WHAT'S IN A MARKING?: AERIAL IDENTIFICATION NUMBERING OF FIRE APPLIANCES

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ABSTRACT

Emergency vehicles worldwide have unique aerial identification numbering on the rooves for ease of identification for aerial support, particularly if the individuals crewing the vehicle need exigent assistance. Drawing on an actual event from the 2013 Blue Mountains Wildfire, this paper highlights how aerial support from a water bombing aircraft was unable to read the existing black aerial identification numbering of a fire appliance because the black identification number coalesced with the black plumes of smoke emitted by the wildfire. Given the extensive technological development in the application of high visibility markings over the past twenty-one years, the current black and aerial identification numbering used by the New South Wales Rural Fire Service on their fire appliances is far from adequate, doing little to provide optimum safety for fire ground crews in a wildfire. This paper concludes that the current black aerial identification numbering should be replaced with high visibility aerial identification numbering markings because these have greater visibility for aerial support in a wildfire particularly in the colours of red, lime, yellow, orange or blue.

Keywords: Aerial Identification Numbering, high visibility, vehicle marking, camouflage

INTRODUCTION

The use of high visibility markings on vehicles was formalised in 1958 under the United Nations (UN) international agreement of Uniform Provisions Concerning the Approval of Retro-Reflective Types for Two-Wheeled Vehicles, under Regulation 88 (UN 1958). Prior to this, there was no global agreement or manufacturing conformity for high visibility markings. The UN agreement standardised global manufacturing standards that included reflective qualities under the scientific references of colorimetric, photometric, and physical and mechanical requirements (UN 1958: 11).

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The adoption of these scientific attributes was premised on research carried-out by the International Commission of Illumination (UN 1958: 5). Part of its study comprised the ability of the retroreflective tape to be resistant to external agents, such as oil, fuels, dust, dirt, rain, washing, and fading. It had to maintain its qualities in extreme heat—up to 50°c—and cold, down -20°c. It had to be resistant to collision or impact with other objects, had to be seen at night and during the day (1958: 20), and once applied to a vehicle it could not be easily removed. In 1985 the same UN suggested that the colours of yellow, white, and red were good for day and night visibility. Australia is a signatory to this UN agreement.

Since the introduction of the UN agreement, the application of high visibility markings has become common place, now extending to *high-vis* vests in sport, school yards, and work places. High-vis markings are on children's tee shirts and workplace shirts and pants, even on running shoes for ease of detecting joggers running at night.

The origins of high-vis clothing stems from International Standard ISO20471 *High Visibility Clothing—Test Methods and Requirements,*" and the American National Standard *ANSI/ISEA 207—American National Standard for High Visibility Public Safety Vests*. Standards Australia adopted the international standard of using high visibility safety garments in risk-prone occupations to help reduce workplace accidents. The first regulated workplace in Australia to enact the wearing of high-vis clothing was under the *Perth Market By-Laws 1990—Regulation 13A (WA),* whereby "High visibility clothing must be worn in certain areas of the market" (Australian Legal Information Institute 2016) to reduce fork lift accidents. The extent to which application of these high visibility markings are now used by-way of regulation or voluntarily in the workplace, at sporting events, on school grounds, or part of leisure apparel, could not have been foreseen in 1958.

BACKGROUND

Aerial Identification Numbers (AIN) are numbers, or a combination of numbers and letters, that are adhered to roofs or bonnets (hoods) of emergency vehicles that identifies them from aircraft. There are an estimated 40,000 emergency service vehicles in Australia, all of which have their own AIN. State and territory police forces, fire services, ambulance services, volunteer fire organisations, State Emergency Services, volunteer rescue associations, and marine rescue organisations, all have their organisations' unique AIN. Add to this, other statutory bodies such as Australian wide correctional services 300 vehicles, national parks 15,000 vehicles, water authorities 210 vehicles, and state transit services 8,000, all have unique AINs. Moreover, if the private security sector vehicles, such as armoured trucks and night patrol vehicles, road and construction plant/machinery are included—approximately 70,000 nation-wide—the total number of vehicles on Australian roads with AIN could be in the order of 133,510.[1]

AIN are all black in colour and are non-reflective. Their importance does not become apparent until an emergency vehicle needs exigent aerial support and the only way to locate and identify the correct vehicle is by their unique AIN. There has been no research into the effectiveness of the existing black AIN's. Notwithstanding, there are four studies that have examined the high visibility markings.

The first study into high visibility colour and design high visibility markings occurred in Canada in 1979. It centered on the value of high visibility markings (or *brandings*, as they were known then) on railway cars. After a spate of accidents, some fatal, in Canadian rail shunting yards, a trial was undertaken to find an effective method to reduce these workplace accidents (Volpe 1998: 9). To reduce shunting accidents, freight rail cars had highly visual white squares applied. These measured 36 x 36 inches (91cm). The squares had to be conspicuous from a minimum distance of 800 feet (243m) during the day and night. To gain optional high visibility, the squares were placed on each side of the rail car. The study resulted in a reduction of shunting yard accidents (the amount was not cited in the paper) because the visibility of the carriage was increased due to the "visual medium" (Wilson & Giese 1977: 1,178). That is to say, the introduction of an object that was vastly different from its background. This study was replicated fifteen years later by the United States Department of Transportation.

In 1994, the United States Department of Transportation under took a study to improve safety of highway railroad crossings where there were no boom gates. To increase the high visibility of bulk grain wagons, they adopted the 1979 Canadian research findings and placed reflective rectangle markings of 24 inches (61cm) x 48 inches (122cm) on the side of grain wagons. However, rather than adopting white as the only coloured rectangle, they trialled nine different colours and colour combinations comprising yellow, red, and white. To this, they also applied two different marking designs. The first were long narrow unbroken high visibility strips running the entire length of the grain wagons. The second were long narrow, but broken, strips running the length of the wagons.

After trialling the nine different colour combinations and designs at 136 sites across the United States, the study found that the quickest mean recognition time for colour and design was the unbroken yellow high visibility strip, which was seen from 3,500 inches (88.9m) (Volpe 1998: 100). The long narrow unbroken yellow high visibility strips and rectangle markings ensured that the entire train could be seen at night—there were no visual blackspot while the wagons passed through the crossing.

The third study on high visibility markings was by the UK Home Office. In 2004 the Home Office's Police Scientific Development Branch undertook the world's first research into high visibility markings of police vehicles. The study looked at the questions of how to create a highly visible police vehicle (Harrison 2004).

The study was motivated by the need for a motorway police vehicle (highway patrol) to reduce traffic accidents by being 'detected' by passing motorists (Harrison 2004: 1; Langham, Hole, Edwards et.al, 2002: 167). The project resulted in what has become known as *battenburg livery* high visibility (i.e. fluorescent or retro-reflective colours) markings of blue, red, white, lime, yellow, and orange in combinations and designs of solid strips, chequered tartan patterns, rectangular patterns, and other designs and permutation of the same. This mix-and-match of colours and designs make vehicles visible throughout the day and night; in rain, fog, and mist, from a minimum viewing distance of 500 meters (Harrison 2004: 3).

The high visibility markings in Australia that have become standard identification of the police is the chequered tartan pattern of blue and white on their vehicles, as well as their uniforms. The common high visibility markings that denote fire and rescue agencies are the colour combinations of red, white, and yellow. For ambulance services, it is red, white, blue and/or green. The State Emergency Service is orange and white chequered tartan, and in the case of the New South Wales Rural Fire Service (NSW RFS) it is red and white stripes. These high visibility colour combinations and designs are now instantly recognisable to the casual observer.

The final study that is considered relevant to this issue was carried-out by the United States Fire Administration (USFA). In 2009, the USFA examined the suitability of high visibility markings in the form of coloured stripes or patterns for day–night visibility for fire appliances. Maintaining the historical significance of red as the dominant fire department colour, high visibility markings of red and white, and/or red and yellow coloured stripes or patterns, were recommended to US fire departments premised on their ability to stand-out not only in rain, fog, and mist, but night and day. These are important qualities in a fire environment. The purpose of the high visibility markings was not to prevent collisions between fire appliances or other emergency agencies at a fire scene, but to increase a fire appliance's prominence to road users, thus reducing collisions between fire appliance and road traffic (Brady 2014: 25).

Despite the USFA study, and the previous research by the United Kingdom Home Office, United States Department of Transport, and the Canadian study into freight wagons, the application of high visibility markings for AIN remains unexplored.

PROBLEM IN CONTEXT

All New South Wales Rural Fire Service (NSW RFS) vehicles have unique AIN that are located on the roofs of its appliances. The purpose of the AIN is to provide aircraft with the identification of fire ground crews. This is useful in three general situations. The first is when the vehicle is used as a reference point for aerial support; that is, to locate a specific nearby fire, and then extinguish it by dropping water. Second, AINs are used by aircraft to locate mobile command posts (e.g. a firefighting vehicle). The final, and arguably the most critical reason AIN are used, is to locate a crew in a fire appliance who, as a last resort, are using their vehicle as a safe-haven because they have been trapped by the fire.

As a case study, take the October 2013 Blue Mountains wildfire. In this blaze, 205 homes were destroyed (NSW Parliamentary Research Office, 2014), and hundreds of fire crews extinguishing structural (building) and bush fires over a 30-square kilometre area. During the wildfire, a water bombing aircraft was requested by a fire ground crew to extinguish a fire. To gain a visual bearing as to where to drop water, air support requested the crews' AIN. But, because of the thick plume of smoke being generated by the fire, the helicopter was unable to locate the vehicle's AIN. The black roof AIN of the fire appliance was camouflaged, coalescing into the environment created by the black smoke. The air observer was not able to distinguish the number in the smoke, so the water bombing never occurred.

RATIONALE

The black AIN regime used by the New South Wales Rural Fire Service has not changed its design or colour since it was introduced in 1995. However there appears that the subject literature provides little guidance; a search shows that there have been no publicly available studies that explored the feasibility of having an AIN that is highly visible for the Australian wildfire environment. In contrast, there have been important developments in high visibility markings, design, and colour combinations over the same twenty-one-year period in other contexts that could be applied to AIN of NSW RFS vehicles. An event during the 2013 Blue Mountains wildfire exposed a serious deficiency in the ability of aircraft to see the AIN of a NSW RFS fire appliance. Given that there are an estimated 133,510 vehicles with AIN, the implications for operational safety, the findings of this assessment could not only apply to the NSW RFS, but other services.

METHOD

To weigh-up the factors in the debate about high visible AIN markings, a plus-and-minus analysis was used. Using the structure of this for-and-against approach allowed the factors, or pressures, that support the status quo (termed *restraining factors*) and those pressures that support a change (*driving factors*) (Cronshaw & McCulloch 2008: 90). This analytic method makes the assessment transparent.

The data used to identify the opposing forces came from publicly available sources—i.e. secondary data—relating to the October 2013 wildfire. Further, data regarding the 2014 bushfire at Warrimoo in the Blue Mountains, and four hazard reductions in 2015, and three hazard reductions in 2016, all in the Blue Mountains, were also used.

The fires in 2014, 2015, and 2016 were within 30 square kilometres of the October 2013 Blue Mountains wildfire. All fires were between 2–15 square hectares in size, all on clear sunny days with no cloud cover or significant wind. The vegetation burnt in the October 2013 wildfire was of the same type that was subject to the 2014, 2015, and 2016 fires; eucalypt-dominated vegetation including wet and dry sclerophyll forests.

RESULTS

Driving Factors for Change

Size of AIN. A weakness of the black AIN on the cabin rooves of NSW RFS vehicles is their size, being very small only 30cm x 10cm. Their size does not exploit all the available roof space of the fire appliance to facilitate ease of aerial identification. Currently the AIN can be increased by ‘three’ to maximise its aerial visual effect that is, locating and reading the AIN. The increase in size is critical when it comes to urgent vehicle identification. The size of the AIN needs to be tailored to the worst-case scenario (environment) as was the situation during the October 2013 wildfire where a fire appliance AIN could not be seen due to the dense black smoke. The larger the AIN the greater the chance of it being identified, standing out for aerial identification.

A case in point is the vehicle AIN marking regime of the New South Wales Police Force. The NSW Police AIN numbers and/or letters consume the entire bonnet and/or most roof space for optimal and rapid identification. The “recognisability” (Chidlow 2012: 6) is of utmost importance for emergency vehicles because it needs to immediately catch the eye of the person scanning the environment for it. As Thomas and Williams (2012: 2) point out when referring to police vehicles operating on roads or at the scene of a crime, “vehicle detection through its high visibility of markings is critical for officer safety as police and their cars are frequently placed in dangerous situations where they may need rapid backup.” Presumably the same can be said for fire crews particularly should they need to take refuge inside a fire appliance if they are to be overrun by wildfire. Rapid aerial identification of the correct fire appliance is paramount, but the need for changing the existing small NSW RFS AIN is also premised on their operating environment, in bushland that can have very limited light.

New South Wales Police vehicles operate in an environment that is urbanised, well-lit by street lights as well as residential and commercial building lights. Therefore, their work environment is open, luminous and is, from an aerial perspective, relatively visually unrestricted. Despite operating in this bright and unobstructed environment, their vehicle AIN are and have remained very large for decades now. Why? For the sole purpose of rapid aerial identification by police aerial support (PolAir) for officer safety. This is not the case with the small black AIN that exist on NSW RFS appliances, appliances that operate in an environment that is frequently dominated by opacity. The larger the AIN, the greater the ability to locate, recognise and decipher it. This is not the situation with NSW RFS AIN.

The lead combat agency response for wildfires in New South Wales is the NSW RFS and their operating environment is commonly in topography that is dominated by escarpments, valleys, gorges and/or in eucalypt forests that have average height of 60m and with a canopy density up to 80% of ground coverage (Givnish, Wong, Stuart-Williams et.al 2014: 5 and Peeters and Butler 2014: 2). This is the type of topography that could be representative of many mountainous regions in Australia. The purpose of the AIN in a bush environment is not only to identify the fire appliance from the air, but more importantly to maximise fire fighters' safety on the fire ground. Just as workplace signage warn staff of potential dangers or hazards on a factory floor or on a building site, so AIN is essential for ensuring fire fighters workplace health and safety in their work environment. Valleys, gorges and tree canopy coverage will vary in density and depth, therefore the degree to which sunlight can penetrate a valley floor will also differ. This divergence will hinder the ability of aerial support to locate and render assistance to a fire appliance and the crew with the existing small black AIN. Very large AIN markings that consume maximum cabin roof space will be easier to locate by aerial support than the existing NSW RFS AIN marking regime.

Size of AIN. The existing design of the NSW RFS AIN is realistic and is a true representation of number identification that it denotes. The numbers are all one dimensional, that is, there is nothing abstract about them, they are all balanced in appearance, and they do not overlap. They are identifiable by aerial support, as has been demonstrated over the decades in fires. Furthermore, across NSW not all fire appliances fight bushfires in topography that has the physical features or vegetation that is found in valleys, gorges or under thick tree canopy. In fact, most of NSW's topography is open and relatively flat plains or grasslands. It does not always consist of thick tree canopy. Given this, it is not necessary for the existing AIN to be altered purely premised on the argument of topography.

Colour of the AIN. Over the past twenty-one years there has been enormous scientific development in retro-reflective high visible algorithms (Yong Xu et.al 2015:2 and Singh, Dhawale & Misra 2013: 355) that now give rise to a host of different "threshold of visibility colours" (Wilson & Giese 1977: 1177) or high visibility markings.

The NSW RFS AIN are black and have a flat black pigmentation that is ineffective in a wildfire because their black colouring coalesces with the black plume of smoke emitted from the fire. In contrast the highly fluorescent or retro-reflective high visibility colours of lime, yellow or orange have proven to be effective in snow, fog, rain and cloud cover (Thomas 2004: 10). The USFA (2009) examined the suitability of day-night time high visibility markings on fire appliances not only in rain, fog, mist and at night but also the chromaticity within a fire environment. Their research validated earlier studies finding that high visibility markings on fire appliances resulted in their greater luminosity. The USFA recommended that fire authorities across the United States should apply retro-reflection markings to their fire appliances for ease of attracting the observer's eye to the fire vehicle in the colours of yellow, lime, orange and red.

Organisational Policy. The policy for the design, size and colour of the current New South Wales Rural Fire Service AIN was established in 1995. This policy is twenty-one years old, and has not been revised. While there have been improvements in engineering of fire-fighting appliances (e.g. roll bars, radiant heat shields inside cabins, vehicle safety sprinkler systems, and improvements in personal protection equipment), the design, size and colour of the AIN has not been subject to policy review.

Restraining Factors

Colour of the AIN. There are three arguments that suggest there should be no change. First, there has been no research into high visibility markings, so the hypothesis that a high visibility AIN is superior to a black small AIN has no basis in evidence. Second, the existing black against the white colour that RFS vehicles is an effective contrast for aerial identification. This colour-pairing does not detract from either pigmentation and therefore brings into question the need for any retro-reflective high visibility markings.

The final argument is the insufficient colour contrast of a green AIN. A retro-reflective green AIN could compromise the safety of a fire appliance and its crew because a green AIN colour could meld into a green tree canopy or undergrowth. This could result in insufficient colour contrast to make the AIN identifiable from the air within a bush environment. This problem was highlighted by Neider and Zelinsky (2006: 2,233) regarding the effects of target-background similarity. They established that a similar coloured background to the primary object prevented the process of identifying objects of the same or similar colours. Like findings were found by Wolf, Oliva, Horowitz, et.al (2002) Hess, Wismer, Bohil, et.al (2013) and Heinrich and Selj (2015).

Organisational Policy. The existing AIN complies with NSW RFS policy, *Circular 152/97*, on commonly accepted AIN standards for all Rural Fire Service vehicles. Further, the AIN complies with the United Nations guidelines on the *Uniform Provision Concerning the Approval of Marking for Vehicles*. Therefore, the AIN conforms to existing Service Standard benchmarks at organisation and at global level. The justification for organisational change is minimal under the circumstances.

DISCUSSION AND CONCLUSION

Density of the black smoke emitted from the 2013 Blue Mountains wildfire merged with the black AIN on the NSW RFS appliance making aerial identification impossible. This melding is like what occurs with military units in combat. The military use tactics on the battle field to shroud military personnel and vehicles from the enemy and one technique is activating obscurant pyrotechnic smoke to screen and protect vehicles and infantry in combat (Pulpea, 2015: 732). Another method of shrouding military personnel or vehicles from the enemy is the application of paint or camouflage to counter object detection (Elias, 2011; Singh, Dhawale & Misra 2013: 351). In both cases the purpose of hiding personnel and vehicles is to "mask the object with the foreground to appear as the background or vice versa so it cannot be seen" (Singh, Dhawale & Misra 2013: 352). This is what occurred with the black AIN in the 2013 wildfire; it merged with the environment. The background of the black AIN appeared as the foreground of smoke. To break this visual relationship, de-camouflaging is applied.

De-camouflaging relies on the theory that intensity of colour and shape can be used to disrupt the foreground, background, and filter response (Elias, 2011; Galun, Eitan, Ronen, et al., 2003: 1; and Schaefer & Stobbe 2006: 2,427). Premised on research, the luminosity of high visibility markings on rail cars, police vehicles and fire appliances of lime, yellow, blue and orange, at night, during the day, in snow, fog, rain, and of particular note, in smoke, the high visibility achieves this interference by fracturing the common hue and/or pigment relationship between the two objects, the smoke and high visibility AIN.

Chidlow (2012: 6) pointed-out that once there is this disconnect recognisability, the capacity to catch the eye of the person scanning the environment will be maximised because the image is enhanced.

Given research findings, it is reasonable to suggest that the application of highly visible AIN in lime and/or yellow or orange are likely to provide optimum attraction to aerial support. The choice of these colours is premised on USFA recommendations that these colour markings stood-out best in a fire environment. Juxtaposed to this was use of the colour of blue to contrast or have a de-camouflaging effect within a bush environment. What research does not support is the existing use of black AIN because the black foreground of smoke blends with the black AIN background.

The research into the use of highly visible AIN markings since 1979, the 1958 and 2010 *UN Agreement Concerning the Adoption of Uniform Conditions of Approval and Reciprocal Recognition of Approval from Motor Vehicles Equipment and Parts*, the adoption of high visibility markings on emergency vehicles around the world, and on work and sporting apparel, demonstrates the importance of highly visible markings.

The current size of the AIN on the roofs of fire appliances has also been questioned. The existing practice of having small AIN that fails to take advantage of the entire cabin roof and does little to enhance the ability of aerial support to identify a specific fire appliance in a wildfire. The entire space on the roofs of NSW RFS fire appliances should be exploited, not the mere portion as is the currently the case.

The arguments for change out-weight those for the status quo. So, the question for policy makers is: Would it not be timely to consider these arguments with the view to re-examine the currently AIN policy?

ENDNOTE

1. The figures cited are only estimates. The numbers validating them were arrived at from the relevant State and Territory Government Agency cited via their websites. Websites of Volunteer Rescue Organisations across each State and Territory were also interrogated. Private Corporations such as Armguard, Chubb, ADT, G4S, Wormald web sites and construction companies of Brookfield Multiplex, John Holland, Downer EDI Works,

Fulton Hogan, Thiess, Leighton Contractors, Lend Lease, BHP Billiton and Laing O'Rourke were also used to arrive at these numbers.

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