

COST ANALYSIS OF FIRE SUPPRESSION SYSTEMS

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DISCLAIMER: This project was neither sponsored nor performed under the auspices of the C-17 Program Office, and is intended to serve only as a research tool to assist in improving the quality and relevance of current fire protection research to the operational military aircraft community. It is not an official or formal trade study or assessment of the merits of modifying the existing fire protection system design of the C-17 aircraft specifically, nor is it intended to be such. Interpretations and simplifications have been made by the investigators in executing this project, to comply within the project scope and purposes for the R&D community and sponsors.

ABSTRACT

The objective of this effort was to perform a comparative cost analysis for existing Halon 1301 fire protection systems and a potential off-the-shelf-alternative (HFC-125) system as integrated into applications similar to several typical military aircraft platforms. This effort developed a methodology to determine the total system costs of an aviation on-board fire protection system, the cost savings incurred by having a fire protection system, and the net cost of the fire suppression system. This methodology is being developed for systems with equivalent performance of Halon 1301 and for a system with varied performance, to optimize benefit per system weight and cost. The methodology has been developed for an application similar to the C-17 engine nacelle fire suppression system with equivalent performance of Halon 1301. Current efforts are adapting this methodology for applications similar to the Navy F/A-18 E/F, the RAH-66 Comanche, and three platforms yet to be determined. Aircraft dry bay and engine nacelle applications are being examined.

BACKGROUND

All three services and their respective platforms have special problems in regard to fires. Each carries munitions, which can be initiated by a fire. In addition, each also contains large quantities of fuel distributed in fuel tanks throughout, with fuel lines running between these tanks and the engine(s).

NEXT GENERATION FIRE SUPPRESSION TECHNOLOGY PROGRAM (NGP)

The goal of the Next Generation Fire Suppression Technology Program (NGP) is to develop and demonstrate, by 2005, retrofitable, economically feasible, environmentally acceptable, and user-safe processes, techniques, and fluids that meet the operational requirements currently satisfied by Halon 1301 systems in aircraft. The results will be specifically applicable to fielded weapon systems, and will provide dual-use fire suppression technologies for preserving both life and operational assets [1].

AIRCRAFT FIRES

In most cases, fire is either the primary cause or a contributing factor of loss of aircraft assets. In many instances, injuries to personnel and loss of mission capability accompany a fire event. Aircraft fires are a significant cost to the Department of Defense. Methods and technologies to mitigate them or “design them out” are imperative, not only to save aircraft, but also to save lives and prevent property damage.

Fire extinguishing systems are used on military and commercial aircraft to protect engine nacelles (the region surrounding the exterior of the jet engine case and shrouded by an outer cover, and typically ventilated), and dry bays (which can include wing leading/trailing edges, landing gear, avionics, and weapons bays). These systems are fixed in configuration and activated remotely to totally flood the compartment in question with fire extinguishant. Auxiliary power units (APU), which provide ground, supplementary or emergency power, are also frequently protected using such systems, either as stand-alone units or in conjunction with the engine nacelle fire extinguishing system.

Engine nacelle fire protection systems are designed to protect against events such as ruptured or leaking fuel, hydraulic fluid, or oil lines within the nacelle. In these circumstances, flammable fluid can leak onto the hot engine case or accessory components and ignite. These systems also protect against catastrophic events such as thrown turbine blades that instantaneously rupture fuel sources or overheating components that can initiate fuel fire scenarios. The two most common types of fire hazard in the engine nacelle are a direct consequence of the means of fuel delivery, i.e., either a spray fire or a pool fire. An additional fire hazard associated with the aircraft engine nacelle is that even after extinguishment is achieved, a strong potential exists for reignition of the fire from hot surfaces. Hot surface reignition remains a threat as long as fuel vapor and air can come in contact with sufficiently hot surfaces. Suppression of the hot surface reignition fire hazard in the engine nacelle requires an additional amount of agent over that required for flame extinguishment in order to maintain extinguishment until the hot surfaces cool.

Dry bays are defined as void volumes within the mold line of the aircraft, excluding air inlets, engine compartments, and exhaust nozzles. Examples include wing leading edge bays, landing gear wheel wells, avionics equipment bays, and weapons bays. Dry bays frequently contain fluid lines, bleed air ducts, and electrical cables and may contain avionics, flight control actuators, hydraulic accumulators, and liquid oxygen dewars. A fire in a dry bay typically requires a rupture of the flammable fluid components and the generation of an ignition source. For this reason, it is assumed that this scenario is created when a ballistic projectile impacts a dry bay in flight, rupturing fuel system components and generating tremendous ignition energy. Although this is the assumed primary initiation means, other initiation sources, such as overheated, shorting electrical circuits in avionics bays, some other form of impact (i.e., bird strike), or burning stored munition propellants, can also be responsible in rare instances [2].

METHODOLOGY

A methodology was developed to determine the net cost of the fire suppression system. This methodology incorporates the cost of the system, which is a function of system size/weight, and the cost savings provided by the system, which are a function of extinguishant effectiveness and the resultant aircraft saved. The net cost is the cost of the system minus the cost savings.

System characterization was necessary to understand fully and appreciate the system cost information. This was accomplished for both a current Halon 1301 system and estimated for the proposed system (HFC-125). Information regarding the current system was available through previous NGP efforts (NGP Element 1A – *Fires Experienced And Halon 1301 Fire Suppression Systems In Current Weapon Systems* [2] and NGP Element 1C – *Relative Benefit Assessment of Fire Protection System Changes - Phase I* [3]), C-17 Technical Orders [4], and information requested and received from the C-17 System Program Office. Information regarding the proposed system was estimated since there is no fielded platform that uses HFC-125. These estimates were made using the AFRL-VA-WP-TR-1999-3068 entitled *Aircraft Engine/APU Fire Extinguishing System Design Model (HFC-125)* [5]. This Design Guide was generated as a part of the Halon Replacement Program for Aviation. Impact estimates (sensitivity analyses) were also made of the potential increase in bottle size/distribution plumbing.

System cost information was developed from the data contained in the FEDLOG system and various traditional costing factors. The Defense Logistics Agency provided access to this system, which contains part numbers, suppliers, and other logistical information specifically for the Service of interest. It is not releasable to the general public because of the proprietary nature of some of the data. Figure 1 shows a standard process used to determine fire suppression system costs.

Cost savings information was obtained by using the *Annual Fire Protection Cost Model [1966-1995; 1996-2025]* [6] and other peacetime incident data.

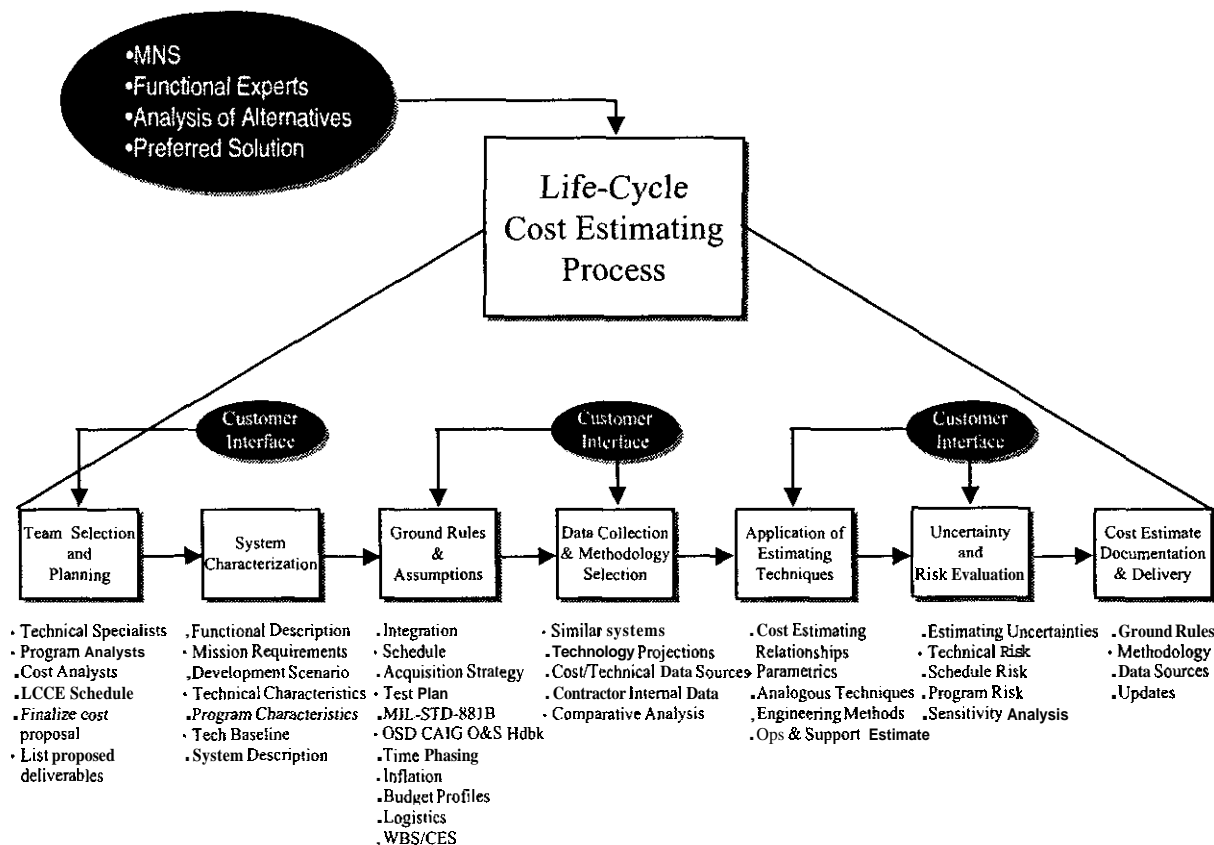


Figure 1. Life cycle cost estimating process

SYSTEM CHARACTERIZATION

Due to space limitations, only results pertinent to aircraft similar to the C-17 platform will be discussed in this paper.

AIRCRAFT

The C-17A is a four-engine, transonic, swept wing transport aircraft with a wide body, T-tail, and a high wing carrying four under-slung, fully reversible Pratt & Whitney F117-PW-100 engines. The commercial version is currently used on the Boeing 757. Each engine is rated at 40,900 lbs of thrust [7].

The C-17 is capable of rapid strategic delivery of troops and all types of cargo to main operating bases or directly to forward bases in the deployment area. The aircraft is also able to perform theater airlift missions when required. A crew of three (pilot, copilot, and loadmaster) operates the aircraft. Maximum payload capacity of the C-17 is 170,900 lbs, and its maximum **gross** takeoff weight is 585,000 pounds. With a payload of 130,000 lbs and an initial cruise altitude of 28,000 ft, the C-17 has an unrefueled range of approximately 5200 nautical miles and a cruise speed of approximately 450 knots.

The C-17 made its maiden flight on Sept. 15, 1991. It was deployed in June 1993. The aircraft is operated by the Air Mobility Command with initial operations at Charleston AFB, SC, with the 437th Airlift Wing and the 315th Airlift Wing (Air Force Reserve). The C-17 program is managed by the Aeronautical Systems Center, Wright-Patterson AFB, OH. The original specification from McDonnell Douglas defined a service life of 30,000 hrs. The unit cost is \$183 M (FY00 constant dollars) [8].

CURRENT FIRE SUPPRESSION SYSTEM DESCRIPTION (HALON 1301)

The C-17A fire protection system is a proven subsystem developed by McDonnell Douglas Aircraft through the C-9A, KC-10, and various commercial programs. The basic design approach placed emphasis on the prevention and containment of fire. The engine nacelle, core, and APU compartments were designated as fire zones where combustible fluids (fuel, hydraulic fluid, and engine oil) and ignition sources coexisted and a single failure in the combustible fluid system could result in a fire. [7]

The aircraft engine nacelle fire suppression system specifications are given below:

- 4 bottles (2 bottles are located between pylons in wing leading edge (WLE))
- 21 lbs each
- 630 cubic in. each
- required concentration 6% by vol for 0.5 sec
- 2-shot potential
- diameter of distribution lines typically 1.5 in.

The APU fire suppression system specifications are given below:

- 1 bottle (1 bottle located in APU region)
- 2.5 lbs
- 86 cubic in.
- required concentration 6% by vol for 0.5 sec
- 1-shot potential
- diameter of distribution lines - 0.5 in.

PROPOSED FIRE SUPPRESSION SYSTEM DESCRIPTION (HFC-125)

Since the C-17 currently uses Halon 1301 (not HFC-125), a potential system description had to be estimated. This was done using the Design Guide weight and volume ratios and C-17 specific parameters.

The existing bottle weights and an estimate of the proposed system individual bottle weights are given below (Table 1). This is only an (proportional) estimate because the larger bottles would have to be designed by a fire suppression system manufacturer using factors such as agent density, agent pressure, percent liquid fill, and required container wall thickness.

TABLE 1. EXTINGUISHER CONTAINER AND AGENT WEIGHT.

	Current Halon 1301 System		Estimated HFC-125- Optimally Distributed		Estimated HFC-125- Non-Optimally Distributed	
	AEN	APU	AEN	APU	AEN	APU
Bottle Weight (lb)	12.8	3.2	13	3.3	41	10.2
Agent Weight (lb)	21	2.5	21.3	2.6	67.2	8
Total Weight (lb)	33.8	5.7	34.3	5.9	108.2	18.2

Efforts were made to determine the potential for distribution and bottle size growth in the C-17 wing leading edge (WLE) section where the bottles are currently stored. These efforts included determining the exact dimensions of the C-17 WLE. The C-17 SPO was contacted to request access to the **WLE** drawings (via either the Part Structure Navigator (PSN) and/or the JEDMCS system). However, these systems contained both limited (proprietary) and unlimited data without a mechanism to restrict access, thus prohibiting access to these systems. A composite ("built-to") drawing also would have provided very useful information, but this information is also proprietary. Fortunately, the C-17 Technical Orders (TO) were accessible and provided some information, but they are not dimensioned drawings.

To overcome these setbacks, the Aircraft Survivability Research Facility (ASRF) located at Wright-Patterson Air Force Base, OH, was contacted because of their involvement in the C-17 Live Fire Test evaluation of the WLE. *Fortunately*, the C-17 LFT WLE test article was still available. The WLE is a very cluttered environment. It contains items such as fuel lines, ribs, anti-ice duct and supporting structure, wiring harnesses, spars, and various other pieces of hardware along with the fire suppression system (bottle and distribution system). Since no test article was available for the APU, no estimate of growth potential is available for the bottle size.

An analysis of the potential for an increase in bottle size and distribution size was conducted. Since dimensioned drawings were not available, an estimate was made by measuring the existing available space in the C-17 WLE LFT test article. As a result, it was estimated that the space could accommodate a bottle diameter expansion of one inch (resulting in a maximum diameter of 12 in.). Furthermore, it was estimated that the space could accommodate a distribution system diameter expansion of up to 3 in. (resulting in a maximum diameter of 4.5 in.).

The Design Guide mass estimate assumes an optimally distributed agent. If the distribution system is optimally designed, HFC-125 can fit in the existing space (with a bottle diameter of 11.5 in.). However, if the distribution system is not optimally designed it will require (using the weight and volume ratio derived from a ratio of design concentrations, molecular weights and liquid densities of the two alternatives) a bottle of 67.2 lb, 16.5 in., and 2583 in³, which is not feasible in the current configuration. This would require either extensive modification of the existing structure, relocation of the bottles, or the optimization of the distribution system. Maintenance personnel suggested there is enough access/available space for additional distribution plumbing or nozzle modification.

A poorly designed distribution system results in an unnecessary increase weight; therefore, there is strong incentive to optimize the system. It is recommended that a distribution optimization study (similar to the Navy's program for the F/A-18 E/F) be performed or else extensive aircraft modification will be required. Prior to the final design of an HFC-125 system, assistance from both extinguisher system manufacturers and airframe manufacturer needs to be sought.

GROUND RULES AND ASSUMPTIONS

Due to space limitations, only sample ground rules and assumptions are given below:

- The base year used was FY00.
- United States Air Force (USAF) inflation indices, dated January 2000, were used.
- The maintenance concept used by the C-17 is contractor logistics support (CLS).
- Halon 1301 per platform requirement is 86.5 lbs.
- HFC-125 per platform requirement was calculated as a range of estimated weights (276.8 and 87.85 lbs corresponding to the two sizing approaches, and including all aircraft fire bottles).
- A 20-year period of a fire system life cycle is considered, with the halon and HFC-125 systems considered over different overlapping 20-year periods, but normalized to FY00 costs.
- HFC-125 system will be fully implemented over 10 years, starting in FY02.
- Due to the current lack of airframer engineering assistance, the significant cost impacts of modifying an aircraft (including structure) to accommodate fire system changes cannot be estimated or included.

DATA COLLECTION AND METHODOLOGY SELECTION

Overall, limited cost information could be obtained for the current C-17 Halon 1301 fire suppression system and the estimated HFC-125 fire suppression system. Since the HFC-125 was not an existing

system for this platform, minimal information was available. However, as this project moves forward to different platforms that are exploring HFC-125 systems, such as the F/A-18 EIF aircraft, more information may become available. The primary data collection sources are described below.

- The C-17 Program Office (Wright-Patterson AFB, OH) provided formal and informal response and C-17 Technical Orders.
- The Defense Logistics Agency (DLA) provided the FEDLOG database. Access to the Weapons Systems CD was requested, but it is restricted to Government personnel only. Therefore, items not located in the FEDLOG database were estimated.
- Cost factors were obtained from the ASC Cost Library and ESC/FMC, which are used by government and industry. These cost factors were then applied to the subsystem costs (**Group A**/Group B kits). The results were similar in total cost to the information provided by the C-17 program office.
- Fire suppression system and chemical manufacturers for Halon 1301 and HFC-125 were contacted for cost information. Vendors included Walter Kidde Aerospace, Pacific Scientific, and DuPont.

APPLICATION OF ESTIMATING TECHNIQUES

As a consequence of the lack of historical data, the following estimating techniques were used to determine the Halon 1301 costs. FEDLOG pricing information was used to determine the cost of the individual components of the fire suppression system hardware. Cost factors were used for development, integration, and management type costs, since the C-17 responded that historical data were unavailable. Analogous techniques for contractor logistics support (CLS) were used. Maintenance costs were based on the maintenance man-hour (MMH) per flight hour provided by C-17 program office. Military personnel costs were based on authorizations (AFI 65-503). The following techniques were used to determine the HFC-125 costs. Engineering methods were used to estimate the container size/weight, which included the Design Guide mass estimation formula and weight ratio. Analogous techniques were used to estimate the cost elements.

UNCERTAINTY AND RISK EVALUATION

An uncertainty and risk evaluation was performed and yielded the following:

- Limited releasable information was available through the C-17 program office.
- Fire suppression system specific cost data are not tracked.
- An HFC-125 system for the C-17 platform is nonexistent.
- Historical costs were unavailable since "development of the C-17 took place well over 10 yrs ago"
- Cost factors were used to supplement lack of information and fill data voids.
- As cost analyses are performed on other platforms, more Halon 1301 and HFC-125 data may be available and impact the results of this study.

COSTS OF CURRENT/PROPOSED SYSTEM

The life-cycle cost of a system includes the acquisition, operation, and maintenance (and possible retrofit) over the life of the system. The HFC-125 system is reusable/rechargeable. The pressure vessels must be hydrostatically tested periodically and the explosive initiators used in the design must be changed periodically due to the limited propellant life. Support equipment and facilities required to service these units add to the life cycle cost. Costs associated with actual system utilization are generally low because of the infrequent need to use the system, although the rate of inadvertent discharge in some older aircraft may be significant. The life cycle cost of a system can be heavily impacted by the potential for increased weight that may result from incorporation of a nonozone depleting fire extinguishing system [9].

Costs estimated in this effort would be incurred in the research, development, test and evaluation (RDT&E), procurement (including retrofit), and operations and maintenance (O&M) phases of an

acquisition. RDT&E costs deal with all costs required to develop the fire suppression technology into a deployable system. Procurement (also called initial or nonrecurring) costs include those associated with the purchase of the fire suppression system (and associated hardware) and suppressant. O&M costs are broad and far-reaching. Included in this category are those costs associated with program management support and life cycle sustainment management.

The detailed cost element structure (CES) of this fire suppression system is based on the DoD 5000.4-M and MIL-HDBK-881 CES. The structure was customized for this particular system and approach. Definitions, explanations, and data sources for this CES are available; however, due to space limitations, it was not feasible to present such details in this paper.

To demonstrate the sensitivity of cost, the following alternatives/modifications (Mods) to a given fire system, and the subsequent impact to various cost elements, are defined (Table 2). These alternatives range from minor container modifications to a major retrofit of the entire distribution system. Mods 1 and 4 are simply replacing the bottle; Mods 2 and 5 are simply supplementing the existing distribution system with additional nozzles and tubing; and Mods 3 and 6 are complete redesigns of the entire distribution system.

TABLE 2. IMPACT OF FIRE SUPPRESSION SYSTEM MODIFICATIONS.

Includes Modifications or Changes to...	Halon 1301	HFC-125 Non-Optimally Distributed (276.8 lbs.)			HFC-125 Optimally Distributed (87.85 lbs.)		
		Mod 1	Mod 2	Mod 3	Mod 4	Mod 5	Mod 6
Container equipment		✓	✓	✓			
Container labor		✓	✓	✓	✓	✓	✓
Agent cost		✓	✓	✓	✓	✓	✓
Nozzle equipment			✓	✓		✓	✓
Nozzle labor			✓			✓	
Distribution system equipment				✓			✓
Distribution system labor				✓			✓
Fuel cost		✓	✓	✓	✓	✓	✓

Container equipment – The existing container accommodates 86.5 lbs of Halon 1301, so the HFC-125 (276.8 lbs) alternatives calculated on the weight ratio will require a larger container. It is assumed that the HFC-125 (87.85 lbs) alternatives do not warrant a container modification or they translate to an insignificant cost.

Container labor – It is assumed that the Halon 1301 container requires 7 hrs to install while the HFC-125 (87.85 lbs) container requires 8 hrs to retrofit. The larger container size of the HFC-125 (276.8 lbs) alternatives is estimated to require 13.6 hrs to retrofit (1.70 people).

Agent cost – The price per pound difference between agents means that a cost difference exists between the alternatives. Halon 1301 has an estimated price of \$35.34/lb, while that of HFC-125 is \$10.50/lb.

Nozzle equipment – The existing Halon 1301 system has 16 nozzles (4 per engine). Based on research done by the F-18 E/F, increasing the number of nozzles is a viable method for adapting the current system to HFC-125. It is assumed that the number of nozzles would need to double to accommodate this agent in the C-17 aircraft for a total of 32 nozzles. Nozzles are estimated at a price of \$480.56 each.

Nozzle labor – To install the additional nozzles (16), the task is estimated to require 8 hrs per nozzle for a total of 128 hrs per aircraft. Nozzle labor is not included in Mods 3 and 6 because the labor is presumed to be covered by the distribution labor estimates.

Distribution system equipment - It is assumed that in Mods 3 and 6, the distribution system requires a 3 in. increase in diameter. Based on the percentage increase for the container, it is assumed that the distribution system would realize a 27% increase as well.

Distribution labor – The task for retrofitting the distribution system is estimated at an average of 6 hrs/ft of the distribution system. The total is 138.125 ft, which translates to 828.75 hrs to retrofit the distribution system per aircraft.

Fuel cost – The additional weight of the HFC-125 alternatives does impact fuels costs. The current Halon 1301 system averages 1.92 lbs of fuel per flight hour. The HFC-125 (87.85 lbs) alternative averages 1.97 lbs of fuel per flight hour. The larger volume of the HFC-125 (276.8 lbs) alternative averages 5.33 lbs of fuel per flight hour. For Mods 3 and 6, the increase of 3 in. to the diameter of the distribution system causes a 2.84 lbs./FH increase in fuel usage.

COST ESTIMATE DOCUMENTATION AND DELIVERY

The life cycle cost estimate summary for the Halon 1301 and HFC-125 fire suppression systems, subject to the prior study assumptions, on an aircraft similar to a C-17 aircraft platform is available in FY00 constant dollars and then-year dollars. However, due to space limitations and potential sensitivity, these cost data are not available in this paper. The HFC-125 life cycle covers FY00-FY20 while the Halon 1301 life cycle includes FY91-11; therefore, the FY00 constant dollar comparison is more appropriate.

In terms of FY00 constant dollars, the Halon 1301 fire suppression system cost is estimated to be \$200 K per aircraft over a 20-year life cycle based on 120 aircraft. This is approximately 0.109 % of the total flyaway aircraft cost of \$183 M. In FY00 constant dollars, the HFC-125 (276.8 lbs.) system is estimated to range from \$256-309 K per aircraft over a 20-year life cycle, while the HFC-125 (87.85 lbs.) system ranges from \$232-285 K, which is approximately 0.128 to 0.169 % of the total flyaway aircraft cost. Also, in terms of FY00 constant dollars, modifications to the distribution system increase overall costs by 42-55% depending on the container size. Modifications to the container and the addition of nozzles raise costs about 27-39%. Container modifications range from 16-28% increase in total cost over the life cycle. Table 3 shows the baseline increase and percentage for each of the alternatives:

TABLE 3. TRANSPORT AIRCRAFT LCCE IMPACT (FY2000 CONSTANT).

Alternative	Increase. %	Increase. \$ M
Halon 1301	Baseline	Baseline
HFC-125 (276.8 lbs)—Mod 1	28	9.9
HFC-125 (276.8 lbs)—Mod 2	39	13.7
HFC-125 (276.8 lbs)—Mod 3	55	19.1
HFC-125 (87.85 lbs)—Mod 4	16	5.6
HFC-125 (87.85 lbs)—Mod 5	27	9.3
HFC-125 (87.85 lbs)—Mod 6	42	14.8

The majority of the impact can be found in the operations and maintenance (O&M) area. The alternatives range from a 45-74% rise in O&M costs in comparison to the Halon 1301 system. Three primary cost drivers have contributed to this increase: Program Management, Flying Hours, and Contractor Logistics Support (CLS).

- (1) First, since the HFC-125 would be a relatively new program, the cost factor used for estimating program management support is lower for Halon 1301 than the HFC-125 alternatives. Halon 1301 program management support was estimated using a lower cost factor for a more mature program.
- (2) Second, HFC-125 starts with a larger fleet of existing aircraft and therefore accumulates more flying hours than the Halon 1301 fire suppression system, which began with a minimal fleet of aircraft

and accumulated flying hours as the aircraft were deployed. Therefore, the total number of flying hours over the course of the HFC-125 life cycle was greater than that for the Halon 1301 life cycle.

- (3) Due to the earlier beginning fiscal year for the Halon 1301 life cycle, CLS is not projected until later in the life cycle. Since the HFC-125 fire suppression technology begins later than the Halon 1301, there are more years of its life cycle planned for CLS. HFC-125 has 18 years worth of CLS in its life cycle vs 9 years in the Halon 1301 life cycle.

The smaller variances in the other areas are attributed to the additional cost of increasing the container size for HFC-125 (276.8 lbs), additional nozzles, and increasing the diameter of the distribution system. Most of the cost elements increased with the rise in equipment costs since many of them are based on cost factors that are a function of the price of the equipment.

COST SAVINGS

Aircraft fires are a significant cost to the Department of Defense. Methods and technologies to mitigate them or “design them out” are imperative, not only to save aircraft, but also to save lives and prevent property damage. In a previous study (*Annual Fire Protection Cost Model*), the historical and projected costs due to fire were determined. By combining the components that comprise the costs of peacetime aircraft losses due to fire, the resulting historical cost (over a 30-yr period) of approximately \$9.271 B was obtained, measured in 1995 dollars; for the costs of combat aircraft losses due to fire, approximately \$5.878 B (\$95), based primarily on Southeast Asia experience was incurred; for the costs of utilizing aircraft fire protection, approximately \$315.651 M (\$95) was experienced. These peacetime and wartime “losses” include aircraft that were damaged by fire and subsequently repaired. Thus, the total historical costs of fire to the USAF from 1966 to 1995 was estimated to be \$15.465 B (\$95). The total projected costs of fire to the USAF from 1996 to 2025 was estimated to be \$15.990 B (\$96). A net present value of over \$1 19M was projected to be the net benefit of fire suppression systems over the next 30 years.

The cost savings for the life cycle period of interest in this study were estimated by using the traditional success rate for existing engine halon systems, the estimated fire costs per flight hour, and the number of flight hours for an aircraft fleet such as the C-17. Field experience of existing engine halon systems on current aircraft, depending on the platform, shows that the systems have a 60 to 80 % success rate. The *Annual Fire Protection Cost Model* postulated that future aircraft losses due to fire incidents were a function of the total number of flight hours (FH) for this period. An historical relationship between fire costs and flight hours was established. The resulting average fire costs per flight hour (\$00) was \$62.846 per flight hour [10]. Table 4 shows the estimated cost savings.

TABLE 4. COST SAVINGS ESTIMATION.

Cost factors	Notes	Total
PAA quantity cumulative	Source: Capt. Brian Godfrey (66 existing aircraft) Annual production based on AF65-503 Attachment A41-1 Nov 99	120
Flying Hours cumulative	Source: AFI 65-503 Attachment A42-2 June 2000 Hrs/PAA (assumes constant rate of aircraft flying hours over period)	3,278,886
Fire cost cumulative	Source: <i>Annual Fire Cost Model</i> (tire cost/flight hour = \$62.846/FH)	\$206,064,870
Cost savings: 60% effective	Source: <i>Assessing the Cost Impact of Fire to the USAir Force</i>	\$123,638,922
Cost savings: 80% effective	Source: <i>Assessing the Cost Impact of Fire to the USAir Force</i>	\$164,851,896

SUMMARY AND CONCLUSIONS

Fire is either the primary cause or a contributing factor in most cases of loss of aircraft assets. In many instances, injuries to personnel and loss of mission capability accompany a fire event. Aircraft fires are a significant cost to the USAF. Methods and technologies to mitigate them or “design them out” are imperative, not only to save aircraft, but also to save lives and prevent property damage.

The objective of this project was to perform a cost analysis for the existing Halon 1301 system and the off-the-shelf-alternative (HFC-125) to define operational cost baseline and goals for NGP technologies. The methodology was developed for an aircraft similar to the C-17 platform and for a system with performance equivalent to that of Halon 1301. The old baseline of Halon 1301 and the new baseline of HFC-125 were used to provide performance goals (in terms of cost of ownership) for the program with Halon 1301 being the upper bound (ultimate goal) and HFC-125 the lower bound.

By utilizing an estimated fire cost per flight hour and the total estimated number of flight hours over the life of an aircraft such as the C-17, the resulting estimated fire cost to such a platform is \$206 M assuming no utilization of the fire suppression system. However, if traditional success rates of between 60 and 80% are used, the estimated cost savings are \$124 -165 M. The estimated net cost is the cost of the system minus the cost savings and is shown for all the various modifications in Table 5.

TABLE 5. NET COSTS OF HALON 1301 AND HFC-125.

FY00 Constant \$	Halon 1301 \$	WFC-125			HFC-125		
		Non-Optimally Distributed (276.8 lbs)			Optimally Distributed (87.85 lbs)		
		Mod 1, \$	Mod 2, \$	Mod 3, \$	Mod 4, \$	Mod 5, \$	Mod 6, \$
System Costs	35,040,604	44,968,514	48,690,728	54,160,442	40,623,918	44,346,132	49,815,846
Cost Savings (60% effectiveness)	123,638,922	123,638,922	123,638,922	123,638,922	123,638,922	123,638,922	123,638,922
Cost Savings (80% effectiveness)	164,851,896	164,851,896	164,851,896	164,851,896	164,851,896	164,851,896	164,851,896
Net Cost (60% effectiveness)	-88,598,318	-78,670,408	-74,948,194	-69,478,480	-83,015,003	-79,292,790	-73,823,075
Net Cost (80% effectiveness)	129,811,292	-119,883,382	-116,161,168	-110,691,454	124,227,977	-120,505,763	115,036,049

These negative values are in effect the benefit of having the fire suppression system on board; consequently, it is obvious that the benefit of having a fire suppression system substantially outweighs its cost. The methodology developed during this effort can be used to assist decision makers obtain the optimum solution for their particular platforms [11].

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- AFMC LSO/SGISA – Shelia Huis
- WPAFB ASRF – Neil Blevins

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