The Department of Defense National Center of Excellence for First Responder Technology Transfer

# Pyrotechnic Thermite Composition

## *Naval Surface Warfare Center, Crane Division*
## *United States Patent 7,632,365 B1*

## *Market Overview*

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## Executive Summary

Thermite is a pyrotechnic composition of a metal powder and a metal oxide. When ignited, thermite produces an exothermic reaction. The thermite reaction is similar to the combustion of wood or gasoline, but involves metals and requires extremely high temperatures for ignition. Thermite is useful when a non-explosive heat source, independent of the external environment, is needed.

United States patent 7,632,365 B1 details a pyrotechnic thermite composition which offers: enhanced material perforation, increased reaction temperatures, and decreased toxicity.[1] These prospective advantages may differentiate the composition from existing thermite formulations and work to provide potential competitive advantage within varied applications.

This analysis examines potential applications and corresponding market opportunities for the pyrotechnic thermite composition. Although this list is by no means exhaustive, there are five primary applications explored:

- Disaster clean-up
- Flares
- Fire starters
- Explosive ordnance disposal (EOD)
- General construction and/or welding

In each of these uses, the thermite composition‘s reaction heat is applied to achieve different objectives. Objectives may include disaster clean up; *perforation*, flares; *illumination*, fire starters; *ignition*, EOD; *perforation/ignition*, and construction or welding; *perforation/fusion*. A general overview of the pyrotechnic thermite composition, and the markets to which it may enter, is provided for potential licensees and other entities with special interest.

It is important to note that this analysis is not undertaken in an effort to recommend one application or market over another. Rather, general overviews of each market are provided in an effort to provide baseline characterizations for further development and investigative efforts. Below is a breakdown of the report with a summary of key points relayed within the full assessment.

### Technology Synopsis

The preferred pyrotechnic thermite composition is composed of magnalium (Mg/AL), copper oxide (CuO), molybdenum ($MoO_3$), and a binder material. The patented composition specifically consists of 24.2% by weight magnalium, 39.8% by weight CuO, 33% by weight $MoO_3$, and approximately 3% by weight of the binder material.

The present formulation was developed with the primary objective of enhanced material perforation. Improvements were also sought for gas production, temperature stability, heat transfer, shelf life and low

[1] Note: *Perforation* connotes the cutting, piercing through, or penetration of materials.



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toxicity. The pyrotechnic thermite composition reported here represents the optimal combination of these characteristics.

Certain considerations should be made for thermite's highly reactive characteristics. Thermite is officially classified as a flammable solid by the Bureau of Alcohol Tobacco and Firearms. However, it is noted by patent holder Steven P. D'Arche that for safety reasons, thermite should be handled more like a categorized explosive.[2] This volatility may add complexity and costs to development. With that said, these factors may be mitigated if the potential licensee has existing experience with pyrotechnics or explosives.

This patent covers only the methodology for creating a new thermite composition. Any development regarding the commercialization of this composition will require further research and due diligence.

## Applications

Within each application, the pyrotechnic thermite composition is applied to achieve perforation, illumination, ignition, and/or fusion. Although embodiments may vary from torch, to flare, to incendiary device; the unifying concept remains concentration of the composition's reaction heat. For each application, the thermite composition's embodiment, corresponding purpose, and relevant strengths and weaknesses are articulated. The table below provides a summary of this analysis.

| **Pyrotechnic Thermite Composition: Potential Applications** | | | | |
|---|---|---|---|---|
| ***Application*** | ***Embodiment*** | ***Purpose*** | ***Relevant Advantages*** | ***Relevant Disadvantages*** |
| Disaster Clean-Up | Thermite Torch Cutter | Perforation | • Increased perforation<br>• Decreased time to target<br>• Decreased toxicity<br>• Miniaturization, UXV[3] potential | • Hot reaction products may pose danger to victims<br>• Supply chain will be need to be established |
| Flare | Thermite Flare | Illumination | • Decreased toxicity (perchlorate-free) | • Less control over color<br>• Marginal advantage over existing solutions. |
| Fire Starter | Fuse-Outfitted Thermite Canister; Explosive Device | Ignition | • Ignition independent of environmental factors<br>• Decreased toxicity | • Safety considerations |
| Explosive Ordnance Disposal (EOD) | Incendiary Device | Perforation; Ignition | • EOD with decreased risk of collateral damage, hazardous conditions, and fragmentation<br>• Decreased likelihood of theft<br>• Decreased potential for weapons creation | • Potential risk is not completely eliminated<br>• Considerable design work required<br>• Precautions for handling |
| General Construction/ Welding | Thermite Torch | Perforation; Fusion | • Increased perforation<br>• Increased reaction heat for fusion<br>• Decreased toxicity<br>• Miniaturization (vs. complex/heavy equipment) | • Potential learning curve, training requirement<br>• Reaction heat may not be suitable for all applications |

[2] Note: Phone interview with inventor, Steven P. D'Arche, on February 11, 2010.
[3] UXV: Unmanned Autonomous Vehicle



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## Markets

Market opportunities corresponding to the above applications are examined. Market relevance may be found within the following uses:

- Civilian First Responder
- Military
- Construction/Welding

Definitions are articulated for each of these general classifications. Although the above uses provide broad-spectrum characterization, direct market potential for the pyrotechnic thermite composition is revealed by examining markets directly correlated to the identified applications. That is, while referenced as ―applications," this assessment also works to explore the markets of:

- Disaster Clean-Up
- Flares
- Fire Starters
- Explosive Ordnance Disposal

The chart below summarizes potential markets by purpose, quantification, and drivers and influences:



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| Purpose | Potential Markets | Markets Quantified By: | Identified Influences |
|---|---|---|---|
| Thermite Torch Cutter/ Perforation | Disaster Clean-Up | • Number of natural disasters<br>• Number of explosive incidents | • Deforestation & global warming<br>• Population density<br>• Terrorist attacks |
| Thermite Flare/ Illumination | Flare<br>• CFR<br>• Military<br>• CEP | • Employment Statistics: CFR, water transportation, truck transportation & number of commercial vehicles<br>• Military enlistment<br>• Number of military vessels | • Factors affecting employment<br>• US Coast Guard regulations<br>• FMCSA regulations<br>• Military engagement and deployments |
| Thermite Fire Starter/Ignition | Fire Starter<br>• CFR<br>• Military<br>• Outdoor Recreation<br>• CER | • Employment Statistics: CFR<br>• Number of natural disasters<br>• Rates & types of outdoor recreation, participation trends<br>• Military enlistment and deployments | • Occurrence of power outages<br>• Factors affecting participation in outdoor recreation<br>• Deployments and combat activity |
| Thermite Incendiary Device/ Perforation & Ignition | EOD<br>• CFR<br>• Military | • UXO occurrence<br>• Relevant DHS budget<br>• Relevant DoD budget (battle against IEDs) | • International & domestic climate change<br>• Shifts in administration and policy<br>• Altered budgetary controls<br>• Technological advancement<br>• Preventative measures<br>• IED: material availability, affordability, knowledge, social factors, circumvention |
| Thermite Torch/ Perforation & Fusion | Construction & Welding | • Total annual construction spending<br>• Employment within construction industry<br>• Value of US market for welding equipment & supplies<br>• Employment within welding industry | • Fluctuations in the greater economy<br>• Factors affecting employment |

*CFR: Civilian First Responder*
*CEP: Civilian Emergency Preparedness*
*FMCSA: Federal Motor Carrier Safety Administration*
*UXO: Unexploded Ordnance*

*Quantification results and detailed analysis of the above market influences can be found within the body of this report. A summary of quantification efforts can be seen in the conclusion of this report.*



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## Competitive Landscape

The base of the pyrotechnic thermite composition‘s competitive advantage is found within the composition itself. The composition‘s prospective advantages—enhanced perforation, increased reaction heat, and decreased toxicity—are briefly revisited within the assessment, followed by an examination of competing solutions for each potential application. The chart below lists the identified existing solutions for each potential application.

| **Pyrotechnic Thermite Composition: Competitive Landscape** | |
|---|---|
| ***Application*** | ***Existing Solutions*** |
| Disaster Clean-Up | • Heavy machinery<br>• Jaws of Life rescue systems |
| Flare | • Combustion Flares<br>• Chemical Solutions<br>• Electric Solutions |
| Fire Starter | • Thermite Fire Starter<br>• Survival Matches<br>• Fuel Lighters<br>• Lenses<br>• Fire Bow<br>• Spark-Lite<br>• Flint & Steel |
| Explosive Ordnance Disposal | • Mechanical Impact<br>• Controlled Detonation<br>• Robotic Devices<br>• Infrared jamming<br>• Electronic jamming<br>• Electromagnetic forced detonation<br>• PAN<br>• Laser systems<br>• Protected vehicles<br>• Protective armor<br>• Bomb blankets<br>• Bomb trolley, basket, sled<br>• Existing thermite solutions |
| General Construction/ Welding | • Hacksaws<br>• Jigsaws<br>• Reciprocating saws<br>• Band saws<br>• Circular saws<br>• Alternative welding techniques<br>• Existing thermite welding |

Based upon the properties of the pyrotechnic thermite composition (as claimed in U.S. patent 7,632,365 B1), market viability may be feasible within each of the markets examined by this assessment. This viability, however, will be heavily dependent upon a licensee‘s ability to competitively package and manufacture the composition.



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## Cautions & Considerations

In light of established market overviews for the varied potential applications of the pyrotechnic thermite composition; there are further cautions and considerations to be made. While by no means exhaustive, this discussion works to address some of the further questions likely to be posed by potential licensees including:

- Switching costs
- Industry attractiveness

The pyrotechnic thermite composition offers improvement over existing thermite formulations and may exist as an alternative solution to existing technologies. As a substitute solution or, in some cases, a ―next generation" technology, switching costs will need to be monitored as development of the pyrotechnic composition ensues. Working to optimize switching costs may foster the likelihood of end-user preference over existing solutions and support efforts of market penetration.

This assessment provides general characterizations of markets specific to the pyrotechnic thermite composition‘s potential use. Issues to be considered with regard to overall industry attractiveness include, but are not limited to: supplier power, threat of substitutes, buyer power, barriers to entry, and degree of competition. A brief examination of these industry components is provided for each of the potential markets.

Ultimately, product-based advantages and disadvantages will likely prove to be a large determinant of viable commercialization. In order for the pyrotechnic thermite composition to successfully penetrate a market, the natural advantages of the technical solution must be aligned with engineering, manufacturing, and cost control.



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# 1 Introduction

United States patent 7,632,365 B1 details a pyrotechnic thermite composition which is claimed to offer enhanced material perforation, increased reaction temperatures, and decreased toxicity. This analysis then works to provide a general overview of the pyrotechnic thermite composition, potential applications, and the markets to which it may enter.

Although this list is by no means exhaustive, there are five primary applications explored:

- Disaster clean-up
- Flares
- Fire starters
- Explosive ordnance disposal
- General construction and/or welding

In each of these applications, the thermite reaction is employed to achieve various objectives. Objectives may include: disaster clean-up; *perforation*, flares; *illumination*, fire starters; *ignition*, EOD; *perforation/ignition*; and welding and construction; *perforation/fusion*. Three overarching uses are identified which encompass the composition‘s potential embodiments and purposes. Market relevance may be found within the uses of:

- Civilian First Responder
- Military
- Construction/Welding

Definitions are articulated for each of these general classifications. Although the above uses do provide broad-spectrum characterization, more direct market potential for the pyrotechnic thermite composition is revealed by examining markets directly correlated to the identified applications. That is, while referenced as ―applications," this assessment also works to more specifically explore the markets of: disaster clean-up, flares, fire starters, explosive ordnance disposal and construction/welding. These markets are defined, quantified and market drivers and influences are explored. The competitive landscape of existing solutions within each potential application is then examined.

Ultimately, a general overview of the pyrotechnic thermite composition, its prospective applications and potential market opportunities is provided. This analysis is not undertaken in an effort to recommend one application or market over another. Rather, general overviews of each market are provided in an effort to provide baseline characterizations for further development efforts and analysis. U.S. patent 7,632,365 B1 covers only the methodology for creating a new thermite composition. Any development regarding the commercialization of this composition will require further research and due diligence.



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## 2 Technology Synopsis

Thermite is a pyrotechnic composition of a metal powder and a metal oxide which, when ignited, produce an exothermic reaction. The thermite reaction is similar to the combustion of wood or gasoline, but involves metals, and requires extremely high temperatures for ignition. It is useful when a non-explosive heat source independent of the external environment, and concentrated in a small area, is needed. Traditionally, thermite applications include, but are not limited to: cutting through metals, welding metal components together by melting a thin film where the components join, flares and incendiary bombs. This analysis explores the specific applications of:

- Disaster Clean-Up
- Flares
- Fire Starters
- Explosive Ordnance Disposal
- General Cutting/Welding

In principle, any reactive metal could be used within a thermite composition, but aluminum tends to be a material of choice due to its chemical composition and large energy release upon oxidization. As originally developed, thermite formulations consisted of a stoichiometric mix of black iron oxide and aluminum, which produced reaction products of aluminum oxide and molten iron. The present composition then represents an improved formulation developed with the primary objective of enhanced material perforation capability. Other characteristics related to the thermite reaction for which improvements were sought include:

- Gas production
- Temperature stability
- Heat transfer
- Shelf life
- Low toxicity

In development of the composition at hand, over 250 different formulations were tested with experimental torches on aluminum targets. Material perforation performance, as measured by mass of target material removed, was found to depend on a combination of thermal, mechanical and chemical actions. In some cases, the penetration was very deep, but narrow, resulting in little target mass removed. Products with the highest heat of reaction, the highest density of reaction products, or the highest melting point did not by themselves necessarily produce the best penetration. There is no known theoretical property by which to explain or predict performance of a pyrotechnic torch composition.

Thermite consists in composition of a metal fuel, an oxidizer and a binder material for holding together the granular mixture. Different fuels, oxidizers and binders were considered in numerous tests to determine which combination offered the most improvement of the above outlined properties. Among metals for use as the fuel, only magnesium, aluminum and mangnalium revealed advanced results. The magnalium alloy performed better than magnesium or aluminum (taken separately or in a mechanical mixture), most likely due to its lower heat of reaction. For the oxidizer, copper oxide (CuO) is acknowledged from prior art, but it was found that an



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admixture of molybdenum ($MoO_3$) yielded superior perforation capability. For the binder material, polytetrafluoroethylene is preferred. The ultimate components of the thermite composition, as detailed in United States patent 7,632,365 B1, are outlined below, followed by the prospective advantages, pricing assumptions, and development and safety considerations.

## 2.1 Components

The pyrotechnic thermite composition described by the present patent is made up of approximately 3% by weight to about 35% by weight magnalium (Mg/Al), from about 30% by weight to 70% by weight copper oxide (CuO), and from about 15% by weight to about 35% by weight molybdenum ($MoO_3$). In addition, the formulation may include a small amount of binder material. After testing a series of formulations with varying ratios of the same components, the preferred embodiment consists of 24.2% by weight magnalium, 39.8% by weight CuO, 33% by weight $MoO_3$, and approximately 3% by weight of the binder material.

As the thermite formulation is a mixture of components, the effect of particle size was also investigated within the composition‘s development. Using ultrasound to blend the components in a hexane solvent, a range of nanometer-size particles was produced. Fine mixtures were determined to be more sensitive to mechanical stimuli and to burn faster than coarser mixtures, but yielded lower target penetration. Ultimately, the preferred range for the size of the atomized particles was found to be from 1 micron to 70 microns in diameter, with 30 microns being the preferred size.

## 2.2 Prospective Advantages

The advantages of the pyrotechnic thermite composition, as claimed in U.S. patent 7,632,365 B1, can be broken down as follows:

| Prospective Advantage | Description |
|---|---|
| Enhanced Material Perforation Capability | The time on target for cutting through 1” diameter rebar is reduced to a few seconds, as compared to prior art which takes a few minutes. Experimental torches employing the present thermite composition are capable of perforating metal casings up to 1” steel. |
| Low Toxicity<br>• Starting Materials | Starting materials have comparatively low toxicity and are free of perchlorate. |
| Low Toxicity<br>• Reaction Products | The pyrotechnic thermite composition’s reaction products have comparatively low toxicity. Since CuO is the preferred oxidizer, as opposed to perchlorate, the issue of environmental safety can be mitigated. The perchlorate-based issue of disposal with regard to existing thermite formulations and their reaction products may be eliminated by the composition at hand. |



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## 2.3 Additional Considerations

### 2.3.1 Development

The present invention covers only the material breakdown of the pyrotechnic thermite composition, primarily for use in thermite torch applications. If the composition is to be employed within any established thermite applications, further development will be needed. Likewise, the possible applications to be explored by this assessment—disaster clean-up, flares, fire starters, explosive ordnance, and general construction/welding—will require further development of the composition‘s corresponding embodiments and manufacturability. This development is briefly outlined in accordance with each suggested application at the end of section 3, Applications. For now, it is noted that the composition is established and proven, as outlined in United States patent 7,632,365 B1, but developmental needs remain for the composition‘s various potential applications.

### 2.3.2 Pricing Assumptions

Beyond the testing and resultant material composition of the thermite formulation, as articulated within United States Patent 7,632,365, little to no commercialization efforts have ensued. Thus, based on raw material pricing data, assumptions are made with regard to the composition‘s potential pricing structure. Aluminum, magnesium and copper are common metals frequently available in large quantities. Molybdenum is used in the production of steel and is also available in large quantities, although its price does fluctuate with the price of steel. World production as of 1998 is given in Table 1.[4]

| Component | World Production (1000 metric tons) | Percent U.S. of world |
|---|---|---|
| Aluminum | 22,100 | 17% |
| Magnesium | 369 | 39% |
| Copper | 11,900 | 18% |
| Molybdenum | 135 | 40% |

The most recently publicly quoted prices for the raw materials on the London Metal Exchange are seen below.

| Component | Price per Pound | Date |
|---|---|---|
| Aluminum | $1.138 | February 2010 |
| Magnesium | $2.00 | December 2007 |
| Copper | $2.86 | February 2010 |
| Molybdenum Oxide | $32.75 | December 2007 |

The magnalium included in the pyrotechnic thermite composition is assumed to be a 50:50 mixture of Aluminum and Magnesium. Copper Oxide is 79.9% Copper by weight and the oxygen can be obtained at no cost from the atmosphere. Based on these figures, the price estimate of $12.10 per pound is obtained for the raw materials of the most preferred embodiment of the thermite composition. The binding material, forming only 3% by weight, is neglected. Clearly, the price of molybdenum will drive the cost of the thermite composition.

[4] "Principal Fuels, Nonmetals, and Metals -- World Production and U.S. Sh." *US Census 2000 on Allcountries.org*. 2006. United States Census Bureau, U.S. Department of Commerce, Web. Mar 2010. <http://allcountries.org/uscensus/1170_principal_fuels_nonmetals_and_metals_world.html>.



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| Component | Percentage by Weight | Price per Pound of Thermite |
|---|---|---|
| Magnalium | 24.2% | $0.38 |
| CuO | 39.8% | $0.91 |
| $MbO_3$ | 33% | $10.81 |
| **Thermite** | **100%** | **$12.10** |

### 2.3.3 Safety

Thermite is a highly reactive material and should be handled with precautions similar to those used for explosives. It is officially classified by the Bureau of Alcohol Tobacco and Firearms as a flammable solid, but patent holder Steven P. D'Arche notes that, for safety reasons, thermite should be handled more like a categorized explosive.[5]

Some of the dangers and potential health effects related to thermite exposure are tabulated below:

| Potential Dangers | Potential Health Effects |
|---|---|
| Mechanical eye and skin irritation | • General eye and skin irritation<br>• Corneal necrosis caused by aluminum particles<br>• Repeated skin contact has been associated with bleeding into tissue, delayed hypersensitivity and ganulomas |
| Digestive and respiratory tract irritation | • Severe and permanent damage to the digestive tract upon ingestion<br>• Irritation to the respiratory tract upon inhalation of dust<br>• Chronic inhalation may cause effects similar to those of acute inhalation; chronic inhalation of finely divided powders has been reported to cause pulmonary fibrosis and emphysema |
| Inhalation of fumes | • May cause metal-fume fever (characterized by flu-like symptoms with metallic taste, fever, chills, cough, weakness, chest pain, muscle pain, increased white blood cell count, olfactory fatigue and delayed pulmonary edema) |

In addition to the individual health concerns above, the thermite flammable solid can burn rapidly with a flare effect if accidently ignited and may re-ignite after fire is extinguished. Likewise, dust from thermite compositions can be an explosion hazard when exposed to heat or flame. Thermite must then be handled properly to avoid accidental release and proper protective equipment should be worn by personnel in direct contact with the material. As fine particles can cause fire or explosion, care must be taken to eliminate ignition

[5] Note: Phone interview with inventor, Steven P. D'Arche, on February 11, 2010.



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sources. Moreover, some guidelines state that material should not be pressurized, cut, welded, brazed, soldered, drilled or ground.[6]

Ultimately, thermite must be handled properly. Use of thermite calls for special precautions and poses an array of dangers to health. These safety considerations are put forth in recognition of the fact that they may add complexity and costs to development initiatives. With that said, difficulties and expenditures may be reduced if potential licensees are companies with existing experience and/or capacity in pyrotechnics or explosives.

[6] "Material Safety Data Sheet." *Thermite*. 2010. Whitney Point CSD, Web. Mar 2010. <http://www.wpcsd.org/education/sctemp/e411377fa821e20a81086bba503644a5/1268086064/Thermite.pdf>.



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# 3 Applications

In light of the pyrotechnic thermite composition‘s functional components and prospective advantages, this assessment now moves to examine potential applications of the composition. Although this list is by no means exhaustive, there are five primary applications explored:

- Disaster clean-up
- Flares
- Fire starters
- Explosive ordnance disposal
- General cutting and/or welding

The physical embodiment of the thermite composition may vary between the above applications, but the unifying concept remains that of concentrated heat. In each, the thermite composition‘s reaction heat may be applied via varied embodiments to achieve different objectives. Objectives may include disaster clean up; *perforation*, flares; *illumination*, fire starters; *ignition*, EOD; *perforation/ignition*, and construction or welding; *perforation/fusion*. For each potential application, the thermite composition‘s embodiment, corresponding purpose, and relevant advantages and disadvantages are explored. A summary chart is produced at the conclusion of this analysis.

## 3.1 Disaster Clean-Up

When embodied within a thermite torch cutter, the pyrotechnic thermite composition may be applied within disaster clean-up activities. The composition‘s exothermic reaction can be concentrated, or focused, by a torch nozzle in order to cut through materials—most frequently metal. Thus, when buildings or other infrastructure collapse as a result of natural or man-made disaster, thermite torch cutters could be employed to cut beams and other structural remnants for removal. The concentrated heat may be applied via torch to enable perforation.

Existing technologies are able to cut through structural components like steel beams in a matter of minutes, where as a thermite torch cutter employing this composition may be able to do so in a matter of seconds. This pyrotechnic composition is claimed to offer increased material perforation capability which may equate to increased speed. This could be advantageous for the post-disaster workflow of clean-up activities, but could also be imperative for quickly reaching victims enclosed within collapsed structures—the pyrotechnic thermite composition may find application in rescue initiatives.

There are considerations to be made for the dangers of the thermite composition‘s reaction products, but the basic application of cutting structural remnants for removal remains relevant, and could be done so with increased efficiency. Considerations for victim safety will become increasingly important as the proximity between the application of thermite torch cutting and trapped individuals increases. With that said, the composition in question is said to offer comparatively low levels of toxicity.

Thermite torch cutters are traditionally light weight and hand-held, proving advantageous over complex or heavy equipment. Moreover, the pyrotechnic thermite composition at hand offers is said to offer the potential for unmanned vehicles (UXVs) to be outfitted with a thermite torch cutter in an effort to access smaller or more



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dangerous disaster locales. Compared to the cutting of steel, the thermite composition‘s perforation capability is degraded when applied to cement materials. The composition is still effective when applied, but less so.

Ultimately, in response to disaster, the pyrotechnic thermite composition may be applied via torch for the purpose of cutting through structural remnants. This could be undertaken in an effort to remove debris in general site clean-up, or within rescue initiatives. In both scenarios, efficiency of workflow may be increased via enhanced material perforation capability, but the latter carries considerations to be made for the toxicity of reaction products (albeit comparatively lessened) harming trapped individuals.

| Application | Embodiment | Purpose | Advantages | Disadvantages |
|---|---|---|---|---|
| Disaster Clean-Up | Thermite Torch Cutter | Perforation | • Increased perforation<br>• Decreased time to target<br>• Decreased toxicity<br>• Miniaturization, UXV potential | • Hot reaction products may pose danger to victims<br>• Degraded perforation capability when applied to cement materials<br>• Supply chain will be need to be established |

## 3.2 Flares

Flares represent a second potential application of the pyrotechnic thermite composition. Flares have become increasingly popular due to their ease-of-use and low cost, and are now used as sources of light and signals of distress by end-users ranging from civilians, to highway patrol, to military entities. With regard to the composition, thermite flares produce their light via the thermite reaction. Thus, the pyrotechnic thermite composition may be embodied within flares to enable illumination in such applications as target marking, distress signaling and general lighting.

One potential advantage of the thermite composition at hand is its lack of perchlorate. Many existing flares, particularly colored and spectrally balanced flares, contain perchlorate. The high stability and level of oxygen associated with perchlorate oxidizers makes them ideal for use within pyrotechnics. The problem, however, of the widespread usage of perchlorate is the environmental hazard encountered within its disposal. In short, perchlorate can rapidly dissolve into ground and surface water. Thus, when perchlorate-flares are disposed of, their perchlorate can be released into the environment—an especially disconcerting scenario when humans then consume the chemical via drinking water. Even in low concentrations, perchlorate is known to adversely affect human health by interfering with iodine uptake to the thyroid gland.[7] As the thyroid gland helps to regulate adults‘ metabolism and hormonal balance, and plays a crucial role in children‘s development, the adverse effects of perchlorate are noted by many to be cause for concern.

2005 research by Silva of the Santa Clara Valley Water District in California indicated that 3.6 grams of perchlorate can potentially leach from each unburned or damaged 20-minute road flare. While numbers are not available for total domestic flare production, assuming an average cost per flare of $0.50 to $1.00 per flare and

[7] Greer, M.A., Goodman, G., Pleuss, R.C., Greer, S.E. (2002). "Health effect assessment for environmental perchlorate contamination: The dose response for inhibition of thyroidal radioiodide uptake in humans". *Environmental Health Perspectives* **110** (9): 927–937.



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annual sales of $20 million by the largest domestic manufacturer, some 20 to 40 million flares may be sold annually.[8] Given this estimate, up to 237,600 pounds of perchlorate could leach from road flares annually.

The negative health and environmental implications of perchlorate-flares, as well as the response from regulatory bodies, are further discussed in section 5 of this analysis. For now, it is recognized that the pyrotechnic thermite composition may find application in flares for the purpose of illumination and the absence of perchlorate is a notable prospective advantage.

| Application | Embodiment | Purpose | Advantages | Disadvantages |
|---|---|---|---|---|
| Flares | Thermite Flare | Illumination | Decreased toxicity (perchlorate-free) | • Less control over color<br>• Marginal advantage over existing solutions |

## 3.3 Fire Starter

The pyrotechnic thermite composition may find application within fire starting embodiments. The established common element of concentrated heat remains relevant as commercially available thermite fire-starters are marketed as "fail-proof" mechanisms of ignition within any environment and of nearly any material. Most commonly, the thermite fire starters are in the form of a container similar to the shape and size of a film canister. The tins contain a few ounces of cast thermite and the canister is outfitted with a fuse for ignition. The thermite reaction burns at extremely high temperatures and produces hot molten reaction products which maintain their temperature for several minutes. Although external ignition is required to light the fuse, thermite fire starters are claimed to be effective even in "three feet of snow or pouring rain."[9] The pyrotechnic thermite composition may be embodied within a fuse-outfitted canister to enable ignition in the fire starting application.

Thermite fire starters may then find application within emergency situations (*i.e.* emergency fire starters), recreational usage (*e.g.* camping, extreme environments), and military initiatives. It is worthy to note that thermite fire starters may prove relevant to military efforts as a source of ignition for fires in the traditional connotation, but also in the adaption of the composition to explosive devices. That is, the thermite composition at hand could meet the basic objective of starting a fire, but can be adapted to provide an increasingly effective explosive. Thermite grenades are already being used on military fronts and this composition remains relevant for such existing applications. The composition at hand may also offer increases in reaction temperatures and increased difficulty in extinguishing resultant fires. This assessment does not, however, consider the application of explosive devices in full as it is limited in its first-responder relevance and/or benefit.

| Application | Embodiment | Purpose | Advantages | Disadvantages |
|---|---|---|---|---|
| Fire Starter | Fuse-Outfitted Canister;<br>[Explosive Device] | Ignition | • Ignition independent of environmental factors<br>• [Increased burn temperatures and difficulty to extinguish] | Safety considerations |

[8] "Alternative Causes of Widespread, Low Concentration Perchlorate Impacts to Groundwater." *Prepared by: GeoSyntec Consultants under contract to the Department of Defense Strategic Environmental Research and Development Program (SERDP)* 05 May 2005: 1-54. Print.

[9] DBC Pyrotechnics. "Thermite Fire Starter 1-9 units."*DBC Pyrotechnics, LLC*. 2010. DBC Pyrotechnics, Web. Mar 2010. <http://www.dbcpyrotechnics.com/servlet/the-948/Thermite-Fire-Starter/Detail>.



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## 3.4 Explosive Ordnance Disposal

With the combined purpose of perforation and ignition, the pyrotechnic thermite composition may be applied within explosive ordnance disposal (EOD). As an alternative to detonation, the thermite composition may facilitate the destruction of explosive ordnances by burning or igniting the devices. In most cases, the thermite reaction (*i.e.* concentrated heat) is focused on an explosive ordnance to burn through the device‘s protective casing. Upon penetration of the casings, explosives or other energetic materials can be ignited, forcing internal combustion. By initiating rapid combustion of the munitions filling and/or trigger components, explosive ordnances may detonate in a much lower grade explosion or simply be incinerated. The risk of collateral damage to infrastructure and people, hazardous conditions, and fragmentation could be decreased.

Within EOD, thermite compositions are frequently embodied within incendiary devices—essentially a combination of torch cutters (*i.e.* perforation) and fire starters (*i.e.* ignition). The incendiary devices can be operated by EOD personnel, but are frequently retrofitted to unmanned vehicles (UXVs). Thus, the pyrotechnic thermite composition may be embodied within incendiary devices to enable perforation and ignition in the application of EOD. As seen within disaster clean-up applications, the pyrotechnic thermite composition‘s enhanced material perforation may again prove advantageous. It is claimed to be capable of piercing metal casings of explosive devices—something not all existing EOD thermite devices can accomplish.

The thermite-based application of explosive ordnance disposal is relevant to both military and civilian EOD personnel. With regard to military initiatives, the composition may find application within both active military efforts and the demilitarization of historical combat zones. The latter may see amplified relevance for the thermite composition in the case that EOD materials and/or technologies are sent from one country to another for use in demilitarization applications. That is, thermite-based EOD mechanisms and substances may be preferred to the provision of highly reactive compounds which can carry increased risk of theft and/or the danger of alternative weapons creation.

| Application | Embodiment | Purpose | Advantages | Disadvantages |
|---|---|---|---|---|
| Explosive Ordnance Disposal (EOD) | Incendiary Device | Perforation; Ignition | • EOD with decreased risk of collateral damage, hazardous conditions, and fragmentation<br>• Decreased likelihood of theft<br>• Decreased potential for weapons creation | • Potential risk is not completely eliminated<br>• Considerable design work required<br>• Precautions for handling |

## 3.5 General Cutting / Welding

Based on the pyrotechnic thermite composition‘s claimed material perforation and increased reaction temperature, the composition may essentially find application in any case that cutting and/or welding is involved. This prompts the potential application of general construction and welding activities. The thermite composition may be embodied within a torch to enable perforation or fusion. The concentration of the thermite reaction may be used to cut through metal, or to weld metal components together (by melting a thin film where two or more components meet).



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As established, thermite torch cutters employing the composition at hand may be able to cut through structural components like steel beams in a manner of seconds. Similar to its application within disaster clean-up, this pyrotechnic composition‘s claimed enhanced material perforation may offer the advantage of increased efficacy and efficiency within construction applications. With regard to welding, thermite torches may be advantageous in that related activities can take place without removing or deconstructing structures to be welded. For example, locomotive axle-frames in need of repair can be mended without removing the part from its installed location. Likewise, thermite torches could be used for quickly cutting or welding without the need for complex or heavy equipment.

| Application | Embodiment | Purpose | Advantages | Disadvantages |
|---|---|---|---|---|
| General Cutting/Welding | Thermite Torch | Perforation; Fusion | • Increased Perforation<br>• Decreased Toxicity<br>• Miniaturization (vs. complex/heavy equipment) | • Potential learning curve, training requirement<br>• Reaction heat may not be suitable for all applications |

In summary, the pyrotechnic thermite composition may potentially find application within: disaster clean-up, flares, fire starters, explosive ordnance disposal, and general cutting and/or welding. While the embodiments of the composition may vary between the applications, the commonality is that of concentrated heat or the focus of the thermite reaction. Pre-existing thermite compositions are employed within the majority of the identified applications, but the pyrotechnic thermite composition at hand is claimed to offer comparative improvements. The application, embodiment, purpose and relevant strengths and weaknesses of the pyrotechnic thermite composition are tabulated below. Further discussion of the composition‘s prospective advantages will ensue in its comparison to competitive products and prior art in section 5.



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| Pyrotechnic Thermite Composition: Potential Applications | | | | |
|---|---|---|---|---|
| ***Application*** | ***Embodiment*** | ***Purpose*** | ***Relevant Advantages*** | ***Relevant Disadvantages*** |
| Disaster Clean-Up | Thermite Torch Cutter | Perforation | • Increased perforation<br>• Decreased time to target<br>• Decreased toxicity<br>• Miniaturization, UXV potential | • Hot reaction products may pose danger to victims<br>• Supply chain will be need to be established |
| Flare | Thermite Flare | Illumination | • Decreased toxicity (perchlorate-free) | • Less control over color |
| Fire Starter | Fuse-Outfitted Thermite Canister; Explosive Device | Ignition | • Ignition independent of environmental factors<br>• Decreased toxicity | • Safety considerations |
| Explosive Ordnance Disposal | Incendiary Device | Perforation; Ignition | • EOD with decreased risk of collateral damage, hazardous conditions, and fragmentation<br>• Decreased likelihood of theft<br>• Decreased potential for weapons creation | • Potential risk is not completely eliminated<br>• Considerable design work required<br>• Precautions for handling |
| General Construction/ Welding | Thermite Torch | Perforation; Fusion | • Increased perforation<br>• Increased reaction heat for fusion<br>• Decreased toxicity<br>• Miniaturization (vs. complex/heavy equipment) | • Potential learning curve, training requirement<br>• Reaction heat may not be suitable for all applications |



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## 3.6 Development

As noted earlier, the present invention covers only the material formula of the pyrotechnic thermite composition. In order for the composition to be employed within any of the above applications, further development will be needed with regard to corresponding embodiments and manufacturability. Seen below are examples of some of the potential development which may need to ensue within each of the potential applications.

| Application | Potential Development to Ensue |
|---|---|
| Disaster Clean-Up | For disaster cleanup applications, it may be desirable to engineer a design for the thermite torch cutter that would be well-adapted to deployment and use in disaster scenarios (*e.g.* ruggedized). As part of the process of developing the present thermite composition, experimental torches consisting of a lower nozzle body and an upper composition holding body were constructed. The nozzle body included an 82-degree converging nozzle and a 0.070" throat. The composition holding body consisted of a 0.5" diameter cavity 1.5" long, inside of which the pyrotechnic formulation was pressed. The torch body was contained in a mild steel housing held together with four grade 8, ½" diameter flange-head bolts. It may be desirable and/or necessary to vary these specifications for a cutting torch to be put into field use. It may also be necessary to come up with a suitable and disaster-proof scheme for storing and distributing the thermite formulation. |
| Flares | Flares frequently come in a standard design for use with existing pyrotechnic formulations. It may be that little modification will be required to integrate the designs with the present thermite formulation. However, consideration may need to be made for the composition's higher reaction temperatures. |
| Fire Starters | The majority of existing fire starters typically involve lighters or a flint-and-steel source of sparks; that is, they operate on a different physical mechanism than the thermite reaction. Special development may be needed to package the thermite formulation for use in an emergency fire starter; for instance, one might want to equip a torch embodiment with multiple nozzles. |
| Explosive Ordnance Disposal | EOD is well-established with regard to existing pyrotechnic formulations. Nevertheless, in order to field the present thermite formulation in EOD further development may be needed. Namely, developing a means of pressing the material into different forms and manufacture of the casing. |

In light of the advantages claimed by the material properties of the present thermite composition, the expenses which may be required to carry out the above development could be justified. To calculate the tradeoff between development cost and potential benefits, a detailed engineering study of the various applications would be needed.



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# 4 Markets

In light of the pyrotechnic thermite composition‘s multiple applications, three overarching classifications have been identified which encompass the composition‘s various embodiments and purposes. Market relevance may be found within the following uses:

- Civilian First Responder
- Military
- Construction / Welding

Definitions and quantifications are articulated for each of these general classifications. Although the above uses provide broad-spectrum characterization, potential market relevance for the pyrotechnic thermite composition is further revealed by examining markets directly correlated to the identified applications. That is, despite being referred to as ―applications” for the composition, this assessment will also work to explore the markets of:

- Disaster Clean-Up
- Flares
- Fire Starters
- Explosive Ordnance Disposal

Each market is defined, quantified, and market drivers and influences are explored. Emphasis is placed on markets within the United States as initial points of market entry may likely prove to be domestic.

## 4.1 Civilian First Responder

Of the five identified applications, *disaster clean-up*, *flares, fire starters*, and *explosive ordnance disposal* may hold relevance for civilian first responder use. Civilian first responders are defined to be civilian personnel who hold first responder employment.[10] First responders then include those grouped within the United States Bureau of Labor Statistics‘ occupational classifications of ―protective services” and ―healthcare practitioners and technical occupations.” These two categories encompass fire fighters, police officers, and emergency medical technicians (EMTs) and paramedics. The Bureau of Labor Statistics articulates the following employment figures.

| First Responder Category | SOC Code | Employment 2008 | Projected Employment 2018 | Change, 2008-2018 | |
|---|---|---|---|---|---|
| | | | | Number | Percent |
| Fire Fighters | 33-2011 | 310,400 | 367,900 | 57,500 | 16% |
| Police Officers | 33-3050 | 665,700 | 723,300 | 57,600 | 8% |
| EMTS & Paramedics | 29-2041 | 210,700 | 229,700 | 19,000 | 8% |
| *Average* | | *1,186,800* | *1,320,900* | *134,100* | *10%* |

[10] Note: civilian personnel are asserted to be persons following the pursuits of civil life, especially one who is not an active member of the military.



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When employment statistics are accepted as a market indicator for the pyrotechnic thermite composition, the civilian first responder market reveals positive indications of growth. Employment projections for each component of the civilian first responder market are positive. It is these first responders who could potentially serve as end-users of the pyrotechnic thermite composition applied within disaster relief, flares, fire starters and explosive ordnance disposal. On the other hand, examining the market via end-users is somewhat ineffectual. For example, the BLS estimated an average of 1,186,800 first responders in 2008. Questions then remain such as—how many of these first responders engage in disaster clean-up or explosive ordnance disposal? Likewise, how often are thermite flares or torches used in either of these applications? Such questions will attempt to be answered by more thoroughly examining the markets more directly related to the composition‘s various applications.

### 4.1.1 Disaster Clean-Up

***Definition and Quantification***

Attempts to define and quantify the market of disaster clean-up can be complicated by variant determinants and qualifiers of what constitutes a disaster, and by the involvement of numerous parties within clean-up efforts. Definitions of a disaster can be subjective with regard to cause and ramifications, and the entities engaged in clean-up activities can run the gamete from public to private and non-for-profit to commercial. As a result, this assessment adopts three main assumptions: one, disasters, however they may be defined, connote clean-up activities; two, disastrous events connote building collapse; and three, the collapse of buildings connotes the use of thermite torch cutters to remove structural remnants. While these assumptions are robust—they enable a starting point of analysis and provide general market indicators.

The disaster clean-up market is first defined by the event of a disaster. As defined by the Merriam Webster dictionary, a disaster is a ―sudden calamitous event bringing great damage, loss or destruction.” These disasters can be either natural or caused by human beings, and can represent many different types of events. Those related to weather and the earth‘s geology are some of the most widely recognized, but as of late such man-made disasters as terrorist initiatives have become increasingly common within the characterization of disasters. Within his 1999 *Epidemiology of Disasters* Thomas Songer of the University of Pittsburgh characterizes disasters as: extreme weather events, extreme geological events, and/or industrial mishaps. Included in the former are: floods, hurricanes/cyclones, tornadoes, earthquakes, volcanic eruptions, tsunamis, avalanches, droughts/famine, and blizzards. Likewise, the Centre for Research on the Epidemiology of Disasters (CRED) articulates the following classifications of natural disasters.



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| Disaster Subgroup | Definition | Disaster Main Type |
|---|---|---|
| **Geophysical** | Events originating from solid earth | Earthquake, Volcano, Mass Movement (dry) |
| **Meteorological** | Events caused by short-lived/small to meso scale atmospheric processes (in the spectrum from minutes to days) | Storm |
| **Hydrological** | Events caused by deviations in the normal water cycle and/or overflow of bodies of water caused by wind set-up | Flood, Mass Movement (wet) |
| **Climatological** | Events caused by long-lived/meso to macro scale processes (in the spectrum from intra-seasonal to multi-decadal climate variability) | Extreme Temperature, Drought, Wildfire |
| **Biological** | Disaster caused by the exposure of living organisms to germs and toxic substances | Epidemic, Insect Infestation, Animal Stampede |

Songer‘s identified *industrial mishap*s refer primarily to accidents of an industrial nature ranging from chemical explosions to the collapse of faulty structural foundations. The latter is that adopted by this assessment and purposeful destruction (*i.e.* terrorist efforts) is added to the classification. Ultimately, this assessment maintains the assumption that disastrous events, however they are caused or defined, connote building collapse and thus, the use of thermite torch cutters to remove structural remnants.

With regard to quantification, the CRED quotes 354 natural disasters to have been recorded for 2008 in the EM-DAT database, a worldwide database on disasters. This 354 is less than the 2000-2007 yearly average of 397 natural disasters. Disaster costs in 2008 were more than twice the 82 billion US$ annual average for 2000-2007, mainly attributed to the Sichuan earthquake in China and hurricane Ike in the United States. China remained the most affected country with 29 natural disasters, and the United States ranked second with 22. China and the United States have occupied the top ranking of disaster occurrence from 2005-2008. CRED reports the following figures to rank the top ten countries by the number of reported disasters in 2008.



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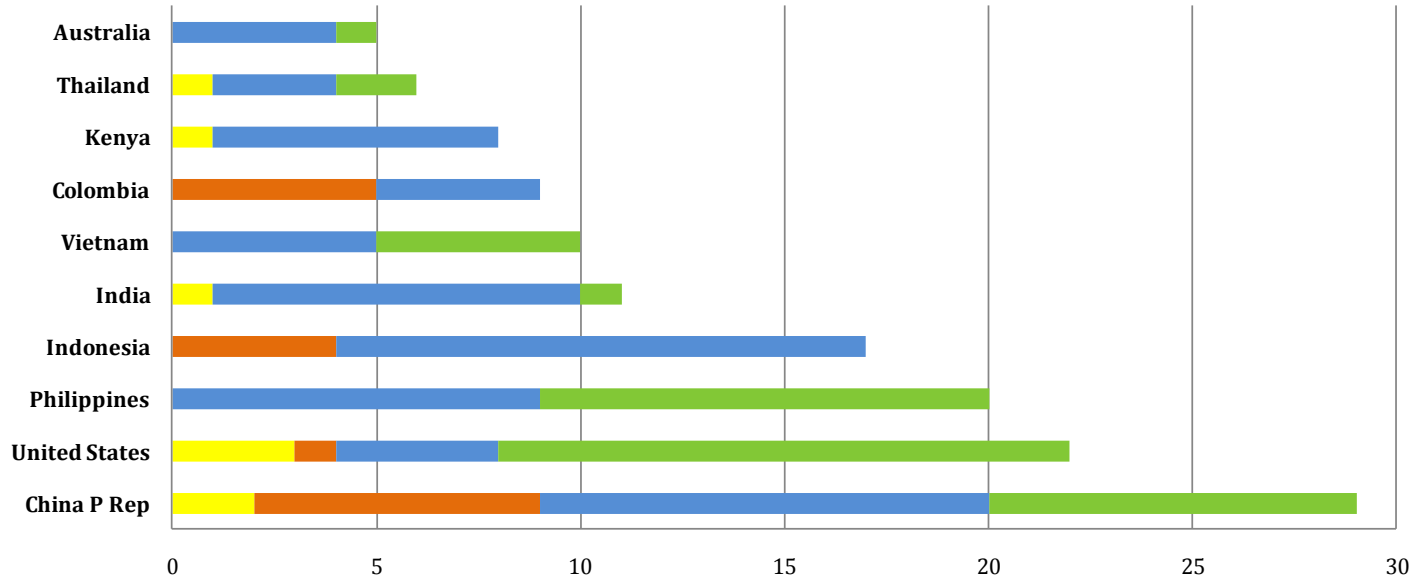


| | China P Rep | United States | Philippines | Indonesia | India | Vietnam | Colombia | Kenya | Thailand | Australia |
|---|---|---|---|---|---|---|---|---|---|---|
| Climatological | 2 | 3 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 0 |
| Geophysical | 7 | 1 | 0 | 4 | 0 | 0 | 5 | 0 | 0 | 0 |
| Hydrological | 11 | 4 | 9 | 13 | 9 | 5 | 4 | 7 | 3 | 4 |
| Meteorological | 9 | 14 | 11 | 0 | 1 | 5 | 0 | 0 | 2 | 1 |

With specific regard to the Americas, the number of reported natural disasters remained stable in 2008 (95) compared to the annual average of 2000-2007 (94). These 95 disasters, however, saw the Americas account for more than 25% of global natural disaster occurrence in 2008. The CRED provides the following break down of natural disaster occurrence by region.

| No. of Natural Disasters | Africa | Americas | Asia | Europe | Oceania | Global |
|---|---|---|---|---|---|---|
| **Climatological 2008** | 10 | 4 | 9 | 9 | 0 | 32 |
| *Avg. 2000-07* | 9 | 14 | 13 | 19 | 2 | 57 |
| **Geophysical 2008** | 3 | 8 | 18 | 2 | 1 | 32 |
| *Avg. 2000-07* | 3 | 7 | 22 | 3 | 2 | 37 |
| **Hydrological 2008** | 48 | 39 | 73 | 9 | 9 | 178 |
| *Avg. 2000-07* | 42 | 39 | 82 | 28 | 5 | 196 |
| **Meteorological 2008** | 10 | 44 | 43 | 13 | 2 | 112 |
| *Avg. 2000-07* | 9 | 34 | 42 | 15 | 7 | 107 |
| **Total 2008** | **71** | **95** | **143** | **33** | **12** | **354** |
| *Avg. 2000-07* | **63** | **94** | **160** | **65** | **16** | **397** |

Maintaining assumptions, the Americas and Asia may represent those geographic markets with (1) the largest occurrence of natural disaster and subsequent clean-up activities, (2) the largest amount of building collapses and (3) the largest use of thermite torch cutters for removal of structural remnants. The pyrotechnic thermite composition may find market opportunity embodied within a thermite torch cutter and applied to the removal of structural remnants within disaster clean-up activities and/or rescue initiatives.



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The number of industrial mishaps within the United States is not directly articulated by governing bodies, nor are the number of terrorist attacks resulting in structural damage and/or building collapse. However, the Bureau of Alcohol Tobacco and Firearms (ATF) quotes the following statistics with regard to explosive incidents in the United States.[11]

| Year | Number of Incidents | Number of Injuries | Number of Fatalities |
|---|---|---|---|
| 2006 | 3445 explosives incidents | 135 injuries | 14 fatalities |
| 2005 | 3722 explosives incidents | 148 injuries | 18 fatalities |
| 2004 | 3790 explosives incidents | 263 injuries | 36 fatalities |

Despite the above ATF quantification, the causes and ramifications of these explosive incidents are not disclosed. If the established assumptions are maintained, it can be said that each explosive incident (classified as a disaster) may result in subsequent clean-up activities, and the use of thermite torch cutters for removal of structural remnants and/or rescue initiatives. In this case, the occurrence of explosive incidents reveals potential market opportunity for the pyrotechnic thermite composition.

Ultimately, public information regarding disasters beyond those which are ―natural" is limited or unreliable. Thus, with regard to market influence and drivers of the disaster clean-up market; this assessment focuses on those potentially driving the occurrence of natural disasters.

***Market Drivers and Influence***

Deforestation, global warming, and general changes to the geography and environment of the earth's composition are frequently attributed to the occurrence of natural disasters. Deforestation is attested to increase the potential for soil erosion and landslides, and global warming may increase the propensity for extreme weather events.[12] Although the number of industrial mishaps cannot be articulated, levels of economic development are commonly attributed to the collapse of faulty structures. That is, decreased levels of economic development can be correlated with decreased structural quality and thus, an increased risk of structural collapse. This relationship may hold independent of natural disasters, while also being amplified in the face of said disasters. When natural disasters occur, the level of structural quality may become a determinant of the number of buildings which can withstand disaster ramifications and those which are damaged or destroyed.

Population density may also prove to hold influence for the market of disaster clean-up. As population density increases, the assumption may be made that levels of infrastructure (*i.e.* buildings and households) also increase. With a larger number of buildings to be potentially damaged by disaster, the market opportunity for clean-up activities, and the removal of structural components and/or rescue initiatives employing thermite torch cutters may also increase. As of July 1, 2009 the U.S. population of 307,212,000 was projected to increase by

[11] Bureau of Alcohol Tobacco and Firearms. "ATF Fact Sheet." *U.S. Bomb Data Center*. 2008. ATF Public Affairs Division, Web. Mar 2010. <http://www.atf.gov/publications/factsheets/factsheet-us-bomb-data-center.html>.

[12] Songer, Thomas. "Epidemiology of Disasters." *Are the Number of Disasters Increasing?*. 1999. University of Pittsburgh, Web. Mar 2010. <http://www.pitt.edu/~epi2170/lecture15/index.htm>.



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1.0% per year through 2020. Population per square mile of land area has increased from 70.3 in 1990 to 79.6 in 2000, a 13.1% increase.[13]

Lastly, this assessment makes note that man-made disasters such as terrorist attacks have become increasingly common in the characterization of disasters. While the number of terrorist attacks within the United States is not available, market drivers and influence may be likely to center on the political climate. While there is some level of random distribution with regard to terrorist attack occurrence, frequency, and distribution; the likelihood of such attacks may be assumed to increase in the face of active combat initiatives and/or political conflict. Albeit an indirect source of market influence for the pyrotechnic thermite composition, if the disaster clean-up market is understood to be reliant on the event of a disaster, and terrorist attacks are a source of disaster occurrence—drivers of terrorist attacks could hold influence over the market need for the thermite composition embodied within a thermite torch cutter.

### 4.1.2 Flares

***Definition and Quantification***

As established, the pyrotechnic thermite composition may find market opportunity within the flare application. Flares are used as sources of light, target markings, and signals of distress by end-users ranging from civilians, to highway patrol, to military entities. These end-users allow for further market definition and quantification.

With regard to the civilian end-user, the previously defined ―civilian first-responder" remains applicable. In addition to the above quantification, the Bureau of Labor Statistics (BLS) further defines ―police officers" to include police and sheriff‘s patrol officers, and transit and railroad police. As these occupational categorizations may imply active field duty, they may be more likely to employ thermite flares than those end-users generally classified as police officers. For example, flares are sometimes used to perform hand signals in rail transport, and to alert commuters of a broken down vehicle on roadways. The BLS quantification of the further specified police and sheriff‘s patrol officers, and transit and railroad police, are seen below highlighted in bold text.

| First Responder Category | SOC Code | Employment 2008 | Projected Employment 2018 | Change, 2008-2018 | |
|---|---|---|---|---|---|
| | | | | Number | Percentage |
| Fire Fighters | 33-2011 | 310,400 | 367,900 | 57,500 | 16% |
| Police Officers | 33-3050 | 665,700 | 723,300 | 57,600 | 8% |
| **Police & Sheriff's Patrol Officers** | **33-3051** | **661,500** | **718,800** | **57,300** | **9%** |
| **Transit & Railroad Police** | **33-3052** | **4,300** | **4,500** | **200** | **5%** |
| EMTS & Paramedics | 29-2041 | 210,700 | 229,700 | 19,000 | 8% |
| *Average* | | *1,186,800* | *1,320,900* | *134,100* | *10%* |

*Please note: numbers are rounded and not all BLS categories are included. The tabulated figures are accurate, but may not total.*

[13] U.S. Census Bureau, . "Population." *The 2010 Statistical Abstract*. 18 Feb 2010. U.S. Census Bureau, Web. 8 Mar 2010. <http://www.census.gov/compendia/statab/cats/population.html>.



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If employment statistics are accepted as market indicators for the pyrotechnic thermite composition embodied within a flare—projections remain favorable. Although the BLS does not further differentiate between types of fire fighters, it is worth noting that within forestry and firefighting, flares can sometimes be used in wildland fire suppression efforts and in the ignition of controlled burns.

In addition to civilian first responders, the civilian flare end-user may include outdoor recreationalists, generally risk-averse consumers, and those employed within maritime and highway-based fields of occupation. That is, flares‘ inclusion in survival packs and safety kits may offer further market opportunity. With specific regard to maritime and highway-based fields of occupation, the BLS estimates that water transportation workers held more than 81,100 jobs in 2008 within the United States.[14] These workers include sailors and marine oilers; ship and boat captains and operators; captains, mates, and pilots of water vessels; motorboat operators; and ship engineers. Although it may be more likely for each vessel to employ a safety kit including a thermite flare (as opposed to each individual), the following BLS statistics may provide for general market indicators.

| Occupation Title | SOC Code | Employment 2008 | Projected Employment 2018 | Change, 2008-2018 | |
|---|---|---|---|---|---|
| | | | | Number | Percentage |
| Water Transportation Occupations | 53-5000 | 81,100 | 93,100 | 12,000 | 15% |
| Sailors & Marine Oilers | 53-5011 | 32,900 | 36,700 | 3,800 | 12% |
| Ship & Boat Captains/Operators | 53-5020 | 36,800 | 42,800 | 6,000 | 16% |
| Captains, Mates, & Pilots of Water Vessels | 53-5021 | 33,100 | 38,800 | 5,700 | 17% |
| Motorboat Operators | 53-5022 | 3,700 | 4,000 | 300 | 8% |
| Ship Engineers | 53-5031 | 11,500 | 13,600 | 2,100 | 19% |
| *Average* | | *33,183* | | *4,983* | *15%* |

Likewise, highway-based occupations (connoting the possession and/or use of roadside safety kits) may be embodied within the BLS defined occupation of *transportation and material moving*. Transportation and material moving is grouped within the occupational category of *truck transportation and warehousing* for which BLS quantification is seen below.[15]

[14] U.S. Bureau of Labor Statistics. "Occupational Outlook Handbook, 2010-11 Edition." *Water Transportation Occupations*. 17 Dec 2009. U.S. Bureau of Labor, Web. Mar 2010. <http://www.bls.gov/oco/ocos247.htm>.

[15] U.S. Bureau of Labor Statistics. "Occupational Outlook Handbook, 2010-11 Edition." *Truck Transportation and Warehousing*. 17 Dec 2009. U.S. Bureau of Labor, Web. Mar 2010. < http://www.bls.gov/oco/cg/cgs021.htm>.



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| Employment of Salary Workers in Truck Transportation & Warehousing; 2008 & Projected Change 2008-2018 (employment in thousands) | | | |
|---|---|---|---|
| **Occupation Title** | **Employment 2008** | | **Percent Change, 2008-18** |
| | **Number** | **Percent[16]** | |
| All Truck Transportation & Warehousing | 2,063.8 | 100 | 11.0% |
| Transportation & Material Moving Occupations | 1,447.2 | 70.1 | 12.7% |
| Truck drivers, heavy and tractor-trailer | 828.6 | 40.2 | 18.4% |
| Truck drivers, light or delivery services | 76.0 | 3.7 | -1.3% |
| Industrial truck and tractor operators | 109.2 | 5.3 | 10.2% |
| *Average* | *904.96* | | |

The above Bureau of Labor quantifications can be supplemented by examining the number of related vessels—watercrafts and trucking units. The United States Coast Guard estimates over 13 million registered watercrafts in the United States as of 2002. The National Marine Manufacturers Association estimates 541,000 boats sold in 2001 at retail, and nearly 17 million boats owned across the United States.

With regard to the number of commercial motor vehicles, the Federal Motor Carrier Safety Administration provides the following breakdown.[17]

| Registered Vehicles and Companies | |
|---|---|
| 2005 All Vehicles | 247,421,120 |
| 2005 Large Trucks | 8,481,999 |
| 2005 Buses | 807,053 |
| 2006 Active Interstate Truck and Bus Companies | 692,997 |
| 2006 Active Hazardous Material Companies | 72,891 |
| 2006 Active Passenger Carrier Companies | 5,211 |

Ultimately, thermite flares may find market opportunity within the civilian first-responder, the risk-averse civilian consumer, and civilian maritime and highway-based occupations. If employment statistics of potential end-users are deemed indicative of market opportunity—that for the flare embodied pyrotechnic thermite composition may be apt. Likewise, based on the figures above, the number of related vehicles is large and may prove to be a point of market penetration for the thermite composition embodied within flares. With regard to the risk-averse consumer, the 2008 Traffic Safety Culture Index Survey by the AAA Foundation found that

[16] Note: Percentages are of the total truck and transportation warehousing strength. As only those most relevant to the use of thermite flare usage are relayed here, the percentages will not total to 100. Please consult the BLS website (http://www.bls.gov/oco/cg/cgs021.htm) for the full occupational breakdown.

[17] Federal Motor Carrier Association. "Commercial Motor Vehicle Facts." *Federal Motor Carrier Association*. 2008. Federal Motor Carrier Association, Web. Mar 2010. <http://www.fmcsa.dot.gov/facts-research/facts-figures/analysis-statistics/cmvfacts.htm>.



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41% of 2,509 respondents ranked ―road safety" as their top national concern. This 41% ranked road safety as a 5, extremely concerned, on a scale of 1-5; 1 being not at all concerned. Road safety ranked fourth out of ten possible national issues including: the price of gas, the state of health care, crime, the economy, pollution, global warming, airline safety, the threat of terrorist attack, and traffic congestion, respectively.[18]

In any case, specific numbers for total domestic flare production are not available. With that said, assuming an average cost per flare of $0.50 and $1.00 and annual sales of $20 million by the largest domestic manufacture, it can be estimated that some 20 to 40 million flares may be sold annually within the United States.[19] One additional means of quantification comes from a 2005 report by GeoSyntec Consultants. Although annual flare consumption data are not available, an examination of annual purchase records by state and federal agencies provides some insight into the volume of flares which may be purchased annually across the nation. The report offers the following summary of the number of flares procured by some large urban centers in the United States.[20]

| Purchasing Entity | Total Number of Flares Procured | Notes & Assumptions |
|---|---|---|
| New York, NY | 93,816 | 2 contracts (initiated in 2004, assumed to be annual), both through NY statewide procurement. Total contract cost and per dozen unit price give- total number of flares based on these figures. |
| Los Angeles, CA | 576,000 | Documentation for contract initiated in 2003 (assumed to be annual) for 4,000 gross. |
| Chicago, IL | 3,600 | Documentation for single purchase (in 4/2002) for 50 cases of flares from local all-purpose supplier. |
| Houston, TX | 115,000 | Bid tabulation for two year contract (FY2001-2003) for two types of flares. Total is for combined flare purchase. |
| San Antonio, TX | 216,000 | FY2003 bid tabulation for 1500 gross. |
| Milwaukee, WI | 25,200 | Contract initiated in 2004 (assumed to be annual). |
| Miami, FL | 204,000 | A 2 year contract beginning 5/04. Only the total price is give- total number of flares based on estimated cost per flare of $0.85. |
| Florida Highway Dept | 293,760 | FY2005 award. Total contract cost and per gross unit price given- total number based on these figures. |
| Pennsylvania Turnpike | 500,000 | FY2005 RFQ. Total number of flares requested. |
| Michigan State Police | 298,080 | A 3 year contract beginning 7/04. Total contract cost and per gross price given- total number of flares based on these figures. |
| Illinois Toll Way | 10,588 | FY2004 contract list (assumed to be annual). Only total price is given- total number of flares based on estimated cost per-flare of $0.85. |

[18] AAA Foundation. *2008 Traffic Safety Culture Index*. April 2008. AAA Foundation for Traffic Safety, Web. Mar 2010. <http://www.aaafoundation.org/pdf/2008TSCIndexFinalReport.pdf>.

[19] "Alternative Causes of Widespread, Low Concentration Perchlorate Impacts to Groundwater." *Prepared by: GeoSyntec Consultants under contract to the Department of Defense Strategic Environmental Research and Development Program (SERDP)* 05 May 2005: 1-54. Print.

[20] Ibid.



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### *Market Drivers and Influence*

If the market is quantified via a market's end-user, an examination of market drivers and influences then focuses on those which may affect the existence of said end-users; namely, that of corresponding employment. As articulated by the BLS, the outlook for employment in water transportation occupations is projected to grow faster than average. Job growth may stem from increasing tourism and growth in offshore oil and gas production. Employment is also projected to rise in and around major port cities due to increasing international trade. As the economy recovers from recession, employment growth may stem from growing interest in using ferries to handle commuter traffic around major metropolitan areas, and demand for bulk products such as coal, iron ore, petroleum, sand and gravel and grain. The BLS also projects that problems with congestion in the rail transportation system will increase demand for inland water transportation. [21]

BLS projections for employment within truck transportation are similarly favorable, especially for long-haul drivers. Overall employment of truck drivers is expected to grow 9 percent over the 2008-19 decade. As the economy recovers, an increase in the demand for goods may lead to increased trucking entities and occupations. The number of heavy and tractor-trailer truck drivers is expected to grow 13 percent between 2008 and 2018, mainly as a result of increasing demand for goods. Employment of light or delivery service truck drivers is projected to grow 4 percent from 2008-2018, also tied to economic growth by the BLS. Growth may indicate increasing need for light trucking services, from the distribution of warehouse goods to the package delivery to households. [22]

As employment can be closely tied to the state of the economy, rates of occupation relevant to thermite flares may prove to be reasonably volatile. If economic growth, theoretically spurring increases in employment and/or transportation units outfitted with thermite flares, does not occur—market opportunity may be hampered. That said, the market opportunity for thermite flares may be divided into existing flare replacement (*i.e.* perchlorate-free) and nascent demand spurred by economic growth. The former may offer an alternative route to market penetration if economic growth does not come to fruition. Given the subjective and indirect nature of trucking and maritime employment, vessel-specific regulations may shed more light on market influence.

The United States Coast Guard approximates 70 million recreational boaters in the United States and over 13 million registered recreational watercrafts in the United States as of 2002. The National Marine Manufacturers Association (NMMA) estimates indicate that 541,000 boats were sold at retail in 2001, and that there are nearly 17 million boats owned across the United States. These vessels are required by law to carry visual distress signals (VDS). Specifically, recreational boats 16 feet and over used on coastal waters or the Great Lakes are required to carry a minimum of either:

1) Three day and three night pyrotechnic devices
2) One day non-pyrotechnic device (flag) and one night non-pyrotechnic device (SOS light)
3) A combination of one and two.

---

[21] U.S. Bureau of Labor Statistics. "Occupational Outlook Handbook, 2010-11 Edition." *Water Transportation Occupations*. 17 Dec 2009. U.S. Bureau of Labor, Web. Mar 2010. <http://www.bls.gov/oco/ocos247.htm>.

[22] U.S. Bureau of Labor Statistics. "Occupational Outlook Handbook, 2010-11 Edition." *Truck Transportation and Warehousing*. 17 Dec 2009. U.S. Bureau of Labor, Web. Mar 2010. < http://www.bls.gov/oco/cg/cgs021.htm>.



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Recreational boats less than 16 feet in size on coastal waters or the Great Lakes need only carry night visual distress signals when operating form sunset to sunrise. The number and type of signals for these vessels is not regulated. The United States civilian maritime-based market for thermite flares may be influenced by regulations requiring VDSs to be on board the nation‘s 13 million registered recreational watercrafts, and approximately 40,000 commercial water vessels.[23] When watercrafts are required by law to carry visual distress signals such as flares, the market opportunity may be in essence legislated into existence. However, there is the concern of nascent verses mature and potentially saturated demand.

With regard to trucking vessels, there are similar regulations regarding emergency equipment. Beyond the levels of truck transportation and warehousing employment, it can be stated that Federal Motor Carrier Safety Administration (FMCSA) requires emergency equipment on board all power units. That is, each truck, truck tractor, and bus must be equipped with warning devices for stopped vehicles including either: three bidirectional emergency reflective triangles that conform to the requirements of Federal Motor Vehicle Safety Standards, or at least six fusees, or three liquid-burning flares. With an estimated 247,421,120 (2005) commercial vehicles in the United States required to carry emergency equipment such as thermite flares, market opportunity may prove to be viable.[24] On the other hand, like the maritime market opportunity, considerations should be made for replacement cycles verses nascent demand within new roadway vessels.

### 4.1.3 Fire Starters

***Definition and Quantification***

As the pyrotechnic thermite composition may find application within fire starting embodiments, market opportunity may be revealed within corresponding usage. That is, within emergency situations, outdoor recreational usage and military initiatives. The latter will be explored within section 5, the Military Market.

With regard to emergency situations (*i.e.* emergency fire starters), the quantification of natural disasters seen in section 4.1.1 may again prove relevant. Just as the assumption was made that natural disasters connote building collapse (and the need for a thermite torch cutter), so too could the assumption be made that the occurrence of natural disasters connotes power outages and/or emergency situations necessitating emergency fire starting capacity. For example, in recent years, hurricanes have caused extensive power outages. Strong snow and ice storms in the Northeastern and Midwestern United States have caused significant power outages, and summer heat waves have strained the power grid and caused blackouts. In any given year, the United States experiences about 10,000 thunderstorms, 2,500 floods, 1,000 tornadoes and six hurricanes, according to the National Weather Service. While a power outage is no guarantee of preference for fire-starting products, it is these weather events which may potentially prompt market relevance for a thermite fire starter.

Outdoor recreational usage of thermite fire starters (*e.g.* camping, extreme environments), is somewhat difficult to quantify given the subjective nature of ―outdoor recreation.” For example, the United States Forest Service‘s National Survey on Recreation and the Environment estimates that 97% of the American population participates in outdoor recreation activities. However, this estimate includes activities which range from bird watching, to

[23] Federal Highway Administration, . "Table 3-2: Number of U.S. Vehicles, Vessels, and other Conveyances." *Freight Management and Operations*. 28 Oct 2009. U.S. Department of Transporation, Web. Mar 2010. <http://ops.fhwa.dot.gov/freight/freight_analysis/nat_freight_stats/docs/04factsfigures/table3_2.htm>.
[24] Ibid.



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bicycling, to scuba diving, to developed camping. Thus, while participation rates are high, it may be inferred that someone who is leisurely biking or bird watching will not have a desire or need for a thermite fire starter. Conversely, someone engaged in rural-based or cross-country recreation activities may be more likely to require or need a thermite fire starter. Further complicating market quantification based on outdoor recreation participation is the consumer trait of preparedness and/or risk aversion. That is, someone who is in fact a leisure-based recreationist may carry such safety equipment as fire starters for use in emergency situations. Given the subjective nature of defining the market of outdoor recreation, this assessment will focus on those activities which most immediately indicate thermite fire starter usage in non-emergency situations.

The 2000 National Survey on Recreation and the Environment (NSRE) was published by the United States Forest Service and involved the collaboration of many agencies including the: National Oceanic and Atmospheric Administration (NOAA), Environmental Protection Association (EPA), National Park Service (NPS) and Bureau of Land Management (BLM). Between July 1999 and July 2002, 57,868 people across the United States were asked about their participation in 12 types of outdoor recreation during the 12 months prior to their interview. Given the scope of the survey's stakeholders, this assessment utilizes the survey results in attempts to quantify the potential outdoor recreation market opportunity for the thermite fire starter. Relevant survey results are relayed below.

| **Fastest Growing Activities from 1982-2002 Among All Categories** | | |
|---|---|---|
| **Activity** | **Growth (millions)** | **Number of Participants in 2002 (millions)** |
| Walking | 85.4 | 179.0 |
| Bird Watching | 50.0 | 71.2 |
| Hiking | 48.4 | 73.1 |
| Swimming (River, Lake, or Ocean) | 36.4 | 92.9 |
| Sightseeing | 32.7 | 114.0 |
| Picnicking | 31.8 | 116.6 |
| Bicycling | 27.4 | 83.9 |
| Developed Camping | 22.8 | 52.8 |
| Motor Boating | 17.8 | 51.4 |
| Off-Road Driving | 17.3 | 36.7 |



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| National Participation Trends from 1994-95 and 2000-02 | | | |
|---|---|---|---|
| **Resource Base Activity** | **1994-95 Participation (millions)** | **2000-02 Participation (millions)** | **Percentage Change 1994-2002** |
| **LAND RESOURCE BASED ACTIVITIES** | | | |
| Bird Watching | 54.1 | 69.0 | 27.5 |
| Hiking | 47.8 | 70.9 | 48.3 |
| Backpacking | 15.2 | 22.8 | 50.0 |
| Primitive Area Camping | 28.0 | 34.1 | 21.8 |
| Off-Road Driving | 27.9 | 37.3 | 33.7 |
| Walking | 133.7 | 176.9 | 32.3 |
| Sightseeing | 113.4 | 110.4 | -2.6 |
| Developed Area Camping | 41.5 | 56.3 | 35.7 |
| Picnicking | 98.3 | 116.1 | 18.1 |
| Bicycling | 57.4 | 84.2 | 46.7 |
| Horseback Riding | 14.3 | 20.7 | 44.8 |
| Hunting | 18.6 | 24.1 | 29.6 |
| | | | |
| **WATER RESOURCE BASED ACTIVITIES** | | | |
| Motorboating | 47.0 | 51.9 | 10.4 |
| Swimming (River, Lake, or Ocean) | 78.1 | 89.1 | 14.1 |
| Water Skiing | 17.9 | 17.3 | -3.4 |
| Fishing | 57.8 | 72.7 | 25.8 |
| Sailing | 9.6 | 10.9 | 13.4 |
| | | *Average* | *26.2* |

Overall, nearly all surveyed activities experienced an increase in participation from 1995-2002. The average percentage increase in participation from 1994-1995 to 2000-2002 over all recreation activities was 26.2%. The substantial increase in the United States population may account for some of the growth in these activities. The highest percentage change occurred for backpacking (50%), followed by hiking (48.3%). In examining only land-resource-based activity, those with a more direct connotation of fire starting, the percent of people participating in activities such as bird watching, hiking, backpacking, off-road driving, walking, developed camping, bicycling, horseback riding, and hunting increased significantly from 1995-2002.

The land-resource-based survey results can be further examined to focus on those activities which may more immediately imply thermite fire starter usage in non-emergency situations. Of the 84.2 million bicycle participants in 2002, 20.9% occurred on back-country roads, trails, or cross country, riding a mountain bike or hybrid bike. 10.8%, or 22.4 million, of the 70.9 million backpackers in 2002 did so on back-country trails or cross-country. 56.3 million people camped at developed sites (includes staying overnight near roads in developed campgrounds), while 33.9 million people camped at primitive sites (lacking most amenities of



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developed campgrounds). For primitive camping, one must carry water and provide all camping facilities. In addition to the 33.9 million primitive area campers, 68.8 million were surveyed to have visited a wilderness or other primitive, road-less area overnight.

Ultimately, the quantification of the outdoor recreation market for thermite fire starters remains subjective in nature. While definitive market opportunity cannot be articulated based on the data examined here, it may be that those with higher rates of participation in outdoor recreation—particularly those of a challenging nature or in a remote location—have increased need for thermite fire starters. The above quantification may provide for general market indicators regarding the outdoor recreation market. If participation levels are accepted to be indicative of market opportunity, that for the pyrotechnic thermite composition‘s embodiment within fire starters may be positive with participation rates of potential end-users increasing.

***Market Drivers and Influence***

As the market for fire starters is here defined within the bounds of domestic (United States) emergency situations and outdoor recreation, market drivers and influences may include (1) the occurrence of emergencies or disasters in which there are power outages (assuming fire to be an alternate source of heat and light), and (2) those factors influencing participation in outdoor recreation activities.

The quantified occurrence of natural disasters may again be relevant with the altered assumption of power outages as a result of the disaster or emergency, and the usage of fire starters to ignite alternate sources of heat and light. Market drivers and influences may then include the previously recognized causes of emergencies and/or natural disasters: deforestation, global warming and general changes to the geography and environment of the earth‘s natural composition and population density.

With regard to participation in outdoor recreation activities, geography and income may be two sources of influence for the corresponding thermite fire starter market. That is, in order to participate in outdoor recreation activities and potentially hold an amplified value for thermite fire starters; prospective purchasers will need to live in an area where such activities can occur and be able to afford (1) the thermite fire starting product and (2) participation in recreation. The following map gives a general indication of potential demand for land-based activities based on rates of participation.[25] The darker the shade of brown, the more concentrated and/or large is the rate of participation in outdoor recreation. As the map is recreated from a third-party source, specific quantification is not provided and the image should only be interpreted as a general overview of geographic influence on recreation activities.

[25] Colorado State Parks. "Participation & Trends in Outdoor Recreation." *SCORP*. 2003. Colorado State Parks, Web. Mar 2010. <http://parks.state.co.us/NR/rdonlyres/708A5060-7883-4C2E-9BB6-92E9D9DE8B7A/0/SCORPCh2.pdf>.



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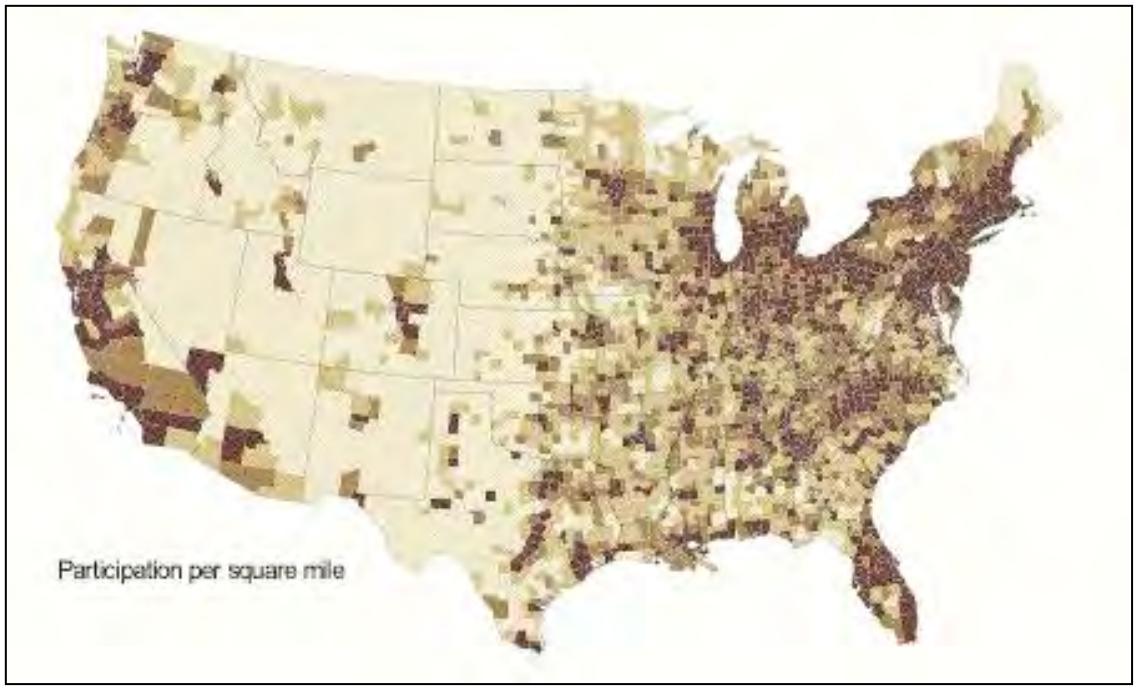


Alongside accessibility, income is dually noted as a potential influence on participation in outdoor recreation. Participants must be able to afford the related equipment, including fire starters, as well as time away from employment. As these activities are in fact ―recreation," it may be assumed that the majority of participation takes place outside of (or in place of) professional employment. This may be supported by the fact that activities which are the most simplistic, inexpensive, and can be undertaken without specialized equipment (hiking, walking and bicycling) have been some of the fastest growing within the NSRE surveys. Ultimately, there are a variety of societal, cultural and economic factors which may also be considered in influence over outdoor recreation participation. However, this assessment acknowledges the two primary forces of *accessibility* and *income* to be potential drivers of outdoor recreation participation. It is this participation which may prompt market opportunity for the thermite fire starter.

### 4.1.3 Explosive Ordnance Disposal

***Definition and Quantification***

Within the civilian first responder use, the pyrotechnic thermite composition may be applied within explosive ordnance disposal (EOD). As an alternative to detonation, the thermite composition can facilitate the destruction of explosive ordnances by burning or igniting the devices. In most cases, the thermite reaction is focused on an explosive ordnance to burn through the device's protective casing. Upon penetration of the casings, explosives or other energetic materials can be ignited, forcing internal combustion. By initiating rapid combustion of the munitions filling and/or trigger components, explosive ordnances may detonate in a much lower grade explosion or simply be incinerated. The risk of collateral damage to infrastructure and people, hazardous conditions and fragmentation can be decreased.

EOD can be undertaken to mitigate both active threats and in the demilitarization of ―historical" threats (*e.g.* remnant explosive devices and munitions within historical combat zones). The latter may be more relevant to



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military end-users, however, there are approximately 1,500 sites covering 15 million acres (the size of Florida) where unexploded ordnances (UXO) have been disposed and require cleanup in the United States. To give an idea of the scale of the effort, in France, 900 tons/year are recovered by government _démineurs' in the Verdun forest alone. According to the EPA, UXO at 16,000 domestic inactive military ranges within the U.S. pose imminent and substantial public health risk and could require the largest environmental cleanup ever, at a cost of at least $14 billion.

Within the bounds of the civilian first responder market—EOD may be enacted by civilian EOD personnel in non-military contexts; namely, by bomb specialists of police and law enforcement agencies and of transportation security organizations. Non-military contexts connote the domestic market of explosive threats within the United States as opposed to EOD applications and/or markets within foreign countries.

Thus far, this assessment has employed labor statistics of the thermite composition's various end users as one method of quantifying corresponding market opportunity. However, statistics regarding the number of EOD personnel in general, and specifically within law enforcement and transportation security, are not readily available. Likewise, figures regarding the frequency of explosive threats are limited in their public dissemination. With that said, federal budgets relevant to EOD have progressively increased since 2001. While federal budgets are not an ideal mechanism of EOD market quantification, increasing relevant budgets may be indicative of a viable EOD market need, as well as potential increases in purchasing power for EOD personnel.

In their report, *2006-2015 Homeland Security and Homeland Defense Global Market*, the Homeland Security Research Corporation (HSRC) claims that the homeland defense market will triple by 2015. HSRC asserts that the market for homeland security and homeland defense products will triple from $130 billion to $400 billion in comparison of the 2001-2005 period and the 2006-2010 period. More specifically, it will grow from $26 billion in 2003 to $178 billion in 2015.

The Department of Homeland Security (DHS) undertakes the mission of securing the United States against all threats through five main action areas:

- Guarding Against Terrorism
- Securing Our Borders
- Smart and Tough Enforcement of Immigration Laws
- Preparing for, Responding to, and Recovering from Natural Disaster
- Unifying and Maturing DHS

The most recent budgetary information is that of the 2010 fiscal year (FY10) budget request. In general, the total FY 2010 budget request for the Department of Homeland Security was $55.1 billion in funding; a 4.9 percent increase over the FY 2009 enacted level excluding supplemental funding. The Department's FY 2010 gross discretionary budget request was $45.7 billion, an increase of 5.9 percent over the FY 2009 enacted level excluding emergency funding. The Department's FY 2010 net discretionary budget request is $42.7 billion.[26]

[26] DHS, "2010 DHS." *U.S. Department of Homeland Security Budget-in-Brief 2010*. Web. Jan 2010. <http://www.dhs.gov/xlibrary/assets/budget_bib_fy2010.pdf>.



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Of the five action areas identified above, *Guarding Against Terrorism (GAT),* reveals direct potential market relevance for pyrotechnic thermite composition‘s EOD application. GAT action is defined by the DHS to be:

*“Protecting the American people from terrorist threats is the founding purpose of the Department and DHS’ highest priority. This Budget expands DHS efforts to battle terrorism, including detecting explosives in public spaces and transportation networks, helping protect critical infrastructure and cyber networks from attack, detecting agents of biological warfare, and building information-sharing partnerships with state and local law enforcement that can enable law enforcement to mitigate threats.”*

GAT action and corresponding budget requests see $9 million for an additional 109 Bomb Appraisal Officers (BAOs) to provide expertise in the recognition of and response to improvised explosive devices at airports. This request is said to provide BAO coverage at 50% more airports and to provide a BAO in every hub-spoke airport system, and to airports that currently have only one BAO assigned.

Similarly, $4.2 million was requested by DHS to enhance improved, coordinated national bombing prevention and improvised explosive device security efforts. This funding is said to provide resources to enhance national awareness and threat mitigation capacities for multiple jurisdictions. A total of $120.8 million, an increase of $24.7 million, was requested to support explosives mitigation research. This request will support DHS‘ Science and Technology Directorate (S&T) in addressing critical capability gaps in detecting, interdicting, and lessening the impacts of non-nuclear explosives used in terrorist attacks against mass transit, civil aviation, and critical infrastructure. Of the $24.7 million, $10.0 million will develop high-throughput cargo screening technology through automated, more efficient equipment. The remaining $14.7 million will build on FY 2009 efforts to counter the threat of improvised explosive devices to mass transit systems by detecting and mitigating all types of explosive threats such as homemade and commercial explosives.

The Department of Homeland Security‘s budget may be interpreted to be representative of the civilian EOD market opportunity. Accepting this representation and the budgetary indication of market priorities, the domestic market for explosive ordnance disposal, and mechanisms such as the pyrotechnic thermite composition embodied within incendiary devices, appear to be on the increase.

***Market Drivers and Influence***

The influences on, and drivers behind, the market for explosive ordnance disposal are broad and complex. Market factors can range from those which enable explosive ordnance creation (*i.e.* material availability, affordability, relevant knowledge), to those which motivate their deployment (*i.e.* religious conviction, political motivations). Without considerable analysis, it can be stated simply that in order for the EOD market to function, there must in fact be explosive ordnances created and deployed. Acknowledging this fact, primary market influences may include:

- International and domestic climate
- Shifts in administration and/or policy
- Budgetary controls
- Technological advancement
- Preventative measures



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The international and domestic climates refer to the ―why" of explosive ordnance deployment. As political climates become more tumultuous, so too may the motivations for, and rates of, violent behavior such as explosive ordnance use increase. Shifts in administration and/or policy relate primarily to the budgetary market quantification adopted by this assessment. Budgets, in addition to political climates, can frequently be set in accordance with administrative and/or policy preferences. In light of current conflict and the widespread use of improvised explosive devices (IEDs), administration and corresponding policy appear to be focused on the ―battle against IEDs." Likewise, fears have lately increased that IED usage will in fact see a migration to the United States and other Westernized nations—potentially playing a role in increasing DHS prioritization of EOD. Shifts in administration and policy then connote potential adjustments to budgetary controls. While budgetary quantification revealed potentially favorable market implications for the thermite EOD tool, budgets can change with priorities and certain end-users (*i.e*. law enforcement and first responders) may have limited purchasing power.

Technological advancement notes the evolutionary nature of explosive ordnances themselves, as well as disposal technologies and methodologies. That is, the EOD market is understood to be driven by the existence of explosive ordnances which are advancing in technological construction. Likewise, as explosive ordnances have evolved, mitigation techniques have followed suit. Some may argue that explosive ordnances adapt to the mitigation technologies, but in any case, the evolutionary relationship is noted as a potential market driver. As evolution continues, market growth may be spurred by next generation technologies on both sides of the battle.



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## 4.2 Military Market

Of the five identified applications, *flares, fire starters*, and *explosive ordnance disposal* may hold relevance within the military market. Definitions and quantifications are articulated for each, and market drivers and influences are explored. Of particular interest within the military market is that of explosive ordnance disposal, as it may prove to be one of the larger market opportunities. Analysis within the civilian first responder market focused on potential domestic points of penetration (United States markets), but the military market is examined regardless of locale.

The military market is first defined to include the five branches of the United States military: Air Force, Army, Coast Guard, Marine Corps and Navy. The tables below relay the United States Bureau of Labor Statistics 2009 estimates of current enlistment.[27] It is these enlisted and officer personnel who constitute the military market and may serve as potential end-users of thermite flares, fire starters, and explosive ordnance disposal embodiments.

| Military Enlisted Personnel by Broad Occupational Category & Branch of Military Service, January 2009 | | | | | | |
|---|---|---|---|---|---|---|
| **Occupational Group - Enlisted** | **Army** | **Air Force** | **Coast Guard** | **Marine Corps** | **Navy** | **Total, all services** |
| Administrative occupations | 6,727 | 17,537 | 1,621 | 9,219 | 22,147 | 57,251 |
| Combat specialty occupations | 132,079 | 480 | 904 | 52,445 | 7,595 | 193,503 |
| Construction occupations | 20,872 | 4,689 | — | 6,759 | 5,521 | 37,841 |
| Electronic and electrical repair occupations | 37,466 | 34,751 | 4,663 | 16,199 | 47,985 | 141,064 |
| Engineering, science, and technical occupations | 42,770 | 41,328 | 1,212 | 26,940 | 38,778 | 151,028 |
| Healthcare occupations | 30,945 | 16,420 | 772 | — | 23,960 | 72,097 |
| Human resource development occupations | 20,251 | 11,321 | 1 | 7,134 | 5,300 | 44,007 |
| Machine operator and precision work occupations | 6,372 | 6,181 | 1,816 | 2,575 | 8,596 | 25,540 |
| Media and public affairs occupations | 8,233 | 6,910 | 152 | 2,518 | 3,659 | 21,472 |
| Protective service occupations | 29,076 | 34,099 | 2,816 | 7,156 | 12,555 | 85,702 |
| Support services occupations | 13,554 | 6,071 | 1,263 | 2,765 | 9,188 | 32,841 |
| Transportation and material handling occupations | 69,454 | 31,396 | 11,748 | 25,909 | 45,176 | 183,683 |
| Vehicle machinery mechanic occupations | 54,771 | 43,409 | 6,119 | 22,068 | 45,209 | 171,576 |
| Non-occupation coded personnel | 1,081 | 6,681 | 326 | 12 | 755 | 8,855 |
| **Total, by service** | **473,651** | **261,273** | **33,413** | **181,699** | **276,424** | **1,226,460** |

[27] United States Bureau of Labor Statistics. "Occupational Outlook Handbook, 2010-11 Edition ." *Job Opportunities in the Armed Forces*. 17 Dec 2009. United States Department of Labor, Web. Mar 2010. <http://www.bls.gov/oco/ocos249.htm>.



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| Military Officer Personnel by Broad Occupational Category & Branch of Military Service, January 2009 | | | | | | |
|---|---|---|---|---|---|---|
| **Occupational Group - Officer** | **Army** | **Air Force** | **Coast Guard** | **Marine Corps** | **Navy** | **Total, all services** |
| Combat specialty occupations | 20,201 | 2,611 | 77 | 5,315 | 1,125 | 29,329 |
| Engineering, science, and technical occupations | 21,676 | 17,800 | 210 | 4,006 | 7,616 | 51,308 |
| Executive, administrative, and managerial occupations | 13,104 | 7,327 | 197 | 2,725 | 5,442 | 28,795 |
| Healthcare occupations | 10,626 | 8,661 | 1 | — | 7,468 | 26,756 |
| Human resource development occupations | 2,676 | 2,293 | 151 | 279 | 520 | 5,919 |
| Media and public affairs occupations | 310 | 305 | 15 | 175 | 290 | 1,095 |
| Protective service occupations | 2,867 | 1,131 | 60 | 353 | 284 | 4,695 |
| Support services occupations | 1,741 | 758 | 3 | 38 | 857 | 3,397 |
| Transportation occupations | 12,519 | 22,828 | 580 | 7,345 | 27,340 | 70,612 |
| Non-occupation coded personnel | 2,597 | 866 | 6,769 | 88 | 386 | 10,706 |
| **Total, by service** | **88,317** | **64,580** | **8,063** | **20,324** | **51,328** | **232,612** |

Within the above tabulations, the total military market (as defined via BLS estimates of officer and enlisted personnel) is that of 1,459,072 members. Of course, some of these occupations are more likely (*i.e.* combat specialty occupations) to employ thermite flares, fire starters, and enact EOD than others (*i.e.* human resources); but, this assessment will adopt the general quantification of enlisted personnel to initially quantify the military market. Ideally, further end-user specification and more accurate quantification will ensue as application-specific markets are explored. It is worth noting that much of the analysis referred to as ―civilian first responder" will remain relevant within military markets. The primary differences will be that of altered application and of non-civilian end-users (*i.e.* active members of the military).

### 4.2.1 Flares

***Definition and Quantification***

The pyrotechnic thermite composition may find application in flares which are used as sources of light, target markers, decoys and signals of distress by military end-users. Ground military forces in need of large-area illumination for artilleries or for an attack can employ parachute flares. Likewise, ground forces may also deploy hand-held flares for aerial or ground signaling to indicate the correct area for releasing ordnances, deploying paratroopers, or landing an aircraft. Military end-users may also employ flares as signals of distress. One specialized mission of flares is that of defensive countermeasures against heat-seeking missiles. These flares are usually discharged by the pilot or automatically by tail-warning devices. Since they are intended to deceive infrared missiles, these flares usually produce a great deal of heat, but relatively little light.[28]

[28] All Experts Encyclopedia. "Flare (pyrotechnic)." *Flare (pyrotechnic): Encyclopedia BETA*. All Experts, Web. Mar 2010. <http://citationmachine.net/index2.php?start=&reqstyleid=1&mode=form&reqsrcid=MLAWebDocument&more=&nameCnt=1#>.



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Ultimately, many of the thermite flare's civilian applications remain pertinent to the military market, initially quantified as 1,459,072 officer and enlisted personnel. Whether or not the pyrotechnic thermite composition at hand is suitable for all of the military-specific applications outlined here will need to be determined as development and manufacture ensues.

With regard to further quantification, many of the applications are assumed to be enacted by "ground" forces, which equates to 1,454,515 potential end-users. This is the number of active duty personnel as of February 28, 2009.[29] While this figure should not be interpreted as direct market size (*i.e.* one flare per service member), the military market appears reasonable in size based on these figures. Another method of market quantification is via examination of the number of military vessels—air, ground and sea—which may employ thermite flares or carry them on board. General estimates of vessels held by the Air Force, Army, Coast Guard and Navy are tabulated below.

| Service Branch | Number of Vessels (Year) |
|---|---|
| Air Force | (2009)<br>• Aircraft: 5,603 |
| Army | (2009)<br>• Aircraft: 3,915<br>• Watercraft: 300<br>• Ground Vehicles: 200,000+ |
| Coast Guard | (2009)<br>• Aircraft: 211<br>• Watercrafts: ≈ 2,000 |
| Navy | (2010)<br>• Deployable Battle Force Ships: 285<br>• Operational Aircraft: 3,700+ |
| Total | ≈ 216,014 |

While this assessment cannot claim that each of these vessels will carry thermite flares, or will replace existing flares with those containing the pyrotechnic thermite composition at hand, these general quantifications may be indicative of market opportunity. As the United States Coast Guard requires recreational watercrafts to carry visual distress signals (*i.e.* flares), it may be assumed that military vessels will encounter similar requirements. Moreover, as these vessels are exposed to increasingly dangerous situations, their need for flares may increase.

### *Market Drivers and Influences*

Military forces are reluctant to publicly disclose much information regarding flares and flare usage for fear of betraying decoy and combat strategies.[30] This reluctance may indicate that active military engagement potentially holds influence over the military market for flares. That is, active initiatives may imply increased market need. If this is the case, the initial quantification of 1,459,072 officers and enlisted personnel remains relevant. More specifically, there are approximately 132,000 troops currently deployed within the Afghanistan

[29] Department of Defense. *Active Duty Military Personnel by Rank/Grade*. 28 Fed 2009. Department of Defense, Web. Mar 2010. <http://siadapp.dmdc.osd.mil/personnel/MILITARY/rg0902.pdf>.

[30] Patton, Phil. "Military Flares are Behind Some UFO Sightings." *Popular Mechanics* March 2009. Web. Mar 2010. <http://siadapp.dmdc.osd.mil/personnel/MILITARY/rg0902.pdf>.



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and Iraq conflict zones.[31] Beyond publicly recognized combat initiatives, there are an estimated 194,895 deployed in foreign countries. Missions range from peacekeeping, to security to military training. The map below provides a breakdown of some the major deployments of US military personnel totaling 326,895 in 2007.[32]

Combat activity may be a potential source of market influence for the military flare market as it could imply increased rates of usage. Although this assessment will not fully delve into the drivers behind combat activity, the deployment of 326,895 troops may represent a large pool of existing end-users. Likewise, as the United States administration recently approved the deployment of an additional 30,000 troops, the market driver of combat activity may remain relevant for the flare market. Considerations should, however, be made for the volatile nature of markets reliant on wartime initiatives and/or the greater political climate.

Another market influence may be the number of, and/or the requirement for, night operations. That is, military activity which is performed in very low light environments or at night. These missions and operations may be more likely to require flares, such as those which employ the pyrotechnic thermite composition. The number of military operations, let alone the time of day or night they are carried out, is not publicly disseminated. However, the market driver of night-time operations may be further explored to reveal market opportunity.

[31] Global Security. "Iraq-US Ground Forces End Stength." *US Ground Forces End Strength*. 30 June 2009. GlobalSecurity.org, Web. 8 Mar 2010. <http://www.globalsecurity.org/military/ops/iraq_orbat_es.html>.

[32] CNN. "CNN.com." *Major U.S. Troop Deployments*. 09 Jan 2007. CNN, Web. Mar 2010. <http://www.cnn.com/interactive/maps/world/fullpage.troop.deployments/world.index.html>.



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### 4.2.2 Fire Starters

***Definition and Quantification***

The definition of the military market for fire starters does not stray significantly from that established within the category of civilian first responder. Rather than usage by civilian first-responders or civilian end-users, the military market sees the stipulation of military end-users within military contexts. As previously noted, the thermite fire starters may remain applicable to military efforts as a source of ignition for fires in the traditional connotation, but also in the adaption of the composition to explosive devices. That is, the thermite composition at hand can meet the basic objective of starting a fire, but could be adapted to provide an increasingly effective explosive. As this latter adaption has limited relevance and/or benefit to the first responder, it is not explored by this assessment. It may be worthy for future licensees, however, to further explore this application and potential market opportunity.

Unfortunately, beyond the loose market definition of military personnel employing thermite fire starters for ignition purposes, market definition and quantification are limited. Attempts to further quantify the market inevitably lead back to enlistment and deployment statistics such as those seen above. These general figures appear favorable and military and government markets tend to traditionally be apt in terms of their size, purchasing power, and the potential for resulting economics of scale. Noting these characteristics, the figure of 326,895 deployed military troops can be adopted as an indicator of potential market size. The thermite fires starting may in fact have a more direct one-to-one relationship with deployed troops as the capsules are usually small and could be carried by each enlistee.

***Market Drivers and Influences***

The predominant market driver of combat activity remains pertinent to the military market for thermite fire starters. While the military market will exist without conflict engagement, combat activity is assumed to amplify the need for soldier equipment and related materials such as the thermite fire starter. In addition, deployment locale may play a role in developing market need. That is, certain locations may be more likely to necessitate the starting of fire; for example, in environments of extreme cold or in settings without electricity.

### 4.2.1 Explosive Ordnance Disposal

***Definition and Quantification***

As within the civilian first responder market, the pyrotechnic thermite composition may find military application within explosive ordnance disposal (EOD). The EOD application remains the same in that, as an alternative to detonation, the thermite composition can facilitate the destruction of explosive ordnances by burning or igniting the devices. In most cases, the thermite reaction is focused on an explosive ordnance to burn through the device‘s protective casing. Upon penetration of the casings, explosives or other energetic materials can be ignited, forcing internal combustion. By initiating rapid combustion of the munitions filling and/or trigger components, explosive ordnances may detonate in a much lower grade explosion or simply be incinerated. The risk of collateral damage to infrastructure and people, hazardous conditions and fragmentation can be decreased.



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With regard to market quantification, EOD may prove to be one of the largest within the military. Specifically, the battle against improvised explosive devices (IEDs) within current military combat may be indicative of a significant market need. Moreover, disposal and neutralization techniques are highly sought after as IEDs are one of the top ranking causes of death within current combat initiatives. As a result of potentially significant market need, and the thermite composition‘s relevant prospective application, this assessment will define the military market for EOD within current military conflicts in foreign locales. This is differentiated from the circumvention of domestic explosive ordnance threats, designated by this assessment to be within the civilian first responder market. Within the following discussion, ―explosive ordnance” and ―IEDs” are used interchangeably as the differentiation does not alter the thermite composition‘s EOD application.

Although threat data is tightly controlled by the Department of Defense (DoD) to avoid revealing feedback about the effectiveness or ineffectiveness of different explosive designs, the threat and toll of IEDs is widely recognized. IED neutralization has steadily risen to the top of military priorities as rates of IED usage and efficacy have also increased. While the IED was not initially a threat to US forces in current conflict, the IED threat has become credible, prevalent, and lethal. Take for example the following figures—quantification which may be indicative of a viable market need for EOD technologies.

Within Afghanistan and Iraq, IEDs have taken the lives of more than 2,000 US troops since 2001.[33] In 2009, US military deaths in Afghanistan doubled compared with a year ago; a tally by the Associated Press shows 304 American service members had died as of December 30, up from 151 in 2008. An astounding 129 of these US fatalities, or more than 40 percent, were caused by IEDs. Similarly, there were more than 7,000 IED incidents in 2009 (including explosions, the discovery and defusing of the bombs or civilians turning over IEDs) compared to a mere 81 in 2003. Estimates place more than three-quarters of American deaths and injuries in Afghanistan as a result of IEDs. The devices may also wreak havoc on the civilian population either deliberately or inadvertently. In the last four months of 2009, 117 Afghan civilians were killed by the devices.

Based on the data above, it may be difficult to debate that the threat embodied within explosive ordnances, especially improvised devices, is bona fide. In an effort to further quantify the market need for EOD technologies such as thermite based incendiary devices, this assessment examines relevant federal budgets. While budgetary quantification is not ideal, relevant budgets may be indicative of significant market need, an ongoing battle, and potential increases in military purchasing power.

According to the Congressional Research Service of the Library of Congress, for FY2006 (the Title IX Bridge Fund and FY06 Supplement) the funding enacted for the Joint IED Defeat Fund was $3.3 billion. For FY2007 (Title IX Bridge Fund and FY2007 Supplement), the amount was $4.3 billion. The FY2008 budget request from the Department of Defense (Baseline DoD and FY2008 Global War on Terror Budget Request) was $4.5 billion and resulted in programs such as Attack the Network ($926,000), Defeat the Device ($2.7 million), and Train the Force ($334,000). The total funding thus far is $12.1 billion.[34]

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[33] Dreazen, Yochi. "The Bomb Squad." *WSJ.com*. 07 Feb 2007. Wall Street Journal, Web. Jan 2010. <http://online.wsj.com/article/SB123397062617659323.html>.

[34] See CRS Report RL33110, *The Cost of Iraq, Afghanistan, and Other Global War on Terror Operations Since 9/11*, and CRS Report RL33999, *Defense: FY2008 Authorizations and Appropriations*.



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With the death toll rising and IEDs ranking at the top of military and federal priorities, the counter IED application and/or the domestic and foreign military and government markets appear to be large and expanding. Although these markets may be subject to such volatile influences as conflict engagement and federal budgets, the thermite composition may be able to exploit the existing battle against IEDs for successful initial commercialization. Moreover, the technology may be able to save lives and may offer prospective advantages over existing thermite-based EOD technologies.

With regard to direct end-user quantification, the number of EOD technicians and/or EOD technologies which exist or are currently deployed in military efforts is unavailable. However, it can be stated that each branch of the US military has some form of specialized EOD capacity including the: Air Force, Army, Coast Guard, Marines and Navy. It is also worth noting that within current efforts, US forces are training foreign militaries in explosive ordnance neutralization and disposal. Said training may serve to expand the number of foreign governments and militaries with EOD units, task forces and technicians to serve as potential end users of the composition embodied with incendiary devices.

***Market Drivers and Influences***

As previously established, primary influences on, and drivers behind, the market for explosive ordnance disposal may include:

- International and domestic climate
- Shifts in administration and/or policy
- Budgetary controls
- Technological advancement

These influences are explored in section 4.1.3 and remain relevant to the military market. One large driver specific to the military market of EOD is that of combat activity. The existence and length of warfare initiatives may play a role in the pyrotechnic thermite composition‘s long term commercial viability, as embodied within EOD modalities. In light of the 2009 decision to deploy an additional 30,000 troops to Afghanistan, the driver of combat activity may be sustained.[35]

In addition to the above outlined market drivers and sources of influence; it is worth noting the market factors which may enable explosive ordnance creation and deployment. That is, a significant source of market influence not yet directly addressed can be found within explosive ordnances themselves. With especial regard to improvised explosive devices, the surrounding factors of creation, deployment and circumvention hold potential influence for the pyrotechnic thermite composition‘s EOD application. Ultimately, in order for EOD markets to exist, explosive ordnances must be created and deployed.

International and domestic climates (i.e. turmoil) essentially explain the ―why," the ―when," and the ―where" of the explosive ordnance disposal markets. However, the ―how" can introduce additional market influences. External to the composition‘s direct technological functionality, the following factors may affect the market for explosive ordnance disposal:

[35] DeYoung, Karen. "Afghan Conflict Will Be Reviewed." *Washington Post* 13 Jan 2009. Web. Mar 2010. <http://www.washingtonpost.com/wp-dyn/content/article/2009/01/12/AR2009011203492.html>.



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- Material availability
- Knowledge availability
- Social context
- Circumvention

Foremost, materials for explosive ordnance creation need to be **available**. In light of the rampant use of IEDs in current military conflict, the widespread availability of related materials has amplified the market need for, and market relevance of, such incendiary devices which can employ the pyrotechnic thermite composition. This is in seemingly stark contrast to the United States, for example, as availability of such materials is much more limited, legally controlled and subsequently, IED and explosive ordnance occurrences are much more limited. Decreases in the deployment of explosive ordnances may negatively influence the size and viability of the explosive ordnance disposal market.

If materials are physically available, they need to then also be ―**affordably**" available. Increased physical availability may indicate increased affordability, especially within improvised explosive devices. For example, current IEDs see the easy acquisition and use of pre-existing components such as garage door openers and cell phones. If materials are widespread in their accessibility, costs and required expenses in order to acquire them can decrease, and the likelihood of their creation and deployment may increase. Available and affordable materials may increase the scope and viability of the explosive ordnance disposal market.

When components are available and affordable, one of the missing factors is that of **knowledge**. In most contexts, knowledge of explosive ordnance creation is limited; the key word being *context*. In current conflict, IED creation is a much more common trade than in the context of Westernized nations and in non-conflict environments. The knowledge to create explosive ordnances inherently exists, but the amount of said knowledge can be either amplified or limited by the existence of information sharing networks, and the ability and willingness to share said information. For example, congressional reports indicate that Taliban forces in Afghanistan appear to have learned some IED techniques from Iraqi insurgents.[36] Similarly, insurgents have been able to build and deploy IEDs by using networks that, for centuries in Afghanistan and Iraq, have formed the sinews of commerce and survival for tribes and factions.[37] Iraq has also seen small, highly skilled IED cells hiring themselves out to other insurgent groups. The knowledge of how to combine physically available, affordable materials needs to exist. The willingness and ability to share this information may then have a positive correlation with rates of explosive ordnance usage and thus, the need for explosive ordnance disposal.

Also touching on the contextual nature of the explosive ordnance neutralization market, **social factors** can play an important role. If the use of explosive ordnances or improvised explosive ordnances is ―socially acceptable," the market for neutralization may increase. An example is articulated by Captain Joseph Garaux in the January 2010 Marine Corps Gazette. Garaux writes, ―Should a US citizen witness an IED being emplaced near his home he would call the police without fear of reprisal, or he would stop the IED perpetrator knowing the community would support such a decision." Effectively, social factors may be heavily related to political climate, but here it is noted that social tolerance of explosive ordnances within these climates may increase the rate of IED

[36] Gen Montgomery Meigs, *On the Offensive: The Battle Against IEDs,* Marine Times, April 16, 2007, http://www.harmonieweb.org:40793/news/Pages/OnTheOffensive.aspx.
[37] Bergen, Peter, ―The Taliban, Regrouped and Rearmed," *The Washington Post*, September 10, 2006.



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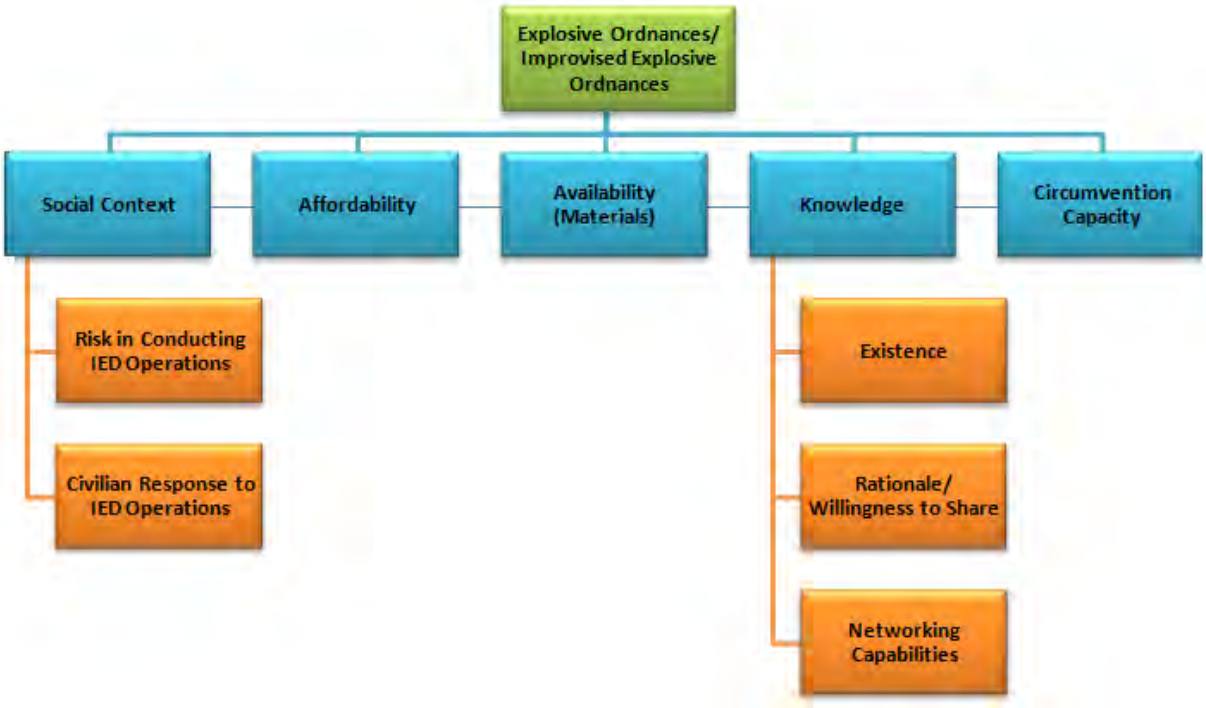
implementation. If insurgents are no longer willing to risk smuggling, manufacturing or emplacing IEDs, then IEDs may decrease in deployment or even be eliminated. If civilian populations no longer allow insurgents to conduct IED operations, then IEDs may no longer exist. If IEDs do not exist, or rates of usage decrease, so does the need to dispose of them.

Lastly, **circumvention** may influence the market of ordnance disposal. Simply put, circumvention of EOD technologies may decrease market size and market relevance for a disposal technology, such as an incendiary device employing the pyrotechnic thermite composition.

Ultimately, explosive ordnances must be created and deployed for EOD markets to exist. Influencing factors of *improvised* explosive devices may include, but are not limited to:

- Materials availability
- Affordability
- Knowledge
- Social context
- Circumvention

These five factors are interrelated to reveal somewhat of a hierarchical relationship:



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## 4.3 General Construction / Welding

***Definition and Quantification***

Within the general construction/welding markets, the pyrotechnic thermite composition may essentially find application in any case that cutting and/or welding is involved. The thermite composition may be embodied within a torch to enable perforation or fusion. The concentration of the thermite reaction can be used to cut through metal or to weld metal components together (by melting a thin film where two or more components meet).

As established, thermite torch cutters employing the composition at hand are claimed to be able to cut through structural components like steel beams in a manner of seconds. Similar to its application within disaster clean-up, this pyrotechnic composition's potentially enhanced material perforation may offer the advantage of increased efficacy and efficiency within construction applications. With regard to welding, thermite torches can be advantageous in that related activities can take place without removing or deconstructing structures. For example, locomotive axle-frames in need of repair can be mended without removing the part from its installed location. Likewise, thermite torches can be used for quickly cutting or welding without the need for complex or heavy equipment.

Ultimately, the general construction market is defined within the bounds of the United States to include both public and private construction efforts. In order to provide a general characterization of market opportunity, the assumption is made that thermite torches may in fact be used in all construction efforts.

According to Cogitamus Consulting, total annual construction spending in the United States grew at an average annual pace of seven percent from 1997 to 2006, rising from $656.2 billion in 1997 to $1.19 trillion in 2006. After modest growth of one percent in 2002, the industry was revamped as it posted a 6 percent gain in 2003 and 11% in both 2004 and 2005. Growth slowed to just 5% in 2006 as the residential market cooled and growth has been continuing to slow in light of the recent economic downturn. Since the beginning of 2006, monthly construction spending showed a dramatic decline in the residential sector that outpaced a reasonably healthy increase in the non-residential sector. As a result, non-residential construction (*i.e.* more likely to involve heavy steel and the need for thermite torch cutters) accounted for 54% of total construction by July 2007, with residential capturing the remaining 46%.

The United States Department of Commerce estimates the following breakdown of seasonally adjusted annual rate of construction spending as of December 2009.[38]

[38] United States Census Bureau. "Construction Spending." *Construction Spending January 2010*. 01 March 2010. U.S. Census Bureau, Web. Mar 2010. <http://www.census.gov/const/www/c30index.html>.



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| Type of Construction | Seasonally Adjusted Annual Rate in Millions of Dollars, December 2009 |
|---|---|
| Private | 592,957 |
| Residential | 260,448 |
| Nonresidential | 332,510 |
| Public | 309,588 |
| State and Local | 279,073 |
| Federal | 30,516 |
| **Total** | **902,545** |

As a whole, the value of construction put in place decreased by an average of 1.2% from November 2009 to December 2009, and by an average of 9.9% from December 2008 to December 2009. This overall decrease in value can be broken down as follows.[39] Please note that details may not sum to totals due to rounding.

| Type of Construction | Value of Construction Put in Place, Seasonally Adjusted Annual Rate in Millions of Dollars, December 2009 | Percent Change December 2009 from: | |
|---|---|---|---|
| | | November 2009 | December 2008 |
| Private | 592,957 | -1.2 | -14.9 |
| Residential | 260,448 | -2.8 | -10.9 |
| Nonresidential | 332,510 | 0.2 | -17.7 |
| Public | 309,588 | -1.2 | 1.3 |
| State and Local | 279,073 | -1.5 | 0.7 |
| Federal | 30,516 | 2.0 | 7.8 |
| **Total** | **902,545** | **-1.2** | **-9.9** |

Previous market quantifications within this assessment have examined rates of employment for potential end-users of the thermite composition‘s various embodiments. Likewise, an examination of the status of employment of construction workers may shed further light on the construction market for the thermite torch.

With 7.2 million wage and salary jobs and 1.8 million self-employed and unpaid family workers in 2008, construction was one of the largest industries in the United States. About 64 percent of wage and salary jobs in construction were in the specialty trade contractors sector; primarily plumbing, heating, air-conditioning, electrical and masonry. Approximately 23 percent of the jobs were in residential and nonresidential with the remaining 77 percent in heavy and civil engineering construction and specialty trades. The BLS breakdown of the distribution of employment within the construction industry is seen below.[40]

[39] Ibid.

[40] United States Bureau of Labor Statistics. "Occupational Outlook Handbook, 2010-11 Edition ." *Construction*. 17 Dec 2009. United States Department of Labor, Web. Mar 2010. < http://www.bls.gov/oco/cg/cgs003.htm>.



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| Distribution of Wage & Salary Employment in Construction by Industry, 2008 (employment in thousands) | | |
|---|---|---|
| **Industry** | **Employment** | **Percent** |
| Construction of buildings | 1,659.3 | 23.0 |
| Residential building | 832.1 | 11.5 |
| Nonresidential building construction | 827.2 | 11.5 |
| | | |
| Heavy and civil engineering construction | 970.3 | 13.4 |
| Utility system construction | 451.3 | 6.3 |
| Highway, street, and bridge construction | 328.9 | 4.6 |
| Land subdivision | 80.8 | 1.1 |
| Other heavy and civil engineering construction | 109.3 | 1.5 |
| | | |
| Specialty trade contractors | 4,585.3 | 63.6 |
| Building equipment contractors | 2,023.1 | 28.0 |
| Foundation, structure, and building exterior contractors | 987.8 | 13.7 |
| Building finishing contractors | 912.8 | 12.7 |
| Other specialty trade contractors | 661.6 | 9.2 |
| | | |
| **Total Construction** | 7,214.9 | 100.0 |

Further breakdown of construction employment can be seen in Appendix B. Ultimately the BLS projects employment growth of approximately 18.5 percent from 2008-2018. This is in contrast to the Department of Commerce‘s decreased valuation of construction put into place as of December 2009.

With regard to welding specifically, the application may pervade commercial and federal manufacturing and is standard in nearly all manufacturing processes. From the soldering of PC boards, to the heavy-duty welding of steel plates for shipbuilding, to the repair of industrial boilers; industry is heavily reliant on welding for the joining of materials. For example, as articulated by the American Welding Society (AWS), the range of manufacturing industries that rely on welding include:

- Automotive
- Heavy Equipment
- Aerospace
- Electronics, Medical Products and Precision Instruments
- Electric Power
- Petrochemical

With such widespread industry implications, one might expect the welding market to be quite large. With that said, the corresponding market opportunity may also be subject to related industries‘ fluctuations. Likewise, integration within processes is not necessarily advantageous when said processes are slowed or halted entirely, resulting in a potentially decreased need for welding technologies. Ultimately, the AWS articulates a definition of the welding industry to incorporate the workforce, using welding technologies to perform welding



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operations; the welding supply industry that provides equipment, products, and consumables to the workforce; and the end-users in the national industrial sector who rely on welding to manufacture their products.

BCC Research estimates the United States and Canadian markets for welding equipment and supplies in 2007 to be $4.6 billion, rising at an annual average growth rate of 3.5%. The world market was estimated at $12.7 billion with an average annual growth rate of 5.0%. BBC notes the fact that the world market for welding equipment and supplies is growing faster than that of North America as welding is used to build increasing infrastructure in third world nations.[41] With such a potentially large scope of industry determinants and potential avenues to quantification—labor statistics again prove readily available, and relevant in accordance with the AWS industry definition.

The BLS groups together welders, cutters solderers, and brazers who in total, held about 412,300 jobs in 2008. Welding, soldering, brazing machine setters, operators and tenders held about 54,100 jobs. Approximately 65 percent of welding jobs were found in manufacturing, concentrated in fabricated metal product manufacturing, transportation equipment manufacturing, machinery manufacturing, architectural and structural metals manufacturing and construction. BLS estimates are tabulated below.[42]

| Occupation Title | SOC Code | Employment 2008 | Projected Employment 2018 | Change, 2008-2018 | |
|---|---|---|---|---|---|
| | | | | Number | Percent |
| Welding, Soldering & Brazing Workers | 51-4120 | 466,400 | 455,900 | -10,500 | -2% |
| Welders, Cutters, Solderers, & Brazers | 51-4121 | 412,300 | 405,600 | -6,700 | -2% |
| Welding, Soldering, & Brazing Machine Setters, Operators & Tenders | 51-4122 | 54,100 | 50,300 | -3,800 | -7% |
| *Average* | | *310,933* | *303,933* | *-7,000* | *-3.7%* |

The BLS predicts employment of welders, cutters, solderers and brazers to experience little or no change, declining by about 2 percent over the 2008-19 decade, while employment of welding, soldering, and brazing machine setters, operators, and tenders is expected to decline moderately by about 7 percent over the same decade. When the welding workforce is interpreted to be indicative of the welding market opportunity, projections for growth are moderate to negative. These projections may be reliant upon the recent economic downturn, decreases in general employment rates, and/or decreases in related market activity such as manufacturing and construction. With that said, employment statistics provide only a general indicator of market size. As an integral part of multiple industries, and in offering prospective improvements over existing welding technologies, the pyrotechnic thermite composition embodied within a welding apparatus may find greater market opportunity than that indicated by welding employment statistics. Likewise, foreign markets

[41] BCC Research. "Metal Welding Equipment and Supplies (AVM040A)." *Advanced Materials Metal Welding Equipment and Supplies*. Oct 2002. BCC Research, Web. Mar 2010. <http://www.bccresearch.com/report/AVM040A.html>.

[42] United States Bureau of Labor Statistics. "Occupational Outlook Handbook, 2010-11 Edition." *Welding, Soldering, and Brazing Workers*. 17 Dec 2009. United States Department of Labor, Web. Mar 2010. <http://www.bls.gov/oco/ocos226.htm>.



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with increasing rates of manufacture and infrastructure creation may reveal increased need for such welding tools.

***Market Drivers and Influences***

The construction market may be highly influenced by the greater economy. Likewise, the welding market‘s integration within multiple industries—also reliant on economic fluctuations—may reveal economic conditions to be a similar market driver.

Despite contradictory estimates from the United States Bureau of Labor Statistics (projections for increasing construction employment) and the Department of Commerce (decreasing valuation of construction put in place); population growth, deteriorating infrastructure, and aging buildings are expected to generate growth in the construction industry. However, current economic stress may delay any major growth as new construction has essentially stagnated in the face of the burst housing market bubble, and both federal and civilian budgets have become increasingly constrained. In general, the industry may become increasingly reliant on renovation activity, as opposed to new construction. The nonresidential replacement of industrial plants and upgrades of medical facilities may sponsor moderate construction activity. As the economic downturn is progressively overcome, construction of schools may need to continue as populations increase. Demand for senior housing and healthcare residences, as populations age, may also prompt construction efforts.

Similarly, bridges can serve as a visible example of the nation‘s deteriorating infrastructure and the need for reparative or renovation construction. This may prompt increases in employment and activity within heavy and civil engineering construction related to highway, bridge and street construction. Voters and legislators in most states and localities appear to be continuing to approve spending on road construction and infrastructure repair, which may prompt market opportunity over the next decade. Another area of potential market growth is in power line and related construction. Even with increased conservation and more efficient appliances, there is an increasing demand for power. Increase demand for workers may equate to increased demand for tools such as a torch employing the pyrotechnic thermite composition.

The thermite composition‘s prospective welding market opportunity may face economic hurdles similar to those found in the construction market. As manufacturing and other processes (on which welding may be reliant) slow due to economic lags, so too may welding market opportunities become limited. The Bureau of Labor Statistics predicted a decline in welding-related employment, which may be due to such downturns in related industry. Likewise, enhancements in productivity and increased automation may be reducing the need for individual welders. That said, the outlook for welders in manufacturing is described to be stronger than that for other occupations in the industry because of the importance and versatility of welding as a manufacturing process in and of itself. The pyrotechnic thermite composition embodied within welding apparatuses may not be directly influenced by the number of actual welders, depending upon its ability to be integrated within increasingly automated processes.

Ultimately, the pyrotechnic thermite composition may find application within the general construction and/or welding markets as the composition may be embodied within thermite torch cutters and welding apparatuses. Both markets appear to be heavily reliant on greater economic conditions, which could not only increase subjectivity, but may not be especially favorable in today‘s economy. With that said, construction opportunity may likely be found within renovation and repair activity (some of which will involve welding), and welding



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opportunity may be found as the application is integrated within a multitude of industries. As economic recovery comes to fruition, both markets could potentially prove increasingly viable for the pyrotechnic thermite composition.



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# 5 Competitive Landscape

Thus far, this assessment has worked to establish the pyrotechnic thermite composition‘s claimed utility, prospective advantages, potential embodiments, applications, and corresponding market opportunities. With regard to the composition‘s competition, it is the existing thermite-based torch cutters, flares, fire starters and incendiary devices which may form the primary competitive landscape within the markets of: disaster clean-up, flares and fire starters, explosive ordnance disposal, and general construction and welding. Within each application and corresponding market, however, the base of competitive advantage will likely be that of the composition itself. That is, subsequent embodiment and product differentiation may stem from the pyrotechnic thermite composition‘s prospective advantages as compared to alternative solutions and existing thermite formulations. The pyrotechnic thermite composition‘s prospective advantages are then briefly revisited below, followed by an examination of competing technologies for each potential application.

## 5.1 Competitive Advantage

The prospective advantages of the composition at hand are that of improvements made over existing thermite formulations. Creation of the pyrotechnic thermite composition in question in fact used prior art‘s disadvantages as a prompt for development. As a result, there are three main sources of potential competitive advantage claimed: enhanced material perforation, increased reaction temperatures and decreased toxicity. The pyrotechnic thermite composition‘s United States Patent 7,632,365 B1 directly discusses the disadvantages of prior art.

With regard to material perforation, the composition at hand is claimed to outperform prior art. For example, inventor interviews revealed the estimated time on target for cutting through 1” diameter rebar to be reduced to a few seconds. This is in comparison to existing compositions‘ ability to do so in a few minutes. The following excerpt from United States Patent 7,632,365 B1 describes the pyrotechnic thermite composition‘s claimed advantage of enhanced perforation capacity.

*“Over 250 different formulations were tested, including formulations from a literature review. Material perforation performance was determined based on the mass of target material removed. In some cases, very deep penetrations were made into the target, but the channels formed were very narrow resulting in little target mass being removed. The formulation described herein performed significantly better than any other formulation tested. A formulation containing 39.8 percent by weight CuO, 33 percent by weight MoO3, 24.2 percent by weight magnalium, and 3 percent by weight polytetrafluoroethylene binder had a ratio of 1.61 of mass of metal removed by the mass of the formulation used. The next best performing formulation, which is similar to that disclosed in U.S. Pat. No. 4,963,203, had a ratio of only 0.86 and a formulation similar to that disclosed in U.S. Pat. No. 6,627,013 had a ratio of only 0.60”*

The pyrotechnic thermite composition‘s second source of potential competitive advantage is that of decreased toxicity. According to the patent, a number of thermite torch formulations exist in prior art. These were developed to have enhanced characteristics related to the thermite reaction and improved use such as gas production, temperature stability, heat transfer, shelf life and material perforation. For example, patent 4963203 discloses a thermite formulation that is claimed to be stable at high and low temperatures; patent 6627013 discloses a thermite formulation with potentially increased heat transfer involving Cu2O as a heat transfer



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agent; a potential increase in shelf life is achieved by patent 4432816 with the addition of a fluorocarbon binder; and good material perforation is claimed in patent 3695951 via a thermite formulation using nickel, aluminum, ferric oxide and powdered tetrafluoroethylene. For the applications considered in this assessment, material perforation is a primary desideratum. However, the starting materials and reaction products of the thermite formulation used in patent 3695951 are toxic, and no other thermite formulation with similar material perforation properties exists in prior art. Therefore, the decreased toxicity of the starting materials and reaction products of the thermite formulation of the present patent, 7632365, may constitute a prospective advantage.

In addition to the above claims regarding decreased toxicity, the pyrotechnic thermite composition is said to be free of perchlorate. As established, many thermite-based technologies, namely flares, contain perchlorate. While it does have a variety of uses, perchlorate is primarily used in the form of ammonium perchlorate as an oxidizer in solid fuels used in explosives, fireworks, road flares and rocket motors. Perchlorate can also be present as an ingredient or impurity in lubricating oils, matches, aluminum refining, rubber manufacturing, paint and enamel manufacturing, leather tanning, paper and pulp processing, and as a dye mordant.

When disposed of, perchlorate-based products can then release perchlorate into the environment and perchlorate salts can rapidly dissolve into ground and service water. Water-absorbed perchlorate may then contaminate sources of drinking water and can adversely affect the thyroid‘s hormone production by inhibiting the uptake of iodide by the thyroid. The thyroid plays a critical role in regulating adult metabolism, hormonal balance, and the normal growth and development of the central nervous system of fetuses and infants.[43] The United States Environmental Protection Agency (EPA) estimates that perchlorate has been detected in public drinking water supplies of over 11 million people of at least 4 parts per billion (ppb).[44]

Several states have already enacted drinking water standards for perchlorate including Arizona, California, Nevada, New Mexico, New York, and Texas. For example, California‘s legislature enacted AB826, the Perchlorate Contamination Prevention Act of 2003, which required the state‘s Department of Toxic Substance Control (DTSC) to adopt regulations specifying best management practices for perchlorate and perchlorate-containing substances. These best practices were adopted on December 31, 2005 and became operative on July 1, 2007. California issued drinking water standards in 2007 and the other five states listed here have established non-enforceable, advisory levels for perchlorate.

United States courts have also taken action regarding the use of perchlorate in manufacturing pyrotechnic devices such as flares. California again serves as an example as a federal district court in the state found that the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) was applicable to perchlorate as it is ignitable, and therefore characteristic of hazardous waste.

A specific example of perchlorate-related problems is that found at the Olin Flare Facility in Morgan Hill, California. Perchlorate contamination beneath the former flare manufacturing plant was first discovered in 2000 (several years after the plant had closed). The plant used potassium perchlorate as one of the main ingredients during its 40 years of operation. By late 2003, the state of California and the Santa Clara Valley Water District

[43] Committee to Assess the Health Implications of Perchlorate Ingestion, National Research Council. "Health Implications of Perchlorate Ingestion." *Health Implications of Perchlorate Ingestion*. 2005. The National Academies Press, Web. Mar 2010. <http://www.nap.edu/catalog.php?record_id=11202#description>.

[44] Ibid.



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confirmed a groundwater plume currently extending over nine miles throughout residential and agricultural communities.

As of December 24, 2009 the EPA had not made a final regulatory determination regarding perchlorate. However, a decision will ultimately be made and, in light of states‘ preemptive action, it may likely negate the inclusion of perchlorate in applications relevant to the pyrotechnic thermite composition. Or, at a minimum, it may foster demand for perchlorate alternatives. As perchlorate is appearing on such influential regulatory radar screens as that of the EPA, and given existing actions trending towards regulation and/or exclusion requirements, the pyrotechnic thermite composition may find advantage in its lack of perchlorate. Present and future regulatory hurdles may be preemptively mitigated.

Lastly, the pyrotechnic thermite composition may find potential competitive advantage in the low cost of its starting materials.[45] Independent research estimates the cost of the composition at hand to be $12.10 per pound (section 2.3.2). While this may in fact be a higher cost than that of existing thermite formulations (some estimate the average cost to be $3.00 per pound), the advantages of enhanced material perforation and decreased toxicity may justify a higher price. The table of prospective advantages originally developed in section 3 is recreated below.

**Pyrotechnic Thermite Composition: Potential Applications**

| ***Application*** | ***Embodiment*** | ***Purpose*** | ***Relevant Advantages*** | ***Relevant Disadvantages*** |
|---|---|---|---|---|
| Disaster Clean-Up | Thermite Torch Cutter | Perforation | • Increased perforation<br>• Decreased time to target<br>• Decreased toxicity<br>• Miniaturization, UXV potential | • Hot reaction products may pose danger to victims<br>• Supply chain will be need to be established |
| Flare | Thermite Flare | Illumination | • Decreased toxicity (perchlorate-free) | • Less control over color<br>• Marginal advantage over existing solutions |
| Fire Starter | Fuse-Outfitted Thermite Canister; Explosive Device | Ignition | • Ignition independent of environmental factors<br>• Decreased toxicity | • Safety considerations |
| Explosive Ordnance Disposal | Incendiary Device | Perforation; Ignition | • EOD with decreased risk of collateral damage, hazardous conditions, and fragmentation<br>• Decreased likelihood of theft<br>• Decreased potential for weapons creation | • Potential risk is not completely eliminated<br>• Considerable design work required<br>• Precautions for handling |
| General Construction/ Welding | Thermite Torch | Perforation; Fusion | • Increased perforation<br>• Increased reaction heat for fusion<br>• Decreased toxicity<br>• Miniaturization (vs. complex/heavy equipment) | • Potential learning curve, training requirement<br>• Reaction heat may not be suitable for all applications |

[45] Note: low cost is claimed in United States patent 7,632,265 B1. Estimate of raw materials costs do reveal the potential for some cost reduction in comparison to existing thermite formulations, but product development and further development will carry varied cost structures. Beyond patent assertions, cost cannot be confirmed to be ―low” without further, product-specific due diligence.



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Within each of the five established applications, there are existing solutions—thermite and non-thermite based—which will likely serve as points of comparison in purchase decisions, serve as potential competitors, and be considered in rankings of efficacy. This assessment then moves forward to examine existing solutions within each application. Although examined here as components of the competitive landscape, it is noteworthy that companies established within relevant market space may also prove to be potential licensees.

## 5.2 Disaster Clean-Up

Similar to the complexity encountered within attempts to define and quantify the market for disaster clean-up, a specific inventory of existing technologies used in disaster clean-up is hard to come by. This is due in part to a lack of definitive market classification and the multitude of parties involved in clean-up activities. With that said, this assessment will explore the general types of equipment and technology likely to be used in disaster clean-up efforts. It is these exiting methodologies which may serve as competition for the pyrotechnic thermite composition embodied within a thermite torch cutter, and applied to disaster clean-up activities, as a means to cut through structural remnants.

General site clean-up efforts are to be distinguished from rescue initiatives. In both scenarios, the efficiency of workflow may be increased via the composition‘s enhanced material perforation capability, but for the latter, toxicity of reaction products is a consideration because victims being rescued could be harmed. Just as the distinction prompts additional safety considerations, the characterization of competitors alters between the two applications. Although both exploit the core function of perforation via concentration of the thermite reaction, there are in fact two varied purposes: (1) cutting through structural remnants to be removed for *general clean-up* and (2) cutting through structural remnants to be removed for the potential *rescue of human life*. With these varied purposes comes varied competition.

### 5.2.1 Removal of Structural Remnants: General Clean-Up

Existing solutions used in the general clean-up of structural remnants range from such heavy equipment as bulldozers, dump trucks and bobcats to such hand-held devices as chain saws, hand tools and thermite torch cutters. Heavy machinery is presumably less preferred as a method of structural remnant removal when human life is at stake. That said, assuming all trapped victims have been freed, or the period in which they are likely to be alive has expired, such methods may be pursued.

Large or heavy equipment may likely surpass the thermite torch in their ability to remove mass quantities of debris. On the other hand, the pyrotechnic thermite composition embodied within a torch cutter may prove complementary to heavy equipment when, for example, steel beams need to be cut prior to removal. The potential competitive ability of the thermite torch cutter as compared to heavy machinery may then be subjective with regard to the type and nature of disaster, as well as the amount and type of debris to be removed. Likewise, heavy equipment may in some cases be able to knock down such core structural elements as steel beams, whereas in others—technology such as a thermite torch cutter may be required. In the case of the latter, and as compared to existing thermite torch cutters, the pyrotechnic thermite composition at hand may offer enhanced material perforation and decreased toxicity.



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With regard to identifying specific product competitors, few thermite-based torches are commercially advertised for comparison. Similarly, the range of heavy equipment and hand-held devices which may be employed within general clean-up initiatives is large in scope. With that said, Caterpillar® serves an industry leader within heavy equipment.

Caterpillar® claims to be one of the world's largest makers of construction equipment—that which can be employed in the removal of post-disaster structural remnants. As an exemplary industry competitor, Caterpillar®'s product offerings alone include 300 different machines and the company is classified by Hoovers to fall within the industry bounds of *construction, mining, and other heavy equipment manufacturing*—companies which manufacture and/or distribute construction, mining, and/or other heavy machinery, including cranes, earthmovers, excavators, and other related equipment and machinery.[46] Whether or not disaster clean-up is characteristic of all firms within this industry is unknown, however, this assessment acknowledges the possibility of such engagement and notes the likelihood of industry firms' machines employment within clean-up activities. Caterpillar® itself has been directly involved in such clean-up initiatives resulting from the attacks of September 11, the recent Haiti earthquake, and the 2008 Myanmar cyclone and Sichuan earthquake. Acknowledging industry relevance, Hoovers identifies primary industry competitors to include:[47]

- AGCO
- Caterpillar
- Charles Machine Works
- CNH Global
- Hitachi Construction Machinery
- Hyundai Heavy Industries
- Komatsu
- Volvo

Further industry competition may also be revealed within Hoover's "remediation and environmental cleanup service" industry—companies that provide engineering and consulting; environmental testing and analysis; and remediation services. The latter, remediation services, is classified as North American Industry Classification System (NAICS) 562910. This industry then comprises establishments primarily engaged in one or more of the following: (1) remediation and cleanup of contaminated buildings, mine sites, soil, ground water; (2) integrated mine reclamation activities including demolition, soil remediation, waste water treatment, hazardous material removal, contouring land and re-vegetation; (3) asbestos, lead paint and other toxic material abatement.[48] Admittedly, some remediation service entities will focus more exclusively on the clean-up of substances hazardous to human health and the environment than on the removal of structural remnants; however, acknowledging the thermite torch cutter's relevance to remediation activities provides a starting point for further analysis. Moreover, remediation activity is frequently prompted by disaster. While this assessment can

[46] Hoovers. "Information." *Construction, Mining & Other Heavy Equipment Manufacturing*. 2010. Hoovers, Web. Mar 2010.
[47] Hoovers. "Caterpillar Inc.." *Caterpillar Inc.*. 2010. Hoovers, Web. Mar 2010.
[48] United States Census Bureau, . "562910: Remediation Services." *NAICS 562910: Remediation Services* . 23 Jan 2001. U.S. Census Bureau, Web. Mar 2010. <http://www.census.gov/epcd/ec97/def/562910.HTM>.



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again not guarantee that NAICS 562910 establishments participate in disaster clean-up initiatives, nor their interest in thermite torch cutters, major competitors within the remediation service industry include:[49]

- Avalon Holdings Corporation
- Environmental Quality Management
- ECC & E2 Closure Services LLC
- TRC Companies Inc.
- Versar Inc.

Ultimately, existing solutions for the removal of structural remnants for general clean-up activities may prove to be complementary or substitute to the thermite torch depending upon the nature of clean-up activities. Heavy equipment, for example, may be preferred for removing mass quantities of debris, but said removal may still require a thermite torch to cut structural components prior to their removal. An examination of existing thermite torch cutters revealed few publicly advertised products. Given the pyrotechnic thermite composition patent's direct reference of such an embodiment, these technologies are assumed to exist, but to not be discussed within public information. In any case, the composition at hand may prove superior for such applications due to its claim of enhanced perforation capability. Primary industry firms within heavy machinery and construction equipment have been identified for further analysis. Remediation service companies may also reveal market insight. Structural remnant removal may be an indirect component of remediation, but nonetheless, remediation firms and technologies may take part in disaster clean-up initiatives and thus, may construct at least a component of the competitive landscape within the disaster clean-up market.

### 5.2.2 Removal of Structural Remnants: Rescue Initiatives

As established, the assumption is made that when removal of structural remnants is undertaken in an effort to rescue trapped individuals, the preference for and/or suitability of heavy equipment may decrease. For example, when industrial excavators or loaders are used to scoop up mass quantities of debris, structural remnants are shuffled and may crush any trapped individuals. Thus, increasingly specified and delicate technologies may be employed when human life is at stake. The pyrotechnic thermite composition embodied within a torch cutter, despite some resounding issues with toxicity, may prove to be such a technology. With regard to competition, a predominant example of technologies specified to that of freeing trapped individuals are the ―Jaws of Life."

The Jaws of Life is a brand of tools, trademarked by the Hurst Jaws of Life Company, but the name is often used when talking about general rescue systems—several types of piston-rod hydraulic tools known as *cutters*, *spreaders*, and *rams*. Primarily employed within automobile and mass transit accidents, these tools can be used to also free individuals from collapsed buildings and structures in general. The majority of these tools are simple hydraulic systems based on the transmission of force from one point to another via fluid. Most of these hydraulic machines use some sort of incompressible fluid (a fluid at its maximum density). Oil is one of the most commonly used fluids in hydraulic machines, however, many the systems grouped within the ―jaws of life" use phosphate-ester fluid which is fire resistant and electrically non-conductive. For these reasons, phosphate-ester fluids tend to be favored over conventional oils at crash and accident scenes.

[49]Hoovers . "Information." *Remediation & Environmental Cleanup Services*. 2010. Hoovers, Web. Mar 2010. <http://bert.lib.indiana.edu:2220/subscribe/ind/factsheet.xhtml?HICID=1296>.



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*Cutters*, as the name suggests, are used to cut through structural remnants in a fashion similar to a pair of giant bolt cutters. *Spreaders* are used to pull pieces of a structure apart, or they can be inserted into the structure to tear sections of it out. The spreader consists of pincer-like, aluminum alloy with tips usually made of heat-treated steel to provide maximum strength. Spreaders do come in different sizes and see alterations in their specifications as to how much spreading force is possessed or how much space can be opened up. The *ram* is the most basic type of hydraulic system as hydraulic fluid is used to move a piston head inside a cylinder to extend and retract a piston rod. A ram can be used to push debris forward or away from trapped individuals as it functions to push apart sections of structural remnants. All three of these technologies may serve as substitutes for the thermite torch cutter in the removal of structural remnants within disaster clean-up applications specific to rescue initiatives.

Given these alternatives to the thermite torch cutter in the application of removing structural remnants for the potential rescue of human life, the question becomes—why would a torch cutter employing the pyrotechnic thermite composition be the preferred technology? Preference may likely stem from the disadvantages of these existing solutions including their: cost, decreased portability, and destruction of structural remnants.

As compared to the pyrotechnic thermite composition embodied within a torch cutter, Jaws of Life technologies are significantly more expensive. Although a torch cutter embodiment may vary in cost as development ensues, existing cutters, spreaders and rams can range in price from $500 to $4,000. Although this is a large range, the lower bound is may still be beyond a probable price of a thermite torch cutter employing the pyrotechnic thermite composition. The following price estimates were obtained from Hurst Jaws of Life, a division of IDEX Corporation. As one of the original and primary manufacturers of the cutters, spreaders and rams now branded as the Jaws of Life, these products may serve as exemplary or preliminary points of competitive comparison. Please note that not all products of the Hurst manufacturer are listed, the prices below are not distributor specific, and they do not include such fees as handling or shipping.

| Product | Features & Benefits | Technical Data | Cost |
|---|---|---|---|
| SP310 Spreader | • Star-grip control permits tool actuation from virtually any gripping position<br>• Dual pilot check valve sustains necessary load requirements if the flow of hydraulic fluid is interrupted<br>• Hose exits the rear tool handle and away from the work area<br>• Fast opening and closing times | • Spreading Force: up to 57,550lbs<br>• Pulling Force: up to 11,500lbs<br>• Spreading Distance: 28.3”<br>• Length: 31.1”<br>• Width: 11.8”<br>• Height: 7”<br>• Weight: 43.2” | $7,850.00 |
| SP510 Spreader | • Quick opening and closing times<br>• Star-grip control permits tool actuation from virtually any gripping position<br>• Dual pilot check valve sustains necessary load requirements if the flow of hydraulic fluid is interrupted<br>• Hose exits the rear tool handle and away from the work area | • Spreading Force: up to 57,550lbs<br>• Pulling Force: up to 13,000lbs<br>• Spreading Distance: 31.5”<br>• Length: 35.4”<br>• Width: 13.5”<br>• Height: 8.5”<br>• Weight: 55lbs | $7,950.00 |
| SP512 Spreader | • Star-grip control permits tool actuation from virtually any gripping position | • Spreading Force: up to 121,400lbs | $7,950.00 |



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| | • Dual pilot check valve sustains necessary load requirements if the flow of hydraulic fluid is interrupted<br>• Hose exits the rear tool handle and away from the work area<br>• Fast opening and closing times<br>• Spreading, peeling, and pulling without changing tips | • Pulling Force: up to 22,000lbs<br>• Spreading Distance: 24”<br>• Length: 31.1”<br>• Width: 15”<br>• Height: 8.5”<br>• Weight: 57.1lbs | |
| S510 Cutter | • Featuring up to 169,000 lbs. of cutting force, the S 510 severs 11/2" round bar stock with power to spare<br>• Curved blade geometry pulls material to the back of the blade for fast, clean severing action<br>• Fast opening and closing action for increased speed during time-critical rescues | • Cutting Force: up to 169,000lbs<br>• Cutter opening : 7.2”<br>• Length: 30.4”<br>• Width: 9.3”<br>• Height: 6.7”<br>• Weight: 42.3lbs | $5,550.00 |
| S511 Cutter | • Curved blade geometry pulls material to the back of the blade for fast, clean severing action<br>• Fast opening and closing action for increased speed during time-critical rescues | • Cutter opening : 5.9”<br>• Length: 30.51”<br>• Width: 8.99”<br>• Height: 6.49”<br>• Weight: 42.32lbs | $5,650.00 |
| S530 Cutter | • With more than 166,400 lbs of cutting force, the S 530 slices through 1 1/2 inch round bar stock with power to spare<br>• Parrot blade geometry grips material firmly for fast clean and smooth scissor-cutting action<br>• Star-grip control permits tool actuation from virtually any gripping position<br>• Dual pilot check valve sustains necessary load requirements if the flow of hydraulic fluid is interrupted<br>• Hose exits the rear tool handle and away from the work area<br>• Fast opening and closing action for increased speed during time-critical rescues | • Cutting Force: up to 166,000lbs<br>• Cutter opening : 11.1”<br>• Length: 30.5”<br>• Width: 9.5”<br>• Height: 6.7”<br>• Weight: 39.5lbs | $5,450.00 |
| S311 Cutter | • Superior cutting performance, curved blade geometry pulls material to the back of the blade for fast, clean, severing action<br>• High strength materials provide durability<br>• Star-grip control permits tool actuation from virtually any gripping position<br>• Dual pilot check valve sustains necessary load requirements if the flow of hydraulic fluid is interrupted<br>• Hose exits the rear tool handle and away from the work area<br>• Fast opening and closing action for increased speed during time-critical rescues | • Cutting Force: up to 95,000lbs<br>• Cutter opening : 6”<br>• Length: 27.7”<br>• Width: 7.9”<br>• Height: 6.4”<br>• Weight: 31lbs | $4,850.00 |
| R430 Ram | • Three stage<br>• Solid Steel telescoping piston rod provides high tensile strength and eliminates side load distortion<br>• Heat-treated steel ram claw features a highly | • Spreading Force: Piston 1- 60,000lbs, Piston 2- 29,900lbs<br>Piston 3- 8,800lbs<br>• Stroke: 32.2” | $5,250.00 |



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| | | | |
|---|---|---|---|
| | durable gripping surface to minimize slippage<br>• Star-grip control permits tool actuation from virtually any gripping position<br>• Dead man control valve reverts back to the neutral position if user's hand slips from the control<br>• Dual pilot check valve sustains necessary load requirements if the flow of hydraulic fluid is interrupted<br>• Retracts into a compact size for easy transportability and minimum storage requirements<br>• Compatible with both Hurst High Pressure ram support attachments | • Length: Closed-51.3" Open-51.3"<br>• Width: 8.3"<br>• Height: 4.4"<br>• Weight: 38.6lbs | |
| R424 Ram | • Three stage<br>• Solid Steel telescoping piston rod provides high tensile strength and eliminates side load distortion<br>• Heat-treated steel ram claw features a highly durable gripping surface to minimize slippage<br>• Star-grip control permits tool actuation from virtually any gripping position<br>• Dead man control valve reverts back to the neutral position if user's hand slips from the control<br>• Dual pilot check valve sustains necessary load requirements if the flow of hydraulic fluid is interrupted<br>• Retracts into a compact size for easy transportability and minimum storage requirements<br>• Compatible with both Hurst High Pressure ram support attachments | • Spreading Force: Piston 1- 60,000lbs, Piston 2- 29,900lbs<br>• Stroke: 34.5"<br>• Length: Closed-24.8" Open-59"<br>• Width: 4.4"<br>• Height: 8.3"<br>• Weight: 46.1lbs | $4,650.00 |
| R414 Ram | • Three stage<br>• Solid Steel telescoping piston rod provides high tensile strength and eliminates side load distortion<br>• Heat-treated steel ram claw features a highly durable gripping surface to minimize slippage<br>• Star-grip control permits tool actuation from virtually any gripping position<br>• Dead man control valve reverts back to the neutral position if user's hand slips from the control<br>• Dual pilot check valve sustains necessary load requirements if the flow of hydraulic fluid is interrupted<br>• Retracts into a compact size for easy transportability and minimum storage requirements<br>• Compatible with both Hurst High Pressure ram support attachments | • Spreading Force: up to 27,600 lbs<br>• Stroke: 27.6"<br>• Length: Closed-35.4" Open-63"<br>• Width: 3.4"<br>• Height: 6.9"<br>• Weight: 51lbs | $3,050.00 |

**Price subject to change with alterations in features, specifications, size of purchase etc.*



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In addition to cost comparison, in which the composition may be more cost effective (based on the figures above), spreading force, pulling force, and cutting force are likely points of evaluation—cutting connoting the most immediate comparison. Whether or not the pyrotechnic thermite composition can match the Jaws of Life capacity will need to be evaluated. However, similar to the relationship with heavy equipment, the composition embodied within a torch cutter may prove complementary to existing Jaws of Life rescue devices. That is, the use of one may not negate the use of the other and in some cases; the use of one may foster use of the other. Ultimately, the above technologies have the potential to affect the composition‘s permeation of the disaster clean-up market specific to rescue initiatives. However, these devices serve only as initial points of comparison and there are additional advantages of the composition to be recognized including portability and decreased destruction.

Portability may be an advantage of a torch cutter employing the pyrotechnic thermite composition. While some Jaws of Life systems have internal power systems, most still rely on an external engine. In the traditional cutter and spreader, for example, a portable engine pumps pressurized hydraulic fluid into piston cylinders through one of two hose ports (a typical machine uses about 1 quart of hydraulic fluid). Fluid is pumped to the hydraulic pump within the machine‘s housing. A typical power unit is a 5 horsepower gasoline engine. In relation to the thermite torch cutter, the Jaws of Life systems may then themselves be heavier, bulkier, and here we see—may require an external power source. Thus, portability and the elimination of external power requirements may prove advantageous to thermite torch cutters employing the composition at hand.

In addition to internalized power systems, portability may also enhance the ability of rescue personnel to take the traditionally light weight and hand-held torches into increasingly remote disaster locales. Where Jaws of Life technologies cannot be employed due to space and/or weight requirements, the thermite torch cutter may serve to bridge capability gaps. Further, the composition at hand is claimed to offer the potential for unmanned autonomous vehicles (UXVs) to be outfitted with the thermite torch cutter—enabling access to smaller or more dangerous disaster locales not suited to rescue personnel access.

A thermite torch cutter may also prove to be less destructive than Jaws of Life alternatives. That is, cutters, spreaders and rams tend to completely demolish the structures to which they are applied as they cut, pull, and push structural remnants. While the term ―remnants” does not connote a structure which is desired to be preserved, this may not always be the case. The thermite torch cutter may then allow more of the remaining structure to be preserved for restoration or even perhaps for evidence preservation.

The consideration of entrapped victim safety has been noted within the composition‘s potential torch cutter embodiment rescue applications. As established, this consideration is that of the toxicity of the composition‘s reaction products potentially harming trapped individuals. When compared to existing thermite formulations, the composition at hand is said to have decreased toxicity but, how does the consideration for entrapped victim safety affect competition exemplified by the Jaws of Life? Immediately, toxicity seems to be of decreased concern for the Jaws of Life systems, although some do still employ oil as their hydraulic fluid which can prove hazardous depending on the environment to which the system is deployed. Primary hazards are then those which result from application of the Jaws of Life; for example: exploding air bags, fragmentation of windows and structural components, and fuel and battery combustion. As of late, concerns of electrical dangers have also surfaced with specific regard to hybrid vehicles. These automobiles can have up to 500 volts running through wires in the vehicles (as opposed to 12 in traditional cars).



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The time to victim release is another competitive factor for the pyrotechnic thermite composition embodied within a torch cutter. Time to release via Jaws of Life deployment is estimated by the majority of news reports and/or testimonials to span 7-15 minutes. This time may be decreased by the pyrotechnic thermite composition as it is said to cut through such structural remnants as steel pillars in a matter of seconds, but further evaluation is needed. For now, it is noted that the comparative variables of victim safety, nature of disaster, and time to release are all considerations to be made as the composition‘s embodiment within a thermite torch cutter may be developed for application in disaster clean-up, specific to rescue initiatives.

Ultimately, the pyrotechnic thermite composition embodied with a torch cutter may find application within disaster-clean up. The thermite reaction may be concentrated to enable perforation of structural remnants for removal in both general clean-up efforts and rescue initiatives. In either case, the efficacy and efficiency of workflow may be increased via the composition‘s enhanced material perforation. Existing thermite torch cutters may provide a direct source of competition, but few of these products are publicly advertised. Within general clean-up activities, the thermite torch cutter may face competition from heavy machinery employed to remove large quantities of debris. The thermite torch cutter may prove complementary to these removal efforts, but may also be surpassed by heavy equipment. Within rescue initiatives and the removal of structural remnants to free trapped individuals, the thermite torch cutter may primarily face competition from technologies such as the examined Jaws of Life systems. The thermite torch cutter‘s competitive ability may likely be dependent on such variables as the nature of disaster, the type of debris to be removed, and the proximity to entrapped individuals. Two predominant barriers to entry may be a reluctance to adopt new technology, and the need to establish new supply chains.

## 5.3 Flares

Another application and potential market for the pyrotechnic thermite composition is flares. The majority of flare manufacturers and distributors do not disclose the components of their flare materials and it is unclear to what extent thermite flares exist, or what share of the flare market they may control. The assumption can, however, be made that the majority of existing flares contain some type of metal and oxidizer composition. Roland Fornoff of the Business Environmental Program of the Nevada Small Business Development Center explains, ―The majority of flares on the market have similar compositions containing strontium nitrate, which is responsible for red coloring of the flame, oxidizers such as potassium perchlorate or potassium nitrate, which are added to provide the energy needed for combustion, and the remaining flare ingredients are either fuels, or a compound which serves as a combination fuel and binder.”[50]

With the purpose of illumination for target marking, distress signaling and the general provision of light—degree of illumination may be a primary point of evaluation for flare end-users. With this in mind, the pyrotechnic thermite composition‘s prospective advantages may not offer direct sources of product differentiation. Namely, enhanced material perforation and increased heat of reaction products may not be directly relevant to flare design. Likewise, the prospective advantages may not outweigh the cost of the composition within the flare market. That is, this assessment has articulated the price estimate of $12.10 per pound of the pyrotechnic thermite composition. While this price tag may be justified when the composition‘s

[50] Fornoff, Roland J. "The Business Assistance Network." 14 Aug 2007. Nevada Small Business Development Center, Business Environmental Program, Web. Mar 2010. <http://www.turboflareusa.com/pdf/incendiaryFlares.pdf>.



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prospective advantages serve as purchase incentives (*i.e.* they are directly relevant to the application at hand), relevance of said advantages may decrease within the flare market and thus, potentially decrease the composition‘s ability to command higher prices. Some estimates place the cost of an average flare at a mere $0.50 to $1.00, a significant decrease from the estimated $12.10 per pound of the pyrotechnic thermite composition.

Enhanced material perforation and increased heat of reaction products are less relevant to the flare market. However, decreased toxicity—the elimination of perchlorate—is an advantage that may potentially foster market penetration. As discussed in section 5.1, perchlorate is primarily used as an oxidizer in fuels of explosive, fireworks, rocket motors, and flares. When disposed of, these perchlorate-containing flares then contaminate ground, surface, and drinking water as perchlorate is rapidly dissolved and absorbed. The consumption of perchlorate can adversely affect the thyroid‘s ability to uptake iodine—a gland crucial in maintaining hormonal balance and fostering normal growth and development of the central nervous system of fetuses and infants. [51]

Such regulatory bodies as the United States Environmental Protection Agency (EPA) have taken note of the problematic nature of perchlorate-based products, and some states have issued formal legislation regarding best management practices. Many other states have enacted advisory levels for perchlorate-containing substances and the EPA is expected to make a final regulatory decision within the next one to two years.[52] Given some states‘ proactive action regarding perchlorate substances, this decision may likely be in favor of perchlorate lessening, elimination, and/or substitution. If this is the case, the ability of the pyrotechnic thermite composition to preempt federal regulatory hurdles may prove advantageous with regard to flare market penetration and could offer a base of product differentiation.

With regard to substitute products, advances in non-combustion based flares may prove a source of plentiful competition. Emerging technologies utilizing chemical and electric lighting systems are focusing on environmental awareness, user safety, and extended life cycles. Many potential alternatives to the thermite flare do not produce heat, potentially reduce fire hazards, are reusable, and may be more cost efficient over a several year life-cycle. In a 2008 report entitled *Evaluation of Chemical and Electric Flares*, sponsored by the Department of Justice (DOJ), primary non-combustion flare alternatives were examined. These alternatives may be potential substitutes for a flare employing the pyrotechnic thermite composition. Interpreted as examples of potential competitors, the products examined within the DOJ report include:

- Orion® Road Flares
- Power Flare®
- Cyalume® Lightsticks
- TurboFlare™
- Tektite® ELZ™
- Galls® 36” Reflective Traffic Cones
- Traffic Safety Store 28” Collapsible Cones

[51] Committee to Assess the Health Implications of Perchlorate Ingestion, National Research Council. "Health Implications of Perchlorate Ingestion." *Health Implications of Perchlorate Ingestion*. 2005. The National Academies Press, Web. Mar 2010. <http://www.nap.edu/catalog.php?record_id=11202#description>.

[52] Ibid.



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- ProFlare™
- Flare Alert™ Beacon Pro
- PDK Technologies Inc, LiteFlare®

Descriptions for each of the above products are provided below with price estimates, and photos can be seen in Appendix D. It is important to note that the majority of these products are primarily employed within road-side safety applications. Thus, they may prove substitute for the thermite flare within such applications, but not necessarily within all of the identified flare end-user purposes.

| Product / Company | Description | Price Estimate* |
|---|---|---|
| Orion® Road Flares | Orion road flares range from 5 to 30 minutes of burn time and are ignited by a friction strike cap located on the tip (similar to a match). Stabilized by a bendable wire stand incorporated to the end opposite to the strike cap. Measure 11.5" long and 0.75" in diameter. | $2.00 - $4.00 per flare |
| Power Flare® | Advertised as waterproof, these are puck-shaped light devices with a 360 degree arrangement of L.E.D's around the circumference powered by CR123 lithium batteries. The unit is housed in a polymer outer shell with an attached lanyard loop. Measures 1.25" high and 4.25" in diameter. Available in rechargeable pack that will hold 6 units at a time and can be connected to car cigarette lighter. An advertised run time of 100 hours per charge or single battery. | $50.00 per flare |
| Cyalume® Light Sticks | Chemical luminescent tubes illuminated by the mixing of two chemical ingredients separated by a breakable vial. To activate, tube is bent to the point where the inner vial containing Hydrogen Peroxide is cracked, introducing it to the outer chemicals which are a mixture of dye and Cyalume. Unit is shook until the contents are mixed and full illumination is reached. No heat is generated. Measure 6" long and weigh approximately 1 ounce. Advertised run time of 30 minutes for standard intensity and 5 minutes for high intensity lightsticks. Waterproof, disposable, individually wrapped and come in variety of lengths and colors. | $1.99 per light stick |
| TurboFlare™ | A puck-shaped, 360 degree L.E.D battery operated light device. Unit's housing is made from DuPont Surlyn and uses 4 AA batteries allowing the TurboFlare™ to run an advertised 3 hours. Measures 2"in height and 8.125" in diameter. Single rotating light pattern, available in 6 colors. | $100 per flare |
| Tektite® ELZ™ | A battery operated xenon strobe system that runs on 2 C-cell alkaline batteries. Light is spring mounted vertically with a weighted base and retro-reflective strip around the middle of the unit. Asserted to be water proof with an advertised run time of 30 hours. Measures 9.5" long and 6" in diameter. | $60.00 per strobe |



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| | | |
|---|---|---|
| Galls® 36" Reflective Traffic Cones | 36 inch tall bright orange cones with two retro-reflective collars and weighted bases. Constructed from PVC and sold in a box of 8. Cone is standard type deployed by most law enforcement agencies for traffic control and construction site demarcation. | $259.99 per box of 8, averaging $32.50 per cone |
| Traffic Safety Store 28" Collapsible Cones | 28" tall, bright orange in color and have two retro-reflective collars. Bases have rubber feet and an internally battery-operated light which operates for an advertised 30 hour runtime. Small switch on base which cycles between two modes of function: steady or flashing. Each set distributed with 4 cones and carrying bag. | $139.95 per set |
| ProFlare™ | Disk shaped, battery operated light with three settings: rotary, steady on, and flashing. Measures 3.5" in diameter and thickness of less than 1" without accessories. Standard unit is distributed with a variety of mounting options including: belt clip, magnet, 45 or 90 degree stand, Velcro armband, suction cups and holes for hardware mounting. Require 4 AAA batteries and has an advertised run time of 100 hours. | $30.00 per flare |
| Flare Alert™ Beacon Pro | Advertised as waterproof, a light with hard plastic housing and red lens. A diameter of 3.75" and 1.75" thick. The kit is sold as 8 electronic flares, 8 metal stake mounting plates with removable weighted metal base and carrying bag. Unit can operate in either flashing or steady pattern. Requires 4 AA batteries with advertised run time of 30 hours. | $20.92 per flare |
| PDK Technologies Inc, LiteFlare® | A palm-sized L.E.D. low profile flare system housed in a hard polymer shell. Similar in design, size and shape as a standard road reflector. Measures 4.25" long, 3.78" wide and 1" thick. Powered by 2 AA batteries with an advertised runtime exceeding 400 hours. Advertised to be resistant to snow, water and fuel-spills. | $14.99 per flare |

**Price subject to change with alterations in features, specifications, size of purchase etc.*

The overwhelming majority of the above products employ off-the-shelf disposable batteries as a power source. The yearly cost of operation is then largely determined by the cost of these batteries, runtime, and the number of battery replacements over that period of time. The Power Flare® was one of the only rechargeable technologies available to negate the purchase of replacement batteries. Take for example the last examined product of LiteFlare® which had one of the longest advertised runtimes. According to PDK Technologies, Inc. the product will operate for a minimum of 400 hours without replacing the batteries. The company approximates the usage of 800 incendiary flares to obtain an equivalent runtime. The company then goes on to provide the following cost breakdown to demonstrate their product's cost effectiveness.[53]

[53] PDK Technologies. "Lite Flare." *Cost Analysis*. PDK Technologies, Web. Mar 2010. <http://www.liteflare.com/cost.htm>.



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## Single Device Comparison

| | Life of Device in Minutes | Life of Device in Hours | Initial Cost | Renewal Cost | Rate of Renewal | Cost Per Minute |
|---|---|---|---|---|---|---|
| LITE FLARE | 24,000 min. | 400-600 hours | $9.99-$14.99 | .80 cents (batteries) | 17-25 days | 0.0004 cents* 0.00003** |
| Incendiary Flare | 30 min. | 1/2 hour | $1.93 | $1.93 | every 1/2 hr. | 0.0640 cents |

*Represents the per minute cost of an "initial" LiteFlare. (Governmnet purchase price)
**Represents the per minute cost of a "renewal" LiteFlare.

| | INCENDIARY FLARES | | | VS LITE FLARE | | |
|---|---|---|---|---|---|---|
| Typical Cost Comparison | Incendiary Flare | Monthly Cost | Yearly Cost | LITE FLARE | Monthly Cost | Yearly Cost |
| 25—1 hr. Traffic Scenes (10 flare points) | 500 Flares | $965/mo. | $11,580 | 10 LiteFlares | $10.41 | $124.87 |
| 4 Fatal Accidents (6 hrs. 25 flare points) | 300 Flares | $579/mo. | $2,316 | 25 LiteFlares | $20.81 | $249.75 |
| One Incendiary Flare= 30 minutes<br>One LiteFlare= 400 hours or 700 30/min. incendiary flares. | | TOTAL | $13,896 reoccuring | | TOTAL | $374 one time only |

## Hourly Consumption Costs

| | INCENDIARY FLARES | | VS LITE FLARE | | |
|---|---|---|---|---|---|
| Number of Hours | Initial Cost | Renewal Cost | Initial Cost | Renewal Cost (2 AA batteries) Battery Costs | Discretionary Funds made available by switching to LiteFlare |
| 300 | $1,158 | $1,158 | $14.99 | $ .80 | $2,300.21 |
| 500 | $1,930 | $1,930 | $29.98 | $1.60 | $3,828.42 |
| 1000 | $3,860 | $3,860 | $44.97 | $2.40 | $7,672.63 |
| 2000 | $7,720 | $7,720 | $74.95 | $4.00 | $15,361.05 |
| 3000 | $19,300 | $19,300 | $194.87 | $10.40 | $38,394.73 |

Although the above cost analysis is likely biased due to its proprietor source, this is likely an exemplary argument to be faced by licensees of the pyrotechnic thermite composition who wish to enter the flare market. That is, the competitive landscape within the flare market may consist of directly competing combustion flares, incendiary devices, and an increasing amount of chemical and electric alternatives. Beyond illumination, durability, cost effectiveness, and ease of deployment may also affect end-user purchase decisions. Further, market entrants should maintain awareness of the possibility for the pyrotechnic thermite composition‘s lack of perchlorate to be matched by such similar perchlorate-free methods of illumination as the electricity-based products examined here. There may, however, be opportunity for mitigation as the light provided by a thermite flare could be greater than that of substitutes. Likewise, thermite flares may be used in complement to the existing and/or alternative flare technologies, and for applications which specifically require a flare—the composition‘s lack of perchlorate may provide initial differentiation.



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With regard to non-product based competition, the majority of flare manufacturers are classified with North American Industry Classification System 325998—miscellaneaous chemical product and preparation manufacturing. These establishments are primarily engaged in the manufacturing of chemical products (except basic chemicals, resins, synthetic rubber; cellulosic and noncellulosic fiber and filaments; pesticides, fertilizers, and other agricultural chemicals; pharmaceuticals and medicines; paints, coatings and adhesives; soap, cleaning compounds, and toilet preparations; printing inks; explosives; custom compounding of purchased resins; and photographic films, papers, plates, and chemicals).[54] Pyrotechnics, including flares, are included within this classification. While companies within this classification range from crayon and pencil manufacturers to those with pharmaceutical products, NAICS 325998 establishments may serve as a base for future competitive analysis.

## 5.4 Fire Starters

The pyrotechnic thermite composition may find application in fire starting embodiments which, within this assessment, reveals the potential market opportunities of emergency use, outdoor recreational usage, and military initiatives. Within each of these markets, the end objective is that of ignition. There are a multitude of substitute products and methodologies for fire ignition, but the pyrotechnic thermite composition may likely find differentiation and competitive advantage in its ―fail-proof" nature. For example, DBC Pyrotechnics offers the commercial Portable Thermite Fire Starter which is advertised to ignite in ―even three feet of snow or pouring rain."[55] Further, this product, which is assumed to employ existing thermite formulations, is advertised to burn at 4,500 degrees. The composition at hand may then offer even higher reaction temperatures and an amplified guarantee of ignition. The composition's lack of perchlorate may again prove advantageous as existing thermite fire starters are likely to contain the pollutant.

With regard to the fire starter market's competitive landscape, there are a variety of potential substitute technologies and alternative ignition methodologies. In the table below, this assessment examines the primary examples of: thermite fire starters, survival matches, fuel-based lighters, DBC Pyrotechnics' Portable Thermite Fire Starter, lenses, fire bows, and flint fire starters. When possible, price estimates for specific or exemplary commercial products are provided and photos can be seen in Appendix E.

| Product/Method | Description | Price Estimate* |
|---|---|---|
| Portable Thermite Fire Starter (DBC Pyrotechnics[56]) | 2" tall and 1.5" wide, container is in the shape of a Kodak film canister with a snap-on lid. Each canister contains 3 ounces of cast thermite. To ignite, (preferable lay out combustible material such as wood) pull out the fuse and ignite. Advertised to burn at 4,500 degrees for 20 seconds producing 2 ounces of white hot molten iron that remains hot for several minutes. | $8.95 per DBC canister |
| Survival Matches (PROFORCE[57]) | Hand-dipped and varnished, PROFORCE survival matches are advertised to be "NATO issued." The matches are said to burn in wind or rain, provide dependable fire starting | $4.99 per PROFORCE bulk tube |

[54] United States Census Bureau. "2007 NAICS Definition." *NAICS-Search Results*. 18 April 2009. U.S. Census Bureau, Web. Mar 2010. <http://www.census.gov/cgi-bin/sssd/naics/naicsrch?code=325998&search=2007>.
[55] DBC Pyrotechnics. "Thermite Fire Starter 1-9 units."*DBC Pyrotechnics, LLC*. 2010. DBC Pyrotechnics, Web. Mar 2010. <http://www.dbcpyrotechnics.com/servlet/the-948/Thermite-Fire-Starter/Detail>.
[56] Ibid.
[57] ProForce. "ProForce Product." *SURVIVAL MATCHES BULK TUBES*. 2005. ProForce Equipment, Web. Mar 2010. <http://www.proforceequipment.com/detalle.php?id=92>.



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| | | |
|---|---|---|
| | capabilities, and burn for an average of 12 seconds. Bulk tubes contain 25 matches and weigh 0.05 lbs. | |
| Fuel-Based Lighters (Cabela's All Weather Lighter[58]- description provided, BIC) | Wind-proof ignition features a Piezo-electronic ignition system with a unique coil design that relights itself. A rubber O-ring gasket keeps the lighter waterproof when closed. The fuel window allows an instant check of the butane level, and refilling takes only seconds. When the lighter is on, a built-in indicator glows to show that the flameless burner is operating, and an adjustment ring allows changes to accommodate different altitudes and temperatures. Measures 1-3/4" x 2-1/8" x 5/8". | $50.00 per Cabela's lighter, $1.25 per BIC lighter |
| Lenses (Fresnel Lenses[59]) | Lenses concentrate the sun's rays into a single point to generate enough heat to cause ignition. Lenses serve to alter the path of parallel sun rays to cause them to converge at a common spot. By converging the rays' to focus on combustible material, heat can be compounded to the point of ignition and lenses can serve as a fire starter. | $3.00 per Fresnel Lense |
| Fire Bow (PrimitiveFire[60]) | Generally consists of a spindle that sits on a fireboard, held in place at the top with a hand-hold. Spindle is spun rapidly back and forth by means of a bow. The bow is a curved piece of wood with a piece of cordage attached at each end. PrimitiveFire Bow Fire Start Kit is a commercialized fire bow kit which contains 1 bow, 2 spindles, 1 fire board, 1 palm rock and 1 leather coal catcher. | $29.99 per Bow Drill Fire Starter Kit |
| Spark-Lite[61] | A commercially available fire starter manufactured by AMK, Spark-Lite is advertised as the official military fire starter. The thumb is rolled over a knurled thumbwheel to generate a flood of sparks directed into a pulled-apart and "fluffed" Tinder-Quick Fire Tab, which easily catches fire. Usually sold in kits which include 1 Spark-Lite Firestarter, 8 Tinder-Quick Fire Tabs, and 1 Water-Resistant Plastic Case. The Spark-Lite Firestarter weighs 0.19 oz and measures 0.25 x 0.25 x 2.25". The tinder-Quick Fire Tab weighs 0.024 oz. Kits' advertised lifetime is 2,000 spark cycles and burn time of the Tinder-Quick Fire Tab is 2-3 minutes. | $11.00 per Spark-Lite Fire Starting Kit |
| Flint & Steel Fire Starter (ProForce[62]) | Flint stick with plastic handle measure 1 1/4", steel stick measure 2 3/4". Advertised to generate a 3000 degree spark in rain or snow. General usage descriptions entail striking the steel across the flint stick to create sparks and ignition. Weighs 0.13lbs. | $14.00 per PROFORCE flint and steel kit |

**Price subject to change with alterations in features, specifications, size of purchase etc.*

[58] Cabela's Inc . "Cabela's Alaskan Outfitter All-Weather Lighter." 2010. Cabela's Inc., Web. Mar 2010.

[59] Elpel, Thomas J. "Fresnel Lenses Emergency Fire Starters for Wilderness Survival Kits." *Fresnel Lenses*. 2009. Greenuniversity.net, Web. Mar 2010. <http://www.grannysstore.com/Wilderness_Survival/Fresnel_Lens _Fire_Starter.htm>.

[60] PrimitiveFire. "Primitive Fire- How to Make a Fire Without Matches, Bow Drill Fire, Flint and Steel Fire, Fire." *Bow Drill Fire Starter Kit*. 2005. PrimitiveFire.com, Web. Mar 2010. <http://www.primitivefire.com/bow-drill-fire-starter-kit-p-5.html?tsSid=7a31c446a4f28b1d734e5edbd45ce0d9>.

[61] "Spark-Lite Firestarting Kit @ Backpacking Light." *Spark-Lite Firestarting Kit*. 2009. BEARTOOTH MOUNTAIN PRESS LLC, Web. Mar 2010. <http://www.backpackinglight.com/cgi-bin/backpackinglight/spark_lite_fire_starter_basic.html>.

[62] ProForce. "ProForce Army Fire Flint and Steel Fire Lighting Device." *ProForce Army Fire Flint and Steel Fire Lighting Device*. U.S. Cavalry, Web. Mar 2010. <http://www.uscav.com/productinfo.aspx?productID=10715&TabID>.



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Each of the above outlined competitors holds the end objective of ignition. The pyrotechnic thermite composition can achieve this objective and in some cases, may offer an increased guarantee of fire starting regardless of environmental conditions. For example, lenses must employ dry materials and the sun must be available as a source of heat. The composition‘s potentially increased ignition guarantee and independence from environmental conditions may hold particular weight for emergency preparedness in which conditions cannot be predicted, and in comparison to such prior art as fuel-based lighters. That is, fuels can leak, lighters can be rendered ineffective at certain altitudes or in certain temperatures, and can require drying time when dampened. Likewise, beyond safety considerations, the thermite based fire starter should require little training. This may be advantageous in comparison to such methodologies as fire bows and lenses.

As the composition at hand is perchlorate-free, this may allow for further differentiation from existing thermite-based fire starters. The estimated cost of $12.10 per pound of the preferred pyrotechnic thermite composition falls within the range of prices of the above competitors—$3.00 to $50.00. Moreover, the claimed guarantees of efficacy, decreased reliance on environmental variables, and decreased training requirements could support the composition‘s pricing ability as embodied within a thermite fire starter.

Established components of this competitive analysis have examined relevant categorizations of the North American Industry Classification System to reveal existing industry and market competitors. With regard to fire starters, the majority of manufacturers of existing fires starters and fire starting kits are classified within the primary NAICS 339920—sporting and athletic goods manufacturing. Companies which fall within this categorization may act as components of the competitive landscape to which a thermite fire starter may face. With that said, the pyrotechnic thermite composition embodied within a fire starter may in fact face an altered source of competition as thermite prompts varied classifications of pyrotechnics and/or chemical manufacturers. While the pyrotechnic thermite composition‘s prospective advantages may foster some mitigation of substitute products, the potentially widespread scope of competitive firms should be recognized.

## 5.5 Explosive Ordnance Disposal

With regard to explosive ordnance disposal, existing disposal methods, systems, and technologies make up the market to which an incendiary device employing the pyrotechnic thermite composition may enter. In general, disposal techniques are frequently designated as either ―passive” or ―active.” *Passive* techniques denote *reactive* or *protective* measures. *Active* techniques refer to *proactive* action taken to disable or neutralize the explosive ordnance, or to control its detonation. As the composition, embodied within incendiary devices, may be grouped amongst *active* techniques, focus is placed on examining similarly classified methodologies. While disposal and neutralization methods may vary depending upon the type of explosive device, there are approximately eleven dominant methodologies. Each method is listed below and is then briefly explored.

It is important to note that although predominant techniques can be asserted, the specifics of render safe procedures and the rates of their usage are generally protected from public dissemination. This protection may be in order to limit access and knowledge, depriving enemy parties of specific technical procedures used to neutralize or dispose of explosive ordnances. Subsequently, efforts to perform direct competitive analysis of existing methodologies are indirect. A summary chart is provided below in which thermite-based incendiary devices are included within the active methodology of ―controlled detonation.”



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| Predominant Explosive Ordnance Disposal Methodologies | |
|---|---|
| **Active** | **Passive** |
| Mechanical Impact | Protected Vehicles |
| Controlled Detonation* | Protective Armor |
| Robotic Devices | |
| Infrared Jamming | Bomb Blankets |
| Electronic Jamming | Bomb Trolley, Bomb Basket, Bomb Sled |
| Electromagnetic Forced Detonation | |
| Percussion Activated Neutralizer (PAN) | |
| Laser Neutralization Systems | |

**Includes thermite-based EOD*

### 5.5.1 Passive Disposal Techniques

As established, passive mitigation techniques denote reactive or protective measures. Predominant examples include protected vehicles, protective armor, bomb blankets, and bomb trolleys, baskets and sleds. These methodologies are passive in the sense that they do not interfere with the detonation of the explosive ordnance, but rather attempt to protect potential victims and surrounding infrastructure. As passive methodologies, the following technologies and tactics will likely serve as indirect competitors and/or complements to the ―active" thermite-based incendiary devices.

***Protected Vehicles***

In general, protected vehicles are automobiles outfitted for combat operations and specifically, to withstand the attack of explosive ordnances. For example, ―mine resistant ambush protected" trucks (MRAPs) are heavily armored trucks which have most recently been deployed in hopes of reducing the US death toll from roadside bombings in Iraq. Joint Light Tactical Vehicles (JLTVs) are also being increasingly deployed to replace existing High Mobility Multi-Purpose Wheeled Vehicles (Humvees). The JLTVs are designed specifically as scout and armored vehicles, whereas humvees were not.

While new generations of protected vehicles may in fact be able to *actively* detect, neutralize and/or dispose of explosive ordnances, they are currently *passive* in the sense that they only protect enclosed individuals and the vehicle itself against resulting detonation.

| ***Claimed Advantages*** | ***Claimed Disadvantages*** |
|---|---|
| Decreased rates of casualty for enclosed entities. | Explosive ordnance is detonated. |
| Protection of enclosed capital. | Hazardous conditions of fire, shrapnel and other projectiles. |
| Increased lifespan of vehicle itself. | Collateral damage to infrastructure and people. |
| | Release and spread of potential contaminants within the ordnance upon detonation. |
| | Potential forensic evidence destroyed upon detonation. |



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***Protective Armor***

Protective armor includes bomb suits, helmets and other protective duty gear made from flame and fragmentation-resistant material. Some suits have advanced features such as internal cooling, amplified hearing and communications back to control areas. Protective armor is most commonly worn by EOD technicians in an effort to increase the odds of survival should direct contact be required with the explosive ordnance and/or an explosive device detonates while they are close to it.

Similar to protected vehicles, protective armor only decreases the risk for those directly utilizing the gear. Protective armor does not itself directly attempt to neutralize the ordnance or control its detonation. While some may argue that the armor enables EOD technicians to decrease the chances of detonation, these chances are sharply offset by the risks and negative externalities inherent in detonation.

| ***Claimed Advantages*** | ***Claimed Disadvantages*** |
|---|---|
| Increased rates of survival for outfitted party. | Connotes direct human contact with explosive: increased rate of individual survival countered by increased risk of close proximity. |
| | Risk of detonation maintained. |
| | Risk of hazardous conditions of fire, shrapnel and other projectiles maintained. |
| | Risk of collateral damage to infrastructure and people maintained. |
| | Potential forensic evidence destroyed upon detonation. |

***Bomb Blankets***

Bomb blankets, usually made of multiple layers of ballistic material, are literally placed over the established or suspected explosive ordnance. Usually deployed with a ~~"~~blast containment ring," the ring is placed around the explosive device and the blanket is placed atop it. Should the device detonate, the ring helps to direct the force of the explosion upwards, away from surrounding pedestrians and infrastructure. The blankets are then designed to flex upon impact in an effort to contain bomb fragments and projectiles.

| ***Claimed Advantages*** | ***Claimed Disadvantages*** |
|---|---|
| Explosion directed upwards to decrease risk for pedestrians and infrastructure. | Connotes direct human contact with explosive. |
| Flex capabilities work to contain explosive fragments. | Explosive ordnance is detonated. |
| Expert and non-expert use. | Hazardous conditions of fire, shrapnel and other projectiles. |
| | Collateral damage to infrastructure and people. |
| | Release and spread of potential contaminants within the ordnance upon detonation. |
| | Potential forensic evidence destroyed upon detonation. |



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***Bomb Baskets/Trolleys/Sleds***

Bomb baskets and trolleys are two transportation mechanisms for relocating explosive ordnances. The units are employed to relocate explosives away from infrastructure and populous areas and frequently, to then pursue active techniques such as: controlled detonation, forced detonation, or examination by an EOD technician. Relocating the explosive device within these containment vessels aims to decrease the level of human contact with the ordnance and to decrease the risk involved in said relocation. Bomb baskets and trolleys are usually constructed from ballistic materials, designed to withstand potential detonation.

"Bomb sleds" generally refer to a type of armored shield, used to protect EOD technicians in close proximity to the ordnance. The shields usually have viewing windows for the technicians to view the ordnance and, in some cases, have holes through which the device can be manipulated.

| ***Claimed Advantages*** | ***Claimed Disadvantages*** |
|---|---|
| Explosive threat can be relocated away from pedestrians and infrastructure. | Risk inherent in relocation efforts involving trolley and basket. |
| Reduced risk of collateral damage. | Explosive ordnance can detonate. |
| Reduced risk of hazardous conditions of fire, shrapnel and other projectiles. | Sled connotes direct human contact with explosive. |
| Potentially increased rates of survival for party employing sled. | Remaining risk of hazardous conditions of fire, shrapnel and other projectiles. |
| Active mitigation techniques can be pursued upon relocation via basket or trolley. | Remaining risk of collateral damage to infrastructure and people. |
| | Release and spread of potential contaminants within the ordnance upon detonation. |
| | Potential forensic evidence destroyed upon detonation. |

***Robotic Devices***

Robotic devices may be classified as both a passive and an active methodology. Passively, robotic devices are used to relocate the explosive ordnance away from surrounding populations and buildings. Explosive ordnances are frequently relocated in order to enable the pursuit of alternative, active methods including: controlled detonation, forced detonation, or examination by an EOD technician. When used to relocate explosive ordnances, the primary objective is to decrease risk and possible collateral damage; not to actively interfere with or control detonation.

Robotic devices may be considered an active technique when they are outfitted with neutralizing technologies to actively interfere with detonation. For example, a robotic device outfitted with a thermite incendiary device could be deployed to actively mitigate, neutralize and/or dispose of the explosive threat. The immediate objective is neutralization.



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**Robotic Devices: Passive Mitigation**

| *Claimed Advantages* | *Claimed Disadvantages* |
|---|---|
| Explosive threat can be relocated away from pedestrians and infrastructure. | Explosive ordnance detonates. |
| Reduced risk of collateral damage. | Remaining risk of collateral damage to infrastructure and people. |
| Reduced risk of hazardous conditions of fire, shrapnel and other projectiles. | Remaining risk of hazardous conditions of fire, shrapnel and other projectiles. |
| Standoff capabilities. | Release and spread of potential contaminants within the ordnance upon detonation. |
| | Potential forensic evidence destroyed upon detonation. |

**Robotic Devices: Active Mitigation**

| *Claimed Advantages* | *Claimed Disadvantages* |
|---|---|
| Explosive threat can be relocated away from pedestrians and infrastructure. | Explosive ordnance may still be detonated. |
| Reduced risk of collateral damage. | Remaining risk of collateral damage to infrastructure and people. |
| Reduced risk of hazardous conditions of fire, shrapnel and other projectiles. | Remaining risk of hazardous conditions of fire, shrapnel and other projectiles. |
| Standoff capabilities. | Release and spread of potential contaminants within the ordnance upon detonation. |
| Active mitigation techniques can be pursued upon relocation:<br>• Detonation temporarily jammed<br>• Controlled and/or forced detonation | Potential forensic evidence destroyed upon detonation. |

### 5.5.2 Active Mitigation Techniques

Active mitigation techniques generally involve proactive measures undertaken to disable or neutralize the explosive, or to control its detonation. Thermite based incendiary devices are here considered to be an ―active" methodology. Correspondingly, the following technologies may more likely serve as direct competitors and/or substitutes for the composition when compared to existing passive techniques.

***Mechanical Impact***

One of the most common characteristics of current, active neutralization methodologies is that of mechanical impact achieved through an aimed projection of mass. A projectile is released to hit the targeted explosive ordnance in order to break the explosive ordnance‘s firing mechanism prior to detonation of the device. By destroying the explosive‘s firing mechanism, full detonation can frequently be averted. However, mechanical impact may still create hazardous conditions for explosive ordnance disposal personnel, and for individuals and infrastructure located near to the explosive ordnance.



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Resulting hazardous conditions include collateral damage caused by shrapnel or other projectiles which may be discharged upon impact. When the disruptor projectile hits the explosive ordnance, the projectile and/or the ordnance can break apart. This can be especially problematic when the explosive ordnance is located in densely populated areas or is surrounded by valuable capital. The method of mechanical impact is also not well-suited to mitigate the threat of chemical/biological/radiological/nuclear (CBRN) ordnances. CBRN threats carry an extremely high level or risk for the release and spread of contaminants upon impact of a disruptor projectile.

| ***Claimed Advantages*** | ***Claimed Disadvantages*** |
|---|---|
| Destruction of explosive ordnance's firing mechanism. | Collateral damage to infrastructure and people. |
| Standoff capabilities. | Hazardous conditions of fire, shrapnel and other projectiles upon impact. |
| Full detonation frequently averted. | Release and spread of potential contaminants within the ordnance upon impact. |
| Standoff capabilities. | Potential forensic evidence destroyed upon impact. |

***Controlled Detonation***

The characterization of controlled detonation is reasonably inherent. It is the detonation of explosive ordnances *controlled* by EOD personnel and/or under *controlled* circumstances. While this may initially seem to be a ~~"~~passive" technique, as the ordnance is still detonated, the efforts to actively control the timing, location and ultimate impact of said detonation lend itself to the classification of ~~"~~active."

Controlled detonation is claimed to be one of the currently preferred methods of explosive ordnance neutralization and disposal employed by the US military. Upon discovery, explosive ordnances and improved explosive devices can be relocated to remote areas. Relocation is frequently under taken using robotic devices, containment vessels, or other automated equipment. As a last resort, EOD technicians or service members can be deployed to physically relocate the device or to place the ordnance in a blast-resistant transportation device. Once isolated, further efforts can be made to neutralize the device or in this case, the explosive ordnance is detonated. Detonation is frequently achieved via direct impact of a projectile, rifle shot or countercharge. Collateral damage and risk can be lessened by isolating the explosive.

| ***Claimed Advantages*** | ***Claimed Disadvantages*** |
|---|---|
| Potential control of timing, location and impact of detonation. | Risk inherent in relocation efforts. |
| Connotes standoff capabilities. | Explosive ordnance detonates. |
| Reduced risk of collateral damage. | Risk of collateral damage to infrastructure and people is not completely eliminated. |
| Reduced risk of hazardous conditions of fire, shrapnel and other projectiles. | Hazardous conditions of fire, shrapnel and other projectiles are not completely eliminated. |
| | Release and spread of potential contaminants within the ordnance upon detonation. |
| | Potential forensic evidence destroyed upon detonation. |



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Thermite based incendiary devices are classified by this assessment to fall within the active category of disposal via controlled detonation. While thermite techniques may in fact be more similar to laser neutralization systems, discussed below, the thermite incendiary devices do work to control detonation. That is, as an alternative to full-force detonation, the thermite composition may facilitate the destruction of explosive ordnances by burning or igniting the devices. In most cases, the thermite reaction (*i.e.* concentrated heat) is focused on an explosive ordnance to burn through the device‘s protective casing. Upon penetration of the casings, explosives or other energetic materials can be ignited, forcing internal combustion. By initiating rapid combustion of the munitions filling and/or trigger components, explosive ordnances may detonate in a much lower grade explosion or simply be incinerated. The risk of collateral damage to infrastructure and people, hazardous conditions, and fragmentation may be decreased.

When compared to existing thermite incendiary devices—essentially a combination of torch cutters and fire starters—the pyrotechnic thermite composition offers the potential advantage of enhanced perforation. Specifically, it is claimed to be capable of piercing metal casings of explosive devices—something not all existing EOD thermite devices can accomplish. Likewise, the composition at hand is said to be well-suited to application via unmanned autonomous vehicles (UXVs). As UXVs are already applied within EOD, and advantageously decrease risk to EOD personnel, retrofitting existing machines with a thermite-based accessory may prove to be a viable point of market entry.

***Laser Neutralization Systems***

Laser neutralization systems generally employ vehicle-mounted lasers. Directed energy from the laser induces a low-order burning or deflagration reaction in the explosive ordnance until it combusts internally. Explosive ordnances to which laser systems are affected are described to then ―just pop” or ―fizzle” in a low-level detonation.[63]

The laser‘s high-intensity thermal light beam is focused on an explosive ordnance. Said laser burns through the explosive‘s protective casings to touch part of the explosive material. As a result of this contact, explosive ordnances may detonate with much less force than if detonated as planned or via mechanical impact. It is the laser‘s thermal engagement which enables the low-order burning to ensue until the device deflagrates. The explosive‘s casing cooks off slowly to detonate in a lower grade explosion. Some estimates claim that laser neutralization systems typically blow up only about thirty percent of the explosive ordnance.[64] Decreased levels of detonation can result in less collateral damage.

[63] Rutherford, Mark. "Laser equipped Humvee pops and fizzles IEDs." *Military Tech*. 27 Nov 2207. cnet news, Web. Dec 2010. <http://news.cnet.com/8301-13639_3-9821842-42.html>.

[64] "U.S. Tests Anti-IED Laser." *Pakistan Defense*. 26 Dec 2007. Defense News.com, Web. Jan 2010. <http://www.defence.pk/forums/world-affairs/8499-u-s-tests-anti-ied-laser.html>.



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| *Claimed Advantages* | *Claimed Disadvantages* |
|---|---|
| Standoff capabilities. | Remaining risk of collateral damage to infrastructure and people is not completely eliminated. |
| Reduced and/or minimized detonation. | Hazardous conditions of fire, shrapnel and other projectiles are not completely eliminated. |
| Reduced risk of collateral damage. | Release and spread of potential contaminants within the ordnance upon detonation. |
| Reduced risk of hazardous conditions of fire, shrapnel and other projectiles. | Potential forensic evidence destroyed upon partial detonation. |

***Jamming: Electronic & Infrared***

Jamming refers to the act of interfering with the signals or commands used to trigger the detonation of explosive devices. Jamming is the *deliberate* transmission of signals to disrupt the communications (i.e. intercept or block) between command devices and the trigger systems of explosive ordnances. In most cases, a transmitter, tuned to the same frequency as the enemy‘s receiving equipment (trigger) and with same type of modulation, can override the signals being sent to the receiver. The objective is to block the trigger signal before it reaches its intended target, preventing detonation. The type of jamming method will vary depending upon the type of signal communication.

Jamming methods have been found to be especially useful in current military conflicts where the majority of roadside bombs and improvised explosive devices are remotely detonated using common household devices: cell phones, garage door openers, key fobs, doorbells, or remote controls for toy cars.[65] These detonation systems are predominantly *electronic* and/or *radio controlled*. Subsequently, electronic or radio frequency jammers are used to intercept the signal going to the remote-controlled IED via radio frequency.

Explosive ordnances can also be detonated via infrared triggers. With regard to improvised explosive devices, these triggers are in effect a conversion of the simple ―light beam” seen in burglar alarms and in the safety mechanism on garage doors. The beams can be left to passively be triggered or, more commonly, are activated remotely by radio controls when a patrol approaches. In either case, when the light beam is crossed, infrared sensors respond to the changes in the infrared/heat signal to detonate the device. Infrared beams are not easily jammed, but when remotely controlled, electronic and/or radio frequency jammers can be used to inhibit the activation of the infrared beams. In an effort to mitigate the risk of infrared triggers, many patrol vehicles are now outfitted with an extended mechanical arm, designed to initiate the infrared trigger before the vehicle and/or full patrol unit crosses its path.

One predominant method of electronic jamming is *barrage jamming* in which multiple frequencies are jammed and a broad range of radio signals and electronic frequencies are knocked out. Barrage jamming is claimed to be advantageous in that several frequencies are jammed simultaneously, but this can also knock out communications and navigations of friendly forces and US troops. Subsequently, convoys are faced with the choice of traveling semi-protected and blind, or traveling with navigational clarity yet completely unprotected

[65] Mihelich, Peggy. "Jamming systems play secret role in Iraq." *Jamming systems play secret role in Iraq- Cnn.com*. 13 Aug 2007. CNN, Web. Jan 2010. <http://www.cnn.com/2007/TECH/08/13/cied.jamming.tech/>.



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from electronically detonated IEDs. It is also important to note that jamming technologies *temporarily* neutralize the explosive ordnance; they do not do so permanently. The vast predominance of jamming systems are vehicle mounted, but there are also portable versions to be embedded in clothing, carried in backpacks, or attached to remotely controlled vehicles and robotic devices.

| ***Claimed Advantages*** | ***Claimed Disadvantages*** |
|---|---|
| Standoff capabilities. | Can hinder friendly communication and navigation. |
| Temporarily neutralizes explosive ordnance. | Neutralization is not permanent. |
| Reduced risk of collateral damage. | Remaining risk of collateral damage to infrastructure and people is not completely eliminated. |
| Reduced risk of hazardous conditions of fire, shrapnel and other projectiles. | Hazardous conditions of fire, shrapnel and other projectiles are not completely eliminated. |
| Widespread efficacy. | Release and spread of potential contaminants within the ordnance upon detonation. |
| | Inability to obtain potential forensic evidence. |
| | Efficacy has resulted in enhanced circumvention efforts and reversion to command-wire detonation systems. |

***Electromagnetic Forced Detonation***

Electromagnetic forced detonation is a type of ―controlled detonation." As opposed to relocating the explosive ordnance, in an effort to alter and control the environment in which detonation occurs, this type of forced detonation favors the tactic of ―blow in place" or ―pre-detonation."

Detonating the explosive ordnance in its place removes the risk inherent in relocation efforts. Conversely, the risks of collateral damage to surrounding individuals and infrastructure are maintained, any forensic evidence is destroyed upon impact, and CBRN threats cannot be effectively mitigated. Ideally, once an explosive was identified, the area would be cleared, the ordnance would be detonated with parties at a safe distance, and the effectiveness of the explosive device would be drastically reduced.

In the case of electromagnetic forced detonation, electromagnetic energy signals (e.g. high intensity light beams or infrared energy) are emitted from either a stationary or mobile device. Within a certain area, IEDs which can be triggered by electromagnetic energy sources will receive the radiated electromagnetic energy signals and be forced to detonate.



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| *Claimed Advantages* | *Claimed Disadvantages* |
|---|---|
| Potential control of timing, location and impact of detonation. | Explosive ordnance detonates. |
| Connotes standoff capabilities. | Remaining risk of collateral damage to infrastructure and people is not completely eliminated. |
| Reduced risk of collateral damage. | Hazardous conditions of fire, shrapnel and other projectiles are not completely eliminated. |
| Reduced risk of hazardous conditions of fire, shrapnel and other projectiles. | Release and spread of potential contaminants within the ordnance upon detonation. |
| Pre-detonation and blow-in place removes risk of relocation efforts. | Potential forensic evidence destroyed upon detonation. |

***Percussion Actuated Neutralizer***

Dating back to the 1970s, the percussion actuated neutralizer (PAN), or water cannon, is a tool used to neutralize explosive devices by destroying specific trigger components. Now widely used, in part due to its durability and minimal maintenance, the PAN fires an explosively propelled jet of water in order to disrupt the circuitry of a bomb. Ideally, the PAN‘s destruction of circuitry will disable the ordnance with a low risk of detonation. The PAN can be mounted on a remotely operated vehicle or robotic device to decrease levels of human involvement.

| *Claimed Advantages* | *Claimed Disadvantages* |
|---|---|
| Potential destruction of explosive ordnance’s firing mechanism. | Remaining risk of collateral damage to infrastructure and people. |
| Full detonation frequently averted. | Remaining risk of hazardous conditions of fire, shrapnel and other projectiles upon impact. |
| Removes risk of relocation efforts. | Remaining risk of release and spread of potential contaminants within the ordnance upon impact. |
| Connotes standoff capability. | Potential forensic evidence destroyed upon impact. |
| Durability and minimal maintenance. | Basic functionality matched by basic circumvention such as increased strength of explosive casings. |

### 5.5.3 Direct vs. Indirect Competition

In general, this assessment understands existing active technologies to be *direct competitors*. These technologies and methodologies can serve as direct substitutes for the pyrotechnic thermite composition embodied within incendiary devices. When the desired end result is that of disposal, active technologies may provide an alternative route to achieving this same objective. This is especially true for existing thermite-based incendiary devices.

Conversely, passive technologies are understood to be *indirect competition* as they may prove to be complementary to a commercialized pyrotechnic thermite composition embodied within incendiary devices.[66]

[66] Note: passive mitigation technologies and techniques are not considered to be ―complements” in the traditional economic characterization. That is, an increase in the demand for incendiary devices employing the pyrotechnic thermite composition does not



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Passive technologies work to achieve a varied end result; that of protection. Thus, passive, protective measures and technologies may continue to be employed in light of the composition‘s market entry.

For example, the composition‘s potential to dispose of explosive ordnances without full-force detonation may not circumvent the driving of protective vehicles, the wearing of protective armor and the use of robotic devices to relocate ordnances (and/or be outfitted with an incendiary device accessory). A large rationale behind this argument is the fact that explosive ordnances, improvised or otherwise, must still be located and identified for the thermite composition to be implemented. Hence, we see a remaining need for protective measures.

The complementary employment of existing, passive technologies should not be a deterrent to the composition‘s development and application to EOD. Although competitive relationships may fluctuate over the long term, these methodologies achieve the varied objective of protection, not disposal. Ultimately, the composition can be used *in conjunction with* passive technologies while it be may used *in place of* active technologies. The previously created summary chart is created below, now designating active disposal techniques as potential direct competitors and passive techniques as indirect.

| **Direct vs. Indirect Competitors** | |
|---|---|
| **Direct: Active Techniques** | **Indirect: Passive Techniques** |
| Mechanical Impact | Protected Vehicles |
| Controlled Detonation* | Protective Armor |
| Robotic Devices | |
| Infrared Jamming | Bomb Blankets |
| Electronic Jamming | Bomb Trolley, Bomb Basket, Bomb Sled |
| Electromagnetic Forced Detonation | |
| Percussion Actuated Neutralizer (PAN) | |
| Laser Neutralization Systems | |

**Includes thermite-based EOD*

With regard to non-product based competition, the pool of suppliers and companies involved in the EOD market are multiple. In their report, *2006-2015 Homeland Security and Homeland Defense Global Market*, the Homeland Security Research Corporation (HSRC) identified 19 major, private sector entities in the disposal of explosive ordnances:

- AB Precision
- Alford Technologies
- Allen-Vanguard Corporation
- Applied Energetics
- BAE Systems
- Elisra
- Force Protection Inc
- Foster-Miller Inc
- General Dynamics

infer an increase in the demand for an existing, passive technology, nor does the composition have to be employed with one of these technologies; the case of perfect complements. No assumptions or assertions are made about cross price elasticity of demand.



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- Idea Products
- iRobot Corporation
- ITT Corporation
- Lockheed Martin
- Navistar International Corporation
- Rheinmetall Defence
- Science Applications International Corporation
- Sierra Nevada Corporation
- SRCTec
- Thales Group

Ideally, the composition‘s claimed enhanced material perforation, increased reaction temperatures, and decreased toxicity may support market penetration. However, established contracts, supply agreements and networks may prove to be significant barriers to entry for licensees.

### 5.5.4 Demilitarization

The majority of the above EOD techniques and technologies may also find application within demilitarization initiatives. This assessment understands demilitarization to indicate historical combat zones, as opposed to EOD of active threats or within active combat initiatives. This connotation may then see amplified relevance and potential advantage for the thermite composition in the case that EOD materials and/or technologies are sent from one country to another for use in demilitarization. That is, when compared to highly reactive compounds, thermite-based demilitarization mechanisms and substances may be preferred in light of their potentially decreased risk of theft and/or danger of alternative weapons creation.

Due primarily to a lack of manufacturer disclosure, the existence and/or prevalence of existing thermite-based demilitarization technologies is not articulated here. With that said, analysis of the demilitarization market revealed two U.K. based companies advertising four thermite-based mechanisms of both demilitarization and EOD application. Disarmco LTD advertises their low temperature thermite, thermal shock induced deflagration system, and thermite destructor (also noted as EOD application). Chemring Group PLC advertises their thermite torch. The information provided for each company‘s respective products is relayed below.



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| Product/Company | Description & Application (as advertised) |
|---|---|
| **Chemring Group PLC** | |
| Thermite Torch A205[67] | A lightweight incendiary device used to facilitate the destruction by burning of the explosives and propellant in unexploded ordnance and to initiate burning of other less combustible materials. Device is fitted with an electric safety fuse for initiation and includes a diaphragm, which can be pierced to allow the insertion of alternative methods of initiation.<br><br>For large UXOs and most small ones the casing of the UXO will have been opened and the Thermite Torch will be placed in direct contact with the explosive or propellant. It will then be ignited. For thin cased UXOs such as flares and some submunitions the incendiary will be placed on the outside of the thin cased UXO and be required to burn through the casing of the UXO and ignite the explosive or propellant inside. The maximum thickness of such a casing is 2.5mm aluminum.<br><br>• 1.18" in diameter<br>• 5.9" in length<br>• Minimum temp of 3272 degree Fahrenheit<br>• Minimum burn time of 25 seconds<br>• Maximum case penetration is 2.5mm aluminum |
| **Disarmco LTD** | |
| Low Temperature Thermite[68] | Low Temperature Thermite (LTT) has been developed for use in demilitarization and EOD activity. LTT is slow burning and is designed to ignite explosive compositions with a reduced risk of high order detonation.<br><br>LTT has been used successfully to ignite a wide range of civil and military explosives. Its packaging provides for maximum heat transfer when placed in a fuse pocket or similar cavity where it will take up the cavity shape and be in contact with the walls. LTT burns for approximately 4.5 minutes at a steady temperature and so causes the explosive to burn rather than detonate. |

[67] Chemring Defence. "HEThermiteTorchA205." Chemring Defence, Web. Mar 2010. <http://www.chemringeod.com/Download.aspx?ResourceId=14875>.

[68] Disarmco, . "Low Temperature Thermite." *Low Temperature Thermite* . 2010. Disarmco, Making Safe Environments, Web. Mar 2010. <http://disarmco.com/products_info.asp?id=13>.



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| | |
|---|---|
| Thermal Shock Induced Deflagration System[69] | Disarmco's Thermal Shock Induced Deflagrators (TSID) are designed to neutralize High Explosive (HE) filled munitions. Rapid transfer of heat causes deflagration of the explosive in the target weapon leading to gas over pressure that bursts the casing without detonation. The exposed explosive is ignited by the residual heat/flame from the molten thermite.<br><br>TSID minimizes fragmentation, blast over-pressure and acoustic pollution by initiating rapid combustion of the munitions filling. TSID units are designed to fit common ammunition profiles to ensure intimate contact but can be further contoured by the user where required. They are initiated using either LTT or a pyrotechnic torch, which is inserted into the igniter recess by the user.<br><br>TSID units are currently available to deal with the following types of HE filled munitions: **TSID 1000**- Projectiles over 155mm, warheads up to 50lbs; **TSID 2000**- HE filled aircraft bombs, torpedo and warheads over 50lbs. |
| Thermite Destructors – Type A | Modified thermite mixes specifically designed to rapidly burn through metal casings and ignite High Explosive (HE) fillings or other energetic materials held within. Advertised to allow burning of munitions without having to actively access/cut through casings and expose explosives. Disarmco claims that units are designed to accommodate common ammunition designs and can be further adapted by the user. Initiated via low temperature thermite (LTT) or pyrotechnic torch—a new igniter system is advertised to be under development.<br>Can be applied to EOD and demilitarization. Said to be packaged in 1.1 lbs bags packed 25 per plastic tub. |

Thermite-based technologies for EOD and demilitarization clearly exist. The pyrotechnic thermite composition may then be able to exploit its prospective advantages as it works to make improvement over existing formulations by offering: enhanced material perforation, increased reaction temperatures, and decreased toxicity. At the time this market overview was written, price estimates had been requested, but not received from the companies above. Although these products may hold application for both EOD and demilitarization, they were revealed within analysis of the demilitarization market and are thus used to note the composition at hand‘s potential application of demilitarization.

Ultimately, the products above serve as exemplary competitors within the EOD and demilitarization markets. It is pre-existing thermite solutions similar to those outlined above which have the potential to directly compete with the pyrotechnic thermite composition at hand.

### 5.5.4 Costs

This assessment has articulated the cost estimate of $12.10 per pound for the preferred pyrotechnic thermite composition. This figure may fluctuate as development ensues and embodiments vary. Efforts to estimate the cost of the composition‘s potential EOD competitors are inadequate. While broad estimates about the range of costs can be made (*i.e.* the cost of existing passive and active technologies can range from $2,000 to $800,000), attempts to design even an average pricing model are hindered by a lack of accurate information. For example, initial endeavors included the collection of ten price points for each technology and/or methodology to be

[69] Disarmco. "Thermal Shock Induced Deflagration System." *Thermal Shock Induced Deflagration System*. 2010. Disarmco, Making Safe Environments, Web. Mar 2010. <http://disarmco.com/products_info.asp?id=16>.



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compared as an average to the composition‘s $12.10 per pound price. However, the ability to obtain said price points was refuted by limited information and/or inaccurate estimates. Further, the costs of ―methodologies” are difficult to accurately assess. The varying components of mechanical impact, for example, see a large array of potentially employed systems and technologies.

In attempts to narrow the large window of $2,000 to $800,000, limited comparative figures are relayed below. Unless noted as otherwise, estimates are based on average of ten price points collected from private retailers within independent research. The figures below should be interpreted as only a general frame of reference.

| Existing Methodology | Average Monetary Cost Estimate |
|---|---|
| Protected Vehicles | $800,000 |
| Protective Armor (Basic Bomb Suits) | $17,000 |
| Bomb Blankets | $2,000 |
| Bomb Basket/Trolley/Sled | Basket: $3,000<br>Trolley: $3,000<br>Sled: $2,000 |
| Robotic Devices (Passive) | <$5,000 |
| Robotic Devices (Active) | <$5,000 |
| Mechanical Impact | Indeterminate |
| Controlled Detonation | Indeterminate |
| Laser Neutralization Systems | Indeterminate |
| Jamming Techniques | Indeterminate |
| Electromagnetic Forced Detonation | Indeterminate |
| Percussion Actuated Neutralizer | $4,000 |
| Low Temperature Thermite | Price Request Submitted |
| Thermal Shock Induced Deflagration System | Price Request Submitted |
| Thermite Destructor | Price Request Submitted |
| Thermite Torch | Price Request Submitted |



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## 5.6 General Construction/Welding

As the pyrotechnic thermite composition may find application in most cases that cutting or welding is involved, corresponding market opportunity may be realized within general construction and welding markets. Throughout this assessment, the pyrotechnic thermite composition‘s claimed enhanced material perforation has been recognized as a primary prospective advantage. Thus, within the construction market, perforation capacity may be a chief determinant of competing solutions. With regard to welding, the thermite reaction can be focused to melt a thin film where components meet, or the molten thermite reaction can be poured between components to form a welded joint. Reaction heat may then be a likely determinant of competing welding solutions.

### 5.6.1 Construction

When perforation is the objective, such that it is within a thermite torch cutter, existing solutions may include, but are not limited to: saws with metal cutting blades and angle grinders with metal cutting blades. These selected cutting tools are all capable of perforating steel or metals, as may be a primary capability of the pyrotechnic thermite composition. The general concepts of these competing methodologies are explored below, alongside exemplary commercially available products.

First, saws and grinders are capable of cutting through metal when outfitted with the appropriate blade. A variety of saws are advertised to be capable of metal perforation and include:

- Hacksaws
- Jigsaws
- Reciprocating Saws
- Band Saws
- Circular Saws

Angle grinders are also frequently included in the categorization of hand tools capable of metal perforation. With regard to exemplary products, Black and Decker‘s DeWALT Power Tools offer an exemplary baseline examination of the potential competitive landscape. The company is one of the leaders in contractor power tools with a product offering of over 200 electric power tools and 800 accessories. Select examples of each of the above types of saws and grinders are provided below and are classified as ―metal working saws.” Pictures can be seen in Appendix F. The object of product comparison is to gauge existing solutions‘ range of capacity and pricing structures. Please note that not all of DeWALT‘s product offerings are listed below and the figures are provided to provide a general overview of existing metal perforation tools present within the construction market.



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| Product (Model No.) | Description | Cost Estimate* |
|---|---|---|
| Hacksaw (DW3970)[70] | One of the most common cutting tools, capable of metal perforation when outfitted with the appropriate blade. Preference decreases as size of job increases and use within construction market is limited to small scale and/or thin cut jobs. Blade measures 10" with 32 teeth per inch (TPI). Advertised to cut through virtually all materials- metals, woods, or plastics. | $22.00 per 10 pack of blades, $25.00 per hack saw frame. |
| Jigsaw (DW317K)[71] | Jigsaws are also capable of cutting most metals as long as equipped with the proper blade. Selected product weighs 6.2lbs. and advertised with 1" strokes capable of making straight or bevel cuts in metal. 5.5 amp motor with maximum 3,100 strokes per minute. | $120.000 |
| Reciprocating Saw: (DW304)[72] | Tool measure 17.5" and weighs 7.0 lbs. 10.0 amp motor with 0-2,800 strokes per minute (SPM). Advertised to cut light to heavy gauge metals with proper blade. | $180.00 |
| Band Saw: (DWM120)[73] | Tool measures 21" and weighs 15.0 lbs. Advertised as the industry best with cutting capacity of 5" round and 5 x 4-3/4" rectangular. 10.0 amp motor with approximated speed of 100-350 ft/minute. | $300.00 |
| Grinder (D28144)[74] | Tool measure 13.0" and weighs 4.6 lbs. 13.0 amp motor with 9,000 revolutions per minute (RPM). | $200.00 |

**Price subject to change with alterations in features, specifications, size of purchase etc.*

One of the prospective advantages of a torch cutter employing the pyrotechnic thermite composition is the potential for internalized power. While some existing hand tools, capable of metal perforation, are cordless or battery operated—the majority still require charge or are outfitted with a cord for external power. The thermite torch cutter may also find advantage in the decreased effort required within usage. Many of the tools and methods described above can require significant exertion and/or time to achieve the objective of perforation. Moreover, the estimated cost of $12.10 is significantly less than the cost estimates of these existing solutions. While the above price estimates may be inflated due to brand-name pricing power, the pyrotechnic thermite composition may have some breathing room as development ensues with existing tools ranging in price from an approximate $30.00 to $300.00.

With regard to non-product based competition, Black and Decker is classified within the North American Industry Classification System (NAICS) 333991, power driven hand tool manufacturing. As described by the

[70] DeWALT. "Hack Saw:Frames | DeWALT Tools." *Hack Saw: Frames*. 2010. DeWALT, Web. Mar 2010. <http://www.dewalt.com/tool-parts/hack-saw-frames-dw3970.aspx>.
[71] DeWALT. "DW317K Compact Jig Saw Kit | DeWALT Tools." *DW317K*. 2010. DeWALT, Web. Mar 2010. <http://www.dewalt.com/tools/saws-jig-saws-dw317k.aspx>.
[72] DeWALT. "DW304PK 10.0 Amp Reciprocating Saw Kit | DeWALT Tools." *DW304PK*. 2010. DeWALT, Web. Mar 2010. <http://www.dewalt.com/tools/saws-reciprocating-saws-dw304pk.aspx>.
[73] DeWALT. "DWM120 Deep Cut Band Saw | DeWALT Tools." *DWM120*. 2010. DeWALT, Web. Mar 2010. <http://www.dewalt.com/tools/metalworking-band-saws-dwm120.aspx>.
[74] DeWALT. "D28144 6" High Performance Cut-Off/Grinder | DeWALT Tools." *D28144*. 2010. DeWALT, Web. Mar 2010. <http://www.dewalt.com/tools/metalworking-grinders-high-performance-small-angle-body-grip-grinders-d28144.aspx>.



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United States Census Bureau, this industry comprises establishments primarily engaged in the manufacture of power-driven hand tools such as drills, screw guns, saws, chains saws and nailers. Cross referenced with other NAICS groupings, these establishments are primarily engaged in:

- Manufacturing metal cutting-type and metal forming-type machines (including home workshop)—are classified in Industry 33351, Metalworking Machinery Manufacturing;
- Manufacturing countersink bits, drill bits, router bits, milling cutters, and other machine tools for woodcutting—are classified in U.S. Industry 332212, Hand and Edge Tool Manufacturing;
- Manufacturing power-driven heavy construction or mining hand operated tools, such as tampers, jackhammers, and augers—are classified in Industries 333120, Construction Machinery Manufacturing and 33313, Mining and Oil and Gas Field Machinery Manufacturing; and

Although the pyrotechnic thermite composition at hand will require development to reach the manufacture-ready stage, existing NAICS 333991 establishments may construct the competitive landscape within the construction market opportunity. It is these entities which manufacture and contract the power tools with metal perforation capacity similar to that of a thermite torch employing the composition, and which hold existing market share. High Beam Business articulates the two largest industry leaders to be Black and Decker Corporation and Danaher Corporation.[75] With 22,300 employees and sales of $4.74 billion in 2009, Black and Decker Corporation carries the seventh most recognized brand name in the United States and the brand is among the 20 most recognized in Europe. Danaher Corporation had 29,000 employees and approximately $11.0 billion in sales in 2009. Other industry parties consist of a variety of diversified firms who also compete within the field of power driven hand tool manufacturing including: Ingersoll-Rand Co., Illinois Tool Works Inc., Stanley Works, and Snap-on Inc. Likewise, Hoover‘s articulates Black and Decker Corporation‘s competition to include the following firms:[76]

- ASSA ABLOY
- Atlas Copco
- Cooper Industries
- Danaher
- Eaton
- Electrolux
- Emerson Electric
- Energizer Holdings
- Exmark Manufacturing
- Fortune Brands
- Hitachi
- Illinois Tool Works
- Ingersoll-Rand
- Jacuzzi Brands
- Kohler

[75] HighBeam Business. "Power-Driven Hand Tools Market Report." *Power-Driven Hand Tools* . 2010. HighBeam Business, Web. Mar 2010. <http://business.highbeam.com/industry-reports/equipment/power-driven-handtools>.
[76] Hoovers. "The Black & Decker Corporation Competitors." *The Black & Decker Corporation*. 2010. Hoovers, Web. Mar 2010.



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- Makita
- Masco
- Panasonic Corp
- Robert Bosch LLC
- Royal Appliance
- Snap-on
- Stanley Works
- Textron
- Toro Company
- Trane Inc.

The composition‘s claimed enhanced material perforation and decreased toxicity may foster market penetration. However, established contracts, supply agreements and brand equity may prove to be significant barriers to entry for licensees.

### 5.6.2 Welding

When welding via focus of the thermite reaction is the objective, reaction heat may prove to be a determinant of competing welding solutions. Existing welding solutions may include, but are not limited to: gas welding, resistance welding and laser welding. The vast majority of welding techniques are categorized as ―arc” welding in their use of direct (DC), alternating (AC) current and consumable and non-consumable electrodes. Electric arcs are created between an electrode and the base material to melt metals at the welding point. Most attribute arc welding‘s widespread use to be a result of its low cost of capital and running costs. Examples of arc welding are described in the table below.



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| Type of Arc Welding | Description |
|---|---|
| Shielded Metal Arc Welding (SMAW) | Also known as manual metal arc welding (MMA) or stick welding. Electric current is used to strike an arc between the base of the material and a consumable electrode rode, made of steel and covered with a flux to protect the weld area form oxidation and contamination by producing $CO_2$ gas during the welding process. Electrode core acts as filler material. Weld times are somewhat slow since consumable electrode must be frequently replaced and slag (residue from the flux) must be chipped away after welding. |
| Gas Metal Arc Welding (GMAW) | Also known as metal inert gas or MIG welding. Semi-automatic or automatic process which uses a continuous wire feed as an electrode and an inert or semi-inert gas mixture to protect the weld. Welding speeds are increased from SMAW since the electrode is continuous. Said to be more complex and expensive than SMAW and to be less portable due to the use of a separate shielding gas. |
| Flux-cored Arc Welding (FCAW) | Uses a wire consisting of a steel electrode surrounding a powder fill material. The cored wire can be more expensive than a standard soil wire, but it may permit even higher welding speed and greater metal penetration. |
| Gas Tungsten Arc Welding (GTAW) | Also known as tungsten inert gas (TIG) welding is a manual welding process that uses non-consumable tungsten electrodes, an inert or semi-inert gas mixture, and a separate filler material. Said to be characterized by a stable arc and high quality welds, but requires significant operator skill. |
| Plasma Arc Welding (PAW) | Plasma Arc Welding (PAW) uses electrodes and ionized gases to generate an extremely hot plasma jet aimed at the weld area. The higher energy concentration is useful for deeper and narrower welds and increased welding speed. |

Other arc welding processes include submerged arc welding, atomic hydrogen welding, carbon arc welding, and stud arc welding. With regard to gas welding, oxy-fuel is one of the most popular existing solutions. Oxy-fuel welding is a process that uses fuel gases and oxygen to weld metal components. The welding process employs a welding torch to focus reaction temperatures and materials. In general, oxy-fuel welding apparatuses then consist of an oxygen source and a fuel gas source (usually cylinders), pressure regulators, flexible hoses (one for each cylinder), and a torch. The torch is the hand-held component which the end-user holds to manipulate and make the weld. It has a connection and valve for the fuel gas and a connection and valve for the oxygen mix, with a tip where the reaction heat is focused. Oxy-fuel processes can use a variety of fuel gases including, but not limited to: acetylene, propylene, liquefied petroleum gas, propane, natural gas, hydrogen, and MAPP gas. The mixture of fuels tends to vary with different proprietors and brands of oxy-fuel welding solutions. In all existing oxy-fuel products, oxygen mixes with the fuel to produce reaction temperatures focused for welding.

In general, resistance welding involves the generation of heat by passing current through the resistance caused by the contact of two or more metal surfaces. Two large electrodes are placed on either side of the surface to be welded, and a large electrical current is passed through the work pieces to heat up the metal in between.



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Resistance welding can categorize high frequency resistance welding, percussion welding, projection welding, seam welding and spot welding.

Electron beam welding is a welding process in which the energy focused to weld metal components is applied by an electron beam. To avoid dispersion of the electron beam, the work piece is typically placed in a vacuum chamber. Welding fusion is achieved as the beam of high velocity electrons is applied to the materials being joined. As the kinetic energy of the electrons is transformed into heat upon impact, and the filler material, if used, also melts to form part of the weld.

Ultrasonic welding sees the delivery of energy to the joint area in the form of high-power ultrasound. High frequency ultrasonic vibrations are applied to the to-be-joined components, held together under pressure, to create a solid weld. Ultrasonic welding is most frequently used for joining plastics and dissimilar materials, but can be used for welding thin gauge metals.

Acknowledging the various existing welding methodologies, why would thermite solutions be advantageous? In short, thermite welding may in some cases be advantageous due to its potentially high reaction temperatures. Power supplies and filler metals, their associated costs, and space limitations could be eliminated. As a result, broken parts and general welding initiatives can be welded on-site and in remote locations. Increased reaction temperatures may at the same time, however, create limitations in the types of metals which can be welded with thermite, and the process may be uneconomical if used to weld cheap or lightweight metals. Ultimately, when reaction temperature serves as a point of comparison and basis for preference, the composition at hand may find strength in its claimed competitive ability via enhanced temperatures. Previously recognized prospective advantages of portability may be maintained within the pyrotechnic thermite composition.

With regard to the industry as a whole, the United States Census Bureau defines the North American Industry Classification System (NAICS) 333992 to be that of welding and soldering equipment manufacturing. It is these firms which are primarily engaged in the manufacture of welding and solder equipment and accessories such as gas, plasma, laser, electron beam, and ultrasonic welding equipment; welding electrodes; coated or cored welding wire and soldering equipment. Establishments within this classification may construct the competitive landscape to be encountered by the pyrotechnic thermite composition applied via torch for welding purposes. According to projections from *Manufacturing and Distribution USA*, 388 establishments operated in this category in 2004, up from a projected 368 from the previous year. Approximately 31% of the industry‘s manufacturers produced arc welding machines and related components or accessories, while another 27 percent made arc welding electrodes. The rest of the industry was split between manufacturing resistance welders, gas welding equipment, and miscellaneous welding equipment.[77] A full list of industry competitors, as defined by their relevant NAICS identification, can be seen in Appendix F.

[77] HighBeam Business. "Electric and Gas Welding and Soldering Equipment Market Report." *Electric and Gas Welding and Soldering Equipment* . 2010. HighBeam, Web. Mar 2010. < http://business.highbeam.com/industry-reports/equipment/electric-gas-welding-soldering-equipment>.



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# 6 Cautions and Considerations

This assessment has worked to provide a market overview for the varied potential embodiments and applications of the pyrotechnic thermite composition. As development of the composition ensues and market opportunities are explored, there are a variety of cautions and considerations to be made. While by no means an exhaustive list, this discussion works to address some of the questions likely to be posed by potential licensees. Strategic considerations such as switching costs and adoption hurdles, for example, will likely affect future products‘ ability to penetrate markets. Such cautions and considerations are discussed below.

## 6.1 Switching Costs

As a potential improvement over existing thermite formulations, and as an alternative solution to existing technologies, the pyrotechnic thermite composition may exist as a ―next generation" technology. Improvements over existing thermite formulations are claimed, the subsequent embodiment of which may offer alternative solutions. However, the question remains, will these improvements hold enough value for end-users to switch from existing technologies?

Take for example the estimate of 20 to 40 million flares having been sold in the United States (an average cost per flare of $0.50 to $1.00 and annual sales of $20 million by the largest domestic manufacturer).[78] This is a large potential market, but it may also be representative of 20 to 40 million existing flares to be replaced. While the potential regulatory push for perchlorate-free flares may foster this replacement-based market entry, end-users may still need to be motivated to switch out their existing flares for those employing the pyrotechnic thermite composition. In order for this to occur, considerations of switching costs should be made. In addition to such licensee considerations made for demand elasticity and general pricing power, working to minimize switching costs for end-users can in some cases help to support the likelihood of product adoption and purchase.

Generally speaking, there are two main switching cost scenarios which may be encountered within the market of existing technologies; first, the replacement and/or upgrade of a functional technology and second, the replacement of a non-functional or malfunctioning technology. These scenarios can be broken down into the following equations. These equations are conceptual in nature, created only as an example of considerations to be made as development ensues, and should not be interpreted as material decision making tools.

**Switching Cost of Replacing and/or Upgrading a Function Technology**

*= (Lost Utility of Existing Functional Technology + Monetary Cost of Pyrotechnic Thermite Composition Embodiment + Opportunity Cost of Pyrotechnic Thermite Composition Embodiment Adoption) – Pyrotechnic Thermite Composition Embodiment ROI*

**Switching Cost of Replacing a Nonfunctional or Malfunctioning Technology**

*= (Monetary Cost of Pyrotechnic Thermite Composition Embodiment + Lost Cost Savings of Repairing the Existing Technology + Pyrotechnic Thermite Composition Embodiment Adoption) - Pyrotechnic Thermite Composition Embodiment ROI*

[78] "Alternative Causes of Widespread, Low Concentration Perchlorate Impacts to Groundwater." *Prepared by: GeoSyntec Consultants under contract to the Department of Defense Strategic Environmental Research and Development Program (SERDP)* 05 May 2005: 1-54. Print.



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Both scenarios involve the consumer bearing the monetary cost of the product (the purchase price), as well as the opportunity cost of embodiments of the pyrotechnic thermite composition. Examples of costs in this regard may be potential training requirements to safely employ thermite-based technologies and any learning time necessitated by adoption. *Replacing and/or upgrading an existing functional technology* sees the specific cost of this technology‘s lost utility. *Replacing a non/malfunctioning technology* carries the specific loss of any cost savings were this technology to be repaired (at a lower cost) as opposed to replaced. While lost utility and sacrificed cost savings can be considered opportunity costs, they are here distinguished for the sake of clarity.

Moving forward, as development of the composition ensues, the questions of which of these variables are known, and which can be minimized can be asked by licensees and development entities. Current estimates place the price of the preferred composition alone at $12.10 per pound. As pricing structures for the pyrotechnic thermite composition‘s varied embodiments are determined, these price points and future variations can be factored into such models as those above in an effort to consider their potential effect on overall switching costs.

Sellers of the composition alone and/or its embodiments may not have control over the lost utility of end-users‘ existing functional technologies. However, the variables of *opportunity cost of pyrotechnic thermite composition embodiments* and *pyrotechnic thermite composition embodiment ROI* could potentially be manipulated. As established, the opportunity cost of pyrotechnic thermite composition embodiment adoption may refer to such costs as training requirements and learning time necessitated by switching to thermite-based solutions. Minimizing these costs may offer one example of potential avenues to optimizing the costs associated with purchase and adoption.

The pyrotechnic thermite composition‘s return on investment is primarily based on the technology‘s claimed advantages. That is, the composition‘s prospective advantages may be what foster purchase motivation and work to counter any corresponding costs. The previously created chart regarding the composition‘s prospective advantages is seen below, now to specifically noting potential sources of end-user return on investment via relevant prospective advantages.



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| Pyrotechnic Thermite Composition: Potential Applications | | | | |
|---|---|---|---|---|
| ***Application*** | ***Embodiment*** | ***Purpose*** | ***Relevant Advantages*** | ***Relevant Disadvantages*** |
| Disaster Clean-Up | Thermite Torch Cutter | Perforation | • Increased perforation<br>• Decreased time to target<br>• Decreased toxicity<br>• Miniaturization, UXV potential | • Hot reaction products may pose danger to victims<br>• Supply chain will be need to be established |
| Flare | Thermite Flare | Illumination | • Decreased toxicity (perchlorate-free) | • Less control over color<br>• Marginal advantage over existing solutions |
| Fire Starter | Fuse-Outfitted Thermite Canister; Explosive Device | Ignition | • Ignition independent of environmental factors<br>• Decreased toxicity | • Safety considerations |
| Explosive Ordnance Disposal | Incendiary Device | Perforation; Ignition | • EOD with decreased risk of collateral damage, hazardous conditions, and fragmentation<br>• Decreased likelihood of theft<br>• Decreased potential for weapons creation | • Potential risk is not completely eliminated<br>• Considerable design work required<br>• Precautions for handling |
| General Construction/ Welding | Thermite Torch | Perforation; Fusion | • Increased perforation<br>• Increased reaction heat for fusion<br>• Decreased toxicity<br>• Miniaturization (vs. complex/heavy equipment) | • Potential learning curve, training requirement<br>• Reaction heat may not be suitable for all applications |

While the above chart is by no means an exhaustive discussion of the pyrotechnic thermite composition‘s prospective advantages, nor is it a full list of return on investment for purchasers; it provides a general overview of potential return on investment sources to which monetary figures can be assigned. Optimizing switching costs along with the relevant disadvantages may help to foster a return greater than end-user investment.

Ultimately, in light of switching cost considerations, the equations above provide one conceptual model of consideration. Sellers of the pyrotechnic thermite composition and its embodiments may be able to control or manipulate some of the variables, beyond that of the lost utility of existing technologies switched out in favor for the pyrotechnic thermite composition. Moreover, the opportunity costs of the pyrotechnic thermite composition adoption (*e.g.* any training or learning requirements related to various embodiments) can be manipulated to optimize end-users‘ switching costs.



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## 6.3 Industry Attractiveness

This assessment is not written with the intention of making application or market selection recommendations. Rather, this analysis works to provide an overview of, and general insight into, markets which may be relevant to the pyrotechnic thermite composition for potential licensees and other entities with special interest. Thus, none of the examined markets are specifically recommended, but here, we do make room for summaries of overall industry analysis which may be incorporated in determinants of market attractiveness. The information tabulated below is by no means exhaustive. Licensees and special interest parties should employ the information provided as a market overview and a baseline for further investigation



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| Embodiment/ Purpose | Markets | Quantification | Influences | Existing Solutions |
|---|---|---|---|---|
| Thermite Torch Cutter/ Perforation | Disaster Clean-Up | • Natural Disasters<br>• Number of explosive incidents | • Changes to the earth's geography and composition<br>• Population density<br>• Terrorist attacks | • Heavy machinery<br>• Jaws of Life rescue systems |
| Thermite Flare/ Illumination | Flare<br>• CFR<br>• Military<br>• CEP | • Employment Statistics: CFR, water transportation, truck transportation & number of commercial vehicles<br>• Military enlistment<br>• Number of military vessels | • Factors affecting employment<br>• US Coast Guard regulations<br>• FMCSA regulations<br>• Military engagement and deployments | • Combustion Flares<br>• Chemical Solutions<br>• Electric Solutions |
| Thermite Fire Starter/Ignition | Fire Starter<br>• CFR<br>• Military<br>• Outdoor Recreation<br>• CER | • Employment Statistics: CFR<br>• Number of natural disasters<br>• Rates & types of outdoor recreation, participation trends<br>• Military enlistment and deployments | • Occurrence of power outages<br>• Factors affects participation in outdoor recreation<br>• Deployments and combat activity | • Thermite Fire Starter<br>• Survival Matches<br>• Fuel Lighters<br>• Lenses<br>• Fire Bow<br>• Spark-Lite<br>• Flint & Steel |
| Thermite Incendiary Device/ Perforation & Ignition | EOD<br>• CFR<br>• Military | • UXO occurrence<br>• Relevant DHS budgets<br>• Relevant DoD budgets (battle against IEDs) | • International & domestic climate<br>• Shifts in administration and policy<br>• Budgetary controls<br>• Technological advancement<br>• Preventative measures<br>• IED: material availability, affordability, knowledge, social factors, circumvention | • Mechanical Impact<br>• Controlled Detonation<br>• Robotic Devices<br>• Infrared jamming<br>• Electronic jamming<br>• Electromagnetic forced detonation<br>• PAN<br>• Laser systems<br>• Protected vehicles<br>• Protective armor<br>• Bomb blankets<br>• Bomb trolley, basket, sled<br>• Existing thermite solutions |
| Thermite Torch/ Perforation & Fusion | Construction & Welding | • Total annual construction spending<br>• Employment within construction industry<br>• Value of US market for welding equipment & supplies<br>• Employment within welding industry | • Greater economy<br>• Factors affecting employment | • Hacksaws<br>• Jigsaws<br>• Reciprocating saws<br>• Band saws<br>• Circular saws<br>• Alternative welding techniques<br>• Existing thermite welding |

*CFR: Civilian First Responder*
*CEP: Civilian Emergency Preparedness*
*FMCSA: Federal Motor Carrier Safety Administration*
*UXO: Unexploded Ordnance*
*IED: Improvised Explosive Device*
*PAN: Percussion Actuated Neutralizer*



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Although not tabulated above, relevant advantages and disadvantages may prove to be a large determinant of marketability. Likewise, consideration should be made for the state of the industry as whole, as opposed to the specific markets examined here. Determinants of industry attractiveness can include, but are not limited to: supplier power, threat of substitutes, buyer power, barriers to entry, and degree of rivalry.

Embodied within a torch cutter, the pyrotechnic thermite composition may find application within disaster clean-up applications. The claimed enhanced material perforation may offer competitive advantage, alongside the composition‘s potential decreased toxicity and miniaturization capacity. Disadvantages are noted to include hot reaction products‘ potential to harm victims within rescue initiatives and the need to establish a disaster-ready and/or disaster-tailored supply chain. There may be some reluctance to adopt new technologies and pricing power could be countered by the existence of well-established substitute technologies and methodologies. Conversely, the claims of enhanced perforation, faster time on target and versatility of the composition may foster market penetration and pricing capacity.

For the purpose of illumination, the pyrotechnic thermite composition may find market opportunity within flares. The composition‘s prospective advantages of increased reaction temperatures and enhanced material perforation may decrease in relevance within the flare market, but the lack of perchlorate may remain a relevant source of differentiation. This could enable pricing power amongst existing thermite and combustion flares. Conversely, pricing power could be negated as chemical and electric flare alternatives can match the composition‘s perchlorate-free status. Although replacement of existing flares is supported by mandated replacement at 42 months past the date of manufacture, based on the products examined, substitutes are low in cost and increasing in efficacy.

As the thermite reaction enables ignition, the pyrotechnic thermite composition may be applied to fire starting. Relevant to such markets as the civilian first responder, military, and outdoor recreationist; pricing power could be supported by the composition‘s ignition efficacy and high reaction temperatures. Barriers to entry may be few, but development cost could require significant capital expenditures.

With regard to explosive ordnance disposal (EOD), the pyrotechnic thermite composition may be embodied within an incendiary device to achieve the objective of perforation and/or ignition. Pricing power within the EOD market may be positively influenced by cost to manufacture and enhanced material perforation, but could be limited by a multitude of substitutes. Further analysis is needed to determine the substitute versus complementary relationship to be realized with existing EOD technologies, but amongst existing thermite formulations and thermite-based EOD techniques—the composition at hand could prove superior. If EOD is indicative of military procurement, economies of scale may be achievable.

Lastly, the markets of construction and welding are prompted by the composition‘s potential application of perforation and/or fusion. Both the construction and welding markets are mature which historically enhances buyer power. New supply chains would likely need to be created for the composition and pricing power may be limited by established substitutes. Likewise, established supply contracts and limited product differentiation could further limit supplier bargaining power and feasibility of market entry.

In all of the above markets, the pyrotechnic thermite composition‘s patent protection should serve as one avenue of competitive mitigation. As the ―military” was designated as one overarching market/user



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classification, it is important to note that buyer power may significantly increase within said markets. The number of buyers can largely decrease while their possession of market share significantly increases.

Ultimately, the pyrotechnic thermite composition is claimed to be technologically viable. However, maintaining this viability as the composition is manipulated into various embodiments may be a primary hurdle for potential licensees. That is, as applications and markets are pursued, manufacturability is yet to be determined and in some cases, may prove to be cost prohibitive. Market selection should include calculations of the tradeoff between development cost and potential benefits, as well as an examination of general industry attractiveness and competitive ability.



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# 7 Conclusion

The pyrotechnic thermite composition, as claimed in United States patent 7,632,365 B1, offers improvement over existing thermite formulations including: enhanced material perforation, increased reaction temperatures, and decreased toxicity. This assessment then examined the potential applications of: disaster clean-up, flares, fire starters, explosive ordnance disposal, and general construction and welding. Within each, the unifying concept is that of concentrated heat as the thermite reaction is focused to achieve the objectives of perforation, illumination, ignition and fusion. The chart below summarizes the pyrotechnic thermite composition‘s potential applications, varied embodiments, and related purposes as examined within the body of this analysis.

| **Pyrotechnic Thermite Composition: Potential Applications** | | |
|---|---|---|
| ***Application*** | ***Embodiment*** | ***Purpose*** |
| Disaster Clean-Up | Thermite Torch Cutter | Perforation |
| Flare | Thermite Flare | Illumination |
| Fire Starter | Fuse-Outfitted Thermite Canister; Explosive Device | Ignition |
| Explosive Ordnance Disposal | Incendiary Device | Perforation; Ignition |
| General Construction/ Welding | Thermite Torch | Perforation; Fusion |

Market opportunities corresponding to the above applications were examined. Market relevance may be found within the following uses:

- Civilian First Responder
- Military
- Construction/Welding

Definitions were articulated for each of these general classifications. Although the above uses provided broad-spectrum characterization, attempts to reveal direct market potential for the pyrotechnic thermite composition were made via an examination of markets more directly correlated to the identified applications. That is, while referenced as ―applications," this assessment also worked to explore the markets of:

- Disaster Clean-Up
- Flares
- Fire Starters
- Explosive Ordnance Disposal
-

Each market was defined, quantified, and market drivers and influences are explored. The tables below summarize the mechanisms of quantification and relevant figures. Please see the body of the report for full market characterizations.



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| Markets | Market Quantified By: | Quantification Results |
|---|---|---|
| Disaster Clean-Up | • Natural disasters<br>• Number of explosive incidents | • Natural disasters: 354 recorded in 2008, United States ranked second most affected country with 22 natural disasters<br>• Explosive incidents: 3,445 in 2006 |

| Markets | Market Quantified By: | Quantification Results |
|---|---|---|
| Flare<br>• CFR<br>• Military<br>• CEP | • Employment Statistics:<br>– CFR<br>– Police & Sheriff Patrol Officers<br>– Transit & Railroad Police<br>– Water Transportation<br>– Truck Transportation<br>• Number of commercial vehicles<br>• Exemplary urban center purchase agreements<br>• Flares sold annually in the US<br>• Military enlistment<br>• Number of military vessels | • Employment statistics<br>– CFR: 1,186,800 in 2008, projected to grow 10% from 2008-2018;<br>– Police & sheriff patrol officers: 661,500 in 2008 projected to grow 9% by 2018<br>– Transit and railroad police: 4,300 in 2008 projected to grow 5% by 2018<br>– Water transportation: 81,100 in 2008, projected to increased by 15% by 2018<br>– Truck transportation: 2,063 in 2008, projected to increase 11% by 2008<br>• Commercial vehicles: 247,421,120 in 2005<br>• Please see body of report<br>• Assuming an average cost per flare of $0.50 and $1.00 and annual sales of $20million by the largest domestic manufacture, estimated 20 to 40 million flares sold annually within the United States<br>• Military Enlistment: 1,459,072 members in 2009<br>• Military Vessels: ≈261,014 |

| Markets | Market Quantified By: | Quantification Results |
|---|---|---|
| Fire Starter<br>• CFR<br>• Military<br>• Outdoor Recreation<br>• CER | • Employment Statistics: CFR<br>• Number of natural disasters (power outage assumption)<br>• Rates & types of outdoor recreation, participation trends<br>• Military enlistment and deployments | • CFR: 1,186,800 in 2008, projected to grow 10% from 2008-2018<br>• Natural disasters: 10,000 thunderstorms, 2,500 floods, 1,000 tornadoes and six hurricanes in any given year in the US<br>• Outdoor recreation: 17.6 million back and cross country bike riders, 70.9 million backpackers on back-country or cross country, 33.9 million campers @ primitive sites<br>• Military enlistment and deployments: 1,459,072 enlisted, 132,000 troops deployed to Afghanistan and Iraq, 194,985 deployed in other foreign countries |



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| Markets | Market Quantified By: | Quantification Results |
|---|---|---|
| EOD<br>• CFR<br>• Military | • UXO occurrence<br>• Relevant DHS budgets<br>• Relevant DoD budgets | • UXO: 1500 sites covering 15 million acres where UXO have been disposed and require clean-up, 16,000 domestic inactive military ranges to require at least $14 billion cleanup effort<br>• DHS: FY10 increased by 4.9% from FY09, $9 million request for additional 109 bomb appraisal officers for 50% more airport coverage; $4.2 million request to enhance national bombing prevention and IED security efforts, $14.7 million to counter threat of IED to mass transit system<br>• DoD: FY06 Joint IED Defeat Fund of $3.3 billion, FY07 amount of $4.3 billion, FY08 was $4.5 billion: attack the network ($926,000 for Attack the Network, $2.7 million for Defeat the Device, $334,000 for Train the Force). Total funding thus far is $12.1 billion. |

| Markets | Market Quantified By: | Quantification Results |
|---|---|---|
| Construction & Welding | • Total annual construction spending<br>• Employment within the construction industry<br>• Value of US market for welding equipment & supplies<br>• Employment within welding industry | • Spending: $902,545 in Dec 2009 seasonally adjusted annual rate in millions of dollars (decrease from Nov 2009)<br>• Construction employment: 7.214 million employed in 2008, growth of 18.5% projected from 2008-2018<br>• Value: $4.6 billion of 2007 rising at an annual average growth rate of 3.5%.<br>• Welding employment: approximately 412,300 jobs in 2008. |

With regard to competitive landscape, existing solutions within each application were examined. As development ensues and product embodiment is realized, competitive advantage and potential product differentiation may likely stem from the pyrotechnic thermite composition‘s prospective advantages. The product-based competitive landscape was then identified to include the examples of:



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| Pyrotechnic Thermite Composition: Competitive Landscape | |
|---|---|
| ***Application*** | ***Existing Solutions*** |
| Disaster Clean-Up | • Heavy machinery<br>• Jaws of Life rescue systems |
| Flare | • Combustion Flares<br>• Chemical Solutions<br>• Electric Solutions |
| Fire Starter | • Thermite Fire Starter<br>• Survival Matches<br>• Fuel Lighters<br>• Lenses<br>• Fire Bow<br>• Spark-Lite<br>• Flint & Steel |
| Explosive Ordnance Disposal | • Mechanical Impact<br>• Controlled Detonation<br>• Robotic Devices<br>• Infrared jamming<br>• Electronic jamming<br>• Electromagnetic forced detonation<br>• PAN<br>• Laser systems<br>• Protected vehicles<br>• Protective armor<br>• Bomb blankets<br>• Bomb trolley, basket, sled<br>• Existing thermite solutions |
| General Construction/ Welding | • Hacksaws<br>• Jigsaws<br>• Reciprocating saws<br>• Band saws<br>• Circular saws<br>• Alternative welding techniques<br>• Existing thermite welding |

With regard to established industry competitors, licensees will need to make considerations for established firms‘ control of market share and their own competitive ability. That is, considerations should be made for the state of the industry as a whole, in addition to the specific markets examined here. Determinants of industry attractiveness can include, but are not limited to: supplier power, threat of substitutes, buyer power, barriers to entry and degree of rivalry. Within each market, licensees will need to analyze such industry facets in relation to their own competitive ability. Within the markets examined by this assessment, the pyrotechnic thermite composition‘s patent protection may serve as one base of competitive ability.

Based upon the properties of the pyrotechnic thermite composition (as claimed in U.S. patent 7,632,365 B1), its prospective advantages, and existing solutions—market viability may be feasible within each of the markets examined by this assessment. This viability, however, may be heavily dependent on a licensee‘s ability to competitively package and manufacture the pyrotechnic thermite composition. The present invention covers only the material composition of the pyrotechnic thermite composition and subsequent commercialized products



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will require further development. Ultimately, this market analysis does not recommend one application or market over another. General market characterizations are provided for each of the pyrotechnic thermite composition‘s potential applications in an effort to supply baseline analysis for further development and investigative efforts. In order for the pyrotechnic thermite composition to successfully penetrate a market, the claimed advantages of the technical solution must be aligned with engineering, manufacturing and cost control.



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# Appendix



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## Appendix A: Construction Employment Figures, Bureau of Labor Statistics

**Employment of wage and salary workers in construction, 2008 and projected change, 2008-2018. (Employment in thousands)**

| Occupation | Employment, 2008 | | Percent Change, 2008-18 |
|---|---|---|---|
| | Number | Percent | |
| All occupations | 7,214.9 | 100.0 | 18.5 |
| | | | |
| Management, business, and financial occupations | 571.4 | 7.9 | 21.6 |
| General and operations managers | 121.2 | 1.7 | 7.8 |
| Construction managers | 176.9 | 2.5 | 26.1 |
| Cost estimators | 128.0 | 1.8 | 32.6 |
| | | | |
| Office and administrative support occupations | 699.6 | 9.7 | 15.8 |
| Bookkeeping, accounting, and auditing clerks | 141.0 | 2.0 | 19.4 |
| Executive secretaries and administrative assistants | 75.9 | 1.1 | 17.5 |
| Secretaries, except legal, medical, and executive | 151.9 | 2.1 | 8.2 |
| Office clerks, general | 159.2 | 2.2 | 19.7 |
| | | | |
| Construction and extraction occupations | 4,741.7 | 65.7 | 18.0 |
| First-line supervisors/managers of construction trades and extraction workers | 442.1 | 6.1 | 22.7 |
| Brickmasons, blockmasons, and stonemasons | 110.5 | 1.5 | 14.3 |
| Carpenters | 721.0 | 10.0 | 15.2 |
| Carpet, floor, and tile installers and finishers | 79.4 | 1.1 | 13.3 |
| Cement masons, concrete finishers, and terrazzo workers | 184.7 | 2.6 | 13.9 |
| Construction laborers | 771.0 | 10.7 | 26.0 |
| Construction equipment operators | 297.5 | 4.1 | 18.1 |
| Drywall installers, ceiling tile installers, and tapers | 151.3 | 2.1 | 15.5 |
| Electricians | 484.0 | 6.7 | 15.3 |
| Painters and paperhangers | 197.6 | 2.7 | 8.2 |
| Pipelayers, plumbers, pipefitters, and steamfitters | 398.0 | 5.5 | 21.6 |
| Roofers | 113.5 | 1.6 | 6.5 |
| Sheet metal workers | 107.9 | 1.5 | 10.1 |
| Helpers, construction trades | 349.2 | 4.8 | 21.0 |
| | | | |
| Installation, maintenance, and repair occupations | 545.8 | 7.6 | 28.6 |
| Heating, air conditioning, and refrigeration mechanics and installers | 178.6 | 2.5 | 42.8 |



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| Employment of wage and salary workers in construction, 2008 and projected change, 2008-2018. (Employment in thousands) | | | |
|---|---|---|---|
| Occupation | Employment, 2008 | | Percent Change, 2008-18 |
| | Number | Percent | |
| **Line installers and repairers** | 83.5 | 1.2 | 21.4 |
| | | | |
| **Transportation and material moving occupations** | 251.8 | 3.5 | 12.6 |
| **Truck drivers, heavy and tractor-trailer** | 104.0 | 1.4 | 15.6 |

NOTE: Columns may not add to total due to omission of occupations with small employment.
SOURCE: BLS National Employment Matrix, 2008-18.



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# Appendix B: Sample Photos, Hurst Jaws of Life Rescue Systems

## SP310, Spreader

## SP510 Spreader

## SP512 Spreader

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## S510, S511, S311 Cutters

## S530 Cutter

## R430, R424 Rams

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## R414 Ram

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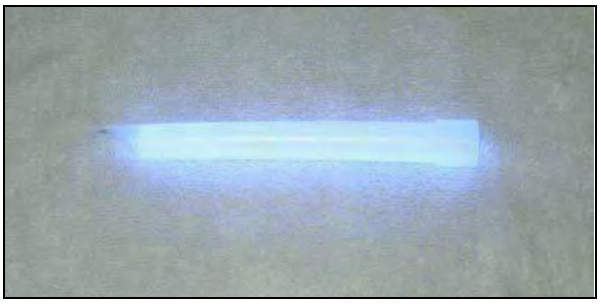
# Appendix C: Sample Photos, Chemical & Electric Flare Products

## Orion® Road Flares

## Power Flare®

## Cyalume® Lightsticks





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## TurboFlare™

## Tektite® ELZ™

## Galls® 36” Reflective Traffic Cones

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## Traffic Safety Store 28” Collapsible Cones

## ProFlare™

## Flare Alert™ Beacon Pro

## PDK Technologies Inc, LiteFlare®

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# Appendix D: Sample Photos, Fire Starter Product

## Portable Thermite Fire Starter: DBC Pyrotechnics

## Survival Matches: PROFORCE

## Flint & Steel Fire Starting Device: PROFORCE

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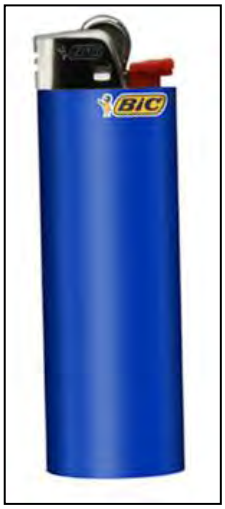
## Fuel-Based Lighter: Cabela's All-Weather, BIC




## Lense: Fresnel Lense Fire Starter

## Fire Bow: PrimitiveFire

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## Spark-Lite: AMK

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## Appendix E: Establishments with NAICS 333992, Welding and Soldering Equipment Manufacturing[79]

- ABB Flexible Automation/Weld
- ABB Robotics AB
- Ador Welding Ltd.
- Air Liquide Welding France S.A.
- Air Liquide Welding S.A.
- Airgas Intermountain Inc.
- Air-Vac Engineering Company Inc.
- Al Shark Electrode Co.
- Alexander Binzel Corp.
- Alexander Binzel Proprietary Ltd.
- Allied Manufacturing Corp.
- Alloy Rods Global Inc.
- AMA Industrial Co.
- American Torch Tip Co.
- Aquilex WSI
- Aro Welding Technologies Inc.
- Assembly Technologies International Inc.
- Automation Controls and Welder
- Automation International Inc.
- Baldsin Corp.
- Bambozzi S.A. Maquinas Hidraulicas e Eletricas
- Bancroft Corp.
- Banner Welder Inc.
- Belsvamo
- Bernard, Weldcraft and Plazcraft Products
- BernzOmatic
- Boehler-Uddeholm AG
- Burco Welding and Cutting Products Inc.
- C and G Systems Inc.
- Cadi Company Inc.
- Carl Cloos Schweisstechnik GmbH
- Castolin GmbH
- Charter Ltd.
- Chuo Seisakusho Ltd.
- Colakoglu Metalurji A.S.
- Cold Heat
- COMETALS
- Conarco Alambres Y Soldaduras S.A.
- Decatur Manufacturing Company Inc.
- Deloro Stellite Company Inc.
- Denco Inc.
- Dengensha Manufacturing Company Ltd.
- Diamond Weld Industries Inc.
- Dockson Corp.
- Ductil S.A.

[79] http://business.highbeam.com/company-profiles/general-machinery-manufacturing/welding-soldering-equipment-manufacturing



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- Dwight Company Inc.
- Dynaflux Inc.
- EF Technologies Inc.
- Egyptian Swedish Welding Electrodes Company ESWECO
- EKE-Yhtioet
- Electric Arc Jamaica Ltd.
- Electron Beam Technologies Inc.
- Elektrode Jesenice proizvodno, trgovsko in stroitveno podjetje, d.o.o.
- Emabond Solutions L.L.C.
- ESAB AB
- Esab GmbH
- Esab Group Ltd. (Waltham Cross, United Kingdom)
- Esab India Ltd.
- Esab Mexico S.A. de C.V.
- Esab S.A. Industria e Comercio
- Eutectic Corp.
- EWAC Alloys Ltd.
- EXPERT-TUeNKERS GmbH
- Fisher Barton Inc.
- Fives Industries S.A.
- Forney Industries Inc.
- Gardner Marketing Services Inc.
- GCE S.R.O.
- Gee Ltd.
- Goss Inc.
- Greenville Metal Works Inc.
- Grossel Tool Co.
- Grupo Industrial Dyfelsa - Dyfimsa
- Gys S.A.S.
- Henrob Corp.
- Hi-Tech Tool Industries Inc.
- Howard G Hinz Company Inc.
- Hyundai Welding Company Ltd.
- Icon Corp.
- nfra-Centre Ltd.
- International Systems and Technology Inc.
- Invertor Joint Stock Co.
- ITW Hobart Brothers Co.
- Janda Company Inc.
- JW Holdings Inc.
- Kaliburn Inc.
- Kawasaki Robotics G.m.b.H.
- Kawasaki Robotics Ltd. (Warrington, United Kingdom)
- Kemppi Oy
- Kirsch GmbH
- L.B. Allen Corp.
- Landre Machines B.V.
- Lincoln Electric Bester S.A.
- Lincoln Electric Co.
- Lincoln Electric do Brasil Industria e Comercio Ltda.



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- Lincoln Electric Mexicana S.A. de C.V.
- Lincoln Electric South Africa
- Lors Machinery Inc.
- Maitlen and Benson Inc.
- Manufacturing Technology Inc.
- Melton Machine and Control Co.
- Merchant and Rhoades Ltd.
- Messer Eutectic Castolin Switzerland S.A.
- MicroJoin Inc.
- Miller Electric Manufacturing
- Miller Weldmaster Corp.
- Miyachi Corp.
- MK Products Inc.
- Neotech Company Private Ltd.
- Nippon Steel Welding Products and Engineering Company Ltd.
- Nitrocor S.A. de C.V.
- NLC Inc.
- Novastar Technologies Inc.
- Obara Corp.
- OBO Bettermann GmbH and Company KG
- Oerlikon Schweisstechnik GmbH
- Oglesby and Butler Group PLC
- Otto Bihler Maschinenfabrik GmbH and Company KG
- Pandjiris Inc.
- Parker Seal De Baja S.A. de C.V.
- Paslin Co.
- Perun S.A.
- P-K Supply Co.
- Polaris Electronics Corp.
- Preston-Eastin Inc.
- Productech Inc.
- Progressive Tool and Industries Co./ Wisne Design
- Przedsiebiorstwo Aparatury Spawalniczej ASPA S.A.
- Ready Welder Corp.
- Reco of IL Inc.
- Robotic Process Systems Inc.
- Rothenberger S.A.
- Schlatter Holding AG
- SDMO Industries S.A.S.
- SGB Starkstrom-Geraetebau GmbH
- Sichuan Atlantic Welding Consumable Company Ltd.
- Sikama International Inc.
- Smith Equipment
- SMS ELOTHERM GmbH
- Sommer Products Company Inc.
- Sonic and Thermal Technologies
- Soudronic AG
- Ssco Manufacturing Inc.
- STI Electronics Inc.
- Stoody Co.



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- Svarnoy Ltd.
- Svejsemaskinefabrikken Migatronic A/S
- Taylor - Winfield Corp.
- Tec Torch Company Inc.
- Technical Devices Co.
- Technolit GmbH Spezialschweisstechnik
- Tecnomatix Technologies Inc.
- The Lincoln Electric Company Proprietary Ltd. (Padstow, Australia)
- Thermadyne Industries Inc.
- Thermal Dynamics Corp.
- Thermatool Corp.
- Tipaloy Inc.
- Tira Austenite Tbk, PT
- Tri-State Management Consltng
- Tucker GmbH
- Ultra Sonic Seal Co.
- Unitek Miyachi Corp.
- Uniweld Products Inc.
- VARSTROJ Tovarna varilne in rezalne opreme d.d.
- Waltex Inc.
- Wasa Proprietary Ltd.
- Weld Tooling Corp.
- Welding Alloys Inc.
- Welding Alloys Ltd.
- Welding Equipment and Supply Inc.
- Welding Technology Corp.
- Weldlogic Inc.
- Weldmation Inc.
- Western Enterprises
- Wolf Robotics Inc.



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# Appendix F: Sample Photos, Construction Products (DeWALT Power Tools)

## Hacksaw (DW3970)

## Jigsaw (DW317K)

## Reciprocating Saw (DW304)

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## Band Saw (DWM120)

## Grinder (D28144)

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T2+2™ Market Overview

# Radio Frequency and Microwave Test and Measurement Equipment For Telecommunication Applications

May 4, 2010

Project Number T2T0452IO
Navy Surface Warfare Center - Crane
was
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Radio Frequency (RF) and microwave test and measurement equipment are tools used in tasks of testing, measuring, analyzing, controlling, calibrating, displaying and recording data in laboratory and other testing situations.[1] Because of this range of testing modalities, there is also a wide variety of technical equipment to meet these needs; examples of these tools include signal generators, spectrum analyzers, phase shifters, oscilloscopes, hybrid couplers, mixers, low-noise amplifiers, and low-pass filters. Additionally, the scope of application areas for RF/microwave products is nearly as broad as the number of technologies themselves,[2] and these tools are extremely useful in aerospace and defense, telecommunications, electronics manufacturing and science and educational applications. Telecommunications is the largest end-user market however, and these networks are exceedingly dependent on the functionality of electronic test and measurement instruments, as the minutest distortion of signals can result in failure to communicate.[3]

In addition to network testing, telecommunications components and related subsystems in wireless devices such as cell phones, are often tested with RF and microwave test equipment to verify not only impedance, but also signal amplitude, distortion, and jitter (phase noise).[4] In terms of usage, radiofrequency test equipment is generally used in applications at frequencies of 1 gigahertz (GHz) and under, while microwave components are used in higher frequency applications. Because of this, there is generally a wider range of applications for RF test and measurement equipment and as the frequencies go up, these tools become increasingly expensive.[5] In light of this, this report will touch on microwave equipment but focus primarily on RF test and measurement equipment, as these appear to be the dominant test and measurement tools used in telecommunication applications.[6] While market sizes are hard to estimate, the following describes how we arrived at an estimate for the total test and measurement equipment market as well as the total RF test and measurement market. We estimate these market sizes to be approximately:

| *Market Niche Size* | | | |
|---|---|---|---|
| ***Market Size in Dollars*** | ***Growth Rate*** | ***Base Year*** | ***Detailed Basis for Estimate*** |

[1] "Test and Measurement Equipment." March 2009. Industry Mart web site. http://www.industrymart.com/articles/2009/03/test-measure-equipment.html (accessed May 4, 2010).
[2] Heavens, Chris et al. "Future Outlook For The RF And Microwave Industry." Tech-Trends. Arlon-Med web site. http://www.arlon-med.com/Future_Outlook_Microwave_Industry.pdf (accessed April 28, 2010).
[3] "Electronic Test & Measurement Market to Reach $4.5 billion by 2010." July 2007. Autotestnews web site. http://autotestnews.com/electronic-test-measurement-market-to-reach-45-billion-by-2010/ (accessed April 28, 2010).
[4] Reed, Greg. "As RF/microwave designs grow in popularity, so does the importance of validating and verifying their implementations." May 2008. Test & Measurement World web site. http://www.tmworld.com/article/320628-Check_electronics_success_with_RF_microwave_test.php?q=microwave+market+billion (accessed April 28, 2010).
[5] Anonymous, (Editor, Online Test and Measurement Magazine) in a phone conversation with Christopher Ahern on May 4, 2010.
[6] "World RF Test Equipment Markets." December 2009. Frost & Sullivan web site (subscription required). http://www.frost.com (accessed May 4, 2010).

| | | | |
|---|---|---|---|
| $1.77 billion (overall test & measurement equipment market) | 4% | 2006 | The revenue generated by the global electronic test and measuring equipment industry was estimated to be $1.77 billion in 2006 and grow to reach $2.33 billion in 2013,[7] representing a compound annual growth rate of approximately 4%. |
| $1.35 billion (RF test equipment market) | 2.33% | 2009 | Total global revenues for the RF test equipment market, which includes spectrum analyzers, signal generators, network analyzers, and power meters should increase from around $1.35 billion in 2009 to $1.48 billion in 2013,[8] which calculates to a compound annual growth rate of approximately 2.33%. |
| ~$400 million (RF test equipment used in communications applications) | 2.38% | 2009 | In communication applications, global revenues for the RF test equipment market are estimated to be around $400 million. This market segment is expected to grow to $450 million by 2014,[9] representing a compound annual growth rate of approximately 2.38%. |

The United States represents the single largest electronic test & measurement instruments market through 2001-2010. Sales in the United States are projected to reach 1.4 million units in 2010.[10] In all other RF applications, aerospace & defense makes up around 27% of global revenues, followed by industrial and electronics applications at around 26%.[11]

Market size and growth rate are a function of the number of people in the market and the anticipated rate of buying. As markets transition between emerging, growth, shakeout, mature, and declining, the basis for competition and the number of competitors usually changes, along with the factors influencing adoption of innovation. The number of and growth rate for customers suggests how many units might be sold.[12]

| *Our Current View on the Phase of the Market* | |
|---|---|
| ***Today*** | ***Trend*** |
| Mature | Mature |

[7] "Test and Measurement Equipment." March 2009. Industry Mart web site. http://www.industrymart.com/articles/2009/03/test-measure-equipment.html (accessed May 4, 2010).
[8] "RF testing market should expand in 2010." February 2010. Test & Measurement World web site. http://www.tmworld.com/article/445822-RF_testing_market_should_expand_in_2010.php (accessed April 28, 2010).
[9] "World RF Test Equipment Markets." December 2009. Frost & Sullivan web site (subscription required). http://www.frost.com (accessed May 4, 2010).
[10] "Electronic Test & Measurement Market to Reach $4.5 billion by 2010." July 2007. Autotestnews web site. http://autotestnews.com/electronic-test-measurement-market-to-reach-45-billion-by-2010/ (accessed April 28, 2010).
[11] "World RF Test Equipment Markets." December 2009. Frost & Sullivan web site (subscription required). http://www.frost.com (accessed May 4, 2010).
[12] For a detailed discussion of the "innovativeness dimension," see Everett M. Rogers, *Diffusion of Innovations*, 4th ed. (New York: Free Press, 1995). For further readings related to market phases and innovation, see also James Utterback, *Mastering the Dynamics of Innovation* (Boston: Harvard Business School Press, 1996) and Vijay K. Jolly, *Commercializing New Technologies: Getting from Mind to Market* (Boston: Harvard Business School Press, 1997).

The global test and measurement industry has been in existence for decades;[13] today, the industry is characterized by a few major players who control the majority of the test equipment market.[14] The market for RF test equipment, in particular, is in a mature stage and is also characterized by strong competition.[15] Despite this market maturity, investments in commercial communications are expected to be strong over the next few years, given the global expansion of third-generation (3G) and fourth-generation (4G) mobile cellular services, including Long Term Evolution (LTE) systems, which should continue to fuel opportunities for new RF and microwave test equipment. In wireless broadband applications, WiMAX also represents a growing market for high-frequency electronic test and measurement suppliers.[16]

Markets can also be described in terms of the basis for competition (best technological performance, best value or the price/performance tradeoff that best matches the end-users' preferences, lowest cost, or best availability or the ability to get the product quickly). This dimension helps to define the context in which a commercialization strategy must be developed.

| *Basis for Competition in the Arena* | |
|---|---|
| ***Today*** | ***Trend*** |
| Best Value | Best Value |

In commercial telecom applications, the market for test and measurement equipment appears to be driven by best value, as the top products are often determined based upon combinations of performance and value.[17] Moreover, recent advances in RF and microwave test equipment and software are generally geared toward simplifying testing, increasing measurement speed, and improving accuracy, or a combination of the three.[18] Another noticeable trend in both RF and microwave testing equipment is the integration of more test capabilities into single, one-box systems that can simplify overall testing processes.[19] Additionally, end users are constantly looking to introduce cheaper and lighter products into their manufacturing facilities and test procedures.[20]

---

[13] "Western Europe General Purpose Test and Measurement Equipment Market: Total General Purpose Test and Measurement Equipment Market." September 2008. Frost & Sullivan web site (subscription required). http://www.frost.com (accessed May 4, 2010).
[14] "An Interview with John Regazzi." February 2010. Microwaves & RF web site. http://www.mwrf.com/Articles/ArticleID/22404/22404.html (accessed April 28, 2010).
[15] "World RF Test Equipment Markets." December 2009. Frost & Sullivan web site (subscription required). http://www.frost.com (accessed May 4, 2010).
[16] Heavens, Chris et al. "Future Outlook For The RF And Microwave Industry." Tech-Trends. Arlon-Med web site. http://www.arlon-med.com/Future_Outlook_Microwave_Industry.pdf (accessed April 28, 2010).
[17] "Top Products of 2009." Microwaves & RF web site. http://www.mwrf.com/Articles/ArticleID/22251/22251.html (accessed April 28, 2010).
[18] "Measuring Advances in RF/Microwave Test Equipment." October 2007. Microwaves & RF web site. http://www.mwrf.com/Articles/Index.cfm?Ad=1&ArticleID=17221 (accessed April 28, 2010).
[19] "RF testing market should expand in 2010." February 2010. Test & Measurement World web site. http://www.tmworld.com/article/445822-RF_testing_market_should_expand_in_2010.php (accessed April 28, 2010).
[20] Mathew, Vijay. "Emergence of the Low-cost Test and Measurement Equipment market." April 2007. Frost & Sullivan web site (subscription required). http://www.frost.com (accessed May 4, 2010).

In each market there may be stakeholders and companies with significant market share that will influence the introduction of your technology. Some organizations or companies that will likely influence the introduction of this technology are the following:

| *Examples of Major Competitors in the Arena* | | |
|---|---|---|
| ***Competitor*** | ***Relevance*** | ***Web site*** |
| Agilent Technologies | Agilent Technologies is a leading provider of RF and microwave testing tools.[21] | http://www.home.agilent.com |
| Tektronix | Tektronix has been developing test, measurement and monitoring devices for sixty years and its products include signal generators, spectrum and logic analyzers, and oscilloscopes among others.[22] | http://www.tek.com |
| Rohde & Schwarz | Rohde & Schwarz is a global manufacturer and supplier of electronic test and measurement equipment, as well as solutions for broadcasting, secure communications, and radio monitoring.[23] | http://www.rohde-schwarz.com |
| Keithley Instruments | Keithley Instruments is a developer and supplier of advanced electrical test instruments and systems from DC to RF ranges. Keithley's products are used in solving emerging measurement needs in production testing, process monitoring, product development, and research.[24] | http://www.keithley.com/ |
| Aeroflex | Aeroflex is a high technology company that designs, develops, manufactures and markets a diverse group of microelectronic and test and measurement products used in supporting communication systems, networks, and automatic test systems.[25] | http://www.aeroflex.com/ |
| National Instruments | National Instruments offers a range of RF and wireless test equipment which operates from DC to 6.6 GHz with up to | http://www.ni.com/ |

[21] "RF & Microwave." Agilent Technologies web site. http://www.home.agilent.com/agilent/application.jspx?nid=-34787.0.00&lc=eng&cc=US (accessed May 4, 2010).
[22] Tektronix web site. http://www.tek.com/ (accessed April 28, 2010).
[23] Rhode & Schwarz web site. http://www2.rohde-schwarz.com/ (accessed April 28, 2010).
[24] "Achieving Accurate and Reliable Resistance Measurements in Low Power and Low Voltage Applications." Microwaves & RF web site. http://www.mwrf.com/whitepapers/Index.cfm?fuseaction=ShowWP&WPID=e448bd36-0ef7-4fee-a212-00a8f7d22a00 (accessed April 28, 2010).
[25] "About Aeroflex." Aeroflex web site. http://www.aeroflex.com/about.cfm (accessed April 28, 2010).

| | | |
|---|---|---|
| | 100 MHz of instantaneous RF bandwidth.[26] | |

| *Examples of Key Stakeholders or Networking Channels with Contact Information* | | |
|---|---|---|
| ***Stakeholder*** | ***Relevance*** | ***Contact Information*** |
| Automated RF & Microwave Measurement Society (ARMMS) | Founded in 1982, ARMMS is an industry group dedicated to supporting all aspects of RF and microwave engineering and has expanded to cover diverse topics in Radio and Radar design and test, metrology, medical, and materials testing.[27] | Roger Hopper<br>Chairman<br>Roke Manor Research<br>Email: roger.hopper@roke.co.uk<br><br>http://www.armms.org |
| Automatic RF Techniques Group (ARFTG) | ARFTG is a technical organization that covers the diverse industry and field of RF and Microwave test and measurement.[28] | Ron Ginley<br>ARFTG Vice President<br>PO Box 228<br>Rome, NY 13442<br>Tel: 303-497-3634<br><br>http://www.arftg.org/ |
| IEEE | The IEEE is a global organization that provides and develops standards, reports, and industry news in areas that include aerospace, telecommunications, electric power, and consumer electronics.[29] | 3 Park Avenue, 17th Floor<br>New York, NY 10016<br>Tel: 212-419-7900<br><br>http://www.ieee.org |
| The International Society of Automation's Measurement, Control & Automation Association | The Measurement, Control & Automation Association is an industry association that seeks to establish an information exchange and to promote cutting edge technology and developments.[30] | Grant Patterson<br>Director<br>Tel: 931-454-5213<br>67 Alexander Drive<br>Research Triangle Park, NC 27709<br><br>http://www.isa.org |
| Semiconductor Equipment and Materials International (SEMI) | SEMI is an international organization that supports the manufacturing supply chains of microelectronic, display and photovoltaic industries.[31] | 3081 Zanker Road<br>San Jose, CA 95134<br>Tel: 408-943-6900<br><br>http://www.semi.org/en/index.htm |
| National Institute of Standards and Technology (NIST) | NIST is a non-regulatory federal agency that seeks to promote U.S. innovation and industrial competitiveness through | 100 Bureau Drive, Stop 1070<br>Gaithersburg, MD 20899-1070<br>Tel: 301-975-6478 |

[26] "RF Wireless and Test." National Instruments web site. http://sine.ni.com/np/app/main/p/ap/mi/lang/en/pg/1/sn/n21:1914,n17:mi (accessed May 6, 2010).
[27] "About ARMMS." ARMMS web site. http://www.armms.org/microwaveradiofrequency.php (accessed April 28, 2010).
[28] "What is ARFTG?" The Automatic RF Techniques Group web site. http://www.arftg.org/what_is_arftg.html (accessed April 28, 2010).
[29] "About Us." IEEE Standards Association web site. http://standards.ieee.org/announcements/PRNESR.html (accessed April 28, 2010).
[30] The Measurement, Control & Automation Association web site. http://www.isa.org/MSTemplate.cfm?MicrositeID=544&CommitteeID=5236 (accessed May 4, 2010).
[31] "Home Page." Semiconductor Equipment and Materials International web site. http://www.semi.org/en/index.htm (accessed April 27, 2010).

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| | the advancement of measurement science, standards, and technology.[32] | http://www.nist.gov/ |
| 3G Americas | 3G Americas is a trade organization established to unite mobile operators and manufacturers in the Americas to provide a single voice to represent the GSM family of wireless technologies – GSM, EDGE, HSPA and LTE.[33] | 1750 - 112th Avenue NE, Suite B220<br>Bellevue, WA 98004<br>Tel: 425-372-8922<br><br>http://www.3gamericas.org/ |
| GSM Association | The GSMA represents the world-wide mobile communications industry, including mobile operators, handset makers, software companies, equipment providers, Internet companies, and media and entertainment organizations.[34] | Seventh Floor<br>5 New Street Square<br>New Fetter Lane<br>London<br>EC4A 3BF<br>UK<br>Tel: +44 (0)207 356 0600<br><br>http://www.gsmworld.com |

Entry barriers are obstacles that remove customer segments from the market for some period of time. They limit the size of the addressable market in general or the market share that can be captured. These barriers must be overcome or avoided to have a successful market entry. Our work to date suggests the following entry barriers may prevent customer segments from buying this type of technology for some period of time.

| *Market Entry Barriers* | |
|---|---|
| ***Name of Barrier*** | ***Description/Why*** |
| ***Increasingly Complexity of Testing Requirements*** | The test process has increasingly become more complex as the test and measurement industry is forced to address the concerns of chip manufacturers and decrease the cost of ownership of test systems.[35] The advent of system-on-a-chip (SoC) devices has highlighted the need to effectively test a wide range of circuit types, including analog circuits, high-speed interfaces, embedded memories, mixed-signal circuits, and RF circuits.[36] Additionally, the growing number of advanced networks is further straining the use of current testing modalities.[37] This increasing complexity of measurement parameters, in addition to demand for lower cost units, may challenge firms to deliver increasingly sophisticated products at lower price points. |
| ***High Capital Costs*** | Capitalization requirements to enter and successfully attain a leadership position in the RF and microwave test and measurement industry are increasing |

[32] "General Information." National Institute of Standards and Technology web site. http://www.nist.gov/public_affairs/general2.htm (accessed May 6, 2010).
[33] "About 3G Americas." 3G Americas web site. http://www.3gamericas.org/index.cfm?fuseaction=page&sectionid=106 (accessed April 27, 2010).
[34] "About Us." GSM Association web site. http://www.gsmworld.com/about-us/index.htm (accessed April 27, 2010).
[35] "RF testing market should expand in 2010." February 2010. Test & Measurement World web site. http://www.tmworld.com/article/445822-RF_testing_market_should_expand_in_2010.php (accessed April 28, 2010).
[36] Allan, Roger. "RF Instruments Must Cope With Massive Market." January 2006. Electronic Design web site. http://electronicdesign.com/article/test-and-measurement/rf-instruments-must-cope-with-massive-market11767.aspx (accessed April 28, 2010).
[37] Heavens, Chris et al. "Future Outlook For The RF And Microwave Industry." Tech-Trends. Arlon-Med web site. http://www.arlon-med.com/Future_Outlook_Microwave_Industry.pdf (accessed April 28, 2010).

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| | dramatically, due to product complexity and the presence of entrenched competitors.[38] This is a common occurrence with mature markets and may pose a barrier to entrants with insufficient capital. |
| ***Conservative Nature of End-Users*** | The conservative nature of some end-users, specifically exhibited in a hesitance toward adopting newer test solutions, has been a major challenge for vendors of modular solutions in the test and measurement market. As end-users have been accustomed to traditional solutions for many years,[39] new or more advanced systems may face adoption challenges in initial product deployments. This challenge may only be a factor for well established applications, as unique, increasingly complex, or newer uses for such equipment may circumvent such a barrier. |

In the test and measurement sector, one issue that continues to gain prominence is the growing complexity of testing regimes and the need to test and measure the wide variety of digitally modulated signals on the market. Today, engineers and technicians require test equipment that can measure many different signals, whether W-CDMA/HSDPA, CDMA/EVDO, WiMAX, or GSM/EDGE, and they must also be able to measure all these complex signals with extreme accuracy.[40] This growing complexity is likely to remain a major challenge for vendors with respect to successful market navigation for the foreseeable future. As test equipment vendors are under constant pressure to keep pace with the latest technology innovations, it has become necessary to implement multiple standards at the same time, which can increase costs and reduce profit margins.[41]

Market drivers are forces that strengthen or weaken the importance of end-user needs over time.

| *Market Drivers* | |
|---|---|
| ***Name of Driver*** | ***Why Significant*** |
| ***Expanding Use in Testing Consumer Electronics*** | Higher demand for test equipment has been a result of increased focus on communications products and equipment.[42] Consumer devices are continually gaining more wireless capabilities and greater functionality. Given this trend, RF and microwave test equipment has correspondingly increased in importance as manufacturers of cellular, Bluetooth, and WLAN devices need to ensure their products meet customer demands and conform to the governing standards.[43] |

[38] "An Interview with John Regazzi." February 2010. Microwaves & RF web site. http://www.mwrf.com/Articles/ArticleID/22404/22404.html (accessed April 28, 2010).
[39] "World RF Test Equipment Markets." December 2009. Frost & Sullivan web site (subscription required). http://www.frost.com (accessed May 4, 2010).
[40] Heavens, Chris et al. "Future Outlook For The RF And Microwave Industry." Tech-Trends. Arlon-Med web site. http://www.arlon-med.com/Future_Outlook_Microwave_Industry.pdf (accessed April 28, 2010).
[41] "Frost: Communication Sector Growth to Boost Revenues for Test, Measurement Equipment Market." October 2007. IHS Global Insight web site. http://electronics.ihs.com/news/frost-test-measurement.htm (accessed May 4, 2010).
[42] "World RF Test Equipment Markets." December 2009. Frost & Sullivan web site (subscription required). http://www.frost.com (accessed May 4, 2010).
[43] Reed, Greg. "As RF/microwave designs grow in popularity, so does the importance of validating and verifying their implementations." May 2008. Test & Measurement World web site. http://www.tmworld.com/article/320628-Check_electronics_success_with_RF_microwave_test.php?q=microwave+market+billion (accessed April 28, 2010).

| | |
|---|---|
| ***Expanding LTE Networks Drive Test And Measurement Needs*** | Today, the need to develop and test handsets to meet the extreme performance requirements (increased data rates, higher spectral efficiency, and lower latency) of LTE (Long Term Evolution) networks will accelerate due to increased deployments of these next generation networks.[44] This also holds true for network test and measurement as well, since LTE network testing is quite complex. During the development, manufacturing, installation, and maintenance of LTE infrastructure, changes and upgrades will have to be made to the test specifications, as well as how tests are conducted,[45] likely further spurring development of new test and measurement systems and protocols. |
| ***Opening Up of New Networks in Emerging Markets*** | Developers of test equipment are becoming more motivated by expected growth in emerging markets.[46] New networks in developing economies have now become major demand drivers for the electronic test and measurement instruments market.[47] |
| ***Economic Downturn*** | The global recession impacted a wide range of industries, including the communications test and measurement equipment market. End-users were very circumspect about their capital expenditure, and as the global economy declined, so did investments in test and measurement equipment.[48] This slow down in demand is likely to only remain an issue for the duration of the downturn, and demand may trend upwards with the expected recovery. |

Despite the maturing of the telecommunications test and measurement market, the establishment of new networks in developing economies and the need to upgrade existing communication infrastructure have become strong drivers of demand in the market.[49] It is expected that the number of smart phones that will run on these new networks will increase dramatically, thus significantly pushing the limits of the infrastructure. This is particularly anticipated in regards to new smart devices which are going to push a lot of data, translating into stringent latency requirements as the entire end-to-end performance and end-user experience will be very visible. Customer turnover is far higher with media rich services and, as a result, the requirement for simulation and scientifically analyzing and gathering data is far greater in these media-rich networks than in the past.[50]

Here are some additional data and sources that can help you better understand the market.

| *Name* | *Description* |
|---|---|

[44] "RF testing market should expand in 2010." February 2010. Test & Measurement World web site. http://www.tmworld.com/article/445822-RF_testing_market_should_expand_in_2010.php (accessed April 28, 2010).
[45] Friedrich, Nancy. "Measurement Equipment Readies For LTE Rollout." October 2009. Microwaves & RF web site. http://www.mwrf.com/Articles/ArticleID/22044/22044.html (accessed May 4, 2010).
[46] "Measuring Advances in RF/Microwave Test Equipment." October 2007. Microwaves & RF web site. http://www.mwrf.com/Articles/Index.cfm?Ad=1&ArticleID=17221 (accessed April 28, 2010).
[47] "Electronic Test & Measurement Market to Reach $4.5 billion by 2010." July 2007. Autotestnews web site. http://autotestnews.com/electronic-test-measurement-market-to-reach-45-billion-by-2010/ (accessed April 28, 2010).
[48] "Movers & Shakers Interview with Atul Bhatnagar, CEO, Ixia." April 2010. Frost & Sullivan web site (subscription required). http://www.frost.com (accessed April 28, 2010).
[49] "Electronic Test & Measurement Market to Reach $4.5 billion by 2010." July 2007. Autotestnews web site. http://autotestnews.com/electronic-test-measurement-market-to-reach-45-billion-by-2010/ (accessed April 28, 2010).
[50] "Movers & Shakers Interview with Atul Bhatnagar, CEO, Ixia." April 2010. Frost & Sullivan web site (subscription required). http://www.frost.com (accessed April 28, 2010).

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| *Microwaves & RF* | *Microwaves & RF* is an online news and industry source that provides up-to-date articles, white papers, products listings and other related material dedicated to microwave and radiofrequency applications and industries.<br><br>For more information please see the following URL:<br>http://www.mwrf.com |
| *Test & Measurement World* | *Test & Measurement World* is a print and online magazine that provides technology trends, product reviews, newsletters, blogs and other resources dedicated to the field of test and measurement.<br><br>For more information please see the following URL:<br>http://www.tmworld.com/ |

T2+2™ Market Overview

# Interoperable Communication Tools for First Responders

May 5, 2010

Project Number T2T0454IO
Navy Surface Warfare Center - Crane
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After the events of September 11, 2001 and Hurricane Katrina in 2005, there has been a surge of interest in developing and implementing interoperable communication systems for first responders.[1] Such voice, data and radio interoperability is a critical need for first responders (police, fire, emergency medical technicians (EMTs), etc) at the scene of an emergency or disaster, [2] whether of natural or manmade origin. The use of properly planned, established, and applied communication tools can enable the dissemination of information among command and support elements and cooperating agencies and organizations.[3] There are a number of ways in which first responders can work collaboratively in terms of communication but this report will focus primarily on hardware and radio-based methods (such as patching, cross-band repeaters, gates, terminals and others).[4] Our research indicated however that specific publically available market data on first responder communication technologies to be lacking except for funding data for grants by the Department of Homeland Security. Additionally we have also provided market data for revenues generated by communication terminals in first responder applications as they are an integral component in the overall first responder communication market. While market sizes are hard to estimate, the following describes how we arrived at a figure for the overall funding to improve communications interoperability. We estimate this funding size to be approximately:

| *Market Niche Size* | | | |
|---|---|---|---|
| ***Market Size in Dollars*** | ***Growth Rate*** | ***Base Year*** | ***Detailed Basis for Estimate*** |
| $4.3 billion | n/a | 2004-2008 | From 2004 to 2008 (the only years which detailed figures are publically available) the U.S. Department of Homeland Security has approved more than $4.3 billion in grant money to improve communications interoperability among first responders. As of 2008, 75% of this funding has gone to hardware development.[5]<br><br>No forward looking growth rates or future funding dollar amounts were provided in this source; however funding is expected to continue to be strong in the near term with additional support from the economic stimulus package.[6] |

[1] Lascow, Sarah. "Are Americas First Responders Better Off Following Billions of Dollars?" February 2010. Daily Estimate web site. http://www.dailyestimate.com/article.asp?id=27768 (accessed May 5, 2010).
[2] "Data Interoperability." COMCARE web site. http://www.comcare.org/Interoperability.html (accessed May 5, 2010).
[3] "Communications and Information Management." Federal Emergency Management Agency web site. http://www.fema.gov/emergency/nims/CommunicationsInfoMngmnt.shtm#item1 (accessed May 5, 2010).
[4] "Public Safety Radio Interoperability Progress and Issues Assessment Markets and Technologies." March 2008. *PracTel Inc.* Research and Markets web site. http://www.researchandmarkets.com/reportinfo.asp?report_id=596463 (accessed May 5, 2010).
[5] Lascow, Sarah. "Are Americas First Responders Better Off Following Billions of Dollars?" February 2010. Daily Estimate web site. http://www.dailyestimate.com/article.asp?id=27768 (accessed May 5, 2010).
[6] Ibid.

| | | | |
|---|---|---|---|
| $200 million (European first responder communications market) | 4.61% | 2009 | In Europe, revenues generated from communications equipment in first responder applications were estimated to be $200 million in 2009. This market is expected to reach nearly $300 million by 2018,[7] a compound annual growth rate of 4.61%. |
| $1 billion (global first responder communications terminal market) | 23.8%. | 2007 | A 2008 report by ABI research on the global market for communication terminals (which receive process and transmit signals[8]) used by emergency first responders estimates the market to grow significantly over the next five years from slightly more than $1billion in 2007 to more than $3.6 billion in 2013,[9] a compound annual growth rate of 23.8%. |
| 100,000+ emergency response agencies in the U.S. | n/a | 2010 | This estimate was derived from the COMCARE – Emergency Response Alliance.[10] Although not a dollar estimate, this figure provides an idea as to the actual scale of the market in terms of end user agencies. |

According to the Federal Emergency Management Agency (FEMA) there are approximately 60 State Offices and Agencies of Emergency Management in the United States.[11] In a catastrophic disaster, FEMA coordinates the federal response, working with 28 federal partners and the American Red Cross to provide emergency food and water, medical supplies and services, search and rescue operations, transportation assistance, environmental assessment, and other services.[12] More over, a conservative estimate by the Department of Homeland Security shows that over 25.3 million individuals work or volunteer as first responders in the United States.[13]

The U.S. Department of Homeland Security's Federal Emergency Management Agency (FEMA) assists first responders through the Commercial Equipment Direct Assistance Program (CEDAP). In 2008, $17.6 million was provided to 1,045 emergency response agencies in 46 states for equipment and training under the CEDAP program.[14]

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[7] "European First Responders C3I Market Assessment: Communication." August 2009. Frost & Sullivan web site (subscription required). http://www.frost.com (accessed May 5, 2010).
[8] "First Responders Guide to Satellite Communications." *Access Intelligence*. Satellite Industry Association web site. http://www.sia.org/guide.pdf (accessed May 5, 2010).
[9] "First Responder Terminal Market to Reach $3.5 Billion by 2013." November 2008. ABI Research web site. http://www.abiresearch.com/press/1289-First+Responder+Terminal+Market+to+Reach+$3.5+Billion+by+2013 (accessed May 5, 2010).
[10] "Data Interoperability." COMCARE web site. http://www.comcare.org/Interoperability.html (accessed May 5, 2010).
[11] "State Offices and Agencies of Emergency Management." Federal Emergency Management Agency web site. http://www.fema.gov/about/contact/statedr.shtm (accessed May 5, 2010).
[12] "Federal-level Partners." Federal Emergency Management Agency web site. http://www.fema.gov/about/fedpart.shtm (accessed May 5, 2010).
[13] Cellucci, Thomas A. "Commercialization: The First Responders' Best Friend." January 2009. United States Department of Homeland Security web site. http://www.dhs.gov/xlibrary/assets/st_first_responder_commercialization_article.pdf (accessed May 5, 2010).
[14] "Commercial Equipment Direct Assistance Program (CEDAP)." Federal Emergency Management Agency web site. http://www.fema.gov/government/grant/cedap/index.shtm (accessed May 5, 2010).

In general few first responder scenarios are simple as most require multiple responses, such as local police, fire and ambulance. Larger incidents such as an airplane crash, large fire, or terrorist attack often require a major commitment from numerous entities including local police, ambulance, fire, state police, state and federal emergency management agencies and possibly the National Guard.[15]

Market size and growth rate are a function of the number of people in the market and the anticipated rate of buying. As markets transition between emerging, growth, shakeout, mature, and declining, the basis for competition and the number of competitors usually changes, along with the factors influencing adoption of innovation. The number of and growth rate for customers suggests how many units might be sold.[16]

| *Our Current View on the Phase of the Market* | |
|---|---|
| ***Today*** | ***Trend*** |
| Growth/Mature | Mature |

Interoperable communications for first responders was first addressed in the early 1970s;[17] since then, strong growth particularly in the last five years was realized as companies have been scrambling to serve the first responder market due to increasing levels of funding and the idea that no single solution fits all needs. Given this, companies from all markets, such as software, communications, hardware, and services have found a range of revenue opportunities in the first responder communication market.[18] Federal funding is likely to continue to play a strong role in the industry as in 2007 alone, the departments of Justice and Homeland Security awarded almost $1.2 billion in grants, for new public-safety and law-enforcement communications projects.[19] Continued government funding, particularly in the U.S., for interoperable first responder communications equipment is expected and as such the market will likely remain in a more growth phase.[20] This currently growth industry however is likely transition to a

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[15] "Interoperability White Paper - First Responder Communications." *Frontier Systems Integrators*. Racom web site. http://www.racom.net/Downloads/Interoperability.pdf (accessed May 5, 2010).
[16] For a detailed discussion of the "innovativeness dimension," see Everett M. Rogers, *Diffusion of Innovations*, 4th ed. (New York: Free Press, 1995). For further readings related to market phases and innovation, see also James Utterback, *Mastering the Dynamics of Innovation* (Boston: Harvard Business School Press, 1996) and Vijay K. Jolly, *Commercializing New Technologies: Getting from Mind to Market* (Boston: Harvard Business School Press, 1997).
[17] "Interoperable Communications for First Responders." *Frost & Sullivan*. AT&T web site. http://www.corp.att.com/stateandlocal/docs/Interop.pdf (accessed May 5, 2010).
[18] "First responder market sees a potential for growth in all technologies." December 2005. EMS1.com web site. http://www.ems1.com/ems-products/aeds/articles/14113-First-responder-market-sees-a-potential-for-growth-in-all-technologies/ (accessed May 5, 2010).
[19] "Agencies Put Federal Funding to Use." Radio Resource Media Group web site. http://www.radioresourcemag.com/onlyonline.cfm?OnlyOnlineID=63 (accessed May 5, 2010).
[20] Lascow, Sarah. "Are Americas First Responders Better Off Following Billions of Dollars?" February 2010. Daily Estimate web site. http://www.dailyestimate.com/article.asp?id=27768 (accessed May 5, 2010).

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more mature market in the medium term as the robust funding activity enjoyed previously in the market is unlikely to be sustained in the longer term. Additionally the presence of such dominant firms like Motorola which controls nearly 80% of the U.S. market[21] is further evidence of market with more mature market characteristics.

Markets can also be described in terms of the basis for competition (best technological performance, best value or the price/performance tradeoff that best matches the end-users' preferences, lowest cost, or best availability or the ability to get the product quickly). This dimension helps to define the context in which a commercialization strategy must be developed.

| *Basis for Competition in the Arena* | |
|---|---|
| ***Today*** | ***Trend*** |
| Best Value | Best Value |

The market appears to be driven by best value as simplicity and price vs. performance are some of the main drivers of hardware based communication systems for first responders.[22] Additionally, funding can be limited for some end users to procure such equipment, [23] and as such high equipment costs can hamper adoption of new technology.[24] Despite these cost concerns, performance is also a critical factor as the communication devices and other tools that form an integral part of public safety and defense systems used by first responders need to be fool-proof and dependable.[25] Factors such as redundancy, resiliency and interoperability are some of the key technology considerations for emergency response communication systems.[26] Given this, new communication technology needs to be field tested by third parties before being implemented.[27]

In each market there may be stakeholders and companies with significant market share that will influence the introduction of your technology. Some organizations or companies that will likely influence the introduction of this technology are the following:

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[21] Ibid.
[22] "Public Safety Radio Interoperability Progress and Issues Assessment Markets and Technologies." March 2008. *PracTel Inc.* Research and Markets web site. http://www.researchandmarkets.com/reportinfo.asp?report_id=596463 (accessed May 5, 2010).
[23] "Call for help: for first responders, high-tech communications still out of reach." March 2008. *National Defense*. Goliath web site. http://goliath.ecnext.com/coms2/gi_0199-7628204/Call-for-help-for-first.html (accessed May 5, 2010).
[24] Latshaw, Greg. "New technology guides first responders." March 2008. USA Today web site. http://www.usatoday.com/tech/news/techpolicy/2008-05-19-emergencygps_N.htm (accessed May 5, 2010).
[25] "Homeland Security Alert: Technologies for First Responders." March 2009. Frost & Sullivan web site (subscription required). http://www.frost.com (accessed May 5, 2010).
[26] "National Incident Management System." December 2008. Federal Emergency Management Agency web site. http://www.fema.gov/pdf/emergency/nims/NIMS_core.pdf (accessed May 5, 2010).
[27] "Call for help: for first responders, high-tech communications still out of reach." March 2008. *National Defense*. Goliath web site. http://goliath.ecnext.com/coms2/gi_0199-7628204/Call-for-help-for-first.html (accessed May 5, 2010).

| *Examples of Major Competitors in the Arena* | | |
|---|---|---|
| ***Competitor*** | ***Relevance*** | ***Web site*** |
| Motorola | Motorola is a leading developer of mission-critical communication solutions for first responder applications.[28] | http://business.motorola.com |
| BAE Systems | BAE Systems' First InterComm™ is a vehicle mounted system that allows first responders to utilize existing radios and frequencies and links all radios at an incident scene and enables talk-groups without the need for towers or infrastructure.[29] | http://www.baesystems.com/ |
| Raytheon | Raytheon's TRP-1000 Transportable Radio Interconnect System enables radio interoperability for situations requiring communications between diverse organizations using different radios and different frequencies.[30] | http://www.raytheon.com/ |
| Advatech Pacific, Inc. | Advatech Pacific's uGATE-ICN provides a portable communication interface that enables a satellite interface as well as connectors for up to three radio networks in up to two talk groups, or sub-networks.[31] | http://www.advatechpacific.com/ |
| Mutualink | Mutualink provides interoperability solutions including portable interoperable workstations that act as the point of communication between entities on a network for voice, text and sharing of data files.[32] | http://www.mutualink.net |
| Impact Technologies | Impact Technologies has developed a platform product called DAKS which is a high-performance, high-availability telecommunications system that delivers | http://www.impacttech.com/ |

[28] "Mission Critical Design." Motorola web site. http://business.motorola.com/publicsafety/missioncritical/index2.asp (accessed May 5, 2010).
[29] "First InterComm™ - First Responder Interoperable Communications." Responder Knowledge Base, Federal Emergency Management Agency web site. https://www.rkb.us/contentdetail.cfm?content_id=168851 (accessed May 5, 2010).
[30] "Raytheon JPS Communication TRP-1000 Transportable Radio Interconnect." Antenna Systems and Solutions web site. http://www.antennasystems.com/JPSRadio/TRP1000.html (accessed May 5, 2010).
[31] "Advatech Pacific's uGATE-ICN." Responder Knowledge Base, Federal Emergency Management Agency web site. https://www.rkb.us/contentdetail.cfm?content_id=189986 (accessed May 5, 2010).
[32] "Our Architecture." Mutualink web site. http://www.mutualink.net/OurArchitecture.asp (accessed May 5, 2010).

| | | |
|---|---|---|
| | mission-critical collaboration and alerting solutions.[33] | |
| Catalyst Communications | Catalyst Communications offers solutions for Primary Dispatch, Back-up Dispatch, and Interoperability solutions based on Radio control over IP (RCoIP) technology.[34] | http://www.catcomtec.com/ |

| *Examples of Key Stakeholders or Networking Channels with Contact Information* | | |
|---|---|---|
| ***Stakeholder*** | ***Relevance*** | ***Contact Information*** |
| Department of Homeland Security (DHS) | In 2004, the DHS directed the development of the National Incident Management System (NIMS) which provides a standard nationwide template to enable Federal, State, tribal, and local governments, nongovernmental organizations (NGOs), and the private sector to work together to prevent, protect against, respond to, recover from, and mitigate the effects of incidents, regardless of cause, size, location, or complexity.[35] | 12th & C Street SW<br>Washington, DC 200024<br>Tel: 202-282-8000<br>http://www.dhs.gov |
| Federal Emergency Management Agency (FEMA) | Part of the Department of Homeland Security, FEMA's mission is to support first responders and improve the capabilities to prepare, protect, respond and recover from all types of hazards.[36] | 500 C Street S.W.<br>Washington, D.C. 20472<br>Tel: 202-646-2500<br>http://www.fema.gov |
| Association of Public-Safety Communications Officials (APCO) | APCO International is a leading organization dedicated to public safety communications and has more than 15,000 members.[37] | 351 N. Williamson Blvd.<br>Daytona Beach, FL 32114<br>Tel: 386-322-2500<br>http://www.apco911.org/ |
| COMCARE - Emergency Response Alliance | COMCARE is a non-profit national advocacy organization with over 100 members that is dedicated to advancing emergency communications.[38] | 1701 K Street, NW<br>Fourth Floor<br>Washington, DC 20006<br>Tel: 202-429-0574<br>http://www.comcare.org/ |
| Telecommunications Industry Association (TIA) | TIA is a trade association representing the global information and communications technology (ICT) industries with efforts including standards development, government | 2500 Wilson Boulevard, Suite 300<br>Arlington, VA 22201<br>Tel: 703-907-7700<br>http://www.tiaonline.org/ |

[33] "Mission Critical Collaboration & Notification." Impact Technologies web site. http://www.impacttech.com/index.php?p=34 (accessed May 5, 2010).
[34] Catalyst Communications web site. http://www.catcomtec.com/ (accessed May 5, 2010).
[35] "National Incident Management System." December 2008. Federal Emergency Management Agency web site. http://www.fema.gov/pdf/emergency/nims/NIMS_core.pdf (accessed May 5, 2010).
[36] "About FEMA." Federal Emergency Management Agency web site. http://www.fema.gov/about/index.shtm (accessed May 5, 2010).
[37] "About APCO." Association of Public-Safety Communications Officials web site. http://www.apcointl.org/new/about/ (accessed May 5, 2010).
[38] "About COMCARE." COMCARE web site. http://www.comcare.org/About.html (accessed May 5, 2010).

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| | affairs, business opportunities, market intelligence, certification and world-wide environmental regulatory compliance.[39] | |

Entry barriers are obstacles that remove customer segments from the market for some period of time. They limit the size of the addressable market in general or the market share that can be captured. These barriers must be overcome or avoided to have a successful market entry. Our work to date suggests the following entry barriers may prevent customer segments from buying this type of technology for some period of time.

| *Market Entry Barriers* | |
|---|---|
| ***Name of Barrier*** | ***Description/Why*** |
| ***Cyclical and Project-Driven Market*** | The first responder market is significantly project-driven and largely cyclical, making it difficult for new entrants to compete against existing firms.[40] |
| ***End User Budgetary Issues*** | While there are many challenges to interoperability, one of the biggest obstacles is budgetary in nature. First responders have complex needs for specialized equipment and personnel and communications infrastructure is one of several critical priorities. Two-way Radio infrastructure is produced by many manufacturers with competing proprietary standards. The costs of replacing all first responder radio systems with compatible and interoperable solutions are often prohibitive.[41] |
| ***Decentralized Procurement Leads to Funding Challenges in the United States*** | In the United States, public safety agencies apply for funding grants to obtain the equipment and training they need for emergency and disaster situations. This decentralized procurement means that the funding mechanisms do not make coordination easy.[42] |

The overall cyclical nature of the market and the decentralized procurement procedures of end users are likely to remain major challenges in this industry. Although funding opportunities today appear to be favorable, budgetary issues are likely to continue to plague certain end user groups that may not have direct access to such support.

Market drivers are forces that strengthen or weaken the importance of end-user needs over time.

| *Market Drivers* | |
|---|---|
| ***Name of Driver*** | ***Why Significant*** |

[39] "About TIA." Telecommunications Industry Association web site. http://www.tiaonline.org/about/ (accessed May 5, 2010).
[40] "European First Responders C3I Market Offers Huge Potential for Civil Security Finds Frost & Sullivan." January 2010. Newswire Today web site. http://www.newswiretoday.com/news/62924/ (accessed May 5, 2010).
[41] "Interoperable Communications for First Responders." *Frost & Sullivan*. AT&T web site. http://www.corp.att.com/stateandlocal/docs/Interop.pdf (accessed May 5, 2010).
[42] "First Responder Terminal Market to Reach $3.5 Billion by 2013." November 2008. ABI Research web site. http://www.abiresearch.com/press/1289-First+Responder+Terminal+Market+to+Reach+$3.5+Billion+by+2013 (accessed May 5, 2010).

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| ***On Going Communication Issues*** | Currently there a more than 100,000 emergency response agencies and the vast majority of these agencies are not able to rapidly, accurately and easily communicate data with each other or the public. Except at the highest levels of government (e.g. state Emergency Operation Centers with DHS), there is also no regional or national emergency data communications capability. Given this, the on going lack of capable communications tools remains a critical homeland security and emergency response problem.[43] |
| ***Ongoing Standards Implementation and Manufacturer Cooperation*** | In march 2010, leading mission critical communication vendors successfully completed interoperability testing using Project 25 Inter-RF Subsystem Interface (P25 ISSI) gateways to communicate using different equipment. This milestone is an example of the growing trend of manufacturers continuing to work together to advance interoperability for public safety, enabling first responders to communicate effectively in emergency situations.[44] |
| ***Rolling Out of New Networks*** | A recommendation from the Federal Communications Commissions (FCC) National Broadband Plan is for the proposed creation of a nationwide interoperable public safety broadband wireless network ("public safety broadband network") for first responders and other public safety personnel. To meet this ambitious goal, public safety agencies could leverage the deployment of 4G (fourth generation) commercial wireless networks to greatly reduce the overall costs of constructing this nationwide broadband network.[45] Such developments are likely to open up a wide range of new opportunities for first responder communication equipment developers to tap these new developments. |
| ***Continued Push for Interoperability and Continuity of Operations Drives Funding Opportunities*** | There has been a surge in emergency communications planning and deployments since Hurricane Katrina as first responders are interested in solutions that can accommodate new technologies and applications as well as higher data rates to support increasing demand for videoconferencing and streaming video from a disaster scene. This area is growing in importance as the current agenda is promote interoperability and real-time switchover between primary and stand-by communications and there is a real push to make continuity of operations a reality. [46] This on going emphasis on interoperability has garnered more grant support from the DHS than to any other initiative and it is expected to continue to gain support in the near term, particularly from the economic stimulus package.[47] |

The U.S. House of Representatives estimates that over 70% of public safety communications equipment is still analog, outdated, and incompatible with

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[43] "Data Interoperability." COMCARE web site. http://www.comcare.org/Interoperability.html (accessed May 5, 2010).
[44] "Motorola and Five Leading Emergency Communications Equipment Manufacturers Demonstrate Project 25 ISSI Interoperability." March 2010. Yahoo Finance web site. http://finance.yahoo.com/news/Motorola-and-Five-Leading-prnews-2750890594.html?x=0&.v=1 (accessed May 5, 2010).
[45] Manner, Jennifer. "Bringing Nationwide Interoperable Communications to America's First Responders." April 2010. Broadband.gov web site. http://blog.broadband.gov/?entryId=391557 (accessed May 5, 2010).
[46] Kusiolek, Richard. "Alternative Uses Of Emergency Communications Networks Driving New Market." June 2008. Satellite Today web site. http://www.satellitetoday.com/via/features/Alternative-Uses-Of-Emergency-Communications-Networks-Driving-New-Market_23236.html (accessed May 4, 2010).
[47] Lascow, Sarah. "Are Americas First Responders Better Off Following Billions of Dollars?" February 2010. Daily Estimate web site. http://www.dailyestimate.com/article.asp?id=27768 (accessed May 5, 2010).

communications systems in neighboring local jurisdictions.[48] Based upon our research it is apparent that a comprehensive interoperable solution for first responder communication is still elusive. Given this, there are likely to be a number of opportunities to meet this vital need. It is important to note however that technology alone is not likely to solve this problem entirely, as proper planning and cooperation on behalf of both industry and the first responder community is essential.[49] In the near term ongoing funding opportunities are likely to continue to be major drivers of growth for such tools and in the longer term, the full roll out of new fourth generation networks may also prove to be beneficial for new product offerings in this space.

Here are some additional data and sources that can help you better understand the market.

| *Name* | *Description* |
|---|---|
| National Incident Management System Report | This report, published by the Department of Homeland Security in 2008, details the National Incident Management System and the many factors and procedures that are involved in implementing such an initiative.<br><br>For more information please see the following URL: http://www.fema.gov/pdf/emergency/nims/NIMS_core.pdf |
| Responder Knowledge Base – List of Bridging/Patching/Gateway Products | The FEMA web site's Responder Knowledge Base provides an extensive listing of products and technologies used in emergence communication applications.<br><br>For more information please see the following URL: https://www.rkb.us/search.cfm?action=filter&typeid=2&subtypeid=421 |

[48] "Interoperable Communications for First Responders." *Frost & Sullivan*. AT&T web site. http://www.corp.att.com/stateandlocal/docs/Interop.pdf (accessed May 5, 2010).
[49] Lascow, Sarah. "Are Americas First Responders Better Off Following Billions of Dollars?" February 2010. Daily Estimate web site. http://www.dailyestimate.com/article.asp?id=27768 (accessed May 5, 2010).