NOVEL HALON ALTERNATIVE CONCEPTS – SYNERGISTIC DEVELOPMENT OF PUBLIC AND PRIVATE SECTORS

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ABSTRACT

Historically the fire protection community, like other technology disciplines, has observed advancements in particular technology capabilities due to the evolutionary development in both the public (such as the military) and private sectors. This often occurs in a synergistic fashion, where the needs of the public sector require the development of certain technology capabilities in fire protection, which then provide additional capabilities for future military or space exploitation, often built on private developmental financing, and at an affordable cost. Alternatively, the challenging operational requirements of military and space operations, and its notable investment in suitable fire protection technology research and development, can result in unanticipated technology opportunities for difficult applications in the private sector, with investments in high-risk technologies that would otherwise prove too risky for private industry. Examples of such fire protection products include reticulated fuel tank foam, which was developed for auto racing fuel tank safety, and then found an application during the Vietnam conflict in military aircraft, and On-Board Inert Gas Generating Systems (OBIGGS), which have been used in recent years on some military aircraft, and are being seriously considered for use on commercial aircraft to protect their fuel tanks.

This relationship has never been more pronounced than in the rapid development of Halon alternative technologies over the last fifteen years. Considerable investments by both the public and private sector, each focusing on their own particular needs, have resulted in such synergistic development of advanced technologies, at a pace otherwise unachievable without both parties' contributions and activities. This process has been enhanced by groups and individuals that have specifically focused on achieving such cross-pollination of development and expertise for fire certain technology concepts and applications. Several current Halon alternative concepts and products will be discussed that have benefited from such concurrent and evolutionary development for both sectors, including the motorsports, police vehicle and even restaurant system applications. A conclusion can be drawn from such activities – for the mutual benefit of all parties, such concurrent and evolutionary development should be planned and coordinated in a more proactive, "intentional" way with enhanced, permanent cross-sector working groups, and by improved communications of various sector technology capabilities and needs, to exploit the full innovative might of the fire protection community.

I. Introduction

The primary premise of this discussion is that the diversity and breadth of the "brain trust" and innovation of the private (commercial) sector of the fire protection industry has not been as fully engaged in the public sector (government related and military-based applications, specifically) fire protection research and implementation, as could be otherwise possible. Based upon the experiences of the author during his career as a fire protection research and technology development specialist, particularly in the last few years, it has been found that there are large communities of fire protection-related companies, both large and small, that have served niche or focused segments of the fire protection market, that have not participated in government-sponsored research and technology development, or provided product solutions for its use. They have largely exhibited an unfamiliarity with government sponsored research and its procedures, are intimidated by the bureaucratic process and requirements to successfully participate, or are "suspicious" of contracts and grants that provide funding for labor, even profits and fees, without perceptible "strings attached". In addition, many of these companies are not aware of the unique technology challenges and special fire protection applications of public sector customers such as the military, and other transportation and facility installations. As a result, many of the brightest minds, and innovative products and companies have not been introduced or exploited for use for these communities. Many of these companies have developed effective products, processes and adaptability to survive in the commercial marketplace to provide high-value products in competitive markets, with a balance of resources allocated to exhibit profitability based upon in-house investment of capital and sales cash flow alone, without governmental underwriting; how much more innovation and acceleration of technology enhancement is possible when such high-performance companies are augmented by strategic governmental investment and leveraging! Similarly, much of the technology and innovations of the military and related government fire protection activities have not been creatively transferred to the private sector and for commercial use, with notable exceptions, due to a lack of intentional efforts to proliferate such technology and plan for such activities in the early stages of development.

One of the reasons why government and commercial fire protection development activities should be further coordinated is that the needs of the government sector, and the priorities of the commercial sector in its pursuit of sales and profits, frequently do not coincide, as has been seen from activities in the Halon replacement efforts of recent years. The fact that the government sector is a relatively small market in the fire protection business, compared to much larger markets such as the clean agent total flood business for commercial buildings, means that the commercial sector will focus their energies in areas deemed most profitable to them, and focus their product development efforts toward those requirements associated with those markets. This fact is largely unrecognized by the military acquisition community, which for some time had relied on the private sector to invest the capital in research and development to "solve" their problems. As a result, for industries like fire protection, the federal government must invest sufficient capital to develop products suitable to their demands and needs, and/or focus on small businesses that can focus on these "niche" markets and operate in a profitable manner with the limited scales of these markets. There are notable examples of successful government/industry partnerships in this field, particularly in the era of Halon replacement research and deployment, and the emergence of successful products and companies resulting from these efforts, which will be discussed further in this paper, along with recommendations of means to enhance the process.

II. Historical Examples of Successful Public/Private Sector Fire Protection Development

A. Reticulated Foam Development for Fuel Tanks

Reticulated foam, the "spongy", open-cell foam used in fuel tanks, was originally devised by and for the auto racing community. It is largely understood that these efforts emanated from the horrific fire that occurred at the second lap of the 1964 Indianapolis 500, when the car of track favorite Eddie Sachs crashed into the disabled vehicle of Dave McDonald, resting in turn 4. The impact resulted in a large fireball and smoke plume, enveloping a large portion of the Speedway (Figure 1), resulting from the discharge of over one hundred gallons of gasoline, and claiming the lives of both competitors. The Scott Foam Co. subsequently developed the first generation foam, to be placed inside the tanks, to reduce fuel slosh, and catastrophic discharge upon impact (and to some extent, reduce the extent of fuel tank tearing as well). This modification, along with the incorporation of rubber bladders and conversion to alcohol fuel for Indy cars, immediately improved the safety of vehicles in competition, with such foam (in newer upgraded embodiments) still in use today (Figure 2). In the late 1960s, the military became interested in the product to improve fuel tank survivability in combat [1], and began implementing first-generation foams in combat aircraft like the F-4 and C-130 at that time, which saw action in Vietnam. It was confirmed that the foam also had an additional benefit under in-flight conditions, by suppressing in-tank explosions that can occur, since fuel-air mixtures can otherwise support deflagrations under these conditions in many cases, particularly when struck by ballistic projectiles. The first aircraft later designed that focused on aircraft survivability, the A-10 Thunderbolt II, placed foam in the fuel tank, and well in the adjoining dry bays, and was successfully used in Desert Storm. It is also used in the F-15 and F-18 fighter aircraft.

Fig. 1 – 1964 Indianapolis Speedway Fire

Fig. 2 – Typical Racing Fuel Cell Design With Foam

B. On-Board Inert Gas Generating System (OBIGGS)

These systems use either gas permeable membranes or molecular sieves to separate oxygen from nitrogen in the aircraft engine bleed air diverted to the unit, with the nitrogen directed to inert the fuel tanks from explosions, and occasionally oxygen to the crew area to breathe. These systems have generally been available since the mid-1980s for military aircraft [1], and have continued to be upgraded over the years to be more efficient and weight effective. Most newer military aircraft, in fact, employ OBIGGS systems for fuel tank protection. In recent years, there has been interest in protecting fuel tanks on commercial aircraft, particularly in light of the TWA Flight 800 in-flight explosion, determined to have been caused from a center wing tank deflagration. In addition, the threat of terrorism and the use of man portable air defense systems (MANPADs) against commercial aircraft has further increased interest in such protection, and recent legislation will now require such protection for current aircraft. The Federal Aviation Administration has studied numerous techniques to provide such protection for aircraft fuel tanks for several years, including inerting the tanks with bottled nitrogen while on the ground before takeoff. It appears they have settled for OBIGGS systems to be installed into existing aircraft for the time being, by transitioning protection technology devised by the military.

Fig. 3 – OBIGGS Air Separation Module for Aircraft

III. Halon Replacement Activities, Experience and Success Stories

A. Recent Halon Replacement Experience

As mentioned previously, acquisition officials in the military and related public sectors viewed themselves as “large” and “important” customers in the fire protection market, when the phase out of Halon production was underway. As such, they assumed that the private sector would independently “solve” their problem and invest research and development funds necessary to produce products suitable for their unique requirements, and preclude the need for the government to invest considerable resources to the matter. However, in reality it can be seen that various sectors of the commercial fire protection market are far larger than their public sector counterparts, with a sales volume sufficiently larger to justify the focus of research funds in that direction. These markets have very different performance standards and other protocols necessary for approval for sale, such as UL testing with witness heptane pans in full scale total flood tests, versus Halonyzer tests requiring the measure of extinguishing agent concentrations in up to twelve sites simultaneously (and the commiserate ability to measure the Halon replacement, for that matter), as is done in aircraft engine certification tests. Additionally, many of the requirements for special applications like military armored vehicle compartments and aircraft engine nacelles, such as the need to function and suppress pyrotechnically explosive fireballs within milliseconds, or fill complex ventilated areas and extinguish fires at temperatures below 40 C, with extreme weight limitations, are typically not covered by most commercial specifications. These extreme requirements and applications are also not the focus of the large-scale commercial sector in terms of devising Halon replacement products (and dedicating the resources to accomplish it) for these special applications. This leads to the "bottom line" that there is little incentive for these large-scale companies to "solve" the military's need for high-performance fire protection products (particularly Halon replacements), given the modest scope of their market. This has led the military to eventually invest considerable sums into dedicated research for these applications, and full scale evaluations unique to their use.

During the course of the development of Halon replacements by the military and related sectors, they began to identify exotic, new extinguishing chemicals, such as CF_3I, but the identification of such promising science was not sufficient. There had to be developed an associated commercial market and capability to produce such products on a scale to make them economically and technically (from a production scale standpoint) viable for both the military and commercial markets, including identifying and justifying the up-front investment to produce them. These efforts were facilitated by groups such as the Advanced Agent Working Group, an ad hoc group of individuals and organizations with a vested interest in facilitating production of these exotic chemicals such as CF_3I. This group, supported by forums such as prior HOTWC meetings, was instrumental in getting these products ultimately to market, and continues these activities to date with newer advanced agents now being considered. Even with these efforts, many of the advanced Halon replacement chemical products developed by industry were primarily targeted for lucrative commercial markets that did not always coincide with military needs. This reality opened the door for enterprising small businesses to capitalize on the opportunity to meet these "niche" military markets with customized products that were practical for smaller scale production. The eventual investment by the government into research in the area, and "blank slate" opportunity to meet these applications without incumbent products to compete against, provided additional impetus for such businesses to pursue these applications.

B. Success Stories of Small Business-Derived Fire Protection Technologies

Over the last approximate fifteen years in which new Halon replacement alternatives have been developed and fielded, a good number of notable technical breakthroughs and innovative technologies and small businesses have emerged that deserve mention as successful advancements of the field. This list, although by no means exhaustive, is indicative of the types of novel approaches that have arisen. It includes devices like aerosol generators, such as are produced by Pyrogen, Spectrex and others, which have shown amazing efficiencies and effectiveness under extreme environments. Various custom blended agents, such as NAFSIII and Halotron, have effectively provided optimal balances of the properties of constituent ingredients to produce an overall effectiveness, operability, environmental and human health impact that make them practical for a wide variety of applications. Gelled agents, such as that produced by Powsus, further provide novel means of mixing diverse agents such as gaseous and powder ingredients, into a product that maximizes their synergistic capability. Water mist systems have also emerged from many vendors, that provide many natural benefits and environmental advantages, and have simultaneously devised a working knowledge of its extinguishment principles sufficiently to optimize its use. Gas generator systems, such as those produced by Aerojet, Atlantic Research and others, have also emerged as exotic, high performance systems for the most challenging applications, whose potential is just being envisioned. Even novel agent delivery systems, such as those offered by Powsus and Firetrace, also offer ways to more effectively exploit a myriad of extinguishing agents in a manner to make them commercially practical. Many more such examples could be cited; the progress of many of these technology breakthroughs can be chronicled in the Proceedings and watershed meetings held at the annual HOTWC enclaves.

IV. THE UNIQUE ADVANTAGES OF COTS TECHNOLOGIES, AND EXAMPLES OF MILITARY/COTS "CROSSOVER" PRODUCTS

A. The Need and Advantages of Commercial-Off-The-Shelf (COTS) Products

There have been several recent incidents that point out the advantages of Commercial-Off-The-Shelf (COTS) fire protection technologies, similar to the ones previously described, to meet the demands of the modern military, in particular. The surprising variety of unanticipated threats in the Iraq conflict has necessitated rapid implementation of new retrofit kits to improve the survivability of vehicles and personnel in the theatre of conflict, particularly for the light or non-armored vehicles like the Humvee, which have been subject to various threats such as Improvised Explosive Devices, mines, rocket propelled grenades and small arms. Vehicle and soldier casualties have mounted from these engagements and ambushes by the enemy on unarmed convoys of vehicles. As a result, there has been interest in retrofitting quick and cost effective solutions for a wide variety of vehicles, first with armor protection, and then with fire protection to protect against the second most likely cause of casualties after contact with the enemy. In addition, even transport fixed wing aircraft have discussed upgrade hardening kits to protect them from Man Portable Air Defense Systems (MANPADs), the shoulder fired weapons that have even wounded commercial freight aircraft entering Baghdad airport.

There are several demands of any fire protection technology that would be a candidate for such urgent and ad hoc applications. Such technologies must be of very modest price, since the need is usually for large lot sizes that were unbudgeted and unforeseen for the conflict, with funds strapped more so while supporting the war effort. Lower cost products also mean they are relevant for lower value assets, such as Humvees in this case, versus just tanks for example. In other words, the retrofit fix should not be comparable in cost to the asset it is being considered to protect. Such products also need to be adaptable to a wide variety of applications and installations, in this case the wide variety of vehicles deployed in Iraq, using the same product kit if possible. Typically, there is not time to perform the exhaustive gauntlet of military standards and other certifications normally required to field a subsystem on a weapons platform; as such, it is preferable to have systems to have other commercial certifications (such as Underwriter's Lab or Factory Mutual) that can testify to a system's ruggedness under a somewhat wide array of environmental conditions. Alternatively, system designs that are inherently simple and rugged, and relatively impervious to wide varieties of environmental conditions, as opposed to having sensitive electronics and similar features, can also suffice to consider its use. For such systems, to be ready for rapid deployment in large lot sizes on a moment's notice, it also helps to have such products already in full-scale production for commercial uses, thereby affirming the merits of COTS alternatives. Custom military-specific systems, however, tend to have a very long acquisition cycle to production, are typically very expensive due to the minimal production volumes for their specialized use, and are not designed to be flexible for a wide array of applications, beyond the specific platform they are designed originally to protect.

B. Military/COTS "Crossover" Product Example 1 – Gas Generator Fire Extinguishers

Gas generator devices (pyrotechnically activated) for fire protection were first demonstrated in the modern era by the U.S. Air Force in the early 1990s (before then it had been proposed and theorized as possible in the literature decades beforehand). They were further advanced by the U.S. Navy in additional development, eventually fielding these units for unoccupied areas on military aircraft such as the F-18 E/F and V-22. They continue to be evaluated for further aircraft under development. Although they have been considered "exotic" and "high-tech" products with high performance (and cost) normally reserved for applications such as the military, some versions of these devices are now proliferating into the commercial sector. Gas generator units are now being used to propel "wet" extinguishing agents for restaurant kitchen fire protection systems being marketed by Nobel overseas. They are also reported to be planned for implementation on 2005 Ford Crown Victoria police interceptors as part of a hybrid system in which the gas generator is used to deploy a foam agent to address gasoline pool fires. In addition, development is underway of a pure gas generator system to protect occupied areas such as computer and telecommunications rooms, in a configuration suitable for occupied areas, and should be approved for use shortly. Such an application will transform the "high-tech" device into the competitive cost and high volume world of commercial total flood fire protection systems.

C. Military/COTS "Crossover" Product Example 2 – FIRE Panels

FIRE Panels are thin, contoured shells constructed of a special polymer, and are filled with a dry chemical fire extinguishant and sealed. The panels are mounted, usually with a heavy-duty adhesive tape, either on or nearby a flammable fluid reservoir, such as a fuel tank. When the region around the fluid reservoir is impacted, the FIRE Panel in proximity shatters, releasing a cloud of extinguishing powder around the ruptured fluid reservoir, preventing the ejected fluid from igniting when encountering ignition sources. Data from the Bureau of Mines [2] has shown that minimal quantities of certain powders (like monoammonium phosphate), as little as 290 grams per cubic meter of air space, can prevent a stoichiometric fuel/air mixture from igniting. This is far less powder than that required to extinguish a preexisting fire. Earlier primitive "powder panel" devices have been used on military helicopters such as the AH-1S Super Cobra to protect their fuel tanks from small arms fire, and newer aircraft such as the V-22. These devices comprised multiple layers of honeycomb and face sheets of generally ductile material. These devices, although very lightweight, often did not discharge their full load of powder due to minimal tearing upon impact, which required oversizing the panels with increased weight. The panels also were expensive to assemble, and generally fragile in terms of normal wear and tear.

The new technology and enhancements of the FIRE Panel design permit its formation as a single step process in manufacturing, thereby greatly reducing assembly and manpower costs, and making it practical for commercial applications. The special polymer makeup of FIRE Panel also facilitates its ability to shatter upon impact, thereby releasing its full powder load and hence high performance. However, it is sufficiently durable to withstand impacts for many rugged applications. This includes its current use in protecting the fuel tanks of Crown Victoria police cars from rear impacts in collisions. An illustration of the FIRE Panel version that fits onto the Crown Victoria fuel tank is shown in Figure 4. This device has been demonstrated in multiple high-speed crash tests with gasoline, including rocket sled tests with ignition sources added, including the Crown Victoria police car crash tests as shown in Figure 5, where a baseline impact with no protection resulted in a fire, and an identical test with the FIRE Panel added that prevented fire. Similar tests have been performed by other independent agencies, such as the Auto Safety Research Institute (on Chevrolet pickup trucks) and by the NASCAR R&D Center.
In addition to the product's proliferation on police vehicles by the thousands, it is currently being used in NASCAR, America's premier racing series, to protect the race car fuel cell, and has been used in other series as well. Other street vehicles, such Bentleys imported into the U.S., also feature FIRE Panels as standard equipment. Other embodiments, such as hood liners for front end vehicle collisions, have also been successfully demonstrated. Recently, the U.S. Army expressed an interest in testing a version of FIRE Panels to protect Humvee and other vehicle fuel tanks from ballistic threats. Such tests are being prepared to be conducted shortly.

Fig. 4 – FIRE Panel for Police Car Application

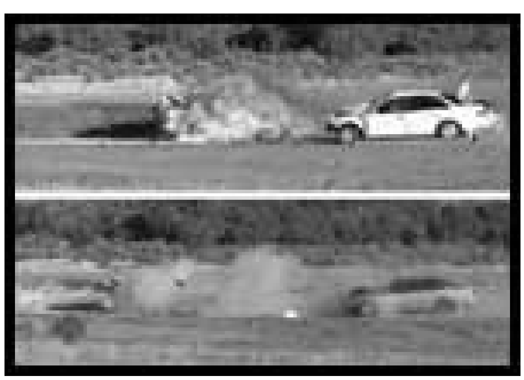

Fig. 5 – Comparison of Protected (bottom), Unprotected (top) Cars in Crash Tests

D. Military/COTS "Crossover" Product Example 3 – Firetrace Tubing Systems

Another "crossover" COTS technology with potential military interest is a flexible tubing fire extinguisher manufactured by Firetrace International. It comprises a flexible tubing element, which is pressurized with a fire extinguishant material – either a dry chemical, liquefied gaseous agent or inert gas. The tubing network may be attached to a bottle or similar reservoir and valve, to add to the capacity of the system (as shown in Figure 6). The tubing network is routed in serpentine fashion throughout an area to be protected – particularly cluttered spaces like electronic equipment racks and machinery spaces. The tubing is formulated of a particular polymer that responds to heat, and will rupture at a precise temperature corresponding to a fire in proximity. Therefore, upon rupture it will direct the entire contents of extinguishant in the network directly onto the site of the fire, wherever it is, as an efficient form of extinguishing deemed "local flooding". The system, as such, serves as its own extinguishant reservoir, fire detector and distribution system. Like the FIRE Panel, it needs no external power to operate, activates automatically and has no other expensive or delicate electronic detectors or other processors. It is both Factory Mutual and Underwriter's Lab approved. It is used for a myriad of applications, including electronics cabinets, agricultural equipment machinery spaces, automobile under hood applications, and even in helicopter engines! It has been used in some military applications now, including protecting jeeps from terrorist attacks such as Molotov cocktails, and on Swedish Army Snow Cat vehicles for use near the Arctic Circle. Recently the Navy offered the opportunity for Firetrace to test their system in an actual aircraft bay application, with full speed in-flight airflow and ballistic projectile fire initiation. The rapid response of the Firetrace tubing to the fire led to a quick extinguishment of the fire, with far less than a pound of extinguishing agent, without the need for expensive detectors, wiring and other equipment (and also without the need for redundancy, since it is difficult to envision disabling the system from functioning by direct ballistic impact) as would be used on traditional military-specific fire protection equipment.

Fig. 6 – Firetrace Tubing System with Additional Reservoir

ACTIVITIES CURRENTLY SUPPORTIVE OF GOVT./INDUSTRY INTERCHANGE

For all the need to encourage greater participation of the commercial fire protection industry in the efforts of the current military research, there are some notable efforts currently to foster such cooperation. The Small Business Innovative Research Program (SBIR) has always been focused on developing new suppliers for government contracts, and strengthen small businesses while encouraging commercialization of the products derived from its sponsored work. This program, in fact, is usually the first opportunity for many companies to begin work with the federal government. However, it has been observed that there have been less SBIR topics and awards in fire protection in recent years, which diminishes its influence. There may be some discouragement on the part of some government agencies to exploit this avenue, since it does not direct funding into the agency or office overseeing the projects, and many government organizations require the prioritization of funding that can pay their own manpower. The Next Generation Fire Suppression Technology Program (NGP) has also funded a good number of cutting edge technology proposals, which featured the innovation of several small businesses. However, funding limitations in recent years have also curtained full exploitation of this venue. Some of the most promising work and partnerships between enterprising small businesses and government agencies are via Cooperative Research and Development Agreements, or CRADAs. In these arrangements, businesses exploit the expertise, facilities and other resources of a federal laboratory, in exchange for compensation of some form to the agency, to develop and refine products typically for both commercial and military/governmental use. These flexible arrangements are thriving in use, but many more such CRADA relationships could be established using the existing federal lab infrastructure. Conferences such as HOTWC also serve as a catalyst in introducing new businesses to opportunities in military and governmental fire technology needs, and in networking with other interested parties, as well as providing a forum for the community to become informed and discuss a myriad of opportunities and issues. Finally, the participation of governmental officials in trade organizations such as the National Fire Protection Association Committees and the Halon Alternatives Research Corporation also help foster joint government/industry collaboration. Unfortunately, many within the government chain of command do not appreciate the merits of participation in such bodies, and expenses involved (such as travel) in supporting such groups can be difficult to get underwritten.

CONCLUSIONS

It can be seen that a major portion of the success in recent years in meeting the challenging governmental/military fire protection requirements have been met by new, innovative businesses, many of which are small businesses by nature. It can also be seen by a review of the contributors in recent years to new technology that many of these new enhancements have been germinated by strategic Government investment in technology development. More, rather than less, of such investments are needed in the future for the Government to continue to maintain access to such commercial capability, with more expansion in such investment desired to assure that the critical needs of the public sector's special fire protection challenges of the future are met (including special threats related to homeland security). It is also desired to improve communication channels to secure the expertise of other fire protection related businesses (or those that could be) by improving marketing of governmental contracting opportunities, the special needs present, and other means. Coordination groups like the AAWG should be more commonplace to help facilitate the development and transition of fire protection technologies for critical applications in a timely fashion.

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