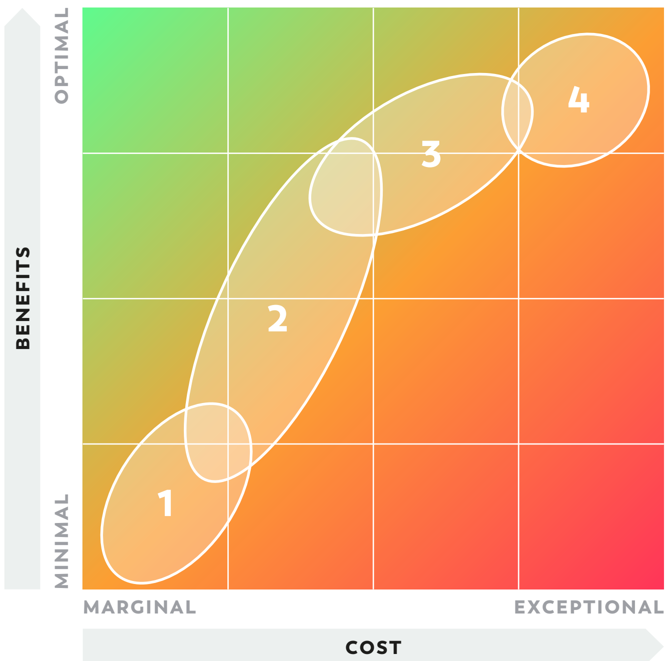
3. Augmented and Enhanced Integrated Data

A further development of Concept 2 incorporating added air and ground repeater nodes (i.e. HAPS) to further enhance network resilience.

4. Sole Source National Platform

A further development of Concept 3 incorporating a bespoke sovereign disaster/fire fighting capability; i.e. dedicated SATCOM network, incorporating Augmented and Enhanced Integrated Data.

VALUE: Cost vs. Benefits Matrix



COMMS CONCEPT 1

Enhanced Current State (Voice Only)

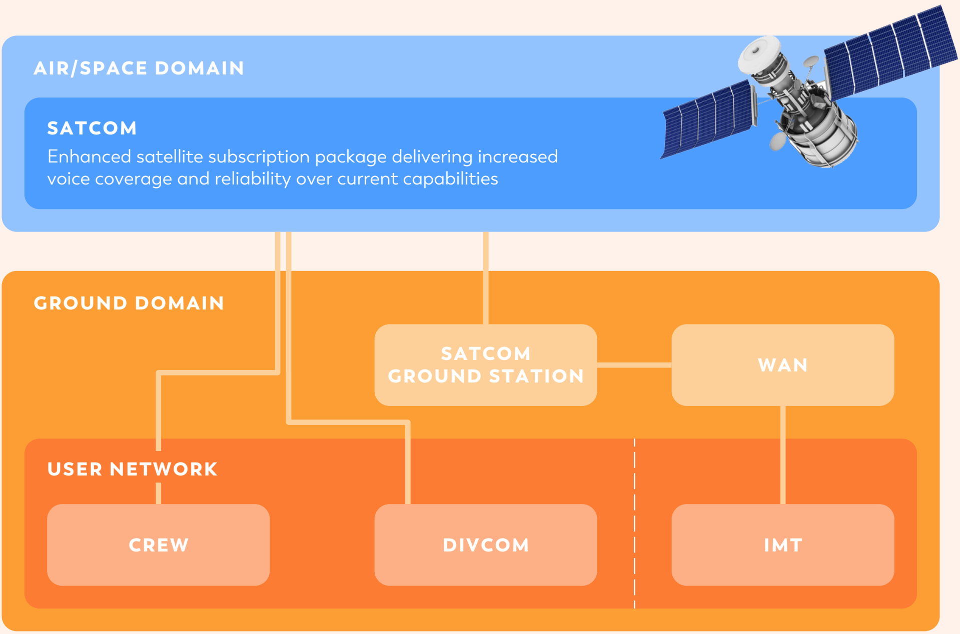
Small scale subscription uplift to commercial satcoms services, including provision of personal devices that connect with the latest generation of satellite network service providers (e.g., Inmarsat, Viasat). Effectively a better stand-alone radio.

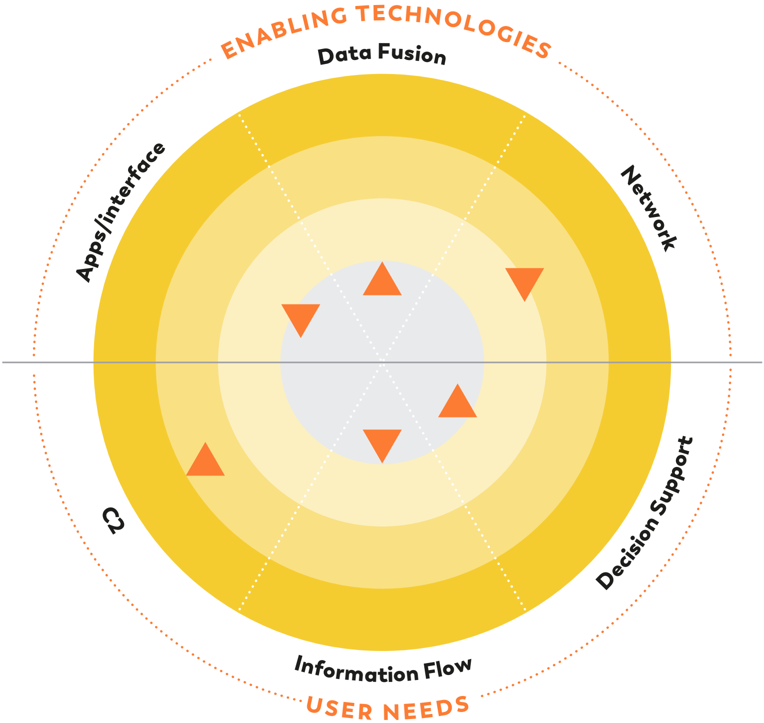
PROS

- High performance voice coverage, enhanced reliability.
- Relatively cheap compared to roll-your-own solutions (e.g., big government projects).

CONS

- Limited ability to integrate with other fireground devices, or to act as a network hub.
- Proprietary standards.
- Inability to intelligently exploit the network to compensate for issues (e.g., by forming a local mesh).





IMPACT ON ENABLING TECHNOLOGIES

Apps / Interface:
No enhancements

Data Fusion:
No enhancements

Network:
Enhanced voice-comms, no enhancement on data comms.

IMPACT ON USER NEEDS

C2:
Enhanced verbal intent and instructions. No enhancement of visual data richness.

Information Flow:
Limited by direct voice. No enhanced meta-data.

Decision Support:
No enhancement of situational awareness (e.g., with mapping etc.)

COMMS CONCEPT 2

Enhanced Integrated Data (Voice and Data)

Subscription to high throughput commercial satcoms services (HTS), integrating personal radios and data hubs/uplinks (e.g., Starlink, OneWeb, Viasat).

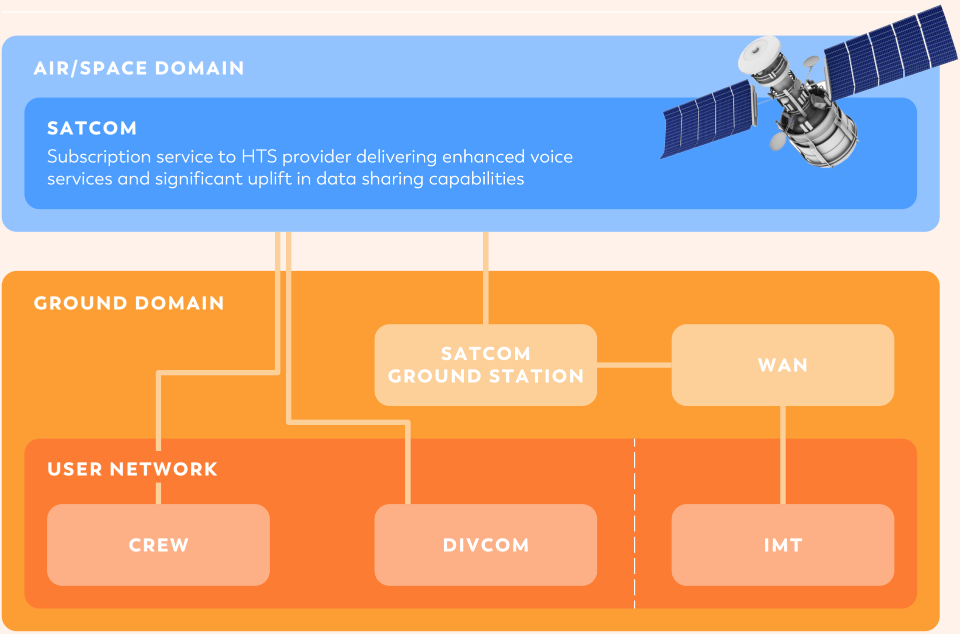
PROS

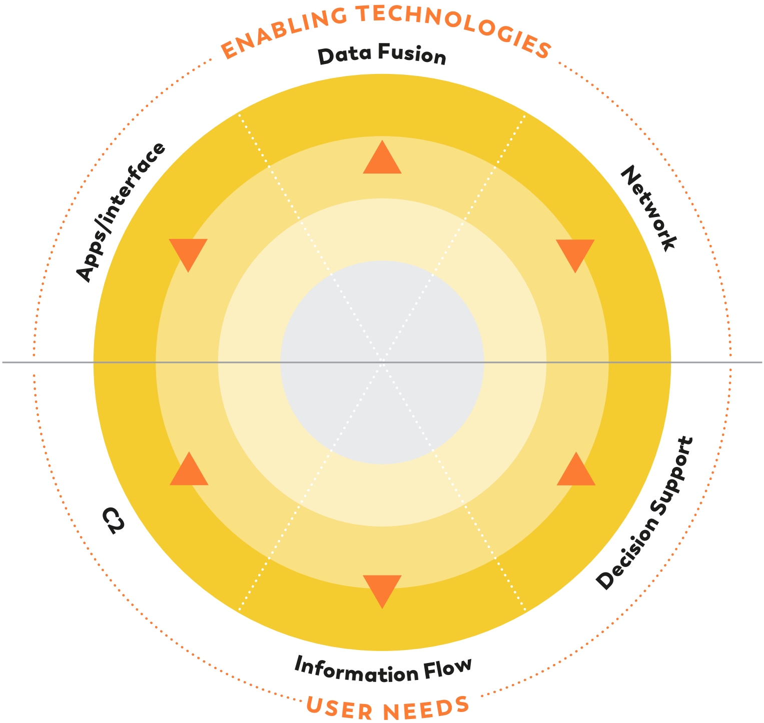
As per Concept 1, plus the following:

- High throughput data service (⊠100 MB/s).
- Significantly enhanced network resilience and availability (especially when accessing satellite constellations, compared to monolithic satellites).
- Accessing and maintaining continuous connectivity.
- Devices that can act as local wireless data routing hubs.
- More expensive than Concept 1, but greater value delivered to end-users; i.e. greater benefit for comparative costs (mid-range cost).
- Scalable to higher bandwidth with little investment.

CONS

- Cost – more expensive than Concept 1.
- May need to supplement with local networks for last mile (depends on whether crews have satellite handsets as nodes).
- Proprietary standards and interoperability may be a concern.





IMPACT ON ENABLING TECHNOLOGIES

Apps / Interface:
Enables local common operating picture (enhanced, near-real-time dynamic mapping).

Data Fusion:
Enhanced flow up/down to IMT and big data providers (mapping, prediction).

Network:
Enhanced voice, maps and meta-data to and from fireground.

IMPACT ON USER NEEDS

C2:
Ability to define and direct tasks and monitor progress in real time.

Information Flow:
Enhanced geospatial data from IMT, ground-truth data from firefighters.

Decision Support:
IMT ingesting real-time information on deployment, status, conditions and supplies. Processed at IMT (limited autonomy on fireground because of lack of sideways communications).

COMMS CONCEPT 3

Augmented and Enhanced Integrated Data

Satellite communication network, further enhanced by local repeaters. These may include a high altitude pseudo-satellites (HAPS) platforms, for example drones or balloons, and/or vehicle-mounted or backpack repeaters.

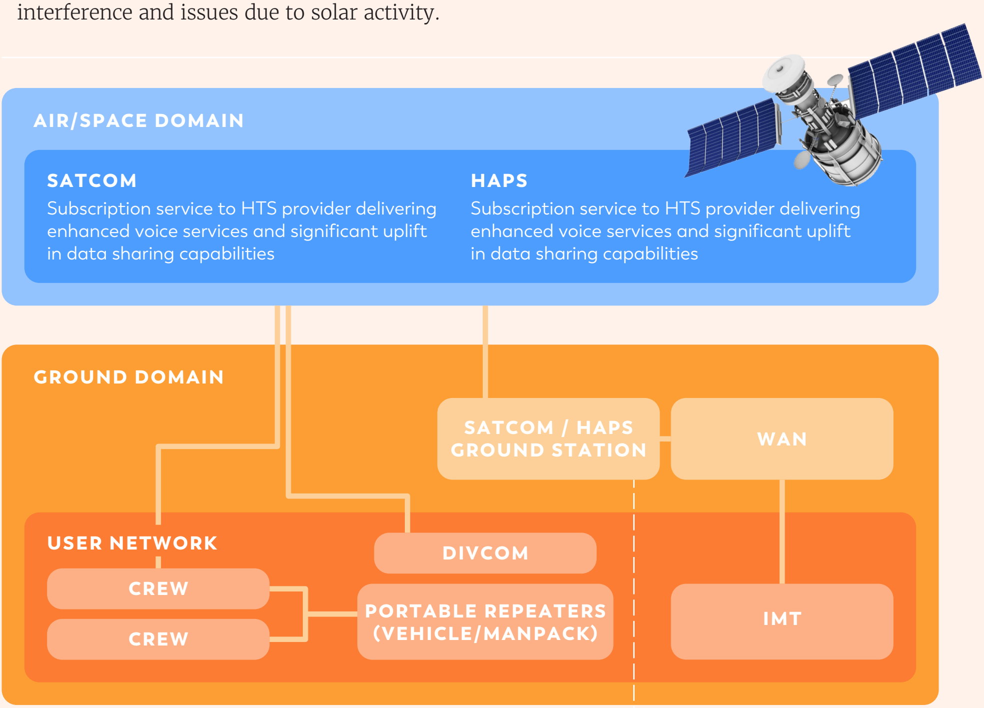
PROS

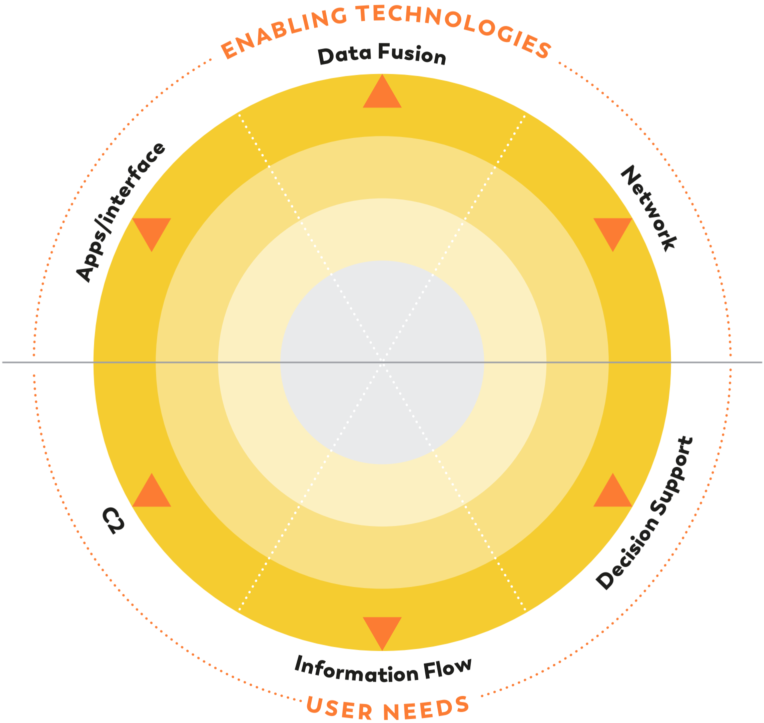
Same as Concept 2, plus the following:

- Higher degree of local network control.
- Greater robustness to satellite network issues; (although unlikely).
- Enhanced coverage in difficult terrain (e.g., canyons such as in parts of the Great Dividing Range in NSW).
- Mitigates against possible atmospheric interference and issues due to solar activity.

CONS

- Increased up-front costs.
- Considerable cost associated with maintenance, training, deployment, software and general support costs.





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COMMS CONCEPT 4

Sole Source National Platform

Sole sourced or substantial share in a dedicated purpose built satcom system, owned and operated by the Australian Government.

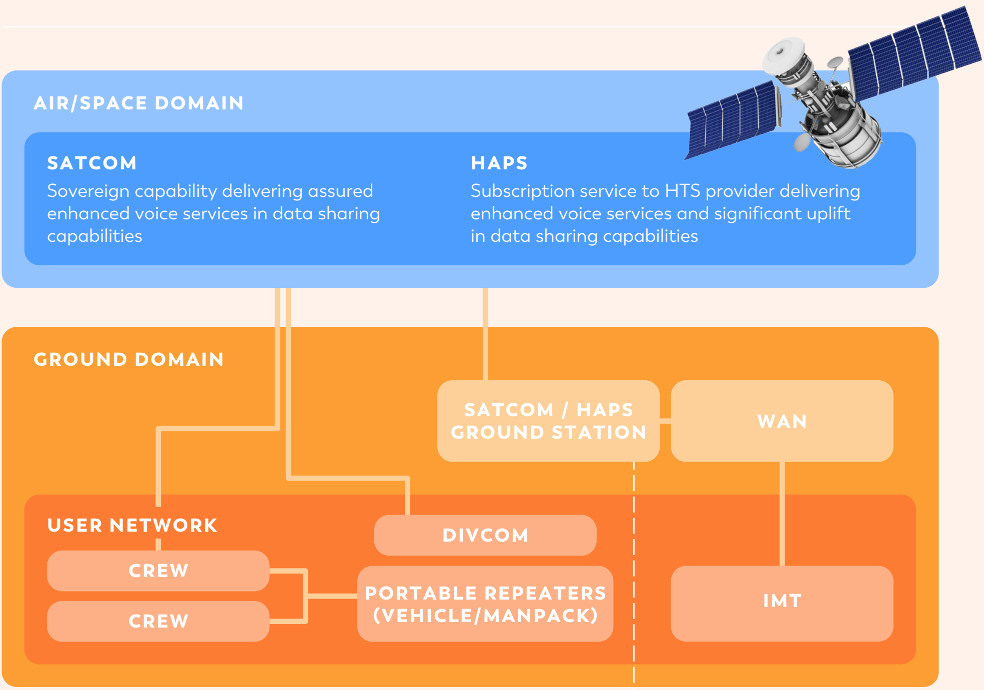
PROS

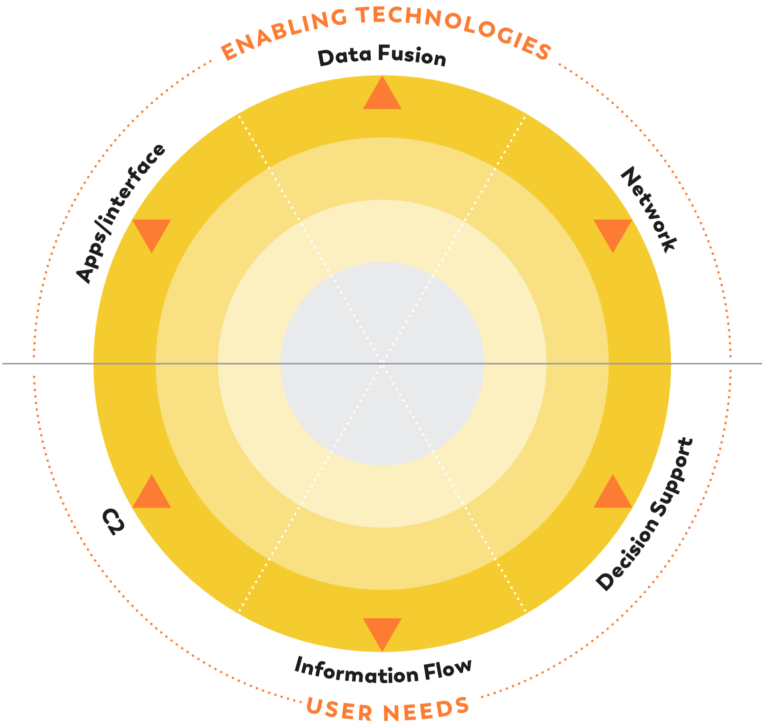
Same as Concept 2 – 3, plus the following:

- Sovereignty: High security for sensitive data.
- Optimal assurance of security.
- Significant benefits for up-skilling the Australian workforce via training and experience.
- In-house skills and future capabilities for R&D (May be worth a separate paragraph).

CONS

- Significantly higher costs.
- Marginal increase in immediate benefit.
- May be less performant.





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OPPORTUNITY

The Future 'Mini-COP' For Fireground Use

Situational awareness on the fireground at the crew level is supported primarily by the incident action plan (IAP) and a ad-hoc mix of mobile applications running on personal devices (apps commonly in use are listed in the Appendix).

Annotating changes on the fireground can be cumbersome and sharing these updates is difficult because of technological and operational barriers. Paper maps can be drawn on and shared during handover at the staging ground at end of shift, and apps like Avenza and FireMapper support sharing of digital annotations via sharing of KML files. While these systems work well, there is huge benefit to be gained from much closer integration and automation.

We propose a fully integrated digital mapping system should be available to each crew and appliance operator. This would be equivalent to the Common Operating Procedure (COP) system at the IMT, but with a simplified user interface – a Mini-COP. Only essential information would be exposed by default, with detailed (or ancillary) information available via a 'drill down' interface.

Ideally, the Mini-COP would be fully connected to other devices via a robust communication network. Changes made on an individual device would propagate instantly to other devices on the fireground and to the IMT, and beyond.

Photo Credit: *Gary Hooker, ACT RFS.*

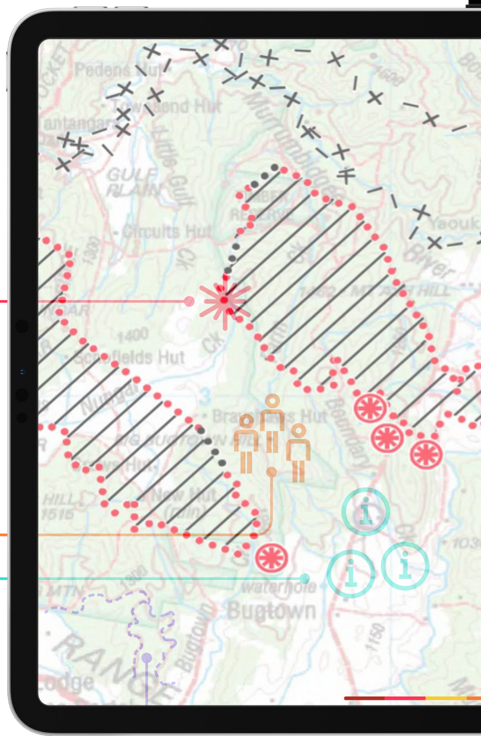
THE FUTURE 'MINI-COP' FOR FIREGROUND USE

Base Mapping Layers
Topo, Fuel Moisture, hydrology, Fuel Load, 4G / Radio Coverage

Protected Mapping Layers: Critical Assets & Utilities
Electricity, water, communications and military infrastructure; cultural sites. (Privacy issues).

Pre-emptive and automatic updates

Automated fireground weather measurements



Editable Standard annotations
(e.g., control lines, fire boundary, spot-fires, fire spread predictions, staging areas, resources).

Personal beacons / locators
Restricted permissions to view and user-controlled with a physical on/off switch.

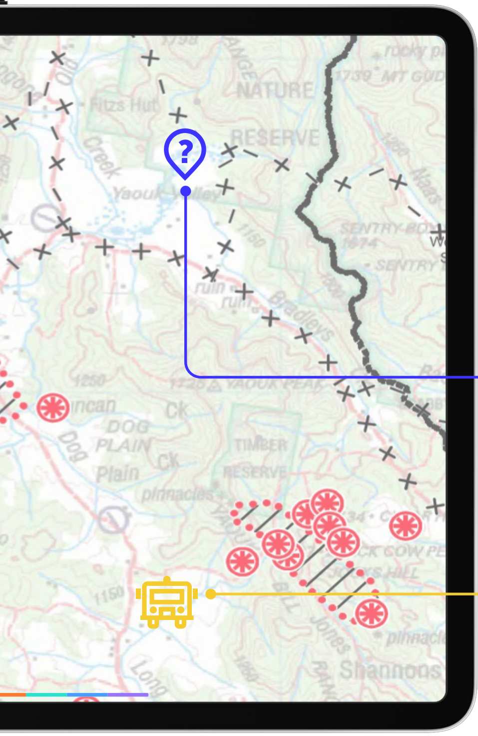
Digital T-Cards
Drill-down information on personnel and equipment next-of-kin, contact information, skills, medical notes, qualifications & training (restricted access). T-Card system also manages assignment of crews, like BART system.

Route and access marking, ad-hoc one-way systems for fireground vehicles.

Fast updates (< 1 hr)

Annotations and local weather information

Dynamic mapping layers
Fire spread prediction, smoke prediction, weather forecast, Hydrology masks with status (suitable, unknown ...), access routes



Distributed Storage
Redundant online data store (local cache to protect against comms drop)

Annotations as queries
e.g., crew marks tentative helicopter landing site to be confirmed by pilot or other authority.

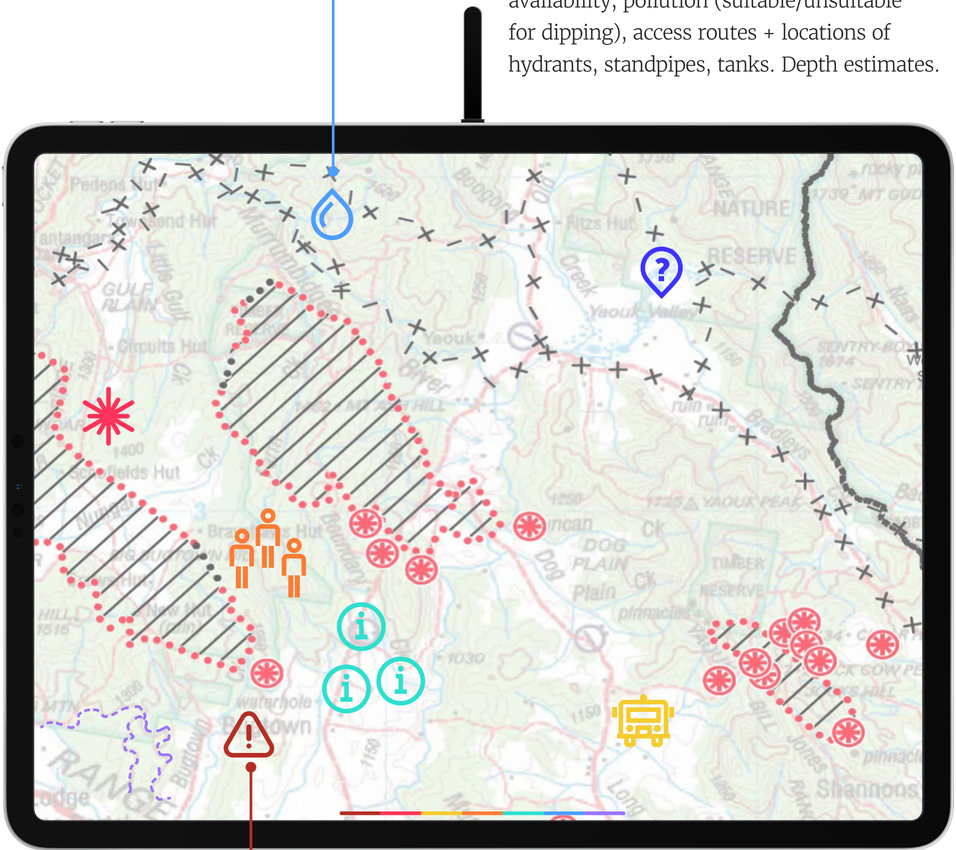
Auto vehicle location with breadcrumb trail
to indicate access. Sync to other local devices.

Map zooms to multiple scales
Ability to zoom to different scales is essential and game-changing. Detail is often obscured by symbols.

Vehicle Tasking and Status
If vehicles are flagged for your sector or incident and estimated time of arrival.

THE FUTURE 'MINI-COP' FOR FIREGROUND USE

Hydrology & water
Water sources marked with occupancy, availability, pollution (suitable/unsuitable for dipping), access routes + locations of hydrants, standpipes, tanks. Depth estimates.



Weather Monitor Points
Set smart monitor points on weather information: "Warn me if the wind changes to southerly at this location". This type of warning can let personnel know to leave before being overrun by a firefront.

OTHER FEATURES:

Dropped pins, annotations and notes
Enter notes and attach photos, mark assets, dangerous trees, record damage to property, flag repair necessary.

Estimate how much water taken for replenishment. Mark a possible water source and access routes. Mark safe retreat spaces along route. Mark route constraints (wash-away, one-way travel, no-turning circle).

Occupancy of house and intentions of residents (evacuate, stay to fight fire).

General note-taking function
That allows embedding of images, video and map cutouts. Pages would be immutable after creation, and date-stamped for auditing. Automatic backup to server

Annotated staging area map
Inset map of staging areas showing locations of resources and services.

Reports on small fires
There can be 400 fires in one day, but most do not transition to using an IMT. Could automate or flag how long to completion, freeing up resources for use elsewhere.

Public Warning System
Monitor public warning system for locally relevant information.

Context Camera
Geo-tagged photos with orientation for deprojection

Manual Weather Report Form
Information flows up to IMT and modelling team

Tasking from IMT and DivCom
Graphical/mapping tasking tool. DivCom can allocate sectors to trucks. First responders should have permission to do this for trucks arriving at small fires (designated as leadership).

Mark areas to be burnt, roads to be closed etc. User can confirm tasks and set status. How has work progressed? IMT can receive updates.

Device Reports status of crews (like current MDT), but add a confirmation of receipts and status (like WhatsApp ticks).

Permissions
Users at crew, sector and division level would have different default permissions for viewing and editing. However, these could be changed by leadership.

Selected annotations default to 'Crew Chief' 'Sector' and 'Division' level – hidden by default unless requested/turned on (this show level is separate to permissions).

KEY DESIGN PRINCIPLES: DEGRADE GRACEFULLY AND PRESENT ONLY NEEDED INFORMATION

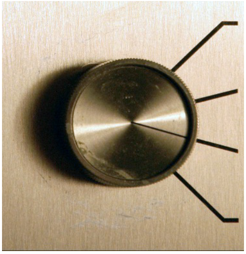
The ideal 'Mini-COP' fireground mapping tool would be fully integrated into operations and would operate with several principles in mind:

- Minimal mapping display should be the default view
  - 'Profiles' for different user roles
  - Only relevant data is given to specific users.
- Defend against role-creep and 'firefighting by data'.
- Resilience built in – failures should not disable core functionality due to simplicity and redundancy.
  - Lightweight needs for core functionality
- Aggregated data
  - Simple output, but complexity available as drill-down request.

IDEA - RESIDENTIAL BEACON:

A simple rotary-dial device, or app, for registering residents who are staying to defend their properties. Advanced versions might have:

- Ability to assign assets a protection priority order that would transmit to Mini-COP.
- Register own plant and firefighting plans.



EVACUATED

PREPARING TO LEAVE

ELSEWHERE ON SITE

STAYING TO DEFEND

BENEFIT: EASIER, MORE RELIABLE HANDOVER

The core goal of the Mini-COP and surrounding systems is to facilitate the flow in information horizontally around the fireground and vertically to-and-from the IMT. The systems should aim to do the bulk of this work automatically, without adding significantly to the workload of the ground-crew.

One major advantage of the Mini-COP is to significantly improve the experience of information handover and shift change on the fireground. Shift change is where most information is exchanged between crews, sector and division commanders ,and the IMT. Managers should be able to interrogate the reasons decisions were made and adjust plans to support residents staying to fight the fire, or who are evacuating in a particular direction.

For crews de-briefing, reflections by crew and commanders on how the efforts went should be based in evidence and data.

An integrated Mini-COP system linked to a data archive would make analysis of firefighting strategy easier, and be a treasure trove of information fueling future research.

Finally, insurance companies and claimants could access a validated account of the fire progression, backed by significant evidence.

Power and batteries
The ability to recharge devices is a significant concern in a campaign fire. This is partially solved if the staging area is near a town, however, the in an extreme fire the infrastructure of towns may be overrun and may not be relied on.

BENEFIT:
AUTOMATED REPORT GENERATION

Retrospective analysis of firefighting performance is essential to improve future firefighting efforts. Fire agencies want to know What interventions were successful?, What safety issues occurred and why? and How can we improve our efforts next time?

Fireground staff currently record and report their actions, and this information is collated by the sector and division commanders. Some time after the fire, a whole-of-fire report is compiled emphasizing:

- conditions faced and the evolution of the fire;
- work done and interventions made, and;
- the outcomes from those interventions.

This information is often recorded in ways that cannot be communicated easily (e.g., in a handwritten notebook). Digitizing this information close to the fireground and automating the reporting would:

- Subtract from the workload of the ground crew, allowing them to concentrate on more important tasks.
- Homogenize the type of information gathered and the standard of reporting.
- Facilitate the post fire analysis by making the intervention-outcome information accessible.

A large database of fire events could be better interrogated for subtile patterns that would not otherwise be obvious, with the intent of improving future firefighting policy.

- Data archive should be build to be archived and searchable for post-action review and research.

EXISTING SYSTEMS

In the ATC RFS, the Mobile Data Terminal (MDT) fulfills some of the roles of a Mini-COP (basic maps and road navigation, crew names, coarse real-time operational status). However, current MTDs have relatively small screens and are fixed to the centre-console of the fire trucks, which severely limits their usefulness.

Personal devices carried by individual firefighters are used to access broadcast mapping information, but not fireground-collected information, which remains a real gap. The table below presents some of the more notable systems.

APPLICATION	DESCRIPTION
Avenza Maps avenzamaps.com	Map display application used to load or download GeoPDF format topographic maps. **Features:** GPS location; annotate with polygons, line and symbols; import/export KML files, offline use supported.
FireMapper firefront.com.au *Fireground Application (10 users) IMT application (enterprise licence))*	Mapping application tailored for firefighting that supports annotation and sharing. **Features:** annotations and fire symbology, geotagged photos, pins with notes, automated vehicle tracks, syncs to a central server and with other users.
Zirkarta zirkarta.com	Real-time map-based project management. **Features:** Real-time map and annotation sharing across the fireground and to the IMT. Browser based, but works in offline mode with opportunistic connections.
Bushfires.io bushfire.io	Free web-based national fire and weather map. **Features:** integrates official alerts and warnings (hotspots, fire locations, road hazards), weather information, historic burn areas.
Heroiq heroiq.io	Resource and personnel management application for iOS devices. **Features:** a virtual and connected 'battleboard' with digital T-cards to track deployment of resources and people, including fatigue and skills. Full search capability.

OPPORTUNITY

Fire Suppression Modelling

Currently, dedicated mapping teams work at the IMT level or above to generate predictions of how a fire will spread over the next 24 hours.

Such maps typically show isochrones outlining the extent of the burnt area and the firefront at set time intervals (see example at right). The predictions are used to plan firefighting actions and also to create fire spread maps for public consumption.

Modern modelling tools, like CSIRO Spark, have the ability to run collections of models to interrogate (for example) the impact of a fire igniting at alternative locations, or see the effect of creating a fire break, or the effect of dropping fire retardant at a particular place.

However, this capability is manually driven and during busy fire seasons the mapping teams lack the capacity to model an ensemble of scenarios including alternative interventions to control active fires.

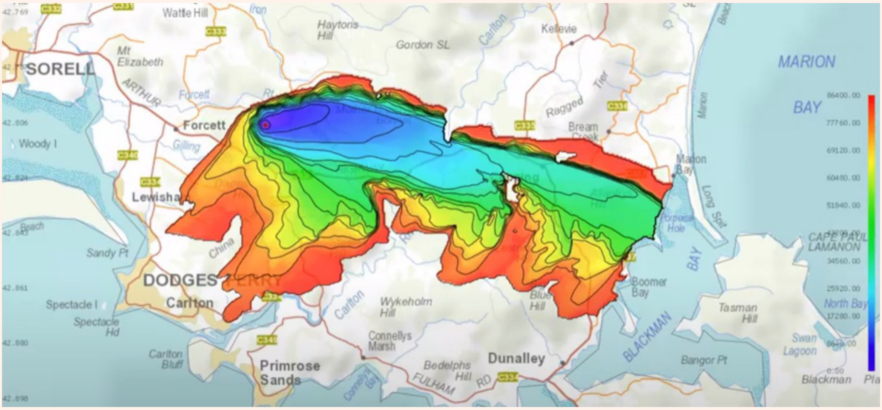
WHAT IF WE COULD BUILD A 'SIRI' FOR TACTICAL FIREFIGHTING?

A fire suppression modelling system could quickly and automatically model hundreds of interventions, sampling parameter space to determine the most effective firefighting tactic.

- To be robust and effective it must:
- Be easy to use in a chaotic environment.
- Be tunable to optimise for different outcomes.
- Understand the latest remote-sensing and environmental data.
- Understand resources and interventions.
- Suggest and triage range of intervention tactics.
- Be transparent in how it makes decisions.
- Be auditable after fire events.

SPARK

A WILDFIRE SIMULATION TOOLKIT



Rainbow-shaded isochrones for a simulated fire near Hobart, Tasmania, generated by the CSIRO Spark wildfire simulation toolkit. Credit: CSIRO Spark web page.

Spark is a next-generation fire simulation platform that already integrates many of the capabilities for fire suppression modelling.

The system can automatically choose appropriate empirical fire-spread models to apply in particular situations and can be controlled via a command line interface, making it suitable for running in batch mode on a server.

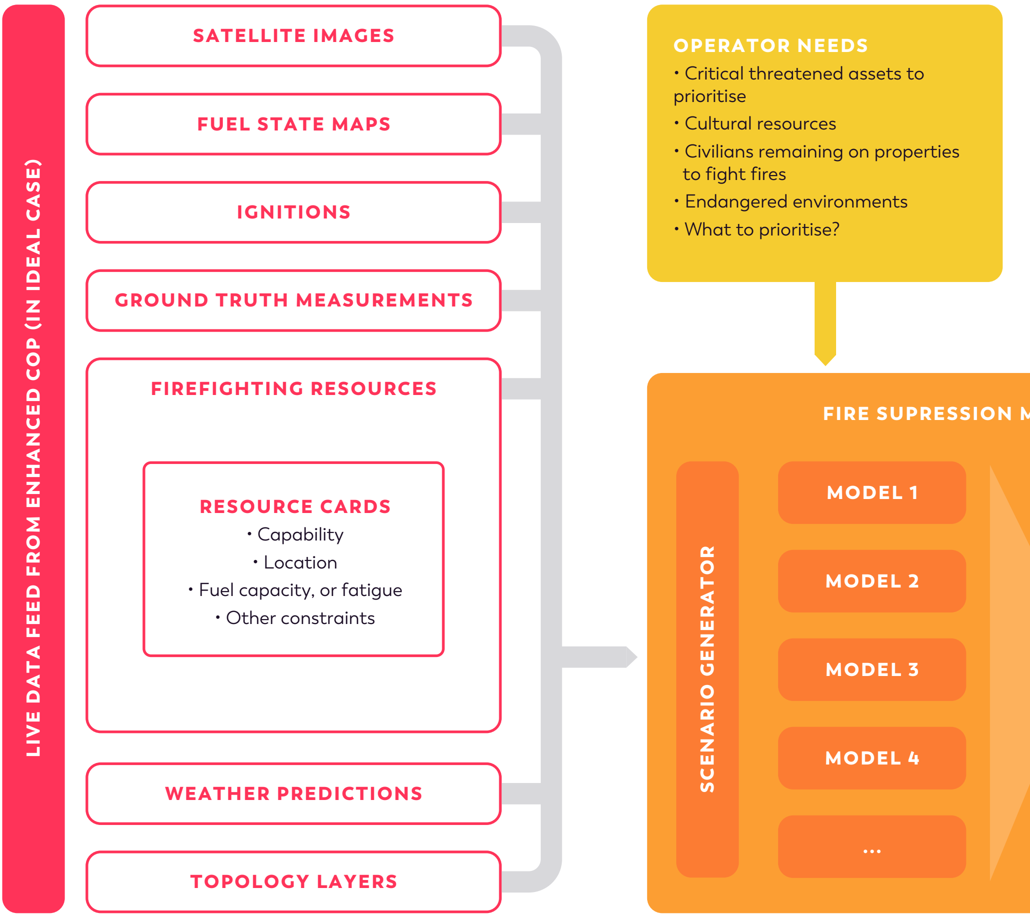
It is designed to be highly configurable in support of new fire spread models and data, and already includes advanced physics-based models for firebrand spread. It is also capable of modelling the impact of a fire on the landscape (e.g., the effect of radiant heat), and – critically – running ensembles of models.

The Minderoo Foundation is supporting a project to develop Spark Operational – a version of Spark tailored for deployment with the fire agencies. Ideally, this will be connected to real-time data feeds of weather, fuel state and ingitions, and produce maps suitable for use

HOW IT COULD WORK

We imagine a tool that is available to the IMT and can make use of available real time feeds that inform the common operating picture. The system would use the best uncertainty estimates to generate a range of likely scenarios and possible solutions, before ranking and sorting. Explainability and auditing would be built into the heart of the system.

An interim system without real-time data access would still be incredibly useful as a decision support tool.



AUDIT REPORT

- Dispersion of scenarios
- Outlier scenarios
- PCA analysis of input and outputs (which inputs were most important and what outputs were most affected?).

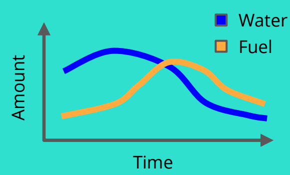
MODELLING SYSTEM

INTELLIGENT MODEL RANKER

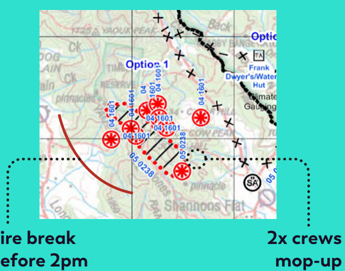
EXPLAINABILITY ENGINE

PRIORITISED FIREFIGHTING STRATEGIES

- Critical inflection points (e.g., when do actions become too late?)
- Resource timeline reports



- Deployment recommendations



- Alternative plans

OPPORTUNITY

Intelligence on the Edge

Up until recently, the advanced processing required to convert satellite data into practical maps would be done on supercomputers, or high-powered desktop computers.

Similarly, creating simulations with sufficient complexity to describe the natural world and sufficient fidelity to be useful required hours, or even days. This is still the case for the gold standard of detailed hydrodynamic fire propagation models, so that all practical tools are based on approximate empirical relationships.

However, the recent advent of dedicated machine learning processors (see box at right) has opened up amazing opportunities to change where and how advanced data processing is done.

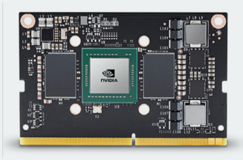
MOVING INTELLIGENCE ONTO THE FIREGROUND

The processors on most modern mobile phone and tables are more than capable of rendering complex visualisations. Firefighters in the field often make use of situational awareness maps like the ones from Zirkarta and bushfires.io at right.

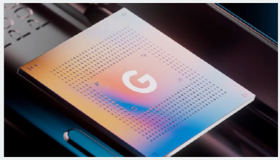
When trained and validated correctly, machine learning will be capable of replicating the processor-intensive parts of fire spread models (amongst others). Work on planetary scale weather simulations has already shown that hybrid physics-informed ML can even deliver the best of both world: the accuracy of detailed physical calculations with the speed of accelerated neural networks.

Machine learning modules may also enhance field-based measurements, by analysing visual scenes or calibrating complex data.

Intel Movidius X



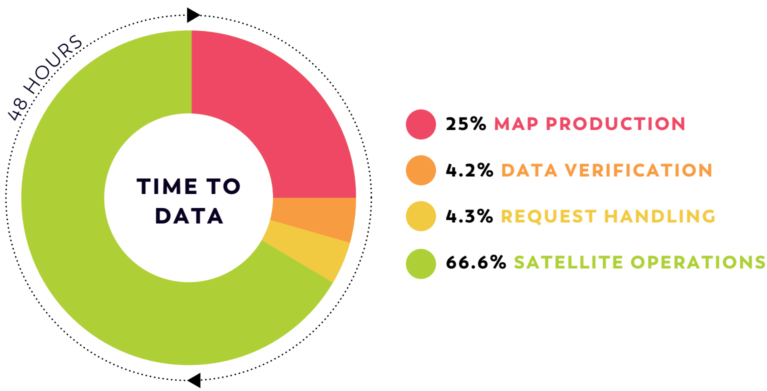
NVIDIA Jetson TX2



Google Tensor Processor

Cheap and highly parallelised tensor maths processors have made it possible to embed capable neural networks on devices in power-constrained environments. Machine learning on the 'edge' is making advanced processing possible on personal mobile devices and on small satellites in Low Earth Orbit.

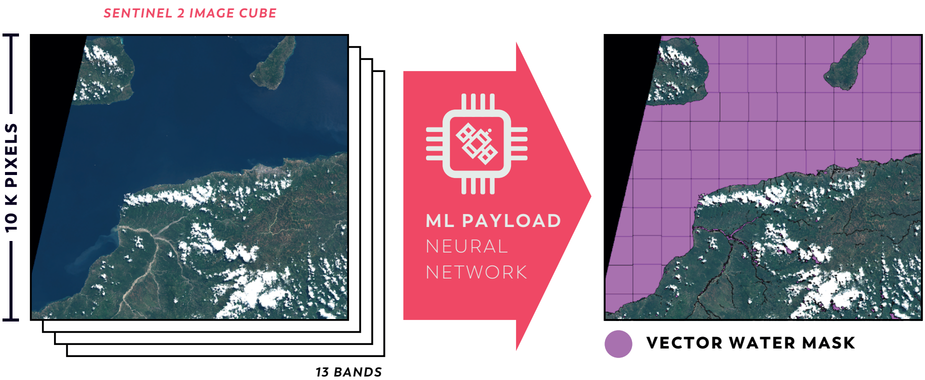
HOW IT COULD WORK



MOVING INTELLIGENCE INTO ORBIT

High-resolution multispectral data cubes from bus-sized satellites like ESA's Sentinel 2 can take up to 48 hours to acquire and process. This is because the raw data are large (typically GB in size) and take time to download, but also because the data require careful calibration onto a physically intensity scale to enable meaningful comparisons with complementary data.

EXAMPLE: THE WORLDFLOODS ML PAYLOAD IN-ORBIT DEMONSTRATOR



The *WorldFloods* **Machine Learning Payload** was developed during Frontier Development Lab Europe 2019 and in June 2020 was launched aboard the D-Orbit Wild Ride mission. It successfully **demonstrated that a ML system could routinely analyse large data in orbit** and **return highly compressed flood-extent products.**

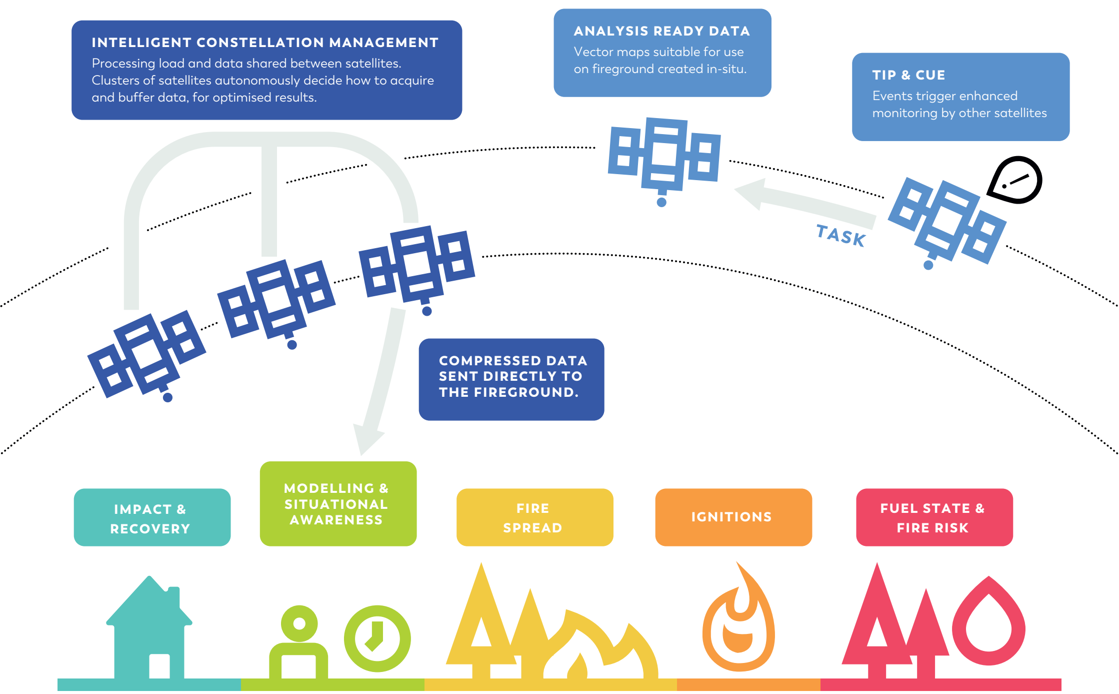
FDL EUROPE FRONTIER DEVELOPMENT LAB
D-ORBIT UNIBAP esa
UNIVERSITY OF OXFORD TRILLIUM EUROPE

Project Parters

There is also a high overhead associated with satellite operations and availability of ground stations. Moving downstream data processing steps on-board satellites in Low Earth Orbit presents significant advantages:

- Calibrated data products can be created in orbit without waiting to download raw data.
- Some secondary data products are significantly smaller in size, especially for complex instruments like multispectral cameras.
- Useful data products can often be encoded in sparse formats opening the possibility of rapidly sending small data packets directly to the fireground from orbit – supporting fast decisions..
- Analysis Ready Data (ARD) enables autonomous decision-making in orbit based on physical thresholds. For example, the satellite could choose to task follow-up observations, or trigger an alert.

HOW IT COULD WORK



OPPORTUNITY

Digital Twins for Bushfire Management

The Australian Black Summer fires have been intrinsically linked to climate change (e.g., see Canadell et al. 2021, Nature Communications) and we can expect more 'megafire years' - and worse to come.

Managing the effort and resources to fight such campaigns is a wicked problem that will stretch the capabilities of all organisations that help fight and prepare for bushfires. However, individual technologies in this report connected together as part of a digital twin for fire management will greatly increase our capabilities.

Most Australian states and territories are implementing spatial digital twins to visualise and query the built and natural environments. For example, features in the NSW Spatial Digital Twin are specifically aimed at telecommunications providers to help protect critical infrastructure during bushfires and other disasters. However, the opportunity in the future will be to integrate near-real-time views of the fireground alongside knowledge of available firefighting resources.

We imagine intelligent tools that will be capable of assessing the current situation across many firegrounds and marshaling predictive models to recommend where, and when, to deploy resources in response to quantified risk.

What is a Digital Twin?
The term 'digital twin' originated in the engineering world to describe a computer-simulated copy of a device, or system, that is updated in near-real-time to reflect the real world. They are used for operational awareness and planning, to predict future events, and to simulate the effect of changes and interventions.

Photo Credit: *Gary Hooker, ACT RFS.*

HOW IT COULD WORK

IN-ORBIT PROCESSING
Sparse data prdics, direct to the fireground in real-time.

REMOT
Satellite
fire hot s
water lo
fuel load

CENTRALISED PROCESSING NODES
National computing platforms (NCI, Pawsey ...)
Cloud computing and data storage services (GCP, AWS ...)
Institute clusters and desktop computers

POST-PROC

AERIAL SENSOR PLATFORMS
Real-time fire front tracking, burnt area measurements, wind & weather measurements, smoke & aerosol assessment, fuel load (via LIDAR), fuel moisture (multi-spec).

WEATHER STATION

FUEL MOISTURE SENSOR

SMOKE DETECTION CAMERA

RADIO FREQUENCY LIGHTNING DETECTOR NETWORK

AI
SE

SPATIAL DIGITAL TWIN CAPABILITIES

The bushfire digital twin will aggregate information from the fireground, remote-sensing feeds and static data layers. Predictive AI modelling tools will support decisions on directing resources days in advance.

MAP LAYERS

Utilities
Cultural assets
Terrain Information
Hydrology
Access routes
Weather forecasts
Fire risk forecasts
Fire prediction models
Real time fire information

FIRE MODELLING

Temporal fire risk
Fire spread prediction
Fuel & drying behaviour
Impact of fire & recovery in advance.

TEMPORAL RESOURCE MODELLING

Personnel availability
Critical resource bottlenecks
(fuel, water, accomodation, food, fatigue, skills & qualifications)

TE-SENSING FEED

data products,
spots,
cations & occupancy,
d & moisture content.

IN-ORBIT ARD

ESSED ARD

LIVE DEPLOYMENT INFORMATION:

Personnel + status
Appliances + status
Consumables + status

PERSONNEL MANAGEMENT APP

Availability & roster,
Skills & qualifications.

ON-DEVICE CAPABILITIES

Fire spread predictions,
shared fireground annotations,
weather forecast and warnings,
personal status (help needed),
tasks and confirmations.

FAR-FIELD COMMS

4G network
Ground Radio Network
Satellite Comms

FIRE TRUCKS

Fireground weather station, processing node, comms node, sensor platform.

PERSONAL DEVICES:

Processing node, weather measurements, map annotations & notes, camera feed, AI-driven scene analysis, wearable sensors.

R QUALITY NSOR

BEFORE AND AFTER THE FIRES

Digital twins are enormously valuable outside of fire season to support risk mitigation and resilience planning, and to manage and monitor recovery operations.

A system incorporating current vegetation-type, land use and fuel state maps, combined with fine-grained weather forecasts, could be used to predict temporal fire risk maps to support fuel removal. Windows of opportunity for conducting prescribed burns will be shorter in the future, and the possibility of a burn escaping control lines greater. An integrated digital twin will include information on infrastructure and environmental assets to support detailed risk and impact assessment.

The success of recovery and rebuilding efforts can also be assessed in a digital twin. The obvious measurement is regrowth of vegetation for the natural world ,and reconstruction of buildings for the built environment. However, a digital twin may also encode economic recovery via dynamic activity such as vehicular traffic, pedestrian and bicycle motion, wifi hotspot activity and many more digital footprints.

Volunteer Management, Call-Up and Alerts
The ACT RFS uses the BART application (bartapp.com.au) to alert, manage and communicate with volunteer firefighters. Volunteers can indicate availability, receive alerts and information about incidents, and respond with status information. Managers can view geospatial information on a dashboard.

However, volunteer availability is always a challenge and situational awareness relies on volunteers updating their availability daily, which sometimes is difficult to do.

Similar systems are in use by the other state and territory fire agencies.

***Photo Credit:** Gary Hooker, ACT RFS.*

Emerging concepts in intelligent systems

Key ML Technology:
Federated Learning
Traditionally, machine learning models are trained on a centralised computer connected to a large data storage system. Models learn slowly and so highly parallel processors (e.g., graphics processing units – GPUs) are used to accelerate the training process.

The federated learning concept decentralises this process by moving the training task to ‘edge’ devices. Each mobile device trains a copy of the model on a small local dataset and the results are transmitted to a central server for aggregation.

This has great benefits for security and privacy, because the central server never sees the data, only the results of the training for each model instance. The focused updates transmitted from each mobile devices are tiny can be uploaded opportunistically and impose much less of a burden on communications networks.

The federated learning concept is ideal for deploying predictive models on the

Key Concept:
Analysis Ready Data (ARD)
Many promising data science and ML tools are hobbled by the relative availability of analysis ready data. This means data that has well-characterised uncertainties, few biases (or biases that are well-documented), is encoded in an open format (or accessible via a validated tool), and has sufficient metadata on the context in which it was acquired and where it might be suitable for use.

Key Concept:
ML-Ops / Model-Ops

Machine learning operations (ML-Ops) is the set of procedures and practices around deploying ML models in the real world. Model efficacy tends to degrade over time as real world situations differ from what the model expects. This means that the performance of ML systems should be monitored and the models re-trained as necessary. New software tools are emerging to support this work.

Key ML Technology:
Active Learning

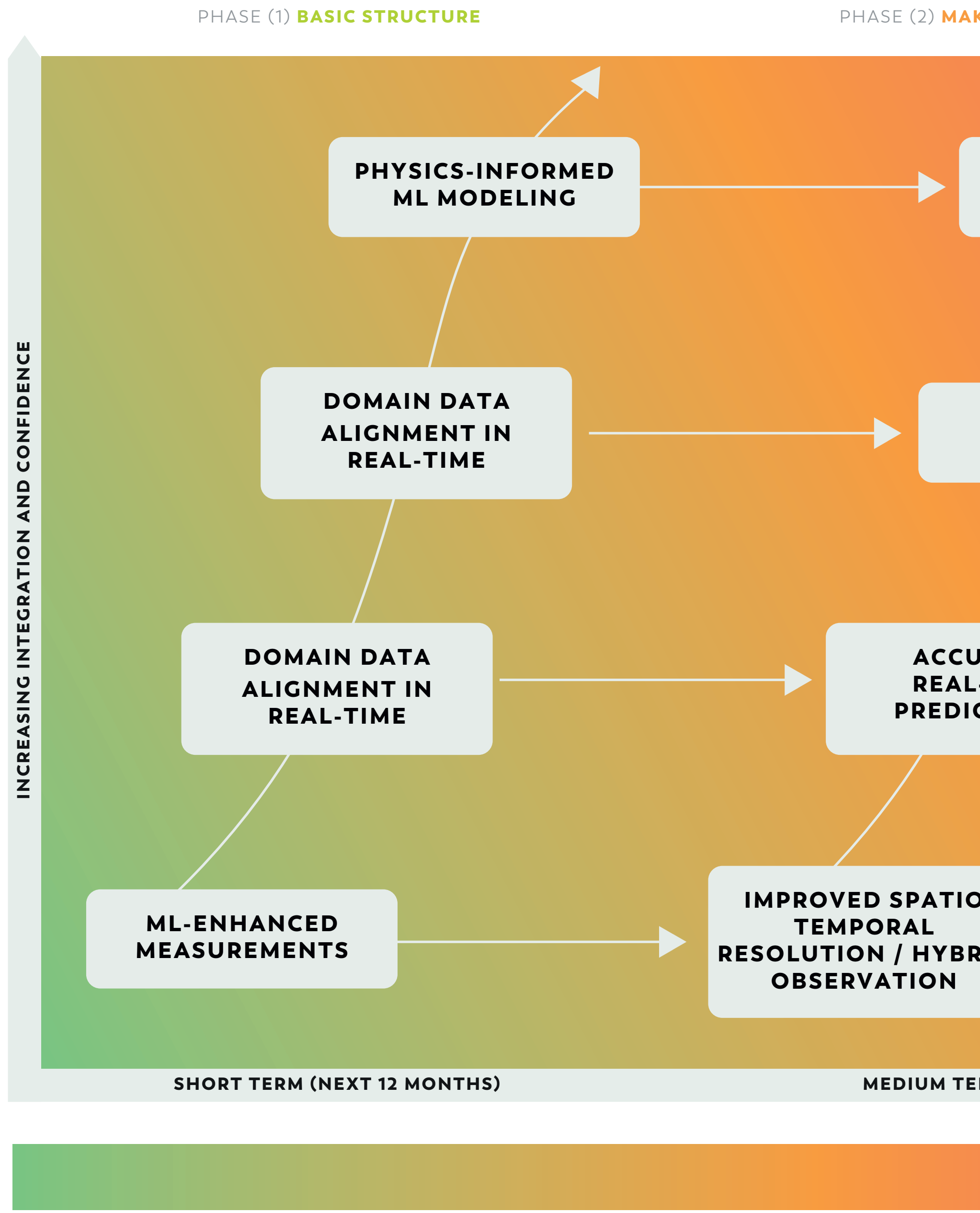
Machine learning predictions are only as good as the data used to train them. However, all datasets contain biases of one kind or another and usually represent a static snapshot of the real world. To be truly robust and useful, machine learning models must be continuously updated and tuned to reflect the conditions into which they are deployed.

Active learning schemes attempt to correct for data and model drift - the performance of ML models degrading over time. This often means re-training the model, but with a greater emphasis on the most difficult data.

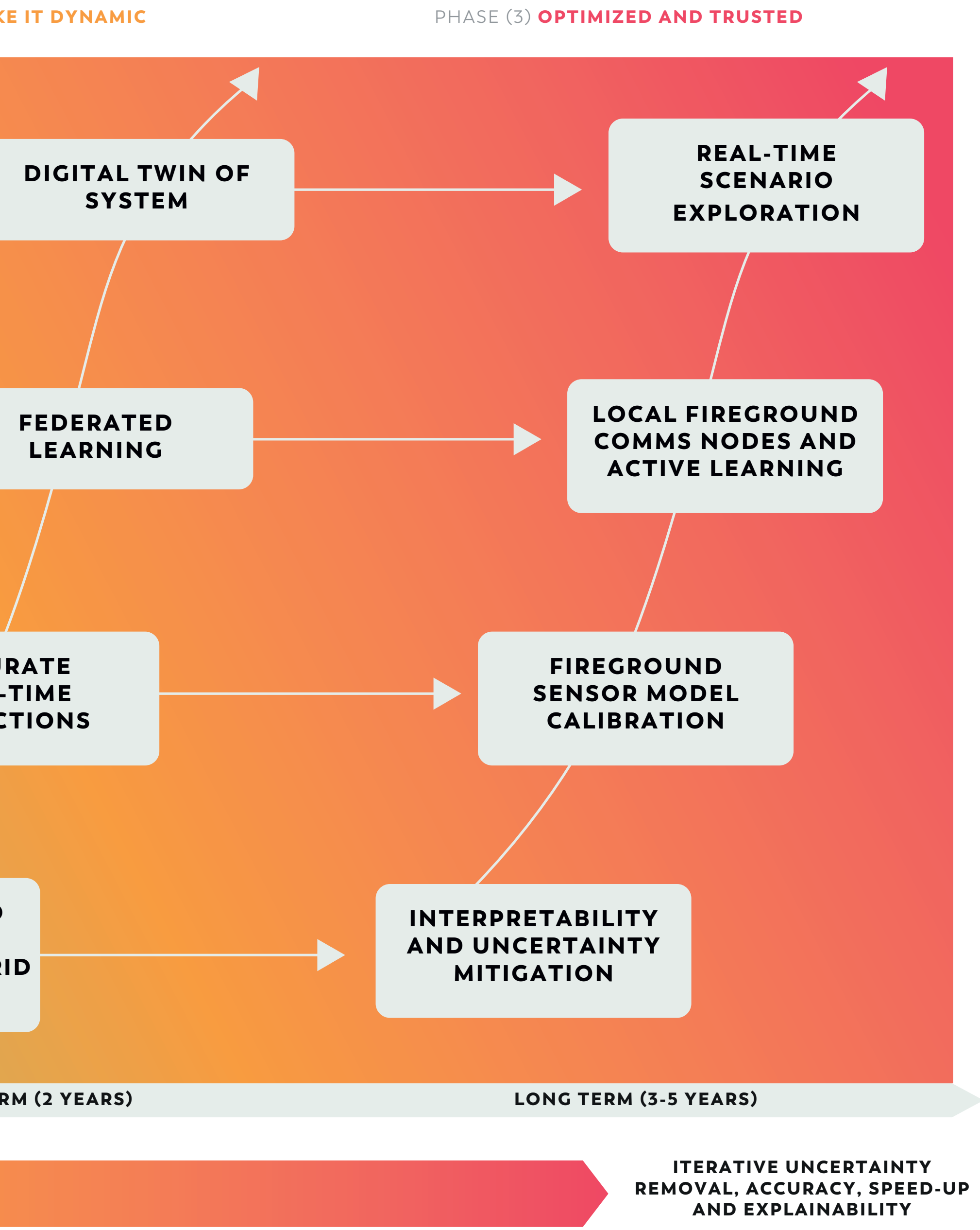
Key Concept:
Human-in-the-Loop Validation

Both data and algorithms that feed into any digital twin for disaster management must have a human in the loop to validate their use. This includes validating that data is internally consistent and fit for purpose, validating that the algorithm is suitable in context and is stable in the expected parameter space, and that user-facing tools are suitable for their intended audience.

Roadmap to active cyber-infrastructure



> Getting to a trusted system will require a holistic perspective; complex dynamic combinations of ML models, data gathering and users in the loop to calibrate insights in real time.



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