Aerial Bushfire Quencher: C-17 Conversion for Fire Fighting Operations

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C-17 Conversion for Fire Fighting Operations

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Abstract

Australian summers are hot and dry and bushfires are a significant risk to life and property. The worst ever recorded natural disaster were the Victorian Black Saturday Bushfires in 2009, where 173 people lost their lives. To limit bushfire damage, an effective firefighting capability is essential. This project investigated the feasibility of using existing military assets and converting them to firefighting/control capability on an as required basis. This paper presents a conceptual design of a RAAF C-17 *Globemaster III* conversion to a temporary firefighting platform that provides three support roles: water drop, in-flight refill of standard firefighting aircraft and in-situ surveillance, command and control. Provisions were made for quick conversion with minor structural modifications to allow return to military status.

Keywords: aerial firefighting, aircraft conversion, aerial refilling, tankage/pump systems

1. Introduction

Bushfires are a major threat to the Australian environment and is the most dangerous natural hazard in terms of risk to human life [1]. Bushfires can originate from both human activity and natural causes with lightning as the predominant natural source, accounting for about half of all ignitions in Australia [2]. The damage due to bushfire costs on average $1.6 billion a year [2]. To reduce the loss of life and property damage, an effective firefighting capability and operations must be implemented. In this project several alternatives were proposed and compared against, for example, drop frequency, drop volume, cost, complexity, etc. The outcome of this study was a proposal to design a system to convert an RAAF C-17 *Globemaster* to a firefighting role; in accordance to an agreement that falls under the banner of a *Military Operation to Civil Power* system [3]. A key benefit of this concept is the use of existing aerial systems. The aircraft can be refitted with a fire retardant/water tank arrangement, as shown in Fig. 1; which is easily installed as per normal cargo loading operations. The C-17 aircraft was decided upon as it has the payload capacity to meet the design requirement of 10,000 gallons (37,854 L/kg of water; C-17 has a payload capacity of 77,519 kg) [4]. Loading ramp capacity is limited to 18,144kg, thus the tank system is build-up from individual tanks which are connected and latched securely, and feeding to a common fire-tank based hose connection system at the rear of the aircraft. This is where the conceptual and novel incorporation of an aerial refilling system of fire retardant has been considered within the C-17 role support system for the purpose of assisting and air-to air refilling of smaller to medium range firefighting airtankers during operations.

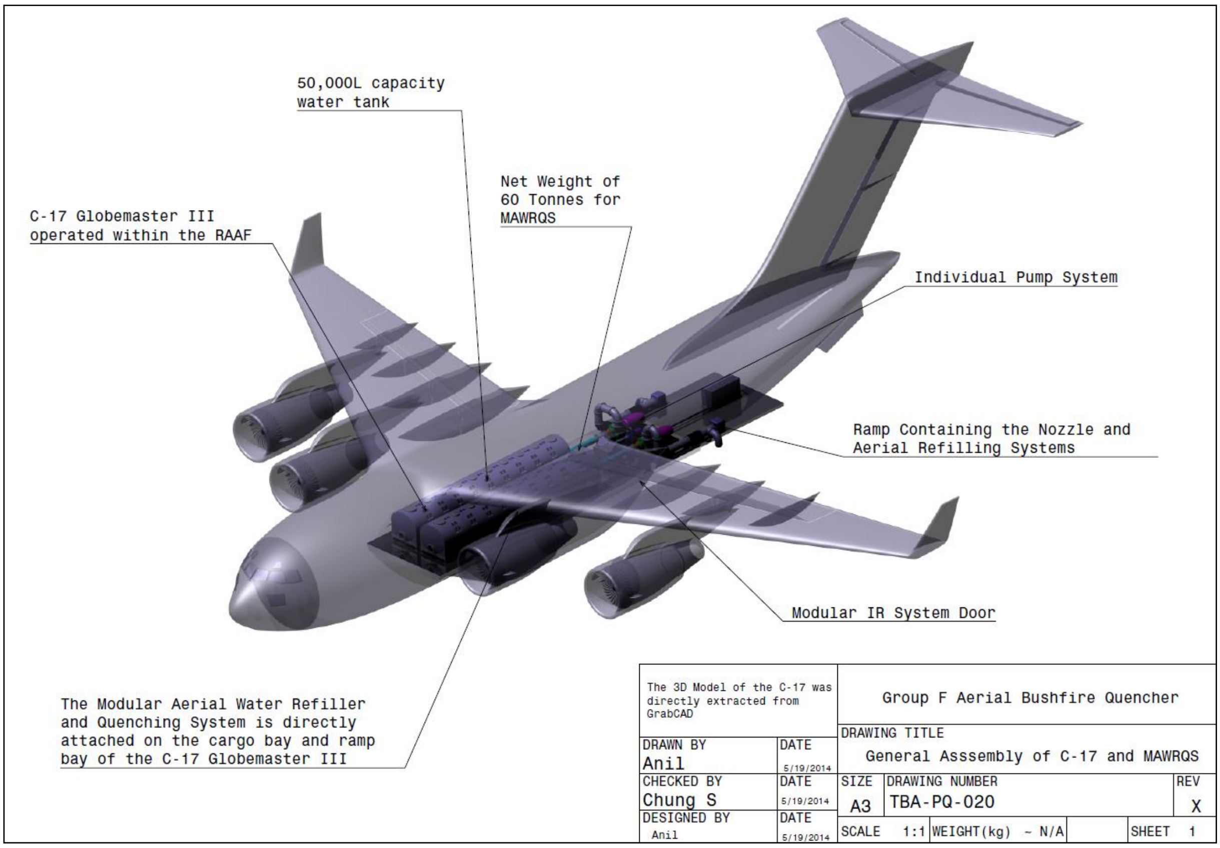

Fig. 1: Overview firefighting conversion system for RAAF C-17 Globemaster III.

This modular design was inspired by the Modular Airborne Fire Fighting System (MAFFS II); a joint project between the U.S. Forest Service and the Department of Defence [5]. This system is a self-contained unit used for aerial firefighting with a C-130 Hercules aircraft. All systems are powered using bleed-power from the aircraft internal auxiliary power units. It is modular in the sense that it is not a permanent installation and does not compromise the original airframe; hence minimizing the certification process on the assessment of fatigue as the modular system in bounded within the loading restrictions of the C-17.

Fig. 2: Modular Airborne Fire Fighting System (MAFFSII).

2. Design Requirements

Summary of key concept points:

- Military operated RAAF C-17 *Globemaster III* platform
- Modular firefighting and aerial refilling systems
- Support role:
  a) Original aircraft configuration is not modified and aircraft is returned to military operation status after fire operations are completed
  b) Command, control and surveillance support
     i. IR tracking provides situational awareness and early detection

ii. Ground personnel tracking
iii. Accurate water/retardant drop

Summary of key design requirements:

- System will comply with CASA CAR 35, NAFC regulations and AAP 7001.059.
- C-17 is already certified for Australia military operations. RAAF C-17 flight crew must be used with mission specific specialists on board.
- System will not cause any environmental damage during operation. The fire retardant will comply with OH&S standards, with a compliant MSDS.
- System must consist of an FLIR camera that can find hot spots.
- Aircraft must be equipped with all required systems to maintain an oversight of the situation and communicate with all personnel.
- The aircraft is capable of fighting fires within 30 m x 400 m area.
- The system is capable of holding 50,000 litres of fire retardant.
- The aircraft is able to cover a 600 km range; within a near bushfire prone area
- Response time must be not more than one hour at the 600 km range
- The take-off field length at full capacity is not more than 2,359 m.

3. Water/Retardant Tank Storage and Drop System

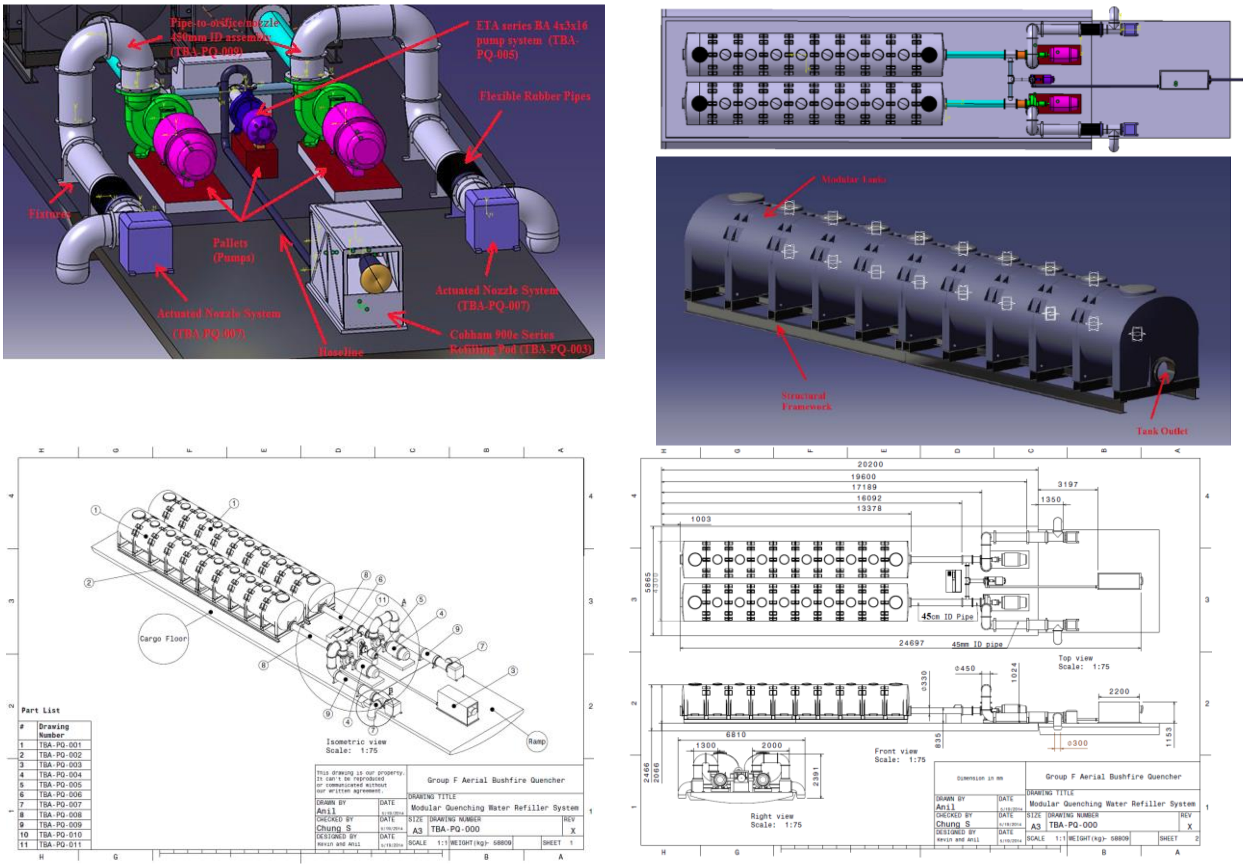

Fig. 3: Water/retardant tank storage and drop system design.

Two main lightweight polyethylene tanks operate in parallel delivering 25,000 litres per tank. The contents weigh approximately 50,000 kg. Additional structural framework, pumps, and piping are estimated to weigh about 60,000 kg for the total system; as this is 79% of the C-17's total payload capacity. To reduce the 'slushing' effect and for ease of loading, each tank consists of 5 smaller tanks which are interconnected and baffled as shown in Fig. 3. Water drop is conducted via nozzles which extend out from the sides of the cargo ramp; in reference to Fig. 5. These nozzles are retracted during travel to and from the area of operation and can be retracted quickly if the ramp needs to be closed. Based on required coverage area and saturation levels, a minimum flow-rate requirement of 18,000 l/min was estimated.

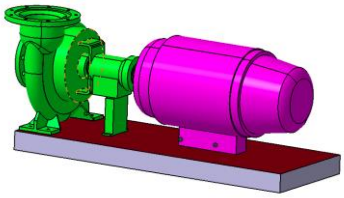

Fig. 4: Carver ETA Series Pump design and installation

Carver ETA Series AD 12x12x13 electric centrifugal pumps were selected with a flow rate of 35,000 l/min each, so 70,000 l/min total, and paired with a new nozzle design calculated to meet the standards. Pump size was limited to available space within the aircraft. The design achieves an orifice nozzle flow rate of 10.14 m/s with an outlet diameter of 275 mm. With a nozzle angle of 16 deg., a flow rate analysis confirms that this design can achieve a coverage area of 15.28 m wide at the appropriate saturation level to put out a fire, given a drop altitude of 200 m. This assumes the aircraft flying at 50 m/s (100 knots). In accordance to the pump specifications and performance, it is noted that at a flow rate of 34,100 l/min (9000 GPM) the differential pressure, known as the total head, is 29 m (2.8 bar). The pump motor must provide at least 275 HP, taking into consideration of the efficiency of the pump (which is approximately 78% at 9000 RPM with a 13.63” diameter impeller.

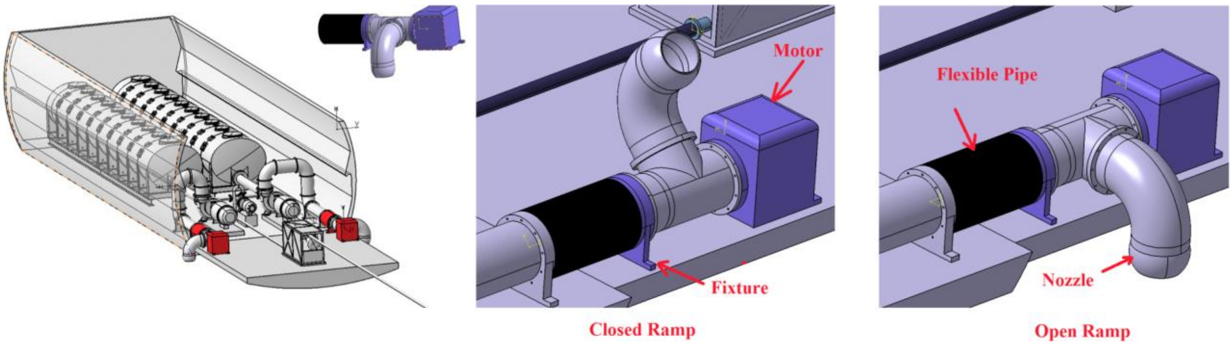

Fig. 5: Swivelling nozzles mounted on either side of the ramp door.

To reduce the complexity of the system, a simple convergent nozzle was chosen and mounted on the cargo ramp door with an actuator to rotate the nozzle when the ramp door needs to be close as shown in Fig. 5. This also frees up the paratrooper door so a Forward-Looking Infra-Red (FLIR) detection system can be attached (see Section 5). The nozzle angle is variable and can be set to achieve a required area of coverage area of 30m by 400m with an approximate saturation depth of 5mm. This overall modular system has been design to fit within the internal constraints and weight restrictions of C-17 Globemaster III.

4. Aerial Refilling

Inspired by military aircraft re-fuelling processes, a system was designed that could safely and efficiently re-fill modified Single-Engine Air Tanker (SEAT) and other multi-engine airtankers which exist in Australia’s infrastructure today. The re-filling of an aircraft mid-air, at the fire location, is intended to save time by eliminating the need for a SEAT to have to journey to a water source such as a lake or even return to an airfield to re-fill, saving time and enhancing the fire-fighting response, particularly in areas where convenient water sources are limited. In order to maintain the system as an all-in-one, a new pump, re-filling pod and drogue system was designed based on existing technologies. An adaption probe system was also designed for the existing fire-fighting aircrafts, which shall channel the fire retardant into their existing storage facilities. However, this is with consideration performance characteristics of C-17 and implication applying deviations and request for change in the adaption of probe system into existing firefighting aerial platforms.

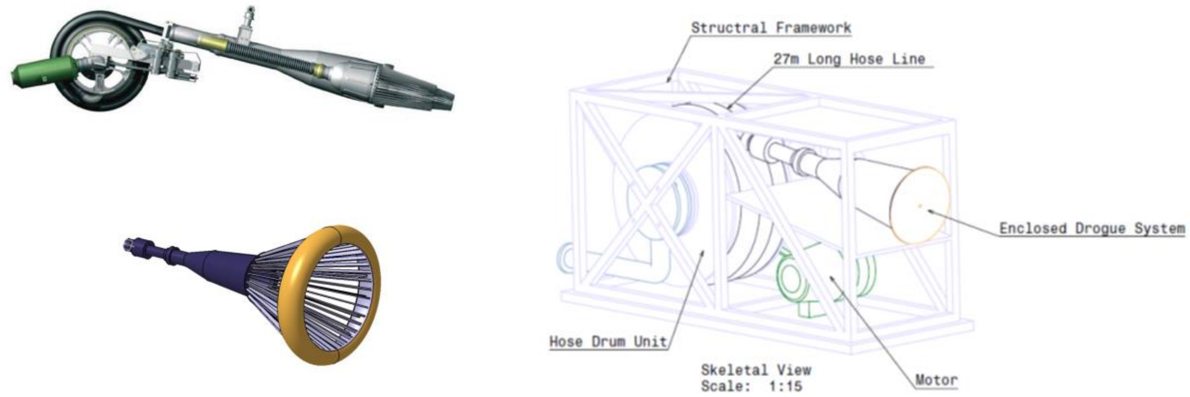

Fig. 6: Aerial water refilling pod and drogue design.

Suitable components include the Cobham FR300 re-fuelling pod (sender), Cobham 900e series drogue and variation of the Cobham refuelling probe system (receiver). With an operational airspeed up to 216 m/s (420 knots) and a re-filling speed of 1500 l/min, the Air Tractor AT802, Australia’s primary fire-fighting platform, can be filled in just 2 minutes compatible [6]. This is with consideration to the C-17’s performance, wake and downwash generated by the wings as the drogue can extend 25 metres behind the ramp.

5. Reconnaissance, Communications and Control

Another function of this concept is providing in-situ reconnaissance and communications capability between the Country Fire Authority (CFA), National Aerial Firefighting Centre, RAAF, ground personnel and airborne personnel. By incorporating audio-visual elements via a communications officer within the aircraft, the use of infra-red video technology can enhance the coordination of fire-bombing efforts and boost overall situational awareness. An appropriate camera for adequate visibility through smoke and during the night hours is the Cloud Cap Technology TASE400LRS [7], featuring gimbal stabilisation, geo-pointing capabilities (coordinate designation) and on-board image processing for target tracking. All of these features are intended to increase the tactical awareness and safety of aerial fire-bombing and ground-personnel safety. To work with the modular design, a new side paratrooper door was designed which can accommodate this technology and be installed with the rest of the system without affecting the original structure of the aircraft. A similar system was used with the MAFFS II, whose quenching nozzle is located within a similar door construction, albeit on the C-130 aircraft [8].

It is proposed that a replacement rear-left paratrooper door be constructed in conjunction with Boeing and their original designs that can incorporate our chosen TASE400LRS camera. The camera will be mounted within this new design as shown in the CAD model below. It consists of weather-proof, aerodynamic extension housing with the TASE400LRS mounted on the bottom of this system, providing a full top-down, left-right vantage to the left of the flight regime. The mission flight plan will have to be coordinated and organized as such to direct the camera appropriately, and also assist aircraft water refilling operations.

Fig. 7: Modular paratrooper door for FLIR installation.

Conclusion

A feasibility study into the conversion of a RAAF C-17 *Globemaster III* to a fire fighting role has been conducted. Although this paper only presents a small subset of the results, the study shows that a conversion water/retardant storage and drop system is technically feasible and would give the C-17 significant support capability as a water drop platform, an aerial refill station and a reconnaissance, command and communications centre for overall operations. The installation does not compromise the airframe structure and the aircraft can be returned to military operation status. The aircraft can carry up to 50,000 litres of water/fire retardant contained across 10 smaller tanks that are loaded separately and then interconnected. The required pumps and piping system have been sized and selected. The total mass of the installation, including water/retardant, is approximately 60,000 kg; hence weighing less than the aircraft's maximum payload limit and no structural modification is required with the exception of replacing the removable door to install the IR system. The estimated cost for each set of a fire fighting conversion systems is about $1.1 million AUD, excluding installation and operation. In conclusion, the study shows that the proposed proof concept is feasible and it is recommended for further detailed investigation; as the C-17 have been known for their role support capabilities from med bays to heavy payload drops. Being a conceptual proof of concept, further research on this design could be to perform FEA analysis on the flight profile to detailed feasibility studies with consultancy. Without the need to design a new airtanker, it would offer the Australian firefighting authorities an additional, cost effective and powerful capability in combating bushfires across the country.

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