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UAS and smartphone integration at wildfire management in Aotearoa New Zealand

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Abstract

Background: From 2016, wildfire emergency response used Remotely Piloted Aircraft Systems (RPAS) also known as Uninhabited or Unmanned Aerial Vehicles (UAVs) and Systems (UAS) or "drones" (hereafter UAS), smartphones and smartphone applications (apps) on-site, for the first time at scale in Aotearoa New Zealand (hereafter New Zealand). This study outlines the deployment and use of this new technology in monitoring at wildfires in New Zealand from 2016, and the conveyance of fire response information to operational personnel.

Methods: A quantitative and qualitative questionnaire, and semi-structured interviews were used to gather feedback on the use of this emerging technology from wildfire management personnel. The results were analysed to determine perception change over time, using retrospective analysis. The issues presented, and the uptake by fire management and personnel for the incorporation of such technology at wildfires in New Zealand are discussed.

Findings: The integration of UAS and visual, infrared/infrared-thermal (IR/TIR) sensors has been used at over ten wildfire management response incidents throughout New Zealand since 2016. The quantitative perception of use and benefit of information technology in wildfire management response improved from the initial viewpoints, from indifferent to strongly supportive, and supportive to strongly supportive for UAS and smartphone use, respectively. Qualitative analysis showed that both positive views on the new technology increased, and indifferent and negative views diminished substantially following exposure to its operational integration into wildfire management.

Conclusions: The use of technology such as UAS has gained support and currently offers the potential to increase safety and reduce suppression and mop-up costs. A reduction in the time taken for hotspot detection and management, combined with the ability to redeploy heavy-lift aircraft away from such tasks would lead to efficiencies in cost and resource utilisation. UAS as platforms for remote-sensing devices (such as cameras and laser scanners), and smartphone apps are now considered important tools for deployment at New Zealand wildfires by operational and Incident Management personnel. The adoption of any new systems or technology requires flexibility, especially in terms of management support, in which regular information, training and instruction should be considered crucial.

Keywords: applications (apps); "Drones"; smartphones; UAV; wildfire response

Introduction

The ecological understanding of wildfire management and impacts is steadily growing, with progress on a range of topics including plant flammability (Alam et al. 2020), the use of green firebreaks (Curran et al. 2018), and spatial burn extent probability on offshore islands (Christensen 2021). During the 1990s and 2000s, New Zealand had around 3000 wildfires burning almost 6000 ha annually (Anderson et al. 2008). These annual values remained similar until the early 2010s (unpubl. data from NRFA 2015). Fires remain a serious hazard for people in the New Zealand rural, forest and wildland environment, with 38 fatalities and 68 serious harm injuries during the last 100 years (Baynes 2019). Estimates put the direct and indirect cost of these wildfires as being over $110m NZD per year (Wu et al. 2009; Christensen 2014). There have been recent large and complex fires in New Zealand, such as the Port Hills Fire Complex 2017, the Pigeon Valley (Nelson, Tasman) Fire 2019, and the Middlemarch Tussock Fire 2019. These fires have affected multiple values, such as residential and rural property, production forest of Monterey pine (*Pinus radiata*), Douglas-fir (*Pinus nigra*) and Corsican pine (*Pinus nigra*), *Eucalyptus* spp. woodlots and plantations, rural production grasslands, and conservation shrublands and tussock grasslands. Summaries of events such as the 2017 Port Hills Fire, outlining the impact and cost, in this case over $30m NZD, are given in Montgomery (2018), Langer et al. (2018), and Pearce (2018). Multiple factors and risks are present at these fires, including people, property, infrastructure and vegetation-types. It is highly important that situational and environmental information is available to fire fighters on the fire ground and fire response managers.

Research has shown that small-scale UAS could be used in monitoring wildfires, and that technological innovation of this kind can offer substantial cost minimisation for wildfire management response (Ambrosia et al. 2003; Christensen 2014; Christensen 2015a). Advances in small-scale UAS technology, especially over the last 10 years, has resolved some technical issues relating to correct geo-location, data quality and usefulness of information for the near real-time monitoring of wildfires, enabling operational incorporation into wildfire management (Parker 2018). In New Zealand, the operation of all UAS falls under regulation of the NZ Civil Aviation Authority (CAA), specifically CAA Civil Aviation Rule (CAR) Part 101. In order to operate UAS at wildfire events, a higher tier of certification (CAA CAR Part 102) is required, enabling an organisation and its pilots to be able to perform operations that are prohibited under Part 101, such as night flying or flying above 400’ (approx. 100 m) AGL. From 2016, Interpine Innovation (Interpine) were certified as a Part 102 organisation, allowing greater flexibility in operationalising this new technology. UAS have since been used by Interpine and are deployed by Fire and Emergency New Zealand (FENZ) since 2017 for wildfire monitoring (Figure 1). FENZ has three UAS Teams (with resources spread across five locations) nationally, connected with their Urban Search and Rescue (USAR) capability, and are active in a range of incident responses, including wildfire management (Jeff Maunder, FENZ, *pers comm*. June 2020).

The uptake and incorporation of new technology in wildfire management is not just a technical issue (Groen and Walsh 2013; Christensen 2015b). Human perceptions, understanding and uptake of new information tools and technology can be problematic (Dillon & Morris 1996). This is especially a concern in an emergency response (McCormick 2016). We were interested in whether the perception of such tools changed following exposure to UAS use. The objective of this study was to describe the use and to capture insights of UAS and smartphone technology at recent wildfires in New Zealand, and to identify future wildfire research information needs. A mixed method approach was taken to gather data for this research.

Methods

Wildfires

Wildfires where UAS were first operationally deployed in New Zealand are listed in Table 1, with examples depicted in Figure 2. The wildfires occurred in several land uses (such as rural land, plantation forestry, rural-urban interface, rural-industrial interface and wildland). Personal property, business, and public (such as Recreational and Scenic Reserves) values were damaged or in some cases destroyed in these wildfires (Pearce 2018).

Specialist (expert elicitation) viewpoints

An expert elicitation method with a questionnaire and semi-structured interviews were used to retrieve and synthesise the opinions of professional fire management responders who were present at the fires, sourced from incident communication lists from FENZ. The responders came from the following organisations: Department of Conservation (DOC), the National Rural Fire Authority (NRFA), FENZ, Nelson Forests, the New Zealand Army of the New Zealand Defence Force (NZDF), Timberlands, and Wildfire Management New Zealand. Advice was sought and received from DOC social science advisors on the methods and questionnaire, as DOC did not have a human ethics committee. We adhered to the standards of integrity and conduct code issued by the State Services Commissioner under Section 57 of the State Sector Act 1988. Only those individuals who potentially were involved with the new technology were invited to participate in the survey, though not the UAS pilots or UAS team members, nor the authors of this study. The participants included Incident Management Team members such as Incident Controllers and Planning Managers, and Operational Fire Responders such as Air Attack Supervisors and Fire Crew Leaders. An email from the primary author was blind carbon copied to all (47) potential survey participants during 2018, with options for face-to-face, Skype or phone conversations. One phone conversation interview was requested, with the primary author conducting this interview and transcribing the participant’s answers. Eight questions were asked, with the first six using a five-value Likert scale (e.g. 5 – strongly support, 4 – support, 3 – neutral, 2 – unsupportive, 1 – strongly unsupportive), as described by Allen and Seaman (2007), including an option for additional feedback:

- Question 1: What was your opinion of UAS use and tablet/smart phone use for fires before the 2017 Canterbury and Port Hills Fires?
- Question 2: How would you describe your level of tablets/smart phones use prior to the 2017 Canterbury and Port Hills Fires?

FIGURE 1: Interpine UAS (DJI Shenzen aerial platforms) used in wildfire monitoring. Clockwise from top left: (a) DJI M600 Pro unit used at Port Hills Fire Complex 2017, showing triple-level GPS receiver system (white circular components) building in redundancy for locational accuracy, 5.5-6kg weight max payload weight, and a total max take-off weight of 15.1kg, DJI Zenmuse XTR 640x512 30hz (FLIR Tau 2) IR thermal sensor. The UAS team brought the kit to the staging area as part of the information given to fire-fighters, and to increase uptake of the mapping apps. Image credit M. Cook, Pumicelands Rural Fire Authority (prior to Fire and Emergency New Zealand establishment in July 2017). (b) DJI Matrice 210 RTK, showing sensor DJI Zenmuse XT2 dual RGB (4K) and 640x512 30hz (FLIR Tau 2) IR thermal sensor, used at fires from 2018/2019 season onwards. Image credit: Interpine. (c) DJI Matrice 100, with DJI Zenmuse XTR 640x512 30hz (FLIR Tau 2) IR thermal sensor at Taupo (Timberlands) burn 2016, with Interpine UAS Pilot, D. Herries. Image credit C. Hindle, Timberlands Ltd. (d) Interpine UAS Pilots, S. Bainbridge (IR Sensor Operator) and C. Scoggins (UAS Pilot) conducting hotspot detection flight operations over Makarara (Chatham Island) Fire 2018, with Incident Management, G. Thompson and Sector Supervisor P. Muldoon observing. Image credit P. Muldoon FFC Okareka, Fire and Emergency New Zealand.

- Question 3: What was your opinion of UAS use and tablet/smart phone use for fires after the 2017 Canterbury and Port Hills Fires (or later fires)?
- Question 4a: Do you think the UAS, maps and tablet use made your work?: (5 – very safe, 4 – safe, 3 – neither safe nor unsafe, 2 – unsafe, 1 – very unsafe)
- Question 4b: Do you think the UAS, maps and tablet use made your work?: (5 – very easy, 4 – easy, 3 – neither difficult nor easy, 2 – difficult, 1 – very difficult)
- Question 4c: Do you think the UAS, maps and tablet use made your work?: (5 – very fast, 4 – fast, 3 – neither fast nor slow, 2 – slow, 1 – very slow)
- Question 5: Any comments on the use of new technology?
- Question 6: Feedback on questions, open discussion and any questions you may have?

Follow-up emails were sent to non-responders during 2018 and early 2019, with five additional participants completing the survey. Of the 47 potential participants to the questionnaire, we had 26 responders, with six non-responders removed due to email addresses being no longer active, giving a final response rate of 63%. All bar one of the responders chose to respond directly via the request email. The raw data for the first six questions was transformed into percentiles of answer density, with a continuity correction factor added to a Wilcoxon rank-sum test for any difference between the participants' responses. All analyses and graphing were performed using the statistical programme R version 3.2.5 (R Core Team 2016).

TABLE 1: Wildfire incidents where UAS and smartphones collectively were first used in New Zealand from 2016.

Wildfire name, location and duration (containment)	**Incident, fire behaviour, extent and values affected**	**Emerging technology use, actions, and key lessons identified**
Taupo (Timberlands) burn 2016 Southern Waikato March 2016	Supervised burn. Pine slash (vegetation fuel load) reduction burn.	UAS (Interpine) with sensor and tablet/smartphone app. trialling at controlled burns (Timberlands), for hotspot detection. Firewhirls and hotspots observed through smoke using UAS with IR/TIR sensors. Established proof of concept (POC) for potential efficiency increase using small-scale UAS with sensors at wildfires in New Zealand.
Rotoehu (Timberlands) Fire 2016 Bay of Plenty September 2016	Forest wildfire. Commercial pine (radiata) plantation and tall native forest fire.	Initial operational use of UAS (Interpine) units at wildfires in New Zealand. Hotspot detection through tall native vegetation canopy (20m). IR/TIR sensing from helicopter was found to be less effective than UAS, likely due to shortened distance between UAS and ground as compared to helicopter use. Methodological and process development: information relay to Incident Management Team and fire fighters via mapping.
Kaingaroa Bark Dump Fire 2016 Bay of Plenty 2 – 7 October 2016	Rural industrial wildfire. Forestry bark dump fuel.	Operations had no line of sight due to thick smoke. UAS (Interpine) and sensors used as directional tool for heavy machinery. Methodological and process development: information relay to heavy machinery (Operations) via Sector radio communication.
Ohaaki 2017 Fire Southern Waikato 11 January – 13 January 2017	Rural wildfire. Grassland, shrubland fire.	First use of UAS (Interpine) and sensor technology at grassland and shrubland fire. Hotspot detection was good, though relative heat contrast not as clear as tall canopy forest (protection and production).
Hawkes Bay (Hastings) Fires 2017 Ruakawa, Te Hauke, Mt Erin, Puketitiri, Tukituki, Waimarama, Hawkes Bay 22 January – 16 February 2017	Rural wildfires. Several grass, shrubland, and commercial pine plantation fires. Fire size over 600 ha (total). Three building structures, and one residential building destroyed. Livestock killed. 60 people evacuated out of Waimarama.	Initial operational use of New Zealand Fire Service (NZFS) USAR UAS Team at wildfires. Interpine staff providing Situation Unit with mapping support remotely from Rotorua. Established proof of concept (POC) for potential efficiency increase using separate agency (Interpine) remote GS and information support for Incident Management Teams at wildfires in New Zealand.

TABLE 1: *continued*.

Wildfire name, location and duration (containment)	**Incident, fire behaviour, extent and values affected**	**Emerging technology use, actions, and key lessons identified**
Port Hills Complex Fire 2017[1] Christchurch, Canterbury 13 February to 3 March 2017 Figure 2a.	Rural and semi-urban wildfire. Mixed fuels: multiple vegetation types; commercial plantation forest of mixed ages (including shelter belts); scrub (gorse, and native); cured grass (including farmland pasture); tussock; residential and out-buildings and property. Public and conservation values (Scenic and Recreational Reserves) damaged. Pine plantations affected and at least one destroyed. Extreme fire behaviour observed, with crowning evident in mature trees, 20 m high fire whirl "firenado" witnessed (and photographed). Likely to have also affected protected reserves, "fire islands". Flame heights exceeding 20 m. Fire size 1660 ha+. Over 450 households evacuated. Fourteen structures, including nine private residences destroyed. Commercial recreational facilities (chairlift) damaged. One fatality, Steve Askin (helicopter pilot) occurred during incident. Approximate cost: $30m.	Large-scale complex fire for NZ. Multi-agency integration. Widespread up-take of mapping apps. for fire crews and fire observers, after exposure and once instructed. Incorporation of multiple (3) Interpine UAS teams sequentially over one week, enabling greater fire ground coverage, and minimising safety risks. Incorporation of one dedicated Geospatial (GS) analyst, for UAS data-information processing and mapping. Split-shift running of UAS teams at dusk/early evening (1900 hrs), and before dawn/early morning (end 0500 hrs), for map preparation for morning briefing (0700 hrs). First time UAS and habited (heavy-lift) aircraft used in same airspace at same time, and managed through NZ airspace control. Piloted (fourteen helicopters, with equipped with monsoon buckets and three fixed wing aircraft) and remotely piloted flight (three DJI M600 Pro units, see Fig. 1) integration using Interpine model (Fig. 4). Initiation of research on end-user engagement regarding technology use and uptake (this article).
Hurunui (Hanmer) Fires 2017 Canterbury 1 March to 2 March 2017	Rural, wildland wildfires. Grass and shrubland fires. Fire size 60 ha (total). At least two houses evacuated.	Interpine UAS team arrived at first night of fire. Windspeed (over 30 km/hr) too high for UAS operation. Fire ground still warm, IR/TIR contrast initially too small for effective hotspot location. Up to 1000 hotspots located within first two days.
Tiwai Point Fire 2018 Bluff, Southland 22 January to 23 January 2018 Figure 2d.	Wildland wildfire. Industrial interface. Within 100 m of overhead electrical transmission lines, and within 400 m of Aluminium shelter. Fire size 130 ha.	Early morning and dusk / early evening Interpine UAS use. Exclusion (temporary grounding) of Interpine UAS while two helicopters, with pilots using night-vision googles performing fire-fighting operations at night.
Burnside Fire 2018 Dunedin, Otago 30 January to 31 January 2018 Figure 2c.	Semi-urban interface and industrial zone fire. Shrubland (including shelterbelts), grassland, and industrial fire (including volatiles and dry firewood stacks). Flame height over 10 m. Wind gusts to 40 kmh, RH low of 20%. Fire size 25 ha. Three industrial buildings, and one shed destroyed. Southern Motorway and main trunk railway line closed. Over 100 houses evacuated.	First use of Interpine (Invercargill Team) UAS at industrial zone fire.[2] First time UAS team directs helicopters (aerial delivery of water via monsoon buckets) to prescriptively attack hotspots.

TABLE 1: *continued*.

Wildfire name, location and duration (containment)	Incident, fire behaviour, extent and values affected	Emerging technology use, actions, and key lessons identified
Makarara (Chatham Island) Fire 2018 Chatham Islands 1 February to 6 February 2018 Figure 2b.	Wildland and rural wildfire. Shrubland fire. Fire size 2500 ha. 19 houses evacuated. The island has no helicopters. Involves significant cost to use helicopters. Approximate cost: $1m.	One Interpine UAS team sent for two-week duration. FENZ lead USAR pilot sent as an observer. UAS performing most aerial monitoring thereby optimising resources.
Pigeon Valley Fire 2019 Nelson, Tasman 5 February – 6 March 2019 (controlled)	Pine plantation, rural, and urban interface wildfire. Forest fire, with mixed fuels: multiple vegetation types; commercial plantation forest of mixed ages; cured grass (including farmland pasture). Spot fires occurring up to 100 m downwind of the fire front. Fire size 2300+ ha. Public and conservation values (Scenic Reserve) damaged. Large pine plantation damaged. Over 3200 people evacuated. One residential structure destroyed. 25 aircraft used at fire's peak (23 helicopters, 2 fixed-wing planes). One helicopter crashed, which injured the pilot. Over 700 animals moved out of fire path. Over 40 animals euthanised. Approximate cost: $13m (fire response).	Integration of FENZ USAR and Interpine UAS at site.

NZUSAR New Zealand Urban Search and Rescue. Additional information sourced from Fire and Emergency New Zealand Incident Action Plans.

[1] For an extensive description of the fire behaviour and chronology on the Port Hills Fire Complex 2017 see (Pearce 2018).

[2] NZUSAR and New Zealand Fire Service (prior to July 2017) have trialled UAS with IR/TIR capability at industrial and urban fires previously, though focus has primarily been on Search and Rescue (Jeff Maunder *Pers comm*. June 2020).

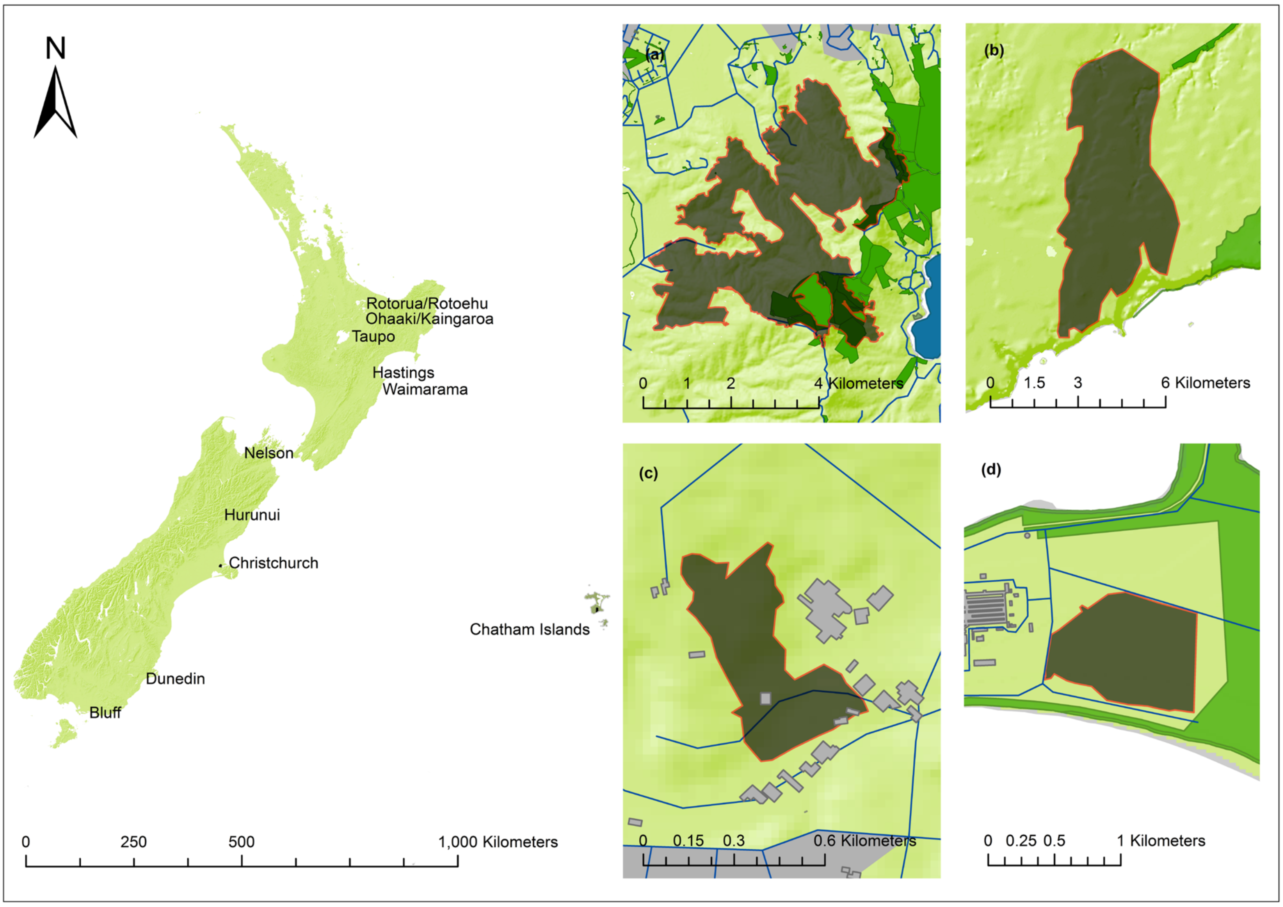

FIGURE 2: Locations in New Zealand from 2017 where UAS and smartphones have been used operationally to monitor wildfires. Extents of four wildfires showing a range of fire size, immediate land use and value complexity: Port Hills Fire Complex 2017 (a), Chatham Island Fire 2018 (b), Burnside Fire 2018 (c), Tiwai Point Fire 2018 (d). Transparent dark grey area is the extent of the fires, with the red line indicating the perimeter. Light grey indicates industrial, urban / built-up areas and buildings, with blue lines indicating roads. Dark green areas show protected parcels such as private land (Ngā Whenua Rahui Kawenata, QEII Conservation Covenants), and Public Conservation Land (Recreational Reserves, Scenic Reserves), and Marine Mammal Reserve: blue area in (a). Data sources: DOC and FENZ GS information.

Qualitative analysis for all questions, and especially the final two questions consisted of (1) coding all the comments emerging from the questionnaire, (2) identifying any key issues and insights for the participants, (3) comparatively reviewing these, especially where apparent contradictions were present, and (4) selecting the most descriptive, representative and useful quotations. This analysis strategy was broadly similar to the elicitation of themes in describing the adaptive capacity of New Zealand communities to wildfire (Jakes & Langer 2014). These comments were also used to further elicit insights and future training needs. We also reviewed official documents such as Incident Action Plans (IAPs) and Fire Incident Reviews, as well as newspaper articles related to the fires. These were key in identifying specific characteristics of the wildfires and the management response.

The comments were also analysed using a basic quantitative method, with the numbers of comment codes averaged for both before and after experiences, with percentage change determined to get an approximate scale of perception transformation, based on the responders' narratives. The comments were considered as an individual sample unit, and thus were not averaged for each participant.

Results

The insights and progression over the first three years trialling and developing an integrated UAS wildfire and hot-spot tracking system in New Zealand are given in Table 1. From the very first trial at a supervised pine slash burn in 2016, emergent and extreme fire behaviour such as fire whirls was visually observed through thick smoke, using UAS as a platform with IR/TIR sensors. By 2017 improved airspace coordination approaches enabled both heavy-lift aircraft and UAS to be used safely in the same airspace at the same time, with ground personnel present at active wildfires. Within three years, by 2019, a complete modular UAS fire (and fire hotspot) monitoring system was developed, including quick (if not rapid) response and deployment across mainland Aotearoa New Zealand.

A clear increase in support for the new technology following its exposure was shown by the participant preference values (Figure 3). The participants' opinion of UAS use and tablet/smart phone use for fires before the 2017 Canterbury and Port Hills Fires (Question 1) had Likert values of mean 2.29, and median 3.0. The participants' description of their level of tablets/smart phones use, prior to the 2017 Canterbury and Port Hills Fires (Question 2) had Likert values of mean 3.25 and median 3.75. The participants' opinion of UAS use and tablet/smart phone use for fires after the 2017 Canterbury and Port Hills Fires or later fires (Question 3) had Likert values of mean 4.67, and median 5.0. The participants thought that the UAS, maps and tablet use made their work (Questions 4 a, b and c) in terms of Likert values of means and medians: for safety 4.39, 4.75; for ease of use 4.61, 5.0; and for efficiency 4.54, 5.0 respectively. There was an initial level of reservation in using the UAS as the median "before" value was 3.0 (indifferent). The "after" value medians were 5.0 (strongly support), with only safety being slightly lower at 4.75 than the other "after" values of 5.0 for "ease of use" and 5.0 for "efficiency" though these were not statistically significantly different from each other.

The responders' narratives following their involvement in the Port Hills Fire Complex 2017, Hurunui Fire 2017, Tiwai Point Fire 2018, and Burnside Fire 2018 are quoted in Additional File 1, with two representative and descriptive examples given here:

> *"I saw how the infra-red camera was used and the mapping data from that, and then how the drones and IR cameras could zoom in on areas,* [to] *produce maps of the hot spots and then how users the next*

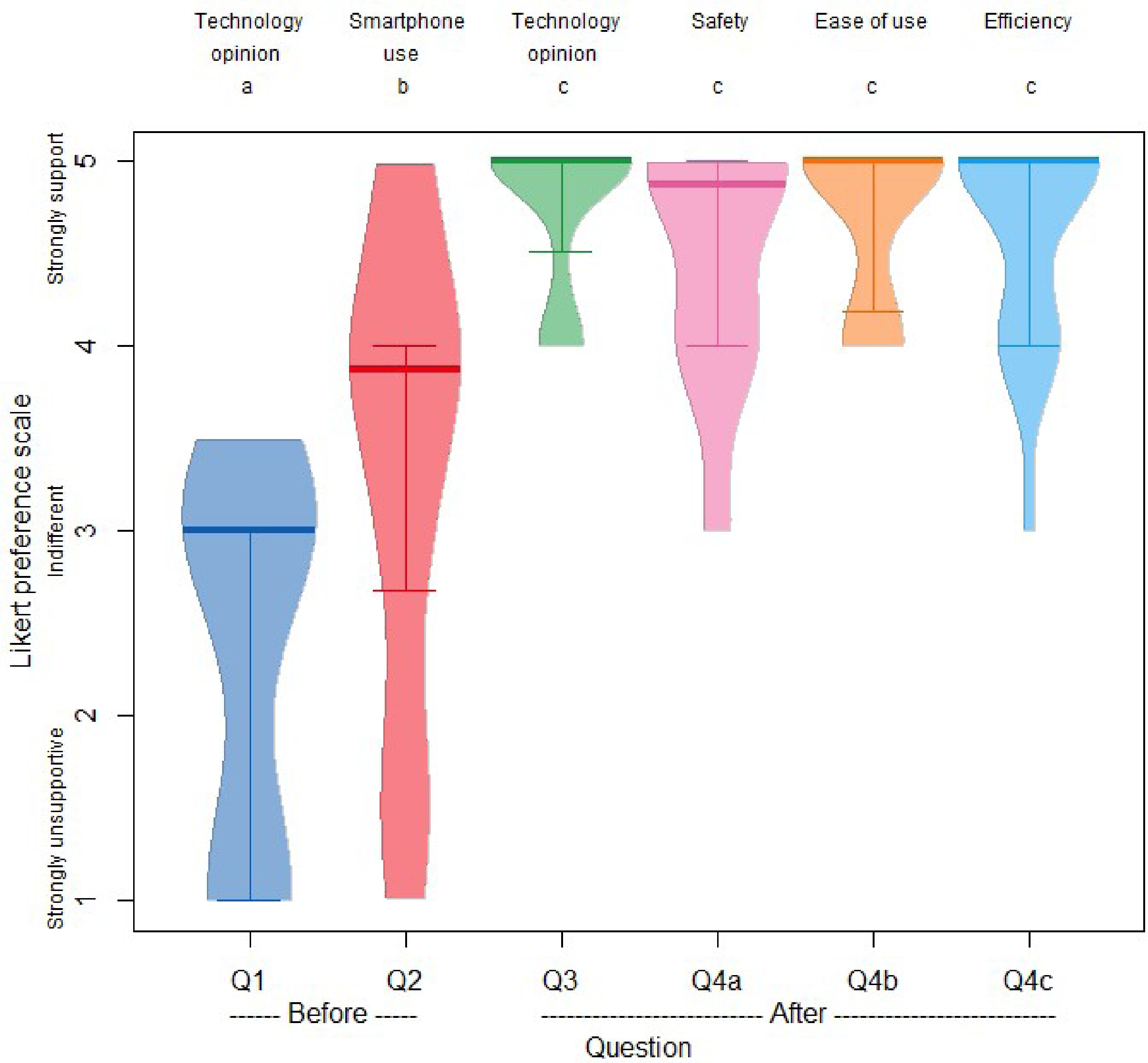

FIGURE 3: Survey participants' percentile preference scores on the six key questions. Lower case alpha-numerals indicate a statistically significant difference between the questions using a Wilcoxon rank-sum test with continuity correction. Shape of columns or "beans" indicate responders' answer density, bars (medians), and whiskers (25% lower, and 75% upper quartiles).

morning could down-load the maps and go to the hot spots all from using the phone GPS system.
It was interesting to see the older technology of the washers with flags on them dropped as a marker, and then the printed maps produced, vs the downloadable maps on the phones. It was a great melding of both to get work done on the ground."

"Really strong place in rural fire-fighting. There are limitations. Where it works well, it works well, though clear areas where it did not work well. Examples: thought drones would be awesome in Section A [Port Hills Fire Complex 2017] *(keeping helicopters away from high tension wires) - though wires did affect flying due to interference (RF). Wind is a limiting factor. Span of fireground. Small fire ground works well. Relied really heavy on helicopter for wider-scale (overview) over fire ground and reserve. A couple of operating tiers (for flying). Mapping (is a great benefit) to give to fire-fighters, "seriously good shit". Drone operators at night to give to FFs at morning briefing (was hugely useful). Gained 3 hrs extra FF time per person day. Drone up at Hanmer* [aka Hurunui Fire 2017] *(breakout), then FF up, though drones did not work well with the high numbers of hotspots (large number 250+). Great intelligence tool, though still need FFs to put fires out".*

The respondents also provided a range of insights and concerns, that could be broadly grouped into three categories: (1) Training in use of this technology and its outputs (48% of all comments), (2) Development of rules for operational capability and safety (45%), and (3) Specific technology outputs such as real-time monitoring of the fire and resources, integration of different resolution and scale of imagery, and remote tracking of resources (7%).

Quantitative results based on the (total numbers of) categorised comments from the respondents, showed that before operational exposure to the technology responders were positive (47%), indifferent or sceptical (42%), and negative (11%). Afterwards, they were positive (77%), indifferent or sceptical (16%), and negative (7%) towards the technology. Percentage change of these categories was positive (30% increase), indifferent or sceptical (26% decrease), and negative (4% decrease).

Discussion

After initial field trialling early in 2016, the progression of UAS use and knowledge has developed into standard operational activities at wildfire management response in New Zealand. Methodological testing, including proof of concept was done at the Taupo supervised burn 2016 and the Ohaaki fire 2016. At the Port Hills fire complex 2017, fire hotspot-tagging and data management were operationally trialled for the first time in New Zealand at a large-scale fire (Parker 2018). At the Port Hills fire complex 2017, substantial increase in technology awareness occurred for fire-fighters, and also provided insights for fire response managers. At this fire, hotspots were GPS-tagged, with maps created overnight which fire-fighters were given at the following morning briefings. Fire-fighters had the option of hard copy maps and/or digital copies using Quick Response (QR) codes printed on the incident management plan via their smartphones using mapping apps (AvenzaMaps, Avenza Systems Inc. Toronto, and FireMapper, Fire Front Solutions, Sydney), see Table 1. At the Port Hills fire complex 2017, the UAS pilots were in continuous contact with the local Air Traffic Control and the fire command structure so that the location of the UAS was known at all times, the UAS was flown predominately at night and very early morning, when the ground was coldest, thus giving the greatest contrast with hotspots, and this also diminished the risk of collision with other aircraft flying at night such as fixed wing or rescue helicopters (Parker 2018). It is important to document such technical procedures, though it is also just as important for Incident Management to note and accommodate operational needs of UAS teams, such as daily split-shifts (early morning and evening). Depending on the size of the fire and UAS team capacity, individual teams may be flying at multiple times during a 24-hour period. Further development in the use and management occurred over the next two years and five fires, most importantly the integration of multiple UAS teams from different agencies at fires (Table 1.)

Following exposure to such technology, a clear willingness and demand was found for UAS and remote sensing capacity at wildfires in New Zealand (see Additional File 1). The incorporation of emerging technology into wildfire management offers substantial benefits, though requires well-considered introduction, engagement and acceptance by fire responders and management. Technical operation and management support of such tools remain highly specialised roles which require specific skill sets that are generally not currently present in emergency staff (for instance, pilots of the FENZ and Interpine UAS teams are fully accredited UAS pilots with New Zealand CAA 1.02 certification). We found a substantial positive change in perception of the new technology (UAS, smartphones and associated apps) following their introduction into operational wildfire management response since 2016 (Figure 3 and Additional File 1). The ubiquitous presence of smartphones allows a new and vast degree of data access and transfer between operational personnel, management and technical specialists. New Zealand wildfire responders and management were generally sceptical about new technology and require direct exposure with such prior to operational integration and support.

Management implications

The integration of such technology in emergency incident management such as wildfire response was performed under a Coordinated Incident Management System (CIMS). This set of systems has been utilised by most New Zealand emergency response agencies. An initial model for UAS integration was developed by the Interpine Innovation UAS team, and was managed under Operations, Air Command through a separate unit to piloted aircraft (see Figure 4). In this model, the Situation Unit (within Planning), determines the priority aerial tasks in concert with Air Operations to go into future IAPs. Data from the UAS teams and piloted aircraft is retrieved and forwarded to the Situation Unit for analysis and interpretation for current IAPs. With the introduction of data-heavy UAS technology (in terms of wildfire response management) with digital sensors such as gimbal-mounted TIR cameras, data transfer and management to the Planning and Intelligence sections may require dedicated personnel. This is a relatively simple example of a systems analysis approach for the application of new (technology) components to a wildfire management system in order to improve the system's performance (Thompson et al. 2017).

Financial concerns are crucial in the incorporation of new technology such as UAS use in wildfire management (Christensen 2015b). Currently, the most advantageous use of UAS-mounted IR cameras is the potential time and costs saved in the support of "mopping-up" tasks at smaller fires where no helicopter support with IR/TIR sensing is present (Christensen 2015b). As technology improves and increases in both scale and applicability, some aspects of such management systems will necessitate system redesign. Additional improved efficiency could be gained through some of the following innovations: real-time monitoring of wildfires, semi-automation of the IAP and resource request systems, and remote tracking of personnel and resources. Further development and integration of the wildfire response management systems through the use of increased information technology may result in the down-sizing of logistics and management support roles in particular. This in turn would enable the redeployment of intellectual and physical resources to operational fire response, or other planning needs. We found that there are key human and social aspects of integrating new technology, primarily on-site operational exposure. For the optimal uptake of this technology within the wildfire management community, we recommend regular on-site operational instruction, updating of information, and training pertaining to the use of new technologies including UAS, data transfer, information flow requirements, and applications.

Conclusions

New technology such as UAS and smartphone apps have gained solid support in New Zealand wildfire management response. As our applied scientific investigation focused on technology integration and incorporation, a multidisciplinary, mixed methods research approach was taken, integrating quantitative and qualitative data (Feilzer 2010). We found that the incorporation of new technology in active wildfire management incidents requires consideration and flexibility, with regular provision of information, training and instruction. The utilisation of ongoing feedback from personnel as any new technology is incorporated into operations has a direct benefit for wildfire management. These insights can be directly integrated into trialling systems, such as the new UAS management system.

The use and development of remote sensing for

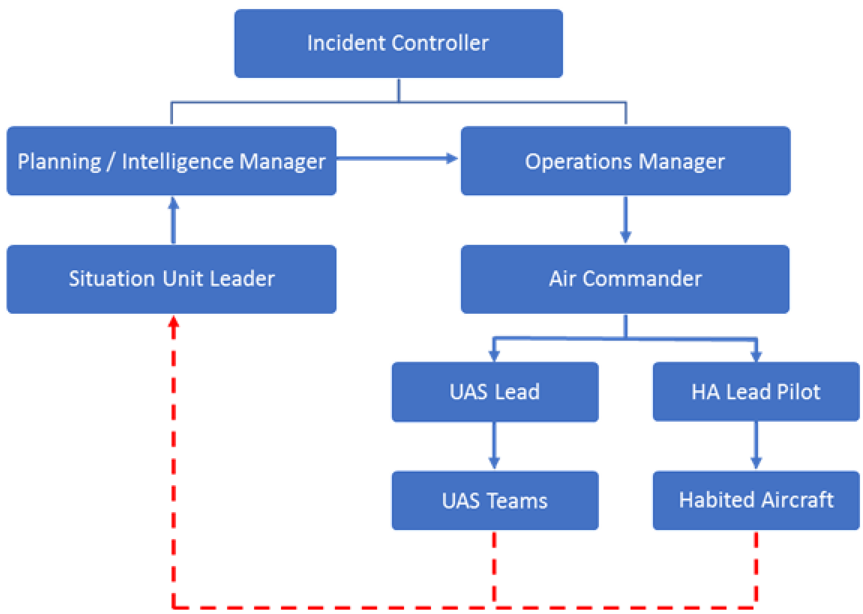

FIGURE 4: Proposed integration of UAS into New Zealand's wildfire management response system. Adapted from Interpine unpublished procedure (2017). HA Habited (or currently Heavy Lift) Aircraft. Primary data transfer, upload ~ red dashed arrows. Aerial operation task information (Situation Unit and Geospatial Advisor/s: data management, data analysis, option development (in concert with Operations) and analysis, recommendations. Planning / Intelligence Manager: review. Operations Manager: decision and direction) flow via Incident Management Meetings and stated in IAPs ~ blue solid arrows.

monitoring wildfires holds high importance to wildfire response managers (Christensen 2014; Christensen 2015a; Yuan et al. 2015). Similarly, as ecologists, foresters, forestry scientists and wildfire managers, we see UAS and remote sensing technology as important to address key long-term research needs, such as post-fire high-resolution terrain mapping, to determine fire severity impact. There remain key research and developmental needs specific to wildfire response using such technology. This study has demonstrated the benefits of pairing research closely with innovation, and that tracking the ongoing development of UAS operational capability at fires is important for practitioner and organisational learning. Future research and innovation in wildfire management is the real-time monitoring of fires and tracking of resources. Furthermore, the quantification of cost efficiencies that these technologies can bring to wildfire management would be highly beneficial.

Mixed methods research takes a pragmatic approach to the integration quantitative and qualitative investigations (Feilzer 2010). As a multidisciplinary team, we took a mixed-methods approach for this research, specifically as we were interested in systems improvements for the integration of UAS technology into operational wildfire response management. Planning and procedures are critical for effective and efficient wildfire response management, as they can improve risk-informed decision making (Dunn et al. 2017). The incorporation of emerging technology into wildfire response management should include reviews of existing systems, including response plans and operational procedures (Thompson & Calkin 2011). The assimilation of UAS command and data transfer/information flow process into the existing air support operations has attempted to incorporate these steps. It is noted that there is a lag time associated with the incorporation of new technology and systems into the established wildfire management response approaches. Examples of impeding factors for the uptake of new technology can include, though are not limited to, participant awareness, acceptance and learning. It remains important to acknowledge the reluctance of some practitioners to new developments and may therefore require direct engagement and exposure to new technology. In addition, we note the success of concurrent review, testing and incorporation of these new technologies into wildfire response management. A key to successful assimilation of new systems and technology is the incorporation of a feedback system for trialling, testing and review.

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Abbreviations

CAA - Civil Aviation Authority of New Zealand
CIMS - Coordinated Incident Management System
DOC - Department of Conservation
EOC - Emergency Operations Centre
FENZ - Fire and Emergency New Zealand
FF - Fire-fighter
FLIR - Forward Looking Infrared
GPS - Global Positioning System
GS - Geospatial
HA - Habited or Heavy-lift Aircraft
IAP - Incident Action Plan
IC - Incident Controller
IR - Infrared
IR/TIR - Infrared/Thermal-Infrared
NRFA - National Rural Fire Authority
NZDF - New Zealand Defence Force
NZFS - New Zealand Fire Service
NZUSAR - New Zealand Urban Search and Rescue
QEII - Queen Elizabeth II National Trust
QR - Quick Response code
RF - Radio frequency
RPAS - Remotely Piloted Aerial or Aircraft Systems
RT - Radio-Telephone
TIR - Thermal/Infrared
UAS - Uninhabited or Unmanned Aerial or Aircraft Systems
UAV - Uninhabited or Unmanned Aerial Vehicle

Competing interests

The authors declare that they have no competing interests.

Additional Files

Additional File 1 Participant responses.

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UAS and smartphone integration at wildfire management in Aotearoa New Zealand

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Additional File 1: Participant responses.

Question 1. What was your opinion of UAV use and tablet/smart phone use for fires before the 2017 Canterbury and Port Hills Fires?

- *TBA. Was involved and very aware of development and potential. Tested at a few places.*
- *I saw a drone flying around near the MTB complex but other than that had no knowledge that drones were being used or what used for.*
- *Very good device for managing a fire at this scale. The helicopter was good at the broad scale part of the operation. The detail from the drones plus the added value of the "travelling salesman walk" from hot point to hot point was excellent.*
- *Very useful.*
- *"UAV – 3 I had seen the outputs but not worked with them previously.*
  Tablets – 4 worked with them and found them very helpful at pervious fires.
- *I had no experience of drones before attending the fire. Phone Apps – 4.*
- *Possibly way of future, question of payloads.*
- *…. probably learnt more in my week on the Port Hills than in any of my previous training, such as it has been. Therefore, not able to offer much feedback. Had no use or involvement with apps, in fact wasn't aware of any.*
  Did consider the mapping of hotspots done each morning by drone to be a very useful concept – didn't always pick up everything but definitely did point us to most.
- *Strongly support UAV usage at fires.*
- *Aware off them, limited exposure to them. Interested via promotion. Spin-off for whole team, and also Chatham Island. Lot of benefit, larger campaign fires.*
- *Never used drone and smartphones before Port Hills.*
- *I don't have one, as these were my first lot of fires, though I thought they were very helpful at the port hills for the guys on the ground.*
- *I had seen a demonstration with a drone at a Fire Operations Course, and could see some value, but to be fair it was not something I was excited about for firefighting.*
- *Reasonable amount of time with and supporting thermal camera at Port Hills fire. Zero visibility with UAV and smartphone tablets prior to fire. Considered it quite experimental in use.*
- *Unknown, while knew about drones, considered integration needed to be considered.*
- *Aware, seeing at use prior to Christchurch fires. Wanted them for Hastings Fire - situation unit. Intel back to the team. Aware of mobile tech.*
- *I hadn't use before but new they were there and of some of the capability, I knew that there were a number of safety concerns when mixing with air operations.*
- *Not really aware of the advantages and capabilities.*
- *Opinion: UAV: "5" strongly support. Have discussed with Richard Parker (Scion) in the past.*
  Phone: "4" mainly used for talking, texting and internet.
- *Smart phone, (5) – found it handy to access weather station information and utilise fire behaviour apps and topo maps and google maps. UAV (1).*
- *I had had some experience with use of Tablets and Smart phone in Tasmania and had found the mapping tool in conjunction with GPS locater helpful in finding hotspots on the ground. Had no experience with UAV.*

Question 2. What was your opinion of UAV use and tablet/smart phone use for fires before the 2017 Canterbury and Port Hills Fires?

- *Was involved and very aware of development and potential. Tested at a few places.*
- *Mainly to check the time! Also used to photograph briefing material. Used at other fires for photos.*
- *For fire mapping 1, but know about Tablets for fire management since 2014.*
- *High user. Use at work/home on a regular basis.*
- *Have used at other fires.*
- *I had no experience of drones before attending the fire. Phone Apps – 4.*
- *IC small fires, fire calculator. Involved in development with SCION.*
- *Basic but get by.*
- *Avenza maps starting to develop. Getting awareness.*
- *I was impressed and have used in training since.*
- *Very high usage.*
- *I have had a lot of exposure to smart phones and tablets, so was really comfortable around them. I struggle across platforms as an Android user (Apple / Android / Windows) but am generally able to bumble my way through my least used platforms.*
- *Familiar with use.*
- *Low. Unknown. Bought adapters for phones for use, though resolution was low.*
- *Aware, seeing before fires. Hastings Fire - situation unit. intel back to the team. Aware of mobile tech.*
- *Was pleasantly surprised how you could link the information received to the devices.*
- *Use to call for resources.*
- *4, again not really aware of the potential.*
- *Opinion: UAV: "5" strongly support. Have discussed with Richard Parker (Scion) in the past. Phone: "4" mainly used for talking, texting and internet.*
- *UAV use - very valuable tool if used by experienced users. A must, a tool with parameters. Still use of a thermal camera from helicopter. UAV good mapping tool. Tablets are now a must, Avenza is a 100% must. Fire mapper is a should have.*
- *Smart phone (5) had practice using them and entering data prior.*
- *Despite having used the mapping tools the technology was above me. As long as someone else could load the maps it was useful.*

Question 3. What was your opinion of UAV use and tablet/smart phone use for fires after the 2017 Canterbury and Port Hills Fires?

- *No change.*
- *Used extensively in Canada with Q codes for maps in the IAP (2017). Also, very good for Avenza mapping, photos and tracking of fire boundaries, prepared lines, post fire damage and assessment etc.*
- *A great tool, I think. Didn't rank 5 as not all people can use technology (some prefer hard copy maps).*
- *Strongly support.*
  I saw how the infra-red camera was used and the mapping data from that, and then how the drones and IR cameras could zoom in on areas, produce maps of the hot spots and then how users the next morning could down-load the maps and go to the hot spots all from using the phone GPS system.
  It was interesting to see the older technology of the washers with flags on them dropped as a marker, and then the printed maps produced, vs the downloadable maps on the phones. It was a great melding of both to get work done on the ground
- *Strongly support use of this technology at wildfires.*
- *Off the scale. Set the benchmark, in hindsight – Chatham islands, week one and week two, a lot of rework. From day one. Week four too late. Tech getting better and better. Briefings. Dug up hotspot (Chatham) – just phenomena. From novice to user. Needed future RT back to operator.*
- *I was not sure it would work but I was wrong.*
- *Very high usage.*
- *Amazing, as soon as I saw what the output was, I was sold. For me the benefits included the Avenza Map compatibility (as opposed to the system of waypoints and paper maps we were*

getting) and the turnaround time – they were ready at 7am not 11am. The one down being coverage is much more localised (given the approx. 2000 ha of the Port Hills fire).

- *Really strong place in rural firefighting. There are limitations. Where it works well, it works well, though clear areas where it did not work well. Examples: thought drones would be awesome in Section A (keeping helicopters away from high tension wires) - though wires did affect flying due to interference (RF). Wind is a limiting factor. Span of fireground. Small fire ground works well. Relied really heavily on helicopter for wider scale (overview) over fire ground and reserve. A couple of operating tiers (for flying). Mapping (is a great benefit) to give to fire-fighters, "seriously good shit". Drone operators at night to give to FFs at morning briefing (was hugely useful). Gained 3hrs extra FF time per person day. Drone up at Hanmer (breakout), then FF up, though drones did not work well with the high numbers of hotspots (large number 250+). "Great intelligence tool, though still need FFs to put fires out".*
- *Application was fantastic. Quickly developed into a needed to have. Also developed a concern on over reliance on tech by teams/crews and forgetting established and basic principles. Also concern overusing too early, could easily develop an inappropriate focus of attention "On Target Lock".*
- *QR code posted, check-in, and mess-tent. Uploading maps as. Take-up was fantastic, real-life imagery, well received. Reminded all staff. Great Barrier Fire. In planning unit working unit.*
- *I was very impressed how the use of UAV could supply very timely info for field use, That the UAV application complements the Normal air operation use of thermal cameras, The ease of transfer of information from the UAV to a tablet and or phone, How the device could then take you directly to the issue, The fact that we could make use of all darkness hour to collect data.*
- *5, became a convert after seeing the uses and potential uses.*
- *"UAV - 5, Smartphone – 5.*
- *After: "5" more interested.*
- *UAV use - very valuable tool if used by experienced users. A must, a tool with parameters. Still use of a thermal camera from helicopter. UAV good mapping tool. Tablets are now a must, Avenza is a 100% must. Fire mapper is a should have.*
- *(5) Biggest issue for P & I was getting timely and accurate information to form their plans. Tablet / smartphone use enables pers on the ground to update EOC / P & I in real time. They can use tools to accurately map fire breaks, control lines and send that information back instantly. Ground Obs. crew can use Google earth to confirm location of buildings when confirming how many buildings maybe lost. UAV (4) worked well to accurately identify hotspots, greatly assisting mop up. Cheap easy way to map perimeter of fire and get a bird's eye view of fire size and what is going on, on the ground.*
- *I was very impressed with the mapping provided by the drones at Port Hills. Having the flights undertaken at night with the maps prepared for the morning briefing was very useful.*

Question 4a. Do you think the UAVs, maps and tablet use made your work: Safe - Unsafe?

- *Don't know.*
- *N/A - I had an office-based role.*
- *Increased Situational awareness.*
- *It didn't affect my work as such.*
- *Greater awareness of hazardous area/s*
- *Reducing exposure. Know something is there. Hand - testing on surface is not good, as knowledge is good to know that hotspot is there. Old tech (DOC) cameras, throwing washers out* [the helicopter] *door, now had GPS.*
- *I don't think it had any effect on safety, that comes with your procedures for working on a fire ground.*
- *No applicable – I was making the maps.*
- *To be fair I didn't really see this making any differences to my work, though I realise it was for the information collection.*
- *Neutral. If possible, to be able to use around high tension wires it would be very good.*
- *Needs careful consideration, including management of* [airspace, RPA / UAV / "drones"] *and unauthorized drones. Needs comms that look at operating drones for these benefits. Needs (structure around) operating hours.*

- *Port Hills. Hearing from crews, photographs e.g. of stumps. Real time comms." Move 3m to left)".*
- *Without a doubt it made the job safer and quicker more efficient.*
- *5 made for a safer approach to tasking and reviews.*
- *Ability to produce pdf map, email it to people. Previously, crews effectively blind. Fire Mapper developer link.*
- *Safety: "3" Neither safe nor unsafe, unless you are flying in the helicopter doing the thermal work; although a drone may fall on you.*
- *Tablet use does, better navigating. Need spare battery power. Better situation awareness. Drones less time in helicopters - safety increased situational awareness. Some situations still need humans in helicopters.*
- *(5) as mentioned above not having fire breaks and control lines correctly mapped, some were non-existent was a real safety risk.*
- *Having accurate fireground mapping with GPS locater provides safety benefits. Having accurate hotspot data would also provide a better understanding of the fire environment.*

Question 4b. Do you think the UAVs, maps and tablet use made your work: Easier - Harder?

- *Don't know.*
- *Easy with an experienced operator and once the system was understood.*
- *Helped to determine vegetation type and burned areas.*
- *Easy to use.*
- *It didn't affect my work as such.*
- *DOC FLIR always previously had to wait. Immediate and transferable. Briefing and maps.*
- *Still very hard physical work reap the reward, great for morale.*
- *I think it made our job easier most areas we were sent we found a heat source.*
- *No applicable – I was making the maps.*
- *It didn't change the work that still needed to be done (as opposed to the previous information collection techniques) but it meant that we had better info in areas of difficulty for Helicopters (around zip lines etc).*
- *Absolutely. Great to direct FFs to the right place on the hillside.*
- *Covers ground substantially quicker, and* [thus] *more efficient. Important to be used at the right time* [of day or night]. *Finer resolution compared with rotor wing (helicopter). Still need on ground observation. Key issue on time lag, when can it be done?*
- *Without a doubt it made the job safer and quicker more efficient.*
- *5, easier and noted that the uptake of the tech was being embraced esp. at Port Hills.*
- *Degree of difficulty: "4" easy, once you learnt about how to use it.*
- *UAV – 1000x easier – more efficient.*
- *Having hotspot information with GPS locater makes finding hotspots easier and can speed up the black-out task. It needs to be remembered though that it is just another tool along with a number of other tools used.*

Question 4c. Do you think the UAVs, maps and tablet use made your work: Quicker - Slower?

- *Don't know.*
- *Easy with an experienced operator and once the system was understood*
- *Helped to make informed decisions.*
- *It didn't affect my work as such.*
- *Agree information feed/speed is quicker providing UAV doesn't crash, LOL.*
- *The quicker get to one and done, the quicker to next one.*
- *I believe that it speed things up.*
- *No applicable – I was making the maps.*
- *As mentioned before, the info was there much earlier in the day. It did not however, seem to speed up the process of dealing to the fire.*
- *Incredible. Key benefit.*

- *Absolutely quicker. Clear enhancement. Also clear limitations on operating, visibility and wind.*
- *Without a doubt it made the job safer and quicker more efficient.*
- *4 and quicker once crews understood the benefits.*
- *Need for technology training for fire crews.*
- *Speed: "4" fast; again use makes you quicker and more efficient.*
- *UAV – 1000x easier – more efficient, cost effective. Still cannot discount other tools.*
- *(5) To pass the information in person would take at least 30mins to get back to EOC, taking you off the fire ground for in excess of one hour. Tablet / phone is instant.*
- *The GPS locater in conjunction with the mapping tool definitely speeds up the black-out task but it is important to recognize that some hotspots were not identified, and some locations were identified as hot spots which were not. Users need to understand that it is a tool to help and is not the only tool and is not a fool-proof system. It was interesting how quickly people came to rely on the mapping and when a drone crashed one night with a lack of mapping available at the morning briefing there seemed to be an unreasonable level of concern regarding our ability to successfully black out for the day.*

Question 5. Any comments on the use of new technology?

- *Strongly support use of tech if it makes a difference on the ground.*
- *Only disadvantage is getting the staff on site fast enough to manage the drones for future events. Cost in the overall amount spent on the Port Hills is nothing.*
- *It would have been good to use the photo capture and software used by the UAV for a plane or helicopter capture of the whole fire ground. The commercial orthophotos took 2 weeks to receive which wasn't ideal. An overnight processing of imagery of the whole fire ground would have been great. (The UAVs only captured maybe 20% of the area. UAV are great for smaller areas (30-100ha) but struggle for large areas.*
- *There are many more things that they could be doing for us but we are not using yet, e.g. remote tracking of resources, check in – out, live data sharing (google burnology). The industry also needs to look at how Avenza is used in relation to the user agreement, as it states we for business use including government we should be paying a user licence but most people are not. However, the registration costs for Avenza are very high for a mobile app. Fire mapper is less well known but outperforms Avenza in several areas especially during initial attack and is very cheap, however is limited in that you can't really import base maps or data.*
- *The advantages of the drone was that they could get a lot closer, they could zoom in on areas and produce much more detailed maps. Much cheaper and safer than using the IR camera from the helicopter.*
- *The helo and camera model however allowed much bigger areas to be covered in just 1-2 hours, and visually was good to have a check done.*
- *FENZ needs to invest or support. A place in all rural fire grounds. So effective at fires, basic FLIR camera - 20 -30ha, so much more efficient. GPS gone so far in last 15 years, now in every vehicle, drone technology going same way. Rural fire appliance 2-5ha, drones – hotspots – cold-trailing since has to be done. IC / Fire manager assurity* [US] *for confidence. Worked really, really well – fear on drones and helicopters working together – did not occur on fires, easy integration. No concerns, no issues.*
- *Strongly support. Merits/advantages will continue to emerge as technology improves. Disadvantages and costs – Non from my point of view.*
- *Advancing tech – quite. Benefit of the costs out-weighed by advantages. Perimeter covered in three days in certainty – 18 hotpots, some not accessible via walking. Still ability to get people to the hotspots, and also repeat visits.*
- *It would have been nice to have had some training before use in a real fire, maybe have a module that can be run so you can practice and have the app installed prior to deployment. I would like to see more use of drones. If DPRFO/PRFO* [Deputy & Principal Rural Fire Officer] *or similar had a small drone available to them you could get a good size up quickly before a helicopter is even on scene and maybe saving on the cost of helicopters by doing so. (doesn't need to be a thermal drone just something to get birds eye view).*

- *I am a big fan as I see the benefits. However, I still think there are improvements, there is definite grounds for live feeding of information which could mean having crews working at the same time, so pinpointing some hotspots is about talking them on to the spot rather than giving a location to go and check. The drone use also seemed to find more hotspots at a localised scale (which I am not sure if this is an interpretation of information thing or an actual thing, but either way, drone maps were more marked than helicopter based flights).*
  Other merits – I like the ability to check over longer periods of time as are able to fly in the dark rather than requiring 'dawn' – I know this helped get the maps out faster also.
  Disadvantages and costs – The Port Hills was an easily accessible location, so getting to a site to start the drone flight was easy. I think other fires would be much less so – however, I suspect the scale (approx. 2000ha vs normally much less) would make other fires much easier (i.e. you are able to overfly the whole fire by the pilot being at one or two spots on the edge). Costing – No comments, I have NO IDEA.
- *"Exciting stuff". Having prior mapping, and repeatable mapping - very useful. Impressive stuff. Professional support from thermal camera operator.*
- *Mgmt. at different fires, too early change to Hurunui Fire. Requires a hierarchy* [guidance or rules]. *Useful to have coarse scale* [satellite, aerial - helicopter] *then finer scale resolution* [RPA / UAV / "drones"]*. Need parameters, entry points, CAA rules. Very cost efficient. New use of technology, key question of where they fit in the structure? Interpine had leveraged their capacity as a self-contained and knowledgeable unit. Mgmt. Team noted risks of deployment. Very positive interaction with briefing and guidance, and mapping capacity.*
- *Hastings Fires - had strong winds. Long-term mop-up, had a great role. Wider environment scans for bigger canopy. Operating close to fires.*
- *The operators were able to do onsite training and set up of staffs' devices, I never heard any complaints that the system was difficult to operate, in fact what I saw was FF lining up to get the info ever morning.*
- *As* [an] *Incident controller I would have this equipment and service at every incident to ensure that both the management team and the field staff have the info required at their fingertips in a timely manner.*
- *Disadvantages and costs Expensive to operate and require deconfliction with Air attack resources.*
- *Other merits. Training and trainers available. Keeping familiarity on technology. Regular refreshers required. Remoteness of technology, need for on-hand advice at site. Prometheus course done awhile back – a few steps need.*
- *Needs to be balanced with existing tech and core training.*
- *5) The hardest thing at large scale incidents is to get timely and accurate information. Smartphone / tablet and UAV allow you to get accurate information instantly enabling the command team to make timely decisions based on good information. This will lead to smaller fires and less risk to life. Disadvantages and costs: Those more experienced in years may be reluctant / need extra training to fully utilise the technology.*
- *Any new technology which speeds up the blackout process, helps to identify a high percentage of hotspots, can provide usable data available at the morning briefing, which can be updated regularly and is transportable to a large number of firefighters is invaluable. I would think there are real cost savings and safety advances associated with drones vs helicopters.*

Question 6. Feedback on questions, open discussion and any questions you may have

- *Happy to go ahead. Interpine and David already pre-approved by CAA. Self-contained unit. Affordable. A very professional package. Understood that 15 aircraft were used each day.*
- *Totally support the use of UAV by a professional group at incidents.*
- *Feedback define acronyms.*
- *My apologies for the late reply. I was safety officer for Waimarama/Hastings and Port Hills fires and watched the UAV in action. I think there is no end of uses for UAV in fire work as you would know yourself. I could even use them to monitor SHW actions!!*
- *I am no expert with this technology but am always impressed by Dave Herries approach to this stuff.*
- *Keen to be involved, and two cents – draft for peer review. Burnside Fire – question of QR side.*

- *Mapping people – need to link together.*
- *LiDAR – 3d model for forester – need for technology and people interface. Practicality takes place.*
- *I was at both the Port Hills Fire (Alpha Division Supervisor) and Hanmer Fire (Operations Manager), but only got to see the drone in use and its thermal work at the Hanmer Fire. Really good tool to have at our disposal. It was used a bit too early on at Hanmer. Hotspots were really still quite visible to the naked eye. We really should have waited for a couple more days before using it.*
- *Being able to download to phone was great. I was recently deployed to the United States where phones are now essential tool, especially the mapping of fire progression, dozer lines etc each morning.*
- *Going back to the drone use, the one downside of its use, was the wind factor. We lost a day of thermal work through this, where as a helicopter thermal flight could have flown quite easily. Knowing the capabilities, in weather condition it can fly in, would have helped with planning. I'm sure this can be overcome.*
- *Thermal capture – still appropriate for thermal camera use.*