Ion Mobility Spectrometer

Patent No.: U.S. 7,751,999 B1

Patent No.: U.S. 7,361,206 B1

Patent No.: U.S. 7,078,680 B1

Market Overview

Naval Surface Warfare Center (NSWC) Crane Division

(May 2012)

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List of Acronyms

Acronym	Definition
AABB	American Association of Blood Banks
AFSC	Air Force Specialty Code
AHA	American Hospitals Association
BADS	Biological Agent Detection Systems
BLS	Bureau of Labor Statistics
BW	Biological Warfare
CBP	Customs and Border Protection
CBRN	Chemical, Biological, Radiological, and Nuclear
CI	Condition Index
CIKR	Critical Infrastructure and Key Resources
COPD	Chronic Obstructive Pulmonary Disorder
CRS	Congressional Research Service
CW	Chemical Weapons
DHS	Department of Homeland Security
DoD	Department of Defense
EDS	Explosives Detection System
EGDN	Ethylene glycol dinitrate
EMT	Emergency Medical Technicians
ERDC	Engineer Research and Development Center
FDA	Food and Drug Administration
FY	Fiscal Year
GDP	Gross Domestic Product
HHS	Health and Human Services
HPLC	High Performance Liquid Chromatography
IED	Improvised Explosive Device
IMS	Ion Mobility Spectrometry
MHS	Military Health System
MMRS	Metropolitan Medical Strike Response system
MOS	Military Occupational Specialties
MTF	Military Treatment Facilities
NAICS	North American Industry Classification System
NSWC	Naval Surface Warfare Center
NENA	National Emergency Number Association
NOBC	Navy Officer Billet Classification
OBP	Officers Border Patrol
OCO	Oversea Contingency Operations
OFO	Officers Field Operations

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POE	Points of Entry
R&D	Research and Development
RDT&E	Research, Development, test and Evaluation
SMS	Sustainment Management System
SPAMS	Single Particle Aerosol Mass Spectrometer
SQL	Structured Query Language
SRM	Sustainment, Restoration, and Modernization
TNT	Trinitrotoluene
TSA	Transportation Security Administration
US	United States
USAI	Urban Area Security Initiative
USDA	United States Department of Agriculture
USFA	United States Fire Administration
USPS	United States Postal Service

Executive Summary

The Naval Surface Warfare Center (NSWC) Crane Division in Crane, Indiana has developed and patented (US Patents 7,751,999, 7,361,206B1, and 7,078,680 B1) for Ion Mobility Spectrometer (IMS) technology. While IMS technology in its earliest form has been used since the 1950s and 1960s to study gas phase ion mobilities and reactions, the current technology greatly expands upon earlier capabilities. Specifically, IMS patents allow for higher efficiencies, reduced maintenance costs, and the ability to conduct field calibration with less training and time.

This analysis provides a general overview of IMS technology and prospective market opportunities. The markets examined within which IMS technology may find particular relevance include, but are not limited to; *military*; *first responder; government;* and *civilian critical infrastructure, pharmaceutical, disease detection,* and *petroleum* markets. Each potential market is defined, quantified, and market drivers and influences are explored. A summary of the information contained within the full assessment is provided below.

Technical Synopsis

In order to increase the accuracy and efficiency of ion mobility spectrometry, U.S. patents 7,078,680 B1; 7,361,206 B1; and 7,751,999 were developed. U.S. Patent No. 7,078,680 B1 is a software patent that includes an algorithm that allows an IMS to operate at higher efficiency. U.S. Patent No. 7,361,206 B1 is a process and apparatus that decreases maintenance costs by employing a water permeable membrane that continuously removes water vapor and reduces the need for filter changes. U.S. patent 7,751,999 enables field calibration of an IMS unit with less training and time. These patents provide a variety of prospective advantages:

- an increase in specificity and selectivity in IMS technology which may allow the equipment to operate at higher efficiencies[1];
- decreased maintenance costs by employing a closed system and a water permeable membrane comprised of Nafion (a fluoropolymer copolymer) that continuously removes water vapor and reduces the need for filter changes[2];
- the removal of acetone that is injected in the counter-flow air stream due to the Nafion so this air flow does not become saturated with acetone[3];
- while IMS systems typically require replacement scrubbers (adsorbents) such as desiccant, this technology makes use of Nafion technology which continually regenerates, thus requiring no desiccant to saturate and replace[4]; and

[1]E-mail correspondence from inventor Jack Fulton dated April 30, 2012.

[2]E-mail correspondence from inventor Michael Jahn dated April 30, 2012.

[3] *Ibid.*

- a two point field calibration check with versatility to get into awkward and tight locations when lab calibrations are impractical and costly[5].

Markets and Competitive Landscape

IMS technology may find specific advantages in detection of explosives and chemical and biological agents in military, first responder, and government markets. In addition, IMS may assist with the detection of chemical and biological agents in critical infrastructure sites, aid safety and quality in the pharmaceutical industry, enable the detection of various lung diseases, and address environmental concerns and process improvements in the petroleum industry.

Competition for IMS technology is extensive. At least fourteen different competing technologies were identified for explosive, chemical and biological agent, toxic industrial chemicals, and narcotics. Some of the competitive systems rely on IMS technology, while others relied on mass spectrometry and other technologies.

Conclusion

These IMS technology advancements have the benefit of being developed and reduced to practice by the Naval Surface Warfare Center (NSWC) Crane Division. While the list of competitors is extensive, IMS has the benefit of experience and success with groups such as NSWC. There are immediate needs to identify specific requirements that may be necessary for the military, first responder, government, pharmaceutical and petroleum industries, which may have their own testing requirements. Also, potential licensees should be identified with established channels to market. The IMS technology advancements investigated in this study present a wide array of potential applications which warrant further investigation and development.

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[4]E-mail correspondence from inventor Norm Popkie dated May 1, 2012.

[5] *Ibid.*

1 Introduction

IMS technology patents have been developed by the Naval Surface Warfare Center (NSWC) Crane Division in Crane, Indiana. These IMS patents allow for higher efficiencies, reduced maintenance costs, and the ability to conduct field calibration with less training and time. These patents may provide the following prospective advantages:

- *an increase in specificity and selectivity in IMS technology which may allow the equipment to operate at higher efficiencies*[6]*;*
- *decreased maintenance costs by employing a closed system and a water permeable membrane comprised of Nafion (a fluoropolymer copolymer) that continuously removes water vapor and reduces the need for filter changes*[7]*;*
- *the removal of acetone that is injected in the counter-flow air stream due to the Nafion so this air flow does not become saturated with acetone*[8]*;*
- *while IMS systems typically require replacement scrubbers (adsorbents) such as desiccant this technology makes use of Nafion technology which continually regenerates, thus requiring no desiccant to saturate and replace*[9]*; and*
- *a two point field calibration check with versatility to get into awkward and tight locations when lab calibrations are impractical and costly*[10]*.*

In addition to examining the IMS technology's key components and operation, and how the advantages may be achieved, this assessment provides an overview of the potential opportunity within the military, first responder, government, and civilian markets. This report is broken down as follows:

- Technical Synopsis and Applications
- Markets
- Competitive Synopsis
- Cautions and Considerations

Ultimately, IMS technology will allow for explosive and chemical and biological agent detection. Based on the data examined, indicators appear positive but are matched by an

[6]E-mail correspondence from inventor Jack Fulton dated April 30, 2012.

[7]E-mail correspondence from inventor Michael Jahn dated April 30, 2012.

[8] *Ibid.*

[9]E-mail correspondence from inventor Norm Popkie dated May 1, 2012.

[10] *Ibid.*

extensive list of potential competitors. It is important to note that this analysis is not undertaken in an effort to dictate commercialization strategies or to recommend a specific market application. Rather, a general overview of the IMS technology's functionality and the potential markets to which it may enter are provided for further strategic analysis.

2 Technical Synopsis

Ion mobility spectrometry (IMS) is an analytical technique that uses a process whereby ionized molecules are separated and identified as they pass through a carrier buffer gas. While in the gas phase, these ionized molecules are distinguished based on their mobility through a chamber. IMS is used most commonly in the detection of drugs and explosives. The U.S. military and government agencies are the most common users of the technology. The devices used for detection that employ IMS technology come in a wide variety of embodiments. These various embodiments have built into them certain drawbacks and challenges that hamper efficiency and accuracy.

In order to increase the accuracy and efficiency of ion mobility spectrometry, U.S. patents 7,751,991 B1, 7,078,680 B1, and 7,361,206 B1 were developed. United States Patent No. 7,078,680 B1 is a software algorithm that increases efficiency of an IMS detection unit by pulsing an ion gate using a temporally spaced pattern of ion admitting periods to achieve an admission duty cycle of about 50% of the total scan time. Adjustments have also been made to the neural network, thus enabling the spectrometer to detect multiple agents at the same time that can be compared to known agents to identify unknown agents. The neural network can also be trained by the algorithm to use a plurality of known agent signatures and allow the logic processors to act as a fuzzy decision maker to compare unknown signatures to known agent signatures.[11]

Patent number 7,361,206 B1 supports an apparatus and method for the removal of water vapor in an ion mobility spectrometer. The apparatus has a self-regenerating water vapor removal system capable of continuously removing water vapor from a closed loop re-circulated sample and regenerating itself in-situ. The apparatus includes a water permeable membrane that has two sides opposite each other. Gas flow is disposed adjacent the first side and exhaust flow, such as ambient air is disposed adjacent the second side of the membrane to remove water vapor that diffuses through the membrane. Additional treatment systems such as charcoal filters can be used in the apparatus to improve efficiency as well. This same invention can also be used in other applications that require the removal of water vapor.[12]

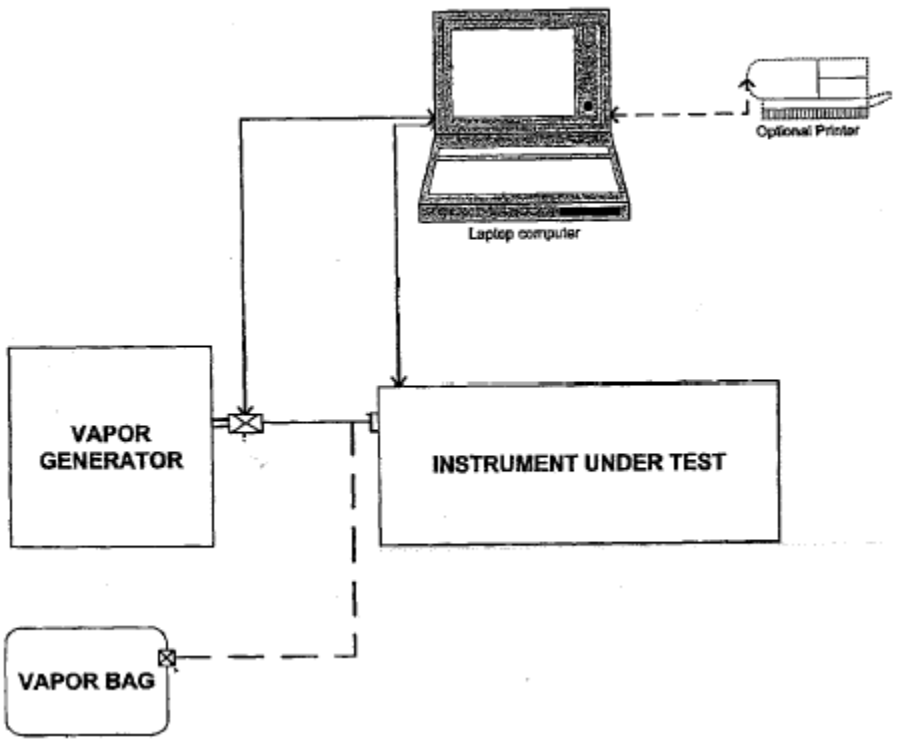
Patent number 7,751,999 B1 is an instrument and process that allows for instrument testing and calibration in the field. The invention incorporates a computing system loaded with testing software and a test substance generating device. The device is portable and allows for more

[11] Griffin et al., "Ion Mobility Spectrometer using Ion Beam Modulation and Wavelet Decomposition," U.S. Patent 7,078,680 B1, July 18, 2006.

[12] Jahn, M.D. et al., "Apparatus and Method for Water Vapor Removal in an Ion Mobility Spectrometer," U.S. Patent 7,361,206 B1, April 22, 2008.

frequent instrument testing and less downtime. This testing is accomplished by measuring an instrument's response to a known concentration of analyte and the results thus obtained from this measurement can be used to field calibrate an IMS unit. This test will give a good confidence check of the IMS unit. The process works by providing at least one standard concentration to the IMS unit and determining the actual response to each such standard and determining the actual response to a known response for such a standard. Along with the benefit of portability, this invention benefits the end user by decreasing disruption in field time because the units will not need to be sent out for testing and calibration as often. This invention will require some training for experienced field personnel. However, once training is conducted, overall efficiencies will be realized. A schematic for this instrument and process is shown in Figure 1 below.[13]

Figure 1: Schematic for IMS Instrument and Process



[1313] McAtee, R.F. et al., "Method and System for Field Calibrating an Ion Mobility Spectrometer or Other Trace Vapor Detection Instrument," U.S. Patent 7,751,999 B1, July 6, 2010.

3 Applications

Currently, the bulk of the usage for IMS is in explosives and drug detection. These applications are the primary usages of IMS technology. These applications are used predominately by the armed forces for the detection of explosive devices and chemical and biological agents. The Department of Homeland Security also employs IMS technology for detection of explosives, chemical agents and drugs at airports. IMS units are also used at the borders to detect drugs that are attempting to be smuggled into the country. These applications include airport security, site security, drug interdiction, forensics, and customs.[14]

There are other applications for IMS technology that are being employed currently and are expected to grow in the future. The pharmaceutical industry employs IMS devices to check for cleanliness in production vessels in order to ensure the integrity of the next run of pharmaceutical products. IMS reduces preparation and process time because any contaminant on the surface to be analyzed can be dissolved on a swab and analyzed in less than 30 seconds, which increases the utilization of production equipment.[15]

IMS is also used in pharmaceuticals as a quality control mechanism to measure the composition of drugs produced. Any situation where an organic compound is supposed to be present or not present can be considered a candidate. IMS has been used to detect the presence of antibiotics, residual allergenics, flavorings, and many other materials.[16]

Potential applications also include the petroleum industry. The petroleum industry is exploring IMS usage for testing the composition of crude oil in order to make decisions regarding the potential for refining activities. IMS technology can also be used in testing applications that include leak detection and process testing. IMS can detect for byproducts such as hydrogen fluoride which is produced by processes such as petroleum refining, aluminum refining, semiconductor processing, and refrigerant manufacturing.[17]

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[14] Kanu, A.B and H.H. Hill, "Ion Mobility Spectrometry: Recent Developments and Novel Applications," *LPI* April/May2004 http://public.wsu.edu/~hillh/Hill%20scan%20papers%20pdfs/2004%20Labplus%20Kanu%20IMS%20recent%20developments.pdf viewed April 18, 2012.

[15] DeBono, R., "Ion Mobility Spectrometry: A Fast, Sensitive, and Robust HPLC Alternative," *Applications in Chromatoraphy* March 2002 http://trace.smithsdetection.com/Documents/LifeSciences/LE203sBarringer.pdf viewed April 18, 2012.

[16] *Ibid.*

[17] Bacon, T., "Ion Mobility Spectroscopy Applications for Continuous Emission Monitoring," Molecular Analytics Publication Date Unknown http://www.jusun.com.tw/IMS%20Application%20for%20CEM.pdf viewed April 18, 2012.

IMS is also being employed more frequently as a testing mechanism for detecting diseases. The results on a diverse set of viral systems suggest that IMS may have broad applications for the analysis of biological complexes. The human pathogen adenovirus (which causes illness of the respiratory system) represents a large and sophisticated biomolecular complex detected in the gas phase.[18]

Based on the applications listed above, the three patents that we are examining can provide increased efficiencies to existing IMS technology. These efficiencies and improvements can translate into market opportunities for the patents in the primary military and homeland security markets. These improvements can also be used to enhance IMS technology usage in the pharmaceutical industry and other industries, such as petroleum, aluminum refining, semiconductor processing, and refrigerant manufacturing.

[18] Thomas, J.J. et al., "Electrospray ion mobility spectrometry of intact viruses," *Spectroscopy* 18 (2004) pp. 31-36.http://masspec.scripps.edu/publications/public_pdf/102_art.pdf viewed April 18, 2012.

4 Markets

This assessment understands the core application of these inventions to be to increase the accuracy and efficiency of IMS. This application may then find particular relevance within markets such as explosives detection, chemical weapon, biological material detection, and drug detection. Traditionally, the threat of bioterrorism is heightened in areas where military personnel are found, such as near military installations. Also, first responder applications could include emergency response or law enforcement personnel in police departments or other locations. Similarly, other government markets, such as for homeland security services, or other civilian applications, such as pharmaceuticals, disease detection, or petroleum applications, may also have relevance for this technology. Thus, overall, IMS may find relevance within:

- Military Markets
- First Responder Markets
- Government Markets
- Civilian Markets

While IMS remains in development, the technology is explored with regard to these prospective market opportunities. Each of the above markets is defined and quantified, and market drivers and influences are explored.

4.1 Military Market

IMS may find relevance and opportunity with the military market. Potential opportunities include detection of explosive devices and agents for chemical and biological warfare. The invention is understood to have been developed in response to the need for a field-deployable method to calibrate an IMS with less training and time and which eliminates the need to send the instrument to a lab. The IMS may therefore find applications in military markets.

4.1.1 Definition and Quantification

The military market is defined to include military end-users within a military context. That is, enlisted and officer personnel who may employ the IMS within a non-civilian context such as a military base, combat zone, or otherwise military designated installation.[19] Military end-users may then constitute those enlisted and officer personnel within the five branches of the United

[19] Note: military personnel are asserted to be persons of, for, or pertaining, to the five branches of the United States military; here, enlisted and officer personnel. Military context denotes non-civilian environments or facilities, or those specific to said personnel. Examples include: combat territories and domestic and foreign military bases.

States military: Air Force, Army, Coast Guard, Marine Corps and Navy. The tables below relay the United States Bureau of Labor Statistics (BLS) 2011 estimates of current enlistment.[20]

Table 1: Military Enlisted Personnel by Broad Occupational Category & Branch of Military Service, August 2011						
Occupational Group - Enlisted	**Army**	**Air Force**	**Coast Guard**	**Marine Corps**	**Navy**	**Total, all services**
Administrative occupations	6,661	15,302	2,274	11,669	19,585	55,491
Combat specialty occupations	129,684	639	616	32,706	7,854	192,499
Construction occupations	20,499	5,185	—	5,067	5,209	35,957
Electronic and electrical repair occupations	40,214	31,048	4,475	14,098	48,118	137,953
Engineering, science, and technical occupations	45,684	47,436	1,288	25,297	48,118	160,141
Healthcare occupations	31,317	15,935	693	—	24,068	72,013
Human resource development occupations	18,974	12,532	—	8,407	4,108	44,021
Machine operator and production occupations	5,398	6,234	1,946	2,532	9,599	25,709
Media and public affairs occupations	8,209	6,848	122	2,381	3,854	21,414
Protective service occupations	27,380	34,738	2,837	9,534	11,959	86,448
Support services occupations	13,109	1,483	1,218	2,119	8,032	25,961
Transportation and material handling occupations	63,566	31,279	10,900	23,154	38,148	167,047
Vehicle machinery mechanic occupations	52,974	42,032	5,554	18,586	47,022	166,168
Non-occupation coded personnel	3,441	13,117	1,663	1,926	606	20,753
Total, by service	***467,110***	***263,808***	***33,586***	***178,476***	***268,595***	***1,211,573***

[20] United States Bureau of Labor Statistics. "Occupational Outlook Handbook, 2012-13 Edition ." *Job Opportunities in the Armed Forces*. 29 March 2012. United States Department of Labor, Web. April 2012. <http://www.bls.gov/ooh/military/military-careers.htm>.

Table 2: Military Officer Personnel by Broad Occupational Category & Branch of Military Service, August 2011						
Occupational Group - Officer	**Army**	**Air Force**	**Coast Guard**	**Marine Corps**	**Navy**	**Total, all services**
Combat specialty occupations	19,029	3,986	—	4,039	6,036	33,090
Engineering, science, and technical occupations	21,573	14,841	3	3,922	9,556	49,895
Executive, administrative, and managerial occupations	12,422	7,760	61	2,620	7,082	29,945
Healthcare occupations	11,092	8,917	—	—	5,896	25,905
Human resource development occupations	2,890	2,989	19	284	3,032	9,214
Media and public affairs occupations	340	297	7	170	270	1,084
Protective service occupations	3,074	1,015	1	358	1,003	5,451
Support services occupations	1,866	685	7	39	928	3,525
Transportation occupations	13,535	18,158	1	6,349	11,374	49,417
Non-occupation coded personnel	12,168	7,088	8,381	4,296	8,375	40,308
Total, by service	***97,989***	***65,736***	***8,480***	***22,077***	***53,552***	***247,834***

Within the above tabulations, the total military market (as defined via officer and enlisted personnel) consists of 1,459,407 members. Admittedly, some of these occupations may be more likely (*i.e.* combat specialty or healthcare occupations) to employ the IMS as opposed to others (*i.e.* media and public affairs). Similarly, this estimate should not be interpreted on a one-to-one basis, as it may be unlikely that each individual military member will directly make use of, or serve as a purchase point for, the IMS. This assessment will therefore adopt the general quantification of enlisted and officer personnel to initially quantify the military market.

Enlisted and officer personnel within the BLS defined combat specialty occupation may have an increased likelihood to employ the IMS. Combat specialty personnel generally constitute those that are actively deployed. If the assumption is established that deployment may equate to increased exposure of biothreats to combat activity, those enlisted and officer personnel designated by combat specialty occupations may further define the market for the IMS.

Acknowledging potentially increased market relevance for healthcare and combat specialty occupations, the BLS estimated that there were 72,013 healthcare positions (including healthcare practitioners and medical/clinical technicians), and 192,499 combat specialty positions, held by

active-duty enlisted military personnel in August of 2011. Officer personnel held an estimated 25,905 healthcare positions, and 33,090 combat specialty positions.[21] These figures are broken down below in the tables below by service branch. The BLS does provide estimates of additional occupation groups, however, healthcare and combat specialty occupations were deemed to be the most relevant for initial quantification.

Table 3: Selected Positions Held by Military *Enlisted* Personnel: Service Branch Breakdown, August 2011						
	Army	**Air Force**	**Coast Guard**	**Marine Corps**	**Navy**	**Total**
Combat Specialty	129,684	639	616	32,706	7,854	192,499
Healthcare	31,317	15,935	693	—	24,068	72,013
					Total	***264,512***

Table 4: Selected Positions Held by Military *Officer* Personnel: Service Branch Breakdown, January 2009						
	Army	**Air Force**	**Coast Guard**	**Marine Corps**	**Navy**	**Total**
Combat Specialty	19,029	3,986	—	4,039	6,036	33,090
Healthcare	11,092	8,917	—	—	5,896	25,905
					Total	***58,995***

One specific example of a military-end user with medical designation, as well as front-line duty connotation, is the Army's healthcare specialist or "combat medic." Charged with providing care to wounded soldiers, the combat medic military occupation is the second-largest in the Army with nearly 38,000 medics spread across active and reserve components. In terms of size, combat medics are second only to the infantry specialty and the Department of Combat Medic Training is said to train 8,000 new medics a year—a prospectively large pool of IMS end-users.[22]

Admittedly, the military occupations of "healthcare" and "combat specialty" can vary greatly in their duties, and neither may guarantee a need for biological or chemical detection or the employment of the IMS. With that said, when military enlistment figures are accepted as potential market indicators for the IMS, the military market appears relatively large and is projected to remain as such. The number of active-duty personnel is projected by the BLS to remain roughly constant through 2018.[23] The BLS also notes that recent conflicts have and will likely continue to lead to an increase in the number of active-duty personnel.

[21] *Ibid.*

[22] Baker, Fred W. III. "Combat Medic Training Evolves to Save Lives." American Forces Press Service 18 Nov 2008. Web. April 2012. <http://www.defense.gov/news/newsarticle.aspx?id=51980>.

[23] *Ibid.*

In addition to the DoD personnel outlined above, federal budgets may also serve as a market indicator for the military market. While budgetary quantification of the market is not ideal, increasing relevant budgets may indicate a viable market need, as well as potential increases in purchasing power for the military end-user (*i.e.* military procurement). That said, as the IMS is examined as a new entrant to the military market, budgetary analysis will prove to be general in nature—neither historical nor predicted expenditures can be explicitly related to the IMS. A budgetary quantification of market opportunity will then examine those budget segments which have the potential to include IMS expenditure, and which may offer general insight into prospective military purchasing power.

The fiscal year (FY) 2013 defense base budget is $525.4 billion, which is down $5.2 billion from the fiscal year 2012 budget of $530.6 billion. This is consistent with efforts to make tough cuts and create savings. This budget adjusts programs that develop and procure military equipment, begins to re-size ground forces, slows the growth of compensation and benefit programs, continues to make use of Defense resources by reducing lower priority programs, and restructures for more efficient approaches to doing business.[24] The table below shows the DoD base budget by appropriation title for FY 2012, FY 2013, and the delta or change between 2012 and 2013.[25]

Table 5: DoD Base Budget by Appropriation Title ($ in Thousands)

Base Budget	FY 2012 Enacted	FY 2013 Request	Delta '12-'13
Military Personnel	141,818,404	135,111,799	-6,706,605
Operation and Maintenance	197,213,485	208,759,219	11,545,734
Procurement	104,527,376	98,823,345	-5,704,022
RDT&E	71,375,712	69,407,767	-1,967,945
Military Construction	11,366,701	9,571,929	-1,794,772
Family Housing	1,682,946	1,650,781	-32,165
Revolving and Management Funds	2,640,085	2,124,320	-515,765
Total	**530,624,709**	**525,449,169**	**-5,175,540**

Within the FY 2013 budget, military personnel, operation and maintenance, construction, family housing, revolving and management funds, procurement and research, development, test and evaluation (RDT&E) allocations may shed light on potential military purchasing power. If the IMS licensees or manufacturers are able to penetrate the military market, procurement and RDT&E allocations may be the funds with which military end-users may purchase or evaluate

[24]"United States Department of Defense Fiscal Year 2013 Budget Request Overview," Office of the Under Secretary of Defense (Comptroller)/CFO, February 2012,http://comptroller.defense.gov/defbudget/fy2013/FY2013_Budget_Request_Overview_Book.pdf viewed March 16, 2012.

[25]*Ibid.*

the IMS, respectively. Procurement appropriation is listed at $104.5 billion in FY 2012 and projected to decrease by 5.5% to $98.8 billion in FY 2013. Similarly, RDT&E appropriation is listed at $71.3 billion in FY 2012, and projected to decrease slightly by 2.8% to $69.4 billion in FY 2013.[26] Given that there are still significant appropriations for both procurement and RDT&E despite the decreases, prospective purchasing power and opportunity for testing and evaluation within the military market will be competitive, but may be available, if the technology is sufficiently developed and deemed a necessity.

In addition to the base budget, there is a separate budget for oversea contingency operations (OCO). Shown below is a table for the OCO budget for FY 2012, FY 2013, and the delta or change between 2012 and 2013.[27]

Table 6: Overseas Contingency Operations (OCO) Funding by Appropriation Title ($ in Thousands)

OCO Budget	FY 2012 Enacted	FY 2013 Request	Delta '12-'13
Military Personnel	11,293,469	14,060,094	2,766,625
Operation and Maintenance	86,775,842	63,986,203	-22,789,639
Procurement	16,052,195	9,687,241	-6,364,954
RDT&E	526,358	245,516	-280,842
Military Construction			0
Family Housing			0
Revolving and Management Funds	435,013	503,364	68,351
Total	**115,082,877**	**88,482,418**	**-26,600,459**

In addition to the expected procurement and RDT&E appropriations, funding for OCO may further reflect on probable military purchasing power. OCO appropriations are projected to substantially decrease in FY 2013, decreasing by $26.6 billion to almost $88.5 billion. In general, these appropriations are believed to primarily support operations in Afghanistan and Iraq.[28] The decrease in FY 2013 funding, however, may be due to the expected drawdown of troop deployments in these Middle East theatres.[29] This may be of some interest as these are the two of the largest sites of U.S. troop foreign deployments. That is, the assumption may be maintained that deployment correlates to an increased exposure to biological threats and subsequently, a potentially increased need for such detection measures as the IMS. The funds

[26] *Ibid.*
[27] *Ibid.*

[28] Amy Belasco, "The Cost of Iraq, Afghanistan, and Other Global War on Terror Operations Since 9/11," 29 Mar 2011, Web, April 2012, <http://www.fas.org/sgp/crs/natsec/RL33110.pdf.>
[29] "Troop Drawdown pace 'about Right for Afghanistan,' General Says - CNN." *Featured Articles from CNN*. 27 June 2011. Web. April 2012. <http://articles.cnn.com/2011-06-27/world/afghanistan.withdrawal_1_afghan-security-troop-drawdown-security-forces?_s=PM:WORLD>.

($88.5 billion) allocated to OCO are primarily for support of operations within Afghanistan and Iraq and are broken down as shown in the table below.

Table 7: Oversea Contingency Operations (OCO) Functional Category Breakout ($ in billions)		
	FY 2012 Enacted	**FY 2013 Request**
Operations	60.2	48.2
Force Protection	6.5	5.1
Improvised Explosive Devices (IED) Defeat	2.4	1.7
Military Intelligence Program (MIP) (Includes ISR)	5.8	4.5
Afghanistan Security Forces Fund (ASFF)	11.2	5.7
Afghanistan Infrastructure Fund (AIF)*	0.4	0.4
Commander's Emergency Response Program (CERP)*	0.4	0.4
Support for Coalition Forces	2.1	2.2
Equipment Reset	13.0	9.3
Military Construction	0.3	-
Temporary End Strength	2.2	6.1
Non-DoD Classified	5.4	4.9
Non-war/Other*	5.8	-
Total	**115.7**	**88.5**
rescissions**	-0.6	-
Total including Rescissions	**115.1**	**88.5**

*Reflects base budget amounts transferred by the Congress to OCO, and congressional non-war adds (e.g., $1B for domestic National Guard and Reserve Equipment).

**Includes rescissions enacted in FY 2012 for FY 2010 OCO appropriations.

This assessment cannot assert within which, if any, category of the OCO budget the IMS would fall. Nevertheless, accepting the OCO budget as a general indicator of market priorities, the potential market for the IMS appears to be reasonably large—approximately 14 percent of the DoD FY2013 budget. If it can be more specifically determined which category of the OCO budget procurement of the IMS would take place, *Force Protection* for example, the prospective market opportunity may be further specified.

4.1.2 Market Drivers & Influences

In recognizing potential relevance within the market of military installations, prospective drivers and influences of the IMS market opportunity have been identified to include:

- Military Enlistment
- Major Troop Deployments
- Military Hospitals and Treatment Centers
- Biological Weapons and Delivery Capability by Country

Military Enlistment

As the market of military installations has been defined via prospective end-users—enlisted and officer personnel—levels of enlistment may then serve as a source of potential market influence. As overall enlistment rises or falls, so too may the number of potential end-users employing the IMS, or involved in the detection of biological hazards, fluctuate. Likewise, increased levels of enlistment may increase market opportunity for the IMS as increasing numbers of new service members could operate the system. With that said, the BLS estimates relatively stable levels of active-duty personnel through the year 2020. However, the drawdown from recent conflicts may lead to a decrease in the number of active-duty personnel. This should be balanced by the need to fill entry-level positions as members of the Armed Forces move up through the ranks, leave the service, or retire. The current goal of the Armed Forces is to maintain a force sufficient to fight and win two major regional conflicts at the same time. Political events, however, could lead to a significant restructuring.[30] Increased (successful) recruitment and enlistment may serve to positively influence the market size embodied by military end-users within military installations. The BLS projected annual recruitment requirement of 165,000, to replace retiring personnel or terminating service agreements—an annual regeneration of enlisted personnel which may serve as a driving force with regard to military market stability.[31]

Major Troop Deployments

As U.S. military forces are deployed globally, the likelihood of combat activity and corresponding risk of combat injury may increase. Although reasons for deployment can range from peacekeeping missions to service assignments, combat activity may exists as a rationale for deployment. When deployment is associated with potential combat exposure, the likelihood of sustaining biological weapon attacks may increase. Correspondingly, these biothreat agents may be released on the forces deployed in theatre, prompting prospective market relevance for the IMS's capabilities to detect chemical and biological agents. As will be explored with the driver and influence of *combat activity*, the IMS may find amplified relevance within deployment locales. Market opportunity for the device may therefore be influenced by the level of *major troop deployments*. The likelihood of combat injury from biological agents may increase as troops are deployed to a greater number of geographic locations and especially to those locales with increased risk of combat activity. While the inherent nature of each conflict may vary, risk of biological and chemical attacks and the need for detection systems in the field is assumed to vary commensurate to deployment.

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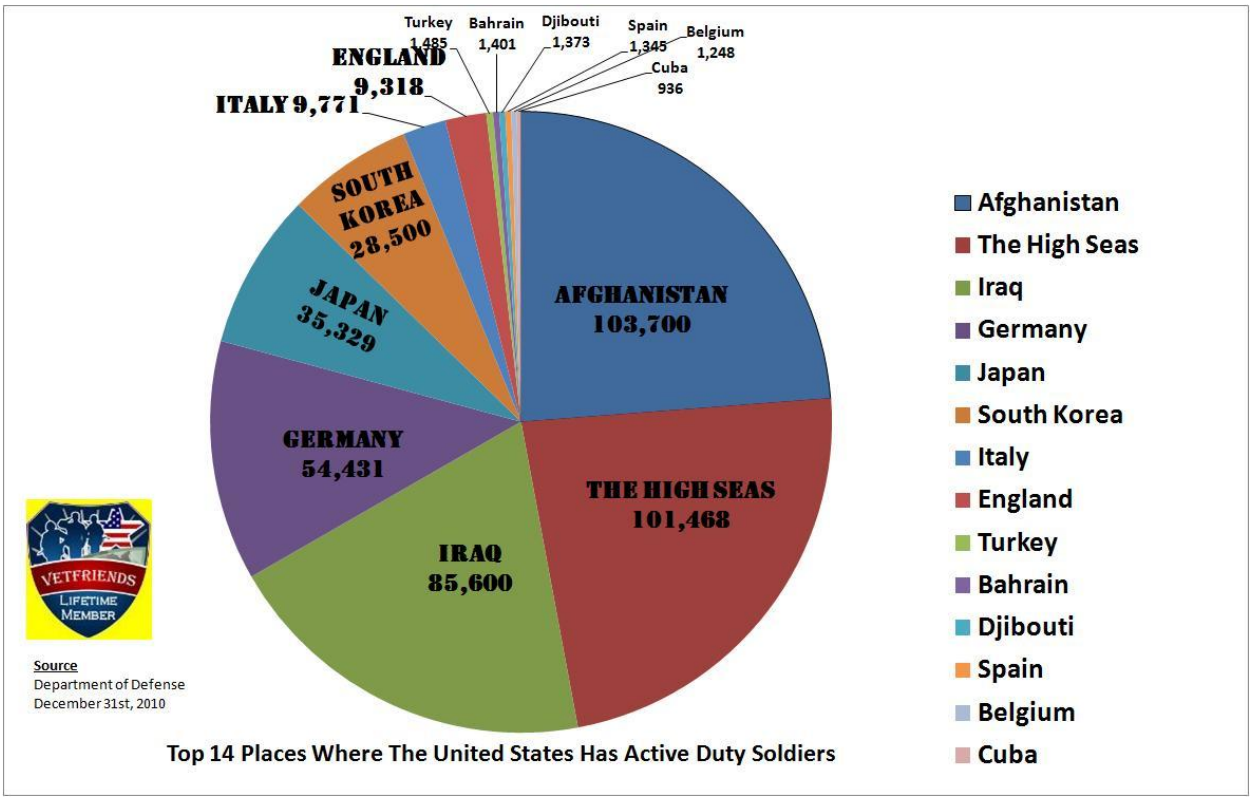
[30] United States Bureau of Labor Statistics. "Occupational Outlook Handbook, 2012-13 Edition ." *Job Opportunities in the Armed Forces*. 29 March 2012. United States Department of Labor, Web. April 2012. <http://www.bls.gov/ooh/military/military-careers.htm>.

[31] *Ibid.*

The U.S. has military personnel in about 150 countries, which is about 75% of the world's nations.[32] There are approximately 139,300 troops currently deployed within the Afghanistan and Iraq conflict zones.[33] Beyond these combat initiatives, there are an estimated 170,700 troops deployed in foreign countries. Missions range from peacekeeping, to security, to military training—all of which may carry varied risk of potential casualty occurrence. Figure 3 shows a chart with some of the major deployments of U.S. military personnel totaling 310,000 in 2012.[34] Table 9 gives a breakdown of deployment locations with the estimated number of U.S. Troops deployed. This figure and table show the potential world locations where the IMS may be implemented.

Figure 2: Major Deployments of U.S. Military Personnel



[32] Vetfriends U.S. Deployment Facts http://www.vetfriends.com/US-deployments-overseas/ viewed February 3, 2012.

[33] *Ibid.*

[34] *Ibid.*

Table 8: Deployment Location and Estimated Number of U.S. Troops Deployed	
Deployment Location	**Estimated Number of U.S. Troops Deployed**
Afghanistan	103,700
Turkey	1,485
Djibouti	1,373
The High Seas	101,468
Europe	76,113
Iraq	35,600
Japan	35,329
Bahrain	1,401
Cuba	936
South Korea	28,500
Total	**385,905**

While the specific nature and motivations behind military conflict are not examined by this assessment, the number of actively deployed troops may serve to drive market need for the IMS. If the assumption is maintained that deployment may carry increased likelihood of both the need for chemical and biological detection systems, market opportunity for the IMS may increase as the number of deployed forces increases.

Also, while the deployments of U.S. troops are not a specific market indicator for the IMS, they provide an understanding of where the IMS may fill a need. This is primarily due to the fact that there may be a direct correlation between the size of the U.S. force deployed and the likelihood of encountering biological and chemical threats. To offer further insight into potential market relevance for the IMS within these tabulations, Military Occupational Specialties (MOS) specifically designated to chemical and biological threat detection should be examined. The Air Force, Army, and Marine Corps have a MOS specifically designated to Chemical, Biological, Radiological, and Nuclear (CBRN) detection or have a MOS which relays biological detection duties. Military end-users classified by the military occupational specialties tabulated and outlined below may carry an enhanced likelihood of utilizing the IMS.

Table 9: Military Occupational Specialties Within Chemical, Biological, Radiological and Nuclear (CBRN) Detection	
U.S. Military Branch	**Occupation Specialty with Potential CBRN Relevance**
Air Force	• AFSC 3EX1 (Explosive Ordnance Disposal) • AFSC 3E9X1(Emergency Management) • AFSC: Air Force Specialty Code
Army	• MOS 74D (CBRN Specialist) • MOS 74A (CBRN Concentration for Officers)
Marine Corps	• MOS 57 (CBRN Defense) • MOS 5711 (Enlisted CBRN Defense Specialist) • MOS 5702 (Officer CBRN Defense Specialist)
Navy	• Navy Enlisted Classification 9598 • NOBC 2715 (Disaster Preparedness Officer) • NOBC 2765 (CBRN Defense Officer)

Two Specialty Codes within the United States Air Force make specific mention of biological training and capacity—Air Force Specialty Codes (AFSC 3E8X1, Explosive Ordnance Disposal and AFSC 3E9X1, Emergency Management). Included in the duties of AFSC 3E8X1 is the use of monitoring and detecting equipment (*e.g.* the IMS) when an ordnance may contain or be contaminated with toxic, biological or radioactive materials, and the detection, monitoring, evaluation and decontamination of explosive, radioactive, chemical or biological ordnance hazards.[35] Included in the duties of AFSC 3E9X1 are the maintenance and inspection of biological equipment, and the conduction of relevant detection, warning, and reporting activities.[36]

The Army's CBRN Specialist is designated by MOS 74D and the area of concentration for officers is 74A. The 74D CBRN Specialists plan, employ, and coordinate CBRN defense systems in support of joint and combined arms operations including CBRN reconnaissance systems, biological agent detection systems (BADS), obscurant systems, CBRN decontamination systems, and other CBRN hazard detection and warning systems.[37] The Army is said to have the

[35] "Air Force Enlisted Job Descriptions 3E8X1- Explosive Ordnance Disposal." *About.com*. The New York Times Company, 2010. Web. April 2012. <http://usmilitary.about.com/od/airforceenlistedjobs/a/afjob3e8x1.htm>.

[36] "Air Force Enlisted Job Descriptions 3E9X1- Emergency Management." *About.com*. The New York Times Company, 2010. Web. April 2012. <http://usmilitary.about.com/od/airforceenlistedjobs/a/afjob3e9x1.htm>

[37] "Army Enlisted Job Descriptions and Qualification Factors 74D - Chemical, Biological, Radiological and Nuclear (CBRN) Specialist." *About.com*. The New York Times Company, 2010. Web. April 2012. <http://usmilitary.about.com/od/enlistedjobs/a/74d.htm>.

largest number of uniformed personnel tasked with the CBRN defense mission, totaling at least 22,000 across the regular army and reserve components.[38]

The Marine Corps MOS 57 is that of CBRN Defense. The CBRN Defense field includes the detection, identification, warning, reporting, protection, avoidance, and decontamination procedures associated with CRBN hazards and contamination on the battlefield.[39] MOS 5711 designates *enlisted* CBRN Defense Specialists, and MOS 5702 designates officer CBRN Defense Specialists. As opposed to the field-based duties of the MOS 5702, the latter CBRN Defense Officers function as supervisors, coordinators, and technical advisors to the commanding *officer* for operational and technical functions associated with CBRN defense related issues.[40]

There is no pure CBRN specialty within the bounds of the Navy. However, enlisted CBRN capabilities are covered under Navy Enlisted Classification 9598 (disaster preparedness operations and training specialist). These specialists focus on preparing for major accidents and CBRN operations. Officer specialties include Navy Officer Billet Classification (NOBC) 2715 (disaster preparedness officer) and NOBC 2765 (nuclear, biological, and chemical defense officer).[41]

While there is not specific quantification for the occupational specialties outlined above, military end-users whose duties are specifically oriented towards CBRN detection and defense may carry increased likelihood of utilizing the IMS. Thus, each branch of the military may have capacity relevant to the IMS application.

Military Hospitals and DoD Treatment Facilities

While military occupations—and particularly health care occupations—may provide a means for quantifying the military market where the IMS may have relevance, the number of hospitals and other medical facilities within the Department of Defense's (DoD) Military Health System may also provide further measures for quantification. The Military Health System (MHS) is the primary source of medical services to active duty members of the military, as well as the major source of medical care—in both military and civilian facilities—to the dependents of active duty personnel, military retirees and their dependents, and survivors of deceased service members.[42] In addition to maintaining the health of military personnel, the MHS includes DoD hospitals,

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[38] Walk, Robert. "Purple Dragons: Should the Chemical Corps Become Joint?." *Army Chemical Review* Winter 2009: 41-43. Print.

[39] "United States Marine Corps Enlisted Job Description and Qualification Factors Field 57, Chemical, Biological, Radiological, and Nuclear Defense." *About.com*. The New York Times Company, 2010. Web. June 2011. <http://usmilitary.about.com/od/enlistedjo2/a/57.htm>.

[40] "Marine Corps Officer Job Descriptions MOS 5702 - - Chemical, Biological, Radiological and Nuclear Defense Officer ." *About.com*. The New York Times Company, 2010. Web. June 2011. <http://usmilitary.about.com/od/officerj3/a/5702.htm>.

[41] Walk, Robert. "Purple Dragons: Should the Chemical Corps Become Joint?." *Army Chemical Review* Winter 2009: 41-43. Print.

[42] *Ibid.*

clinics, and other medical personnel. These facilities—known as military treatment facilities (MTFs)—consist of 59 inpatient medical facilities and 661 medical and dental clinics serving an eligible population of 9.3 million. These are medical facilities and clinics specifically designated for the care of military personnel and their families, and are usually located on or near a military base.

Additionally, according to the American Hospital Association (AHA), there were a total of 5,815 hospitals in the United States registered with the Association in 2008.[43] Of these, 213 are designated at "federal government hospitals" which may be distinguished for inclusion in the military market quantification.[44] In addition to the estimated 213 federal hospitals in the U.S., this reveals a total of over 933 MTFs where the IMS could be deployed to test bioaerosol sampler detector systems. Similarly, there is consideration to be made for military field hospitals in foreign locations; namely, those facilities operated by the military first responder. While accurate figures are not articulated by relevant sources, due primarily to issues of security, the previously examined deployment figures may prove indicative of theatre operations, including those medical in mission, which may have equipment needs, specifically those of biological detection and identification. Thus, in combining the number of MTFs within the DoD and federal government hospitals, the total number of medical facilities that may have relevance for the deployment of the IMS within the military for the purposes of biological detection and identification at over 1850.

Table 10: Number of Military Treatment and Veterans Health Facilities

Facility	# of facilities
DoD Inpatient Medical Centers	59
DoD Medical and Dental Clinics	661
VA Medical Centers	153
VA (Community-based) Outpatient Clinics	773
Federal Government Hospitals	213
Totals	***1859***

Biological Weapons Capabilities within the Global Community

As referenced previously in this section, the U.S. maintains thousands of military sites and facilities and hundreds of thousands of U.S. troops worldwide. Because of the vast allocation of U.S. troops in the global community, there are more potential targets for adversaries to attack. Similarly, it would seem reasonable to assume that a larger number of potential adversaries increase the threat to U.S. troop deployments. In terms of chemical, biological, radiological, and

[43] American Hospital Association, "Fast Facts on US Hospitals," *Health Forum, LLC*, Updated 11 Nov 2009, Assess by Web, June 2011, <http://www.aha.org/aha/resource-center/Statistics-and-Studies/fast-facts.html>

[44] Note: Further information on the civilian market in terms of the number of civilian hospitals within the U.S. can be found in the *Civilian Market* section of this report.

nuclear (CBRN) threats, the assumption can therefore be made that troop deployment may carry increased exposure to CBRN threats, and subsequent need for such detection measures as the IMS. This section will examine the potential biological and chemical weapons capabilities of various countries worldwide. Understanding where the CBRN threats may originate from may drive the need for IMS devices in field.

The potential use and proliferation of biological and chemical weapons remains a viable threat to the global population.[45] For example, according to recent intelligence reports, Iran's biological warfare (BW) efforts may have evolved beyond the initial research and development (R&D) phases and into production.[46] As the knowledge and materials required in developing biological agents (to be used in biological warfare) become more readily available, the threat may become more diverse and sophisticated in nature. Current estimates by the United States intelligence community indicate that many countries have active biological weapons programs or capabilities.[47] The Congressional Research Service (CRS) sheds further light on some of the countries with biological weapons capabilities by breaking down each in terms of biological weapons capacity and the status of their respective programs. Below is a list of select countries identified by the CRS to have said weapons capacity.[48] The list of countries, while by no means exhaustive, provides insight into the prospective biological and chemical agent threat which may prompt market value of the IMS.

Table 11: Biological and Chemical Weapons by Country, 2008[49]

Country	Biological Weapons Capability	Chemical Weapons Capability
Algeria	_	Suspected
China	Likely[a]	Suspected[b]
Egypt	Known R&D[c]	Likely
France	Ended	Ended
India	_	Has Had[d]
Indonesia	_	Sought
Iran	Likely	Has Had[e]
Iraq	Ended[f]	Ended[g]

[45] General Michael D. Maples, U.S. Army, Annual Threat Assessment, Statement Before the Committee on Armed Services United States Senate, March 10, 2009. Pg.33.

[46] *Ibid.*

[47] Laljer, Charles. "Joint Chemical Agent Detector (JCAD) The Future of Chemical Agent Detection (U)." *National Defense Industrial Association* Mar 27 2000: Print.

[48] "Chemical and Biological Weapons Proliferation at a Glance." *Arms Control Association*. Arms Control Association, Sep 2002. Web. June 2011. <http://www.armscontrol.org/factsheets/cbwprolif>.

[4949] Kerr, P.K., "Nuclear, Biological, and Chemical Weapons and Missiles: Status and Trends," Congressional Research Service, 20 <http: www.fas.org/spg/crs/nuke/RL30699.pdf> February 2008

Israel	Likely R&D	Likely
Kazakhstan	_	Suspected[h]
Libya	_	Ended[i]
Myanmar	_	Suspected
North Korea	Likely	Known
Pakistan	_[j]	Likely
Russia	Suspected[k]	Known
Saudi Arabia	_	Suspected[l]
Serbia	_	Ended
South Afri.ca	Ended	Suspected
South Korea	_	Suspected[m]
Sudan	_	Suspected[n]
Syria	Seeking	Known[o]
Taiwan	_[p]	Likely
United Kingdom	Ended	Ended
United States	Ended	Known
Vietnam	_	Likely
Federal Republic of Yugoslavia	_	_[q]
Notes 'a' through 'q' are found below.		
China	a. The State Department, in its 2005 report to Congress *Adherence to and Compliance with Arms control, Nonproliferation, and Disarmament Agreements and Commitments* (hereafter *Compliance 2005*), noted that China previously had a biological weapon program and that it was highly probable that China remained noncompliant with obligations under the BW Convention. DoD stated that "…China may retain elements of its biological warfare program."[50] b. Regarding chemical weapons, *Compliance 2005* reported that China retained the capacity to mobilize production, though information is insufficient to determine if it has a current R&D program.	
Egypt	c. According to a 1998 Arms Control and Disarmament Agency compliance report, "The United States believes that Egypt has developed BW agents by 1972. There is no evidence to	

[50] Department of Defense, *Proliferation: Threat and Response*, <http://www.dod.gov/pubs/ptr20010110.pdf> January 2001.

	indicate that Egypt has eliminated this capability and it remains likely that the Egyptian capability to conduct BW continues to exist." These concerns are not expressed in similar reports issued in 2001 and 2005.
India	d. When it became a state party to the Chemical Weapons Convention, India admitted that it had produced a chemical weapons stockpile, but it has since hosted all required Chemical Weapons Conventions inspections. It retains the capability to produce CW.
Iran	e. Iran used chemical weapons in 1987 during the Iran-Iraq War and also supplied Libya with chemical weapons which were later used in Chad. "It is also believed to be conducting research on nerve agents."[51]
Iraq	f. Iraq destroyed its CW and BW stockpiles during the 1990's. g. Iraq used CW against Iran and against its own Kurdish population in the 1980's.
Kazakhstan	h. Kazakhstan reportedly retained some Soviet-era CW stockpiles.
Libya	i. Libya used Iranian-supplied chemical weapons in Chad. Libya declared to the Organization for the Prohibition of Chemical Weapons on March 4, 2004 that it had produced 23 tons of mustard gas at Rabat between 1980 and 1990 and stored those materials at two sites. Libya also declared thousands of unfilled munitions.
Pakistan	j. Pakistan is believed to have resources and capabilities to support a limited biological warfare research and development effort.[52]
Russia	k. Russia acknowledged it had a clandestine BW program and claims to have stopped production. However, the U.S. is not assured that Russia is in compliance with the Biological Weapons Convention.
Saudi Arabia	l. There are unconfirmed reports that Saudi Arabia may have developed chemical warheads for its CSS-2 missiles.[53,54]

[51] *Ibid.*

[52] *Ibid.*

[53] NBC Capabilities, Saudi Arabia, *Jane's NBC Defense Systems 1998-1999.*

[54] *Defense and Foreign Affairs Weekly*, April 1991.

South Korea	m. Possesses a chemical weapons stockpile and is destroying it under the Chemical Weapons Convention.
Sudan	n. Sudan "may be interested in a biological weapons program as well." Sudan, a party to the Chemical Weapons Convention, has been developing the capability to produce chemical weapons for many years. It historically has obtained help from foreign entities, principally in Iraq."[55]
Syria	o. Possesses sarin, which it can deliver by aircraft or ballistic missile, and is working to develop other means. Key elements of its program rely on foreign sources.[56]
Taiwan	p. A 1998 Arms Control and Disarmament Agency compliance report states that the United States "believes that Taiwan has been upgrading its biotechnology capabilities," but adds that "the evidence indicating a BW program is not sufficient to determine if Taiwan is engaged in activities prohibited by the Biological and Toxins Weapons Convention." This concern is not mentioned in similar reports issued in 2001 and 2005.
Federal Republic of Yugoslavia	q. Possesses weaponized CS; suspected of having un-weaponized mustard and sarin and, possibly, weaponized BZ.[57]

While U.S. military forces do not have a presence in all of the countries listed above, the potential existence of biological and chemical weapons programs may create sustained demand for preparedness among the U.S. military in countries where forces are deployed. This demand for preparedness may then support prospective military market opportunity for the IMS.

As discussed in this section, the U.S. maintains thousands of military sites and facilities and hundreds of thousands of U.S. troops worldwide. Because of the vast allocation of U.S. troops in the global community, there are more potential targets for adversaries to attack. Similarly, it would seem reasonable to assume that a large number of potential adversaries increase the threat to U.S. troop deployments. In terms of biological and chemical threats, the assumption can therefore be made that deployment may carry increased exposure to such threats, and subsequent need for detection and calibration measures such as the IMS. Understanding where these threats may originate may drive the need for equipment such as the IMS.

[55] Director of Central Intelligence, WMD/ACM December 2001.

[56] *Ibid.*

[57] *Ibid.*

Countries with Biological Weapon Delivery Capacity

Another potential source of influence over the military market for the IMS is the technology available with which countries can use to weaponize biological agents. However, unlike chemical weapons which would likely be deployed with the use of ballistic threats (e.g. artillery shells, land mines, rockets, and bombs), biological weapons may be more likely to be disseminated through simpler methods, (e.g. mailed envelopes, intentional human vectors, and spray devices).[58,59] Biological weapons are also difficult to detect and symptoms of infection may be delayed for an extended period of time. According to the former Assistant Secretary of Defense for Health Affairs William Winkenwerder, because bioterrorism is very unpredictable (for the reasons mentioned above); protective measures against biothreats are a vital part of the defensive measures of U.S. forces around the world.[60] Thus, because the delivery capability of biological weapons can be accomplished through low-technological means, the IMS may have increased market relevance in any country with a history of a biological weapons program. Because U.S. troops are deployed worldwide, this poses a threat to many U.S. military personnel in several different countries. This continues with the assumption that deployment may carry increased exposure to biological threats, and subsequent need for devices to calibrate IMS systems in the field.

Military Market Summary

Ultimately, the IMS may find market relevance within the market of military personnel. Market opportunity may be favorably driven by the ability to calibrate IMS systems in the field with minimal training. Positive and increasing rates of enlistment may prompt growing market opportunity as the risk of biological and chemical attack may be proportional to troop deployment and number of deployment locales. Considering the market for field compatible equipment, the IMS may offer an efficient and cost effective method to detect chemical and biological weapons in the field.

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[58]"Chemical Weapons and Dissemination," Noblis, Web, September 2010, <http://www.noblis.org/MISSIONAREAS/NSI/BACKGROUNDONCHEMICALWARFARE/CHEMICALWARFAREAGENTSANDCHEMICALWEAPONS/Pages/ChemicalWeaponsDissemination_20.aspx>

[59]"AVIP -Questions and Answers." *ANTHRAX VACCINE IMMUNIZATION PROGRAM - The Official DoD Anthrax Information Web Site*. Web. June 2011. <http://www.anthrax.osd.mil/resource/qna/qaAll.asp?cID=301>.

[60]*Ibid*.

4.2 First Responder Markets

4.2.1 Definition & Quantification

The civilian first responder market denotes civilian end-users having an emergency response or law enforcement role within a non-military context. Unique to the civilian first responder market is the characterization of civilian personnel *who hold first responder employment*. First responders may then include those grouped within the United States BLS' occupation classification of "protective services" and "healthcare practitioners and technical occupations." These two categories encompass the traditionally connoted civilian first responders of fire fighters, police officers, and emergency medical technicians (EMTs) and paramedics. The BLS articulates the following employment figures for 2008 and the projected change from 2009 through 2018.[61]

Table 12: Occupational Employment, May 2010

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%***

When employment statistics are accepted as a market indicator for the IMS, the civilian first responder market reveals positive projections of growth. Employment projections for each component of the civilian first responder market are positive, although modest in size over a ten-year period. While a one-to-one ratio of deployment is unlikely, it is these first responders who may serve as end-users of the IMS. Moving forward, an examination of historical relevant threats faced by civilian first responders may help to further specify end-user value of the IMS's applications. The determinant of threat relevance is maintained from analysis of the general civilian market—those historical threats which may be mitigated or eventually prevented by IMS deployment.

[61] Bureau of Labor Statistics, United States Department of Labor. " Occupational Employment Statistics." Protective Service Occupations. U.S. Bureau of Labor Statistics, 14 May 2010. Web. April 2012. <http://www.bls.gov/oes/current/oes330000.htm>.

According to the BLS' National Census of Fatal Occupational Injuries, an estimated 800 police and sheriff patrol officers (710 classified as local government, 90 state government), 990 fire fighters (local government), and 50 EMTs and paramedics (local government) endured nonfatal occupational injuries and illnesses, requiring days away from work, in 2008 due to exposure to harmful substances or environments.[62] Eighty nonfatal occupational injuries requiring days away from work were recorded for police and sheriff patrol officers in 2008 and attributed to fire and explosion. Five hundred injuries were recorded for fire fighters.[63] When exposure to harmful substances or environments and fires and explosions are accepted as hazards relevant to the IMS, historically relevant threats resulted in a total 2,370 nonfatal occupational injuries for civilian first responders. Based on historical data, it can be said that civilian first responders are indeed exposed to threats, risks, and hazards which may prompt IMS market relevance and prospective end-user value.

Acknowledging levels of civilian first responder employment and levels of historical relevant threats, it is important to note that the above occupations traditionally involve some form of deployment. That is, fire fighters may respond to fires, police officers may respond to emergency calls, and EMTs and paramedics may respond to injury occurrence or health incident. This response activity may then imply that civilian first responders are not at their respective place of employment—fire station, police station, hospital, or emergency services station—while on duty. In contrast to immobile or stationary mechanisms to challenge bioaerosol sampler detector systems in the lab, the IMS may be well-suited for deployment applications due to its mobility. In addition to then providing a challenge to bioaerosol sampler detector systems in the field, the IMS can also be used *within* first responder facilities and be deployed with first responders to the scene of emergencies. Readily transportable, the IMS may be brought to, and used at, the place of need. Correspondingly, market quantification may examine both the number of first responder facilities, as well as the number of relevant emergency responses.

The United States Fire Administration (USFA) reports the existence of 30,170 fire departments in 2009 with an estimated 52,400 fire stations in the United States.[64] The most recent data provided by the Bureau of Justice Statistics cites 17,876 state and local law enforcement agencies with the equivalent of at least one full-time officer operating in the United States in

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[62] U.S. Bureau of Labor Statistics, . "Nonfatal Occupational Injuries and Illnesses Requiring Days Away From Work for State Government and Local Government Workers, 2008." *osh2.pdf*. U.S. Bureau of Labor Statistics, 24 Feb 2010. Web. Sep 2010. <http://www.bls.gov/news.release/pdf/osh2.pdf>.

[63] *Ibid.*

[64] United States Fire Administration, U.S. Federal Emergency Management Agency. "Fire Departments." *USFA Fire Departments*. FEMA, 12 Nov 2009. Web. May 2010. <http://www.usfa.dhs.gov/statistics/departments/index.shtm>.

2004.[65] The largest fifty law enforcement agencies are outlined in Appendix A, in accordance with the number of full-time sworn personnel.

With regard to the occurrence of incidents to which civilian first responders respond, and at which the IMS may be deployed, a fire department is said to respond to a fire in the United States every 22.0 seconds with an estimated 1.5 million fires in 2008.[66] The table below outlines 2008 fire fighting responses by reason:

Table 13: 2009 Fire Fighting Response Breakdown[67]		
Response	**Number**	**% Change from 2008**
Fires	1,348,5000	-7.1
Medical Aid	17,104,000	+8.5
False Alarms	2,177,000	-2.9
Mutual Aid/Assistance	1,296,000	+6.7
Hazmat	397,000	+0.6
Other Hazardous (Arcing wires, bomb removal etc.)	625,000	-10.3
All Other (smoke scare, lock-outs etc.)	3,586,500	+2.9
Totals	***26,534,500***	***+5.1***

Based on historical data, the IMS may find prospective market opportunity as deployed to the hazmat responses (*i.e.* for chemical and biological agent detection). Nonetheless, this assessment understands that a field-deployable detection device like the IMS may not necessarily be the most appropriate system to use in all such situations for chemical and biological agent detection.

Additionally, the numbers of EMT, paramedic, police and sheriff patrol dispatches are not accurately or comprehensively reported. The Cellular Telecommunications & Internet Association does, however, report over 51 million wireless emergency service calls for the year 2000. That is, nearly 140,000 emergency calls made from cellular telephones per day in response to life threatening situations.[68] More recently, the National Emergency Number Association

[65]Bureau of Justice Statistics, Office of Justice Programs. "Census Of State And Local Law Enforcement Agencies, 2004." Bureau of Justice Statistics (BJS) - Publication and Product Details. Bureau of Justice Statistics, 23 Apr 2010. Web. May 2010. <http://bjs.ojp.usdoj.gov/index.cfm?ty=pbdetail&iid=539>.

[66]United States Fire Administration, U.S. Federal Emergency Management Agency. "Fire Departments." *USFA Fire Departments*. 2009. Web. June 2011. < http://www.usfa.dhs.gov/statistics/estimates/nfpa/index.shtm>.

[67]United States Fire Administration, U.S. Federal Emergency Management Agency. "Fire Departments." *USFA Fire Departments*. FEMA, 12 Nov 2009. Web. May 2010. <http://www.usfa.dhs.gov/statistics/departments/index.shtm>.

[68] Wireless Internet. "Wireless Emergency Service Calls Near 140,000 Per Day, 96 Calls Per Minute - Brief Article - Statistical Data Included." *Wireless Emergency Service Calls Near 140,000 Per Day, 96 Calls Per Minute - Brief Article - Statistical Data Included*. Information Gatekeepers, Inc., Gale Group , 2001. Web. Sep 2010. <http://findarticles.com/p/articles/mi_m0IGV/is_7_3/ai_77379483/>.

(NENA) reports an estimated 240 million calls to be made to 9-1-1 in the U.S. each year.[69] While the number and reason for dispatch of EMTs, paramedics, police and sheriff first responders is unavailable, it is not unreasonable to assume that said 9-1-1 calls may be at least partially indicative of the frequency of said dispatches. In any case, when deployed to the scene of a relevant emergency (*i.e.* hazardous material, contaminant, or biothreat), the IMS may be deployed alongside first responders.

It is worth noting that some first responder entities may have relatively increased need for the IMS or may have an increased likelihood of employing such detection mechanisms. For example, some major cities in the United States have a Metropolitan Medical Strike Response System (MMRS) organized by the Public Health Service. These units are described to be "highly specialized, fully equipped, deployable teams to combat civilian threats from weapons of mass destruction."[70] They are primarily medical providers who provide emergency medical services, decontamination, detection and treatment. The first such team was organized in 1995 in Washington, DC, and the second was organized for the 1996 Olympics in Atlanta. They are now understood to be present in 124 jurisdictions.[71] Similarly, some law enforcement and emergency medical service organizations may have specifically designated hazmat teams for response to chemical/bio emergencies and those threats understood to be directly relevant to the IMS. Or, for example, some special police departments are tasked with safeguarding transportation systems and facilities. As the civilian market was in part quantified by way of critical infrastructure, including transportation system, it may be such specifically tasked civilian first responders who hold relatively increased value for the IMS. In this regard, a total of 130 special police departments served transportation-related jurisdictions, such as mass transit systems, airports, bridges, tunnels, and port facilities in 2004, the most recent available data. These agencies employed roughly 9,100 full-time sworn officers, as tabulated in Appendix A.

Of 130 transportation system/facility agencies, employing 9,073 full-time sworn officers, the two largest are the Port Authority of New York and the New Jersey Police Department. Combined, the two agencies employed 1,067 officers, 25% more than the last survey period (2000 to 2004). The Port Authority Police served: LaGuardia, Kennedy, and Newark Airports, the Lincoln and Holland Tunnels; the George Washington and Staten Island Bridges; the Port Authority Trans-Hudson (PATH) train system; the Port Authority Bus Terminal; and the Port Newark and Port Elizabeth Marine Terminals. Many of the nation's largest transit systems have their own dedicated police forces (*i.e.* potential IMS end-users). The five largest were in New York, Washington, D.C., Atlanta, Philadelphia, and Boston metropolitan areas. Collectively, the 10 largest transit police departments employed 20% more sworn personnel in 2004 than in 2000.

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[69] National Emergency Number Association. "9-1-1 Statistics." *9-1-1 Statistics National Emergency Number Association* . National Emergency Number Association (NENA), 2010. Web. Sep 2010. <http://www.nena.org/911-statistics>.

[70] Davis, Griffin. "CBRNE- Chemical Detection Equipment." *eMedicine.medscape.com*. WebMD, 10 Dec 2008. Web. 16 May 2010. <http://emedicine.medscape.com/article/833933-overview>.

[71] *Ibid.*

The ten largest transit system law enforcement agencies are tabulated below by their number of full-time sworn personnel.[72]

Table 14: 10 Largest Transit Police Departments in the U.S., 2004	
Transit System Law Enforcement Agency	**Full-Time Sworn Personnel**
New York Metropolitan Transit Authority Police	646
Washington Metropolitan Area Transit Authority Police	365
Metro Atlanta Rapid Transit Authority Police	297
Southeastern Pennsylvania Transit Authority Police	248
Massachusetts Bay Transportation Authority Police	238
New Jersey Transit Police	208
Dallas Area Rapid Transit Authority Police	197
Bay Area (CA) Rapid Transit Police	189
Houston Metropolitan Transit Authority Police	175
Maryland Transit Administration Police	153

Among the ten largest airports in the United States, Los Angeles, Dallas-Ft. Worth, and Minneapolis-St. Paul had their own dedicated airport police department. New York's Kennedy Airport was served by the Port Authority Police. In Atlanta, Chicago, Las Vegas, Denver, Phoenix, and Houston, the airports were policed by units of their respective local police departments. The ten largest airports by full-time sworn personnel are tabulated below.[73]

Table 15: Ten Largest Airports by Full-Time Sworn Police Personnel	
Airport Law Enforcement Agency	**Full-Time Sworn Personnel**
Los Angeles (CA) International Airport Police	354
Metropolitan Washington (DC) Airports Authority Police	185
Wayne County (MI) International Airport Police	170
Dallas-Ft. Worth (TX) Airport Police	169
Lambert-St. Louis (MO) International Airport Police	90
Palm Springs (CA) International Airport Police	88
Ontario (CA) International Airport Police	83
Kansas City (MO) International Airport Police	79
Minneapolis-St. Paul (MN) International Airport Police	77
Tampa (FL) International Airport Police	66

[72] *Ibid.*
[73] *Ibid.*

With specific regard to the IMS, those first responders specifically tasked with responding to hazards and threats directly relevant to the IMS, or specifically tasked with safeguarding components of critical infrastructure, may have relatively increased value for mechanisms to challenge bioaerosol sampler detector systems like the IMS. While transportation systems are just one component of critical infrastructure, said first responders may be representative of a potentially pointed avenue of entry into the civilian first responder market.

In addition to levels of first responder employment to which the IMS may be deployed, an examination of market revenues may shed light on prospective market opportunity. As the IMS is examined as a unique market entrant, however, direct revenue trends are unavailable. That said, in their 2008 report, *The Chemical and Biological Detection Market: Not So Toxic After All*, Frost and Sullivan develop spending projections on the state and local level. Projections by Frost and Sullivan asserted that within the chemical and biological detection market, spending at the state and local level will increase from $20.3 million in 2006 to $35.3 in 2012. This represents an overall increase of 73%. These base figures, tabulated below, can then be used to develop growth projections through 2015. Based on an annual average growth rate of 4.2%, spending at the state and local level is estimated to increase to roughly $56 million dollars in 2015.

Table 16: State and Local Chemical and Biological Detection Spending, 2006-2012[74]

Total Chemical & Biological Detection Market Spending by Segment ($ million)*								**Independent Projections****		
Year	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
State & Local Spending Levels	20.3	27.1	28.4	31.2	34	34.6	35.3	41.2	48.0	56.0

Notes:
**Base Year 2007, All Figures are Rounded*
***Based on 3 year average annual growth rate of 4.2%*

In light of historical growth and positive projections for spending on the state and local level, the outlook for civilian first responder market opportunity appears favorable. (Please note that the independent projections above are just that, projections, and they should be treated as such. These numbers will be subject to economic conditions that cannot be predicted by this assessment.) This is under the assumption that such protective mechanism as the IMS may encounter market conditions similar to biological detection technologies. It is these state and local expenditures, within the biological detection market, which may represent civilian first responder procurement capacity. Increasing expenditures relevant to IMS application may be indicative of favorable market conditions and potential market opportunity.

In addition to levels of state and local spending, programs such as Urban Area Security Initiative (UASI) of the United States Department of Homeland Security (DHS) may serve as

[74] Hendrix, Ryan. "Frost and Sullivan Analyst Briefing: The Chemical and Biological Detection Market: Not So Toxic After All." *Slideshare.net*. Frost and Sullivan, 17 Dec 2008. Web. September 2010.

representative of market relevance for the IMS and offer insight into budgetary quantification of market priorities. The UASI allocates federal funds directly to high-risk urban areas for the purpose of purchasing specialized homeland security equipment, paying first responder overtime costs due to heightened threat levels, training first responders, and planning and executing civilian first responder exercises.[75] For FY2011, the DHS budgetary requests set aside $4 billion to support civilian first responders and national preparedness and response capabilities. Of this $4 billion, $1.1 billion will be allocated to supporting first responders in metropolitan vicinities with higher threat levels by way of the UASI.[76] While these funds may not directly translate into the purchase of a biological detection device such as the IMS, a correlation is not unreasonable. Moreover, the continued allocation of funds to first responders and state and local preparedness efforts may indicate favorable market conditions for the IMS as procurement of detection equipment may be supported by these funds.[77]

With this in mind, the UASI is just one component of the Department of Homeland Security's Assistance to States and Localities. Since FY2002, Congress has appropriated more than $33 billion for homeland security assistance to states, specified urban areas and critical infrastructures, the District of Columbia, and the U.S. insular areas. The Grants Programs Directorate and the National Preparedness Directorate, within the Federal Emergency Management Agency, administer these programs for the Department of Homeland Security. Each assistance program has either an all-hazards purpose or a terrorism preparedness purpose, and is primarily used by first responders, which include fire firefighters, emergency medical personnel, emergency managers, and law enforcement officers. In any case, market prioritization and potential first responder procurement, as indicated by federal funding initiatives for state and local programs, appear favorable to prospective IMS market opportunity and quantification.

4.2.2 Market Drivers & Influences

As the IMS may find potential relevance within the civilian first responder market, drivers and influences have been identified to include, but are not limited to:

- Employment Conditions
- First Responder Dispatch
- Population Density
- Multi-Factor Relationship
- Civilian First Responder Purchase Considerations

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[75] Department of Homeland Security Assistance to States and Localities: A summary and Issues for the 111th Congress, Congressional Research Service, 2009. Pp5.

[76] Note: Funds are allocated based on a risk management methodology developed by the DHS

[77] "Department of Homeland Security Funding Highlights 2011." *GPO Access*. U.S. Government Printing Office, 02 Mar 2010. Web. 15 May 2010. <http://www.gpoaccess.gov/usbudget/fy11/pdf/budget/homeland.pdf>.

Many of the identified market drivers and influences are carried over from preceding sections of analysis as first responders are largely charged with responding to those threats established to be relevant, and to occur within components of critical infrastructure and locations of occupational injury. Likewise, potential drivers and influences are essentially a byproduct of market definition and methods of quantification. For example, as the civilian first responder market was in part quantified by levels of first responder employment, *employment conditions* may affect IMS market opportunity by way of influence on the number of prospective IMS end-users. As previously noted, the United States Bureau of Labor Statistics (BLS) predicts positive growth for each of the identified civilian first responder employment categories. Employment projections for fire fighters, police officers, and EMTs and paramedics are positive through 2018, growing by 16%, 8%, and 8%, respectively. While this appears favorable for the prospective IMS market opportunity, multiple and multifaceted factors which may affect employment levels and conditions are noted to hold prospective weight and influence.

First responder dispatch is noted as a potential source of market influence as said end-users *respond* to emergency situations. While this may not negate the IMS's efficacy or market relevance, and may in fact foster value of the device's mobility, it may alter deployment locales and frequency of use. That is, it is unlikely that the IMS will find application within first responder facilities, but will rather be deployed at the site of hazard for chemical and biological agent detection. Correspondingly, beyond general precaution and preparation, first responder rates of, and reasons for, dispatch may exert influence over prospective IMS market relevance. With this in mind, market quantification revealed 1,451,500 fires, 397,000 hazmat responses, 3,586,500 responses categorized as "other" within which the IMS may find application. Recognizing the fact that the IMS may not have a one-to-one purchase ratio with each first responder, in addition the end-user trait of deployment, agencies and bureaus, or the number of first responder vehicles, may prove more indicative of quantified market opportunity. For example, there are an estimated 48,384 ambulances in the United States within which the IMS may be carried for emergency deployment.[78] The number of fire "trucks" is not articulated by relevant sources, but there are an estimated 68,200 pumpers (installed on vehicle), 6,725 aerial apparatus (installed on vehicle), and 75,300 other suppression vehicles (including tankers, brush vehicles etc.) reported by the U.S. Fire Administration for 2006-2008.[79] As these vehicles may be deployed to the scene of relevant emergency, they may exist as points of IMS deployment. At a minimum, it is not unreasonable to assume that with 52,500 fire stations in the United States, each may have at least one fire truck within which the IMS may be dispatched to an emergency scene. In any case, the IMS's mobility may favorably play into the influence of first responder

[78] American Ambulance Association. "Ambulance Facts." *AAA // Ambulance Facts*. American Ambulance Association, 2007. Web. Sep 2010. <http://www.the-aaa.org/media/ambulance_facts.html>.

[79] United States Fire Administration, U.S. Federal Emergency Management Agency. "Fire Departments." *USFA Fire Departments*. FEMA, 12 Nov 2009. Web. May 2010. <http://www.usfa.dhs.gov/statistics/departments/index.shtm>.

dispatch, enabling the device to be used on-site at emergency locales. As previously noted, strategic branding may be required to prompt end-user value of precaution and preparation for actual or perceived threats, as well as the device's ability to be readily transported.

Population density is another potential market driver and influence maintained from preceding analysis of the civilian market. Increased population density and growth may affect characterizations of critical infrastructure, to which first responders may be dispatched or be specifically tasked with safeguarding, as well as increased levels of actual or perceived risk. Population density may also increase the size of first responder establishments. Simply stated, major cities and more densely populated areas may have larger first responder agencies, larger pools of prospective end-users, a greater number of first responder vehicles within which the IMS may be transported for emergency deployment dispatch, and relatively higher levels of perceived or actual threat. With regard to the latter, market analysis of drivers and influences within the general civilian market noted overall trends within terrorism which included the favoring of acts with the propensity to result in mass casualty. One clear avenue to affecting mass casualty is then the attack of densely populated areas. Also noted is the generally increasing risk of chemical and biological terrorism, also likely to be enacted in densely populated areas. Alternatively, facilities housing relevant materials (*e.g.* chemical facilities and other components of critical infrastructure) may be targeted, again prompting likely increased market relevance of the IMS to be deployed by a general or specifically tasked civilian first responder. The table below notes levels of population density.

Table 17: Select Metropolitan Area Growth Projections Through 2020[80]

	2012	2014	2016	2018	2020	Change 2010-2020	Average Growth Rate	Growth 2010-2020
Boston	4,584,545	4,615,703	4,647,073	4,678,657	4,710,454	156,857	0.7%	3.4%
Chicago	9,803,793	9,923,018	10,043,692	10,165,834	10,289,462	603,461	1.2%	6.2%
Dallas	6,937,137	7,279,472	7,638,702	8,015,658	8,411,217	1,800,317	4.9%	27.2%
Washington	5,648,854	5,800,078	5,955,351	6,114,781	6,278,479	776,908	2.7%	14.1%
Los Angeles	13,115,904	13,239,168	13,363,591	13,489,183	13,615,955	622,167	0.9%	4.8%
New York	19,342,286	19,512,245	19,683,697	19,856,655	20,031,133	857,324	0.9%	4.5%
Philadelphia	5,912,641	5,950,079	5,987,753	6,025,667	6,063,820	188,381	0.6%	3.2%
Growth Rates Based on US Census Bureau Metropolitan Growth Projections 2000-2008								

Each of the metropolitan areas noted above falls within the first quartile of the largest fifty law enforcement agencies by full-time sworn personnel. The areas rank twenty fourth, second, seventeenth, eleventh, third, first, and sixth, respectively. Such a correlation, between population

[80] "Metropolitan and Micropolitan Statistical Area Estimates." *U.S. Census Bureau*. U.S. Census Bureau, 2008. Web. 15 May 2010. <http://www.census.gov/popest/metro/CBSA-est2008-annual.html>.

density and size of law enforcement (*i.e.* civilian first responders) is not unexpected and may enhance prospective IMS market opportunity—which should increase as related variables are positively correlated. With this in mind, the last identified market driver and influence of a *multi-factor relationship* is again relevant. As discussed within analysis of market drivers and influences for the general civilian market segment, there are multiple variables which may play into risk and threat assessments, levels of real and perceived hazards and classifications of critical infrastructure. Noted within analysis of the civilian first responder market segment are the additional factors of variable end-user value schemes, relatively stringent budgetary requirements, and varied levels of training and exposure to those threats understood to be relevant to the IMS. It may prove pertinent for purveyors of the IMS to maintain awareness of, and strive to adapt to, such multi-factor relationships, varying with each end-user segment.

It is worth noting that while civilian first responder purchase considerations may vary based on the specific type of equipment and application in question (*e.g.* detection apparatus versus life saving equipment), there are several considerations understood to be common throughout the first responder market segment. In reviewing several civilian first responder guides for the selection of equipment published by the National Institute of Justice and the Department of Homeland Security, the factors tabulated below arise as thematic points of civilian first responder purchase evaluation when considering the procurement of new equipment.

Table 18: DHS Equipment Procurement Considerations[81]

Point of Evaluation	Description
Training Requirements	This factor considers the resources required to train first responders in the usage of the equipment. This primarily consists of time required to develop proficiency in the operation of the first responder equipment. Generally speaking, products that provide ease of training are considered favorably, holding all else constant.
Operator Skill Level	This factor considers the skill level and training required for the operation of an instrument. Depending on the type of equipment, varying degrees of skill may be required for operation. Resource scarcity in the form of first responder skill level may present a hurdle if operational requirements are such that

[81] "Guide for the Selection of Personal Protective Equipment for Emergency First Responders." *National Criminal Justice Reference Service*. U.S. Department of Justice, Nov 2002. Web. 27 May 2010. <http://www.ncjrs.gov/pdffiles1/nij/191518.pdf>.
"Guide for the Selection of Chemical and Biological Decontamination Equipment for Emergency First Responders." *National Criminal Justice Reference Service*. U.S. Department of Justice, Oct 2001. Web. 16 Jun 2010. <http://www.ncjrs.gov/pdffiles1/nij/189724.pdf>.
"Guide for the Selection of Drug Detectors for Law Enforcement Applications." *National Criminal Justice Reference Service*. U.S. Department of Justice, Aug 2000. Web. 16 Jun 2010. <http://www.ncjrs.gov/pdffiles1/nij/183260.pdf>.
"Guide for the Selection of Chemical Detection Equipment for Emergency First Responders." *National Institute of Standards and Technology*. U.S. Department of Homeland Security, Jan 2007. Web. 27 May 2010. <http://www.eeel.nist.gov/oles/Publications/dhs100-06.pdf>.

	advanced degrees or high levels of specialized training not common among the civilian first responders are inherent requirements of operation.
Durability	This factor considers the ability of the equipment to withstand or function in harsh environments, often called ruggedness. The alignment of durability with environmental considerations may be an integral product feature that factored into the purchase decision. Evaluation of durability may include such variables as product life cycle, or the expected length of usage for the equipment.
Unit Cost	This factor typically includes the cost of the primary unit and all supporting and consumable equipment. While high unit cost does not necessarily equate to lower potential for purchase, an overall cost-benefit assessment may influence overall purchase decisions.[82]
Quality/ Equipment Effectiveness	This factor is usually specific to the type of equipment being considered. Based on the purpose and specific criterion against which performance is measured, this factor may be considered a primary purchase consideration. Holding all else equal, equipment effectiveness or performance is likely to be at the center of the purchase decision.

It is not unreasonable to assume that the likelihood of end-user adoption (*i.e.* purchase) may be a function of the above tabulated factors. Favorably, if purveyors of the IMS are able to optimize said factors, and effectively brand the device as such, market penetration may be fostered. As established, based on the particular type of equipment in question, some of these factors may hold more or less significance for the end-user and may alter their weighted contribution to the likelihood of purchase. Keeping in mind the interrelated or functional nature of the above variables, a prospective purchase decision may be characterized by the following conceptual equation.

Equation 1: Likelihood of Equipment Purchase

$$\boldsymbol{Likelihood\ of\ Purchase}\ (\boldsymbol{Equipment_x}) = Training\ Requirements\ (b_1) + Skill\ Level\ (b_2) + Durability\ (b_3) + Unit\ Cost\ (b_4) + Effectiveness\ (b_5)$$

Each factor has an associated weight of importance (b_n) based on the specific technology considered. As potential licensees are able to develop a better understanding of the true purchase motives that exist within the prospective end-user segments, respective of the IMS, it may be possible to influence market penetration by controlling and optimizing product features which increase the likelihood of purchase. For example, the IMS is understood to be easy-to-use in a variety of environmental conditions, requiring little specialized training—both factors which may be effectively branded to favor purchase decision. In any case, awareness of the multiple

factors which may affect end-user value schemes as well as prospective market relevance may serve to influence IMS market opportunity.

First Responder Market Summary

Thus far, this assessment has examined prospective IMS market relevance via end-user value of the unit's application. For example, when the risks of biothreats increase, the end-user value of the IMS's ability to challenge bioaerosol sampler detector systems in the field may also increase. This rationale is maintained within the civilian first-responder market.

As first responders *respond* to emergency situations, they may have some value for the IMS in situations involving acts of bioterrorism or hazardous materials. With regard to the deployment of the IMS to first-responders, those end-users which are located in high-risk areas, with increased population densities, or those locales with increased risk of biothreats, may see an increase in end-user value for the IMS. Rates of first responder call response (*i.e.* how frequently the facility is left) and the biothreat level of a given area may then serve to influence the civilian first-responder market.

The examination of population density above is applicable for the civilian first responder market. As previously noted, there tends to be a positive correlation between population density and rates of crime occurrence. As rates of crime occurrence increase, civilian first responders may be subject to increased levels of biothreats in the field. Budgetary concerns, the availability of biological detection equipment, and laws and regulations may also exert market influence as these factors can affect the need for biothreat detection devices.

There may be additional end-user variables to consider as entry in to the civilian first responder market segment is pursued. Throughout this assessment, the variable of threat "relevance" has been articulated. For example, the IMS may find little market relevance or end-user value in the face of a ballistic threat, but may find relatively high levels of relevance and value when an end-user is posed with a hazardous vapor, migrating contaminant, or biological agent to be identified. Recognizing hazardous materials and chemical and biological agents to fall within the range of threats which may be identified by IMS deployment, the civilian first responder market may vary from military end-users, for example, in that levels of training are narrowed, experience with chemical and biological agents may be limited, and budgetary constraints may be greater. While a full discussion of these variables is beyond the scope of this assessment, they may prove to influence prospective market opportunity for the IMS as end-user preferences and value schemes may fluctuate. That said, the IMS's prospective advantages may serve to support market relevance within the civilian first responder market—the device may prove to offer a readily transportable and rapidly deployable mechanism of detection and identification. Said advantages and the device's operation, understood to be simple, may foster market adoption. Ultimately, recognizing, understanding and aligning the IMS with end-user variances such as those outlined throughout this report may support viable penetration strategies.

4.3 Government Market

IMS may find relevance and opportunity within Department of Homeland Security or other government markets for detection of explosives, chemical and biological agents, and drugs. IMS units are also used at the borders to detect drugs and explosive devices that are attempting to be smuggled into the country. These applications include airport security, site security, drug interdiction, forensics, and customs and border patrol.[83] A discussion about the various government markets follows.

4.3.1 Definition and Quantification

The U.S. explosive detection market was $1.5 billion in 2009 and it is expected to reach $3.3 billion by 2014. This figure includes all types of services, installations and equipment, including trace explosive detection equipment, the market for which was $210 million in 2009 and which is expected to grow to $420 million by 2014.[84]

4.3.2 Market Drivers & Influences

As the IMS may find potential relevance within the government market, drivers and influences have been identified to include, but are not limited to:

- American Recovery and Reinvestment Act
- Deployment of state-of-the-art explosives and weapon screening systems at airports
- Transportation Security Administration (TSA) budget for explosive detection systems

American Recovery and Reinvestment Act

Growth in the government market is being driven by the 2009 American Recovery and Reinvestment Act. This Act pledged $1.05 billion of support for explosives detection through 2012.[85] Since its enactment in February 2009, $752 billion has been distributed funds through tax benefits ($297.8 billion); contracts, grants, and loans ($230.5 billion); and entitlements ($223.7

[83]Kanu, A.B and H.H. Hill, "Ion Mobility Spectrometry: Recent Developments and Novel Applications," *LPI* April/May2004 http://public.wsu.edu/~hillh/Hill%20scan%20papers%20pdfs/2004%20Labplus%20Kanu%20IMS%20recent%20developments.pdf viewed April 18, 2012.

[84] Unknown, "Forecast: Explosive Detection Market Poised for Rebound," 2009 Homeland Security Market Research http://www.homelandsecurityresearch.com/2009/10/forecast-explosive-detection-market-poised-for-rebound/ viewed April 24, 2012.

[85] *Ibid.*

billion). The contracts, grants, and loans budget includes Department of Homeland Security-Office of the Under Secretary for Management spending.[86]

Explosives and Weapon Screening Systems at Airports

The technology that is the most successful and most widely used for the detection of explosives is IMS. There are currently 10,000 IMS units in use at airports worldwide. There are also roughly 50,000 IMS units being used in the United States Army.[87]

The primary system for detecting explosives is a portal costing about $160,000. A burst of air hits the passenger standing in the portal and IMS analyzers in the roof of the portal screen the resulting particles for explosives and the result is delivered in about fourteen seconds. This is significantly longer than the time required than the time to walk through a metal detector; so many portals would have to be deployed in an airport to permit the screening of all passengers.[88]

TSA Budget for Explosive Detection Systems

The TSA requested a budget of $367 million ($117 million in appropriated funding and $250 million from the Aviation Security Capital Fund) for Explosives Detection System (EDS) procurement and installation for FY 2013.[89] In addition, a FY 2012 legislative change that allows Aviation Security Capital Fund fees to be used for the procurement and installation of EDS equipment will maintain adequate resources for TSA's checked-baggage screening.[90]

4.3.3 Customs and Border Patrol (CBP)

The United States Customs and Border Protection (CBP) is an agency within the Department of Homeland Security (DHS) tasked with ensuring the safety and protection of the U.S. borders. CBP protects the nation's borders from terrorism, human and drug smuggling, illegal migration, and agricultural pests while simultaneously facilitating the flow of legitimate travel and trade.[91]

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[86] Unknown, "Recovery.gov Track the Money," U.S. Government's Official Website for Recovery Act Spending data as of April 13, 2012 http://www.recovery.gov/Pages/default.aspx viewed April 24, 2012.

[87] Zolotov, Y.A., "Ion Mobility Spectrometry," *Journal of Analytical Chemistry*, **61** (6): 519 (2006).

[88] D'Arcy, M. et al., "Protecting the Homeland 2006/2007," *Brookings Institution Press*, p. 141 (2006).

[89] B. Rayburn, "Written testimony of Transportation Security Administration (TSA) Administrator John Pistole for a House Committee on Appropriations," Subcommittee on Homeland Security hearing on President's budget request for TSA for Fiscal Year 2013, U.S. Department of Homeland Security Website released February 28, 2012.

[90] *Ibid.*

[91] United States Customs and Border Protection, Department of Homeland Security, *About CBP, Retrieved July 2010,* <http://www.cbp.gov/xp/cgov/about/mission/cbp_is.xml>

Under the umbrella term of CBP, there are several offices in operation, including the Office of Field Operations and Office of Border Patrol.

CBP officers have a wide variety of roles including processing travel passengers and pedestrians, apprehended persons attempting to enter the country illegally, seizing narcotics and illicit currency, rescuing persons in trouble, and monitoring over 100,000 miles of border- and coastline. According to the CBP website, on a typical day, officers execute the following actions all throughout the U.S.:

Table 8: CBP Actions on a Typical Day (2009)[92]

Action	Statistics
Processing	989,689 passengers and pedestrians 240,407 international 45,735 sea 703,546 land 57,761 truck, rail and sea containers 271,278 incoming privately owned vehicles
Seizures	72 fraudulent document 6,643 kilograms of narcotics $300,582 of illicit currency 4,291 prohibited food byproducts 454 agricultural pests
Rescued	1281 people in 488 events

In addition to their various actions taken daily throughout the U.S., there are numerous types of officers employed by CBP. While employees within CBP are frequently referred to in their efforts patrolling for illegal immigration along the southern border of the U.S., there are many agents throughout the country carrying out a wide assortment of duties. These include agents patrolling both northern and southern U.S. borders, agriculture specialists, and air and marine specialists. The following table provides a list of several of the different types of agents and the number employed by CBP.

Table 9: US Customs and Border Protection Employees[93]

Type	Number
Border Patrol Agents	20,119
Air and Marine Agents	1,212
Officers and Agriculture Specialists	21,058

[92] United States Customs and Border Protection, "*On a Typical Day in Fiscal Year 2009, CBP…*", 16 February 2010, Web, June 2010, <http://www.cbp.gov/xp/cgov/about/accomplish/fy09_typical_day.xml>

[93] U.S. Customs and Border Protection. *SNAPSHOT: A summary of CBP facts and figures*, Web. June 2010. http://www.cbp.gov/linkhandler/cgov/about/accomplish/snapshot.ctt/snapshot.pdf.

• Air Enforcement Officers • Air Interdiction Officers • Marine Interdiction Officers	47 823 342
Total (including all other employees)	**~52,000**

While CBP officers are largely recognized for their efforts along the southern border of the U.S. with Mexico, their duties extend elsewhere in the country. CBP agents are positioned along the northern U.S./Canadian border and cover the entire U.S. coastline. This amounts to over 100,000 miles of coastline to protect by an agency of just over 50,000 total employees, of which many are not field agents.

Within CBP, two of these offices, Field Operations (OFO) and Border Patrol (OBP), may have extensive uses for explosives and chemical and biological agent detection. Officers within OFO are federal law enforcement officers serve the CBP at the hundreds of various ports across the United States. An OFO Officer's primary responsibility is to detect and prevent terrorists and weapons of mass destruction from entering the United States, while facilitating the orderly flow of legitimate trade and travelers.[94] OFO Officers perform a wide range of duties including inspection and passenger and cargo analysis, in addition to their duties enforcing the law at ports of entry.

While there are several applications within OFO for explosives and chemical and biological agent detection, there are two which have been identified may be of most benefit for OFO officers:[95]

1) General aviation at airports, especially for chartered flights
2) Points of entry (POE) that currently do not have explosives or chemical and biological screening capabilities

Additionally, there are OBP officers within CBP. These are Border Patrol Agents tasked with preventing terrorists and terrorist weapons from entering the United States, detecting and preventing the smuggling and unlawful entry of undocumented aliens into the United States, and apprehending those people found to be in violation of the immigration laws.[96] OBP has many similar needs and device and operational requirements as OFO. However, because OBP officers

[94] United States Customs and Border Protection, *GS-1895-5?7 Customs and Border Protection Officer*, Revised April 2009, Retrieved July 2010, <http://www.cbp.gov/linkhandler/cgov/careers/customs_careers/officer/officer_fact_sheet.ctt/officer_fact_sheet.pdf>

[95] International Biometric Group (IBG). *Final Report. SBIR FY07.1 Phase I. Portable Acquisition and Search System*. May 2008. p 2.

[96] U.S. Customs and Border Protection, "Your Career as a Border Patrol Agent", Web, July 2010, <http://www.cbp.gov/xp/cgov/careers/customs_careers/border_careers/bp_agent/>

may have more significant duties in checkpoints and remote areas between POEs that lack any substantial infrastructure, they may desire features such as portable equipment.

Government Market Summary

The Department of Homeland Security market for enhanced IMS devices for explosive detection are positively influenced by factors such as the American Recovery and Reinvestment Act of 2009, explosives and weapons screening at airports, and the TSA's budget for explosive detection systems. In addition, the Customs and Border Protection agency may provide a market for enhanced IMS devices for explosives and chemical and biological agent detection as it works to protect our nation's borders from terrorism and drug smuggling. It is probable that investment in technologies for explosive detection and baggage and passenger screening will continue in the coming years as potential threats become more sophisticated and the potential consequence for failure could be devastating to our nation's security.

4.4 Other Civilian Markets

Because the IMS is used for explosive and chemical and biological agent detection, military and first responder applications are likely to be the most relevant market segments worthy of analysis. However, there are other civilian markets that may also warrant some further analysis and discussion. While biological agents may be used in *attacks* against U.S. troops and large civilian populations in major cities or transportation venues, these biothreats may also be used in other civilian areas. The following lists several of these civilian markets:

- Critical Infrastructure Sites
- Hospitals, Blood Collection Centers, and Other Medical Treatment Facilities

In addition, the IMS can be used for other applications. These applications include:

- Pharmaceutical Manufacturing
- Petroleum Chemical Manufacturing
- Disease Detection

4.4.1 Critical Infrastructure Sites

4.4.1.1 Definition & Quantification

Acknowledging the multitude of civilian installations to which the IMS may be applied, it is unrealistic to expect the civilian consumer base in its entirety to serve as representative of market opportunity. In other words, many consumer segments for which the IMS may not be optimized will likely be removed from immediate market opportunity, *i.e.* market relevance will not be consistent or constant throughout all civilian market segments. One mechanism of then further

defining and quantifying the civilian market for the IMS is an examination of the need for, or value offered by, the present invention. In considering the commonality of biological weapons and the means of which to deploy them, this assessment moves to examine the value which may be placed upon the IMS's detection applications by the general civilian population. Quantification is then pursued by way of examining *levels of critical infrastructure*, which may have increased need for detection mechanisms such as the IMS.

Critical infrastructure is generally understood to include components of the national infrastructure that are critical to the national and economic security of the United States and the well being of its citizenry. This infrastructure, due in part to its pivotal function within the greater economy, is relatively more vulnerable to disruption by acts of terrorism, warfare and is considered to be likely targets of said opportunity.[97] Critical infrastructure is commonly grouped with *key resource sectors*, which are publicly or privately controlled resources essential to the minimal operations of the economy and government. With regard to the IMS, establishments, facilities, and operational resources characterized as critical or key may then have an increased need for detection mechanisms. Due to relatively increased actual or perceived risk, as well as generally acknowledged vitality, market relevance of the IMS's detection applications may be amplified. Examples of critical infrastructure and key resource sectors (CIKR) include, but are not limited to:

- Agriculture and Food
- Postal Services and Shipping
- Water

The above categorizations of industries characterized as critical infrastructure with specific relevance to this technology are further tabulated below:

Table 19: Critical Infrastructure & Key Resources Sectors[98]

Classification	Subsector Overview	Subsectors, Dependencies & Interdependencies
Agriculture and Food	The Agriculture and Food Sector has the capacity to feed and clothe people well beyond the boundaries of the nation. The sector is almost entirely under private ownership and is composed of an estimated 2.1 million farms, approximately 880,500 firms and over one million facilities. This sector accounts for roughly one-fifth of the nation's economic activity and is overseen at the federal level by the U.S.	Water, for clean irrigation and processed water; Transportation Systems, for movement of products; Energy, to power the equipment needed for agriculture production and food processing; and

[97] United States Department of Defense, "The Department of Defense Critical Infrastructure Protection (CIP) Plan," 18 November 1998, Web, September 2010, <http://www.fas.org/irp/offdocs/pdd/DOD-CIP-Plan.htm>

[98] *Ibid.*

	Department of Agriculture (USDA) and the Department of Health and Human Services' (HHS) Food and Drug Administration (FDA).	Banking and Finance, Chemical, Dams, and other sectors as well.
Postal and Shipping	The Postal and Shipping Sector is an integral component of the U.S. economy, employing more than 1.8 million people and earning direct revenues of more than $213 billion per year. The Postal and Shipping Sector moves over 720 million messages, products, and financial transactions each day. Postal and shipping activity is differentiated from general cargo operations by its focus on small- and medium-size packages and by service from millions of senders to nearly 150 million destinations. The sector is highly concentrated, with a handful of providers holding roughly 94 percent of the market share. Sector-specific assets include: over 400 high-volume automated processing facilities; over 40 thousand local delivery units; many and varied collection, acceptance, and retail operations; over 50 thousand mail transport vehicles including vans, trucks, tractor trailers and aircraft; and information and communications networks.	Every sector of the economy depends on the service providers in the Postal and Shipping Sector to deliver time-sensitive letters, packages and other shipments. These time-sensitive delivery needs are critical to the Banking and Finance, Government Facilities, Commercial Facilities and Healthcare and Public Health sectors. Major interdependencies with other sectors include those with the Transportation Systems, Energy, Information Technology and Communications sectors.
Water	The Water Sector includes both drinking water and wastewater utilities. There are approximately 160,000 public drinking water systems and more than 16,000 publicly owned wastewater treatment systems in the United States. Approximately 84 percent of the U.S. population receives their potable water from these drinking water systems, and more than 75 percent of the U.S. population has its sanitary sewerage treated by these wastewater systems. The Water Sector is vulnerable to a variety of attacks including contamination with deadly agents, physical attacks—such as the release of toxic gaseous chemicals—and cyber attacks. If these attacks were realized, the result could be large numbers of illnesses or casualties and/or a denial of service that would also impact public health and economic vitality.	Critical services such as firefighting or healthcare and other dependent and interdependent sectors, such as Energy, Transportation Systems, and Agriculture and Food, would be negatively impacted by a denial of service from the Water Sector.

Beyond recognition of market relevance and the probability of increased need for detection systems such as the IMS, market quantification of critical infrastructure remains abstract. In other words, a categorization of every component of CIKR is beyond the scope of this assessment. Additionally, some facets of CIKR lend themselves more towards IMS deployment and installation than others. For example, research into the number of *dams* in the U.S. revealed

an estimated 8,100 major dams in the United States.[99] Given the fact that it has been assumed throughout this assessment that preventing structural damage is not an application of the IMS, while dams may be locations of critical infrastructure, they are likely to be irrelevant to this technology. This is largely due to the fact that a non-structural, chemical or biological attack on a dam would not interfere with its primary purpose of water impounding and storage. The water supply stored within the dam, however, may be of relevance as contamination of the water supply is commonly considered to be a risk to national security.[100] Thus, many of the aforementioned CIKR sectors will be considered as relevant to the civilian market, but not thoroughly quantified.

To begin, the North American Industry Classification System (NAICS) classifications of *agricultural farming* may first be used to quantify the Agriculture and Food sector of the civilian market. In general, farming is characterized by the production, processing and use of food in open fields and unenclosed areas. Because farmers or other individuals within the agriculture industry may be able to utilize the IMS to detect and identify biothreats in a short amount of time, the number of farms may have relevance for the IMS. Research into the number of farms reveals an estimated 2.1 million farms within the U.S. This market sector may be important due to the fact that the U.S. food supply has been described as being a high value terrorist target—as well as an attack to which the U.S. may be unprepared for a response.[101] Additionally, food *manufacturers* may reveal a pertinent quantification within the agriculture and food CIKR sector. Food manufacturers are defined by the NAICS to be those entities which transform livestock and agricultural products for intermediate or final consumption in enclosed spaces. The table relaying the U.S. Census Bureau's most recent released count of food manufacturers can be found in Appendix B.

Of particular note is the potential for the contamination of food manufacturing facilities and the food supply in general. Deliberate contamination of the nation's food and water supply is considered a real and viable threat, and the economic and psychological implications are extensive.[102] However, while even U.S. government officials have warned of the vulnerability of terrorist contamination of the food and water supply, there are very few incidents of people deliberately contaminating these resource supplies. The closest example of what can be referred

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[99] "Major Dams of the United States," National Atlas, Web, June 2011, <http://www.nationalatlas.gov/mld/dams00x.html>

[100] Kevin Coleman, "Protecting the Water Supply," Directions Magazine, 16 January 2005, Web, September 2010, <http://www.directionsmag.com/articles/protecting-the-water-supply-from-terrorism/123563>

[101] Thomas F. Stinson, Jean Kinsey, Dennis Degeneffe, and Koel Ghosh, "Defending America's Food Supply Against Terrorism: Who is Responsible? Who should pay?" Choices, 1st Quarter 2007, 22(1), Web, September 2010, <http://www.choicesmagazine.org/2007-1/grabbag/2007-1-12.pdf>

[102] Thomas F. Stinson, Jean Kinsey, Dennis Degeneffe, and Koel Ghosh, "Defending America's Food Supply Against Terrorism: Who is Responsible? Who should pay?" Choices, 1st Quarter 2007, 22(1), Web, September 2010, <http://www.choicesmagazine.org/2007-1/grabbag/2007-1-12.pdf>

to as "bioterrorism" of this sort occurred in 1984 in the U.S., where members of a religious group known as the Rajneeshes contaminated several restaurant salad bars with salmonella, sickening 751, hospitalizing 45, and killing no one.[103] Thus, this would appear to suggest that the ability of terrorist organizations to effectively contaminate food and water supplies may not be as easy was once thought. While no direct correlation of this assumption can be made to the market viability of the IMS, it may be worthy of consideration, particularly for civilian market segments of agriculture and food and water utilities.

Moving forward with regard to critical infrastructure, based on the data examined, *postal and shipping* establishments may also be well aligned with IMS application. Given past biological attacks involving the United States Postal System, heightened precautionary measures may be especially valued by respective end-users. For example, in 2001, letters containing anthrax spores were mailed to several news media offices and to two U.S. senators. Five people were killed and 17 others are reported to have been infected. Recognizing the postal and shipping system to be the point from which the anthrax was disseminated, and assuming the IMS can detect chemical and biological agents, market relevance appears applicable. As noted above, the postal and shipping sector moves over 720 million messages and products per day, to nearly 150 million destinations. With such wide reaching branches of operation, the postal system may remain a target for purposeful release of chemicals, biological weapons and other hazards and may have corresponding increases in value for the IMS as a detection system. There are an estimated 34,000 post office and retail outlets operated by the United States Postal Service (USPS), but this figure does not account for privately owned distribution operations. Combined with 400 high-volume automated processing facilities, the postal and shipping market may be loosely quantified at 34,400 establishments to which the IMS may find relevance.[104]

In continuing the discussion of critical infrastructure sites and their vulnerability to biological threats, water and energy may be of relevance. These segments may be indirectly quantified by way of NAICS classification, grouped in NAICS 22, *utilities*. Said industry segments provide electric power, natural gas, steam supply, water supply, and sewage removal through permanent infrastructure of lines, mains and pipes. The U.S. Census Bureau quantification of said establishments totals 16,578. Establishments are grouped together based on the utility service provided and the particular system or facilities required to perform the service. The table found in Appendix B outlines the U.S. Census Bureau's quantification of said establishments, to which the IMS may find relevance. As with many large structural key infrastructure facilities, the IMS may have little relevance as it does not protect against damage to the structure itself.

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[103] Bruce Schneier, "Attacking the Food Supply," 14 May 2009, Web, June 2011, <http://www.schneier.com/blog/archives/2009/05/attacking_the_f.html>

[104] "Could your post office be closing?" MSN, 26 June 2009, Web, September 2010, <http://articles.moneycentral.msn.com/Investing/Extra/could-your-post-office-be-closing.aspx>

4.4.1.2 Market Drivers & Influences

Thus far, this assessment has examined prospective IMS market relevance via end-user value of the unit's ability to detect chemical and biological agents. For example, when biothreats increase in frequency, end-user value of the detection methods offered by the IMS may increase. This rationale is maintained within the civilian market.

With regard to end-users within the civilian markets outlined above, those facilities and individuals located within areas or industries identified as *critical infrastructure* sites may have an increased value for the IMS. The value of IMS's deployment would also be likely to increase should these sites be located in high-risk areas, with increased population densities, or those locales with increased levels of potential biothreats.

Additionally, the previous examination of population density, examined as a potential driver and influence within the civilian first responder market, may remain applicable for the civilian market. As previously noted, there tends to be a positive correlation between population density and the risk of bioterrorism. As the risk of biothreats increase, civilian critical infrastructure sites may be subject to increased levels of hazmat or biothreat accidents and attacks, potentially requiring systems for detecting and identifying biological agents. Arms availability, budgetary concerns, and laws and regulations may exert market influence as these factors can affect the level of biothreat detection equipment within these critical infrastructure sites.

Ultimately, an examination of the potential market drivers and influences for prospective IMS market opportunity appear multi-faceted and potentially, interrelated. Systematic risk not alleviated by existing screening measures and detection technologies may prompt market value for technologies able to supplement safety or mitigate this remaining risk. Moreover, if the device is implemented in a fashion which can decrease the time required for testing for chemical and biological agents and lead to the minimization of fallout from potentially hazardous biological attacks, corresponding cost implications may be minimized and market value may be fostered.

4.4.2 Hospitals, Blood Collection Centers, and Medical Treatment Facilities

4.4.2.1 Definition and Quantification

Because hospitals, blood collection centers, and medical treatment centers present a possibility for biological or chemical attack, they may provide potential application for equipment to test for chemical and biological agents. Therefore, the IMS may find application at these facilities.

Blood collection centers are understood to be those local or regional blood centers that collect blood from donors and supply blood, components, and cross-matched blood products to relevant facilities (*i.e.* medical clinics and hospitals). Pre-screening of blood donors, testing for bacteria, viruses and other infections, likely occurs within these centers and further testing may occur on-site or at an off-site laboratory.

Given prospective market relevance of the IMS within hospitals and other medical facilities, quantification may then focus on the number of hospitals within the United States. According to the American Hospital Association (AHA), there were a total of 5,815 hospitals in the United States registered with the Association. The table below breaks down this figure by ownership and types of care.

Table 20: AHA Classification of Hospitals in the United States		
AHA Classification	**Number**	**Notes**
Total Number of All U.S. Registered Hospitals	5,815	Registered Hospitals are those that meet AHA's criteria for registration as a hospital facility. Registered hospitals include AHA member hospitals as well as nonmember hospitals. Please see Appendix D for AHA Registration Requirements.
Number of U.S. Community Hospitals	5,010	Community hospitals are defined as all nonfederal, short-term general, and other special hospitals including obstetrics and gynecology; eye, ear, nose and throat; rehabilitation; orthopedic; and other individually described specialty services. Excluded are hospitals not accessible by the general public, such as prison hospitals or college infirmaries.
Number of Nongovernment Not-for-Profit Community Hospitals	2,923	
Number of Investor-Owned (For Profit) Community Hospitals	982	
Number of State and Local Government Community Hospitals	1,105	
Number of Federal Government Hospitals	213	
Number of Nonfederal Psychiatric Hospitals	447	
Number of Nonfederal Long term Care Hospitals	129	
Number of Hospital Units of Institutions (Prison Hospitals, College Infirmaries etc.)	16	

Based on the figures above and AHA classifications, there are an estimated 5,815 hospitals within which the IMS may find market opportunity.

As noted, blood collection centers are understood to be those local or regional blood centers that collect blood from donors and supply blood, components, and cross-matched blood products to relevant facilities.[105] Although blood center and blood bank classifications can vary, the American Association of Blood Banks (AABB) provides a listing of all non-hospital-based blood collection facilities in the 50 states. The AABB reports a total of 1,284 accredited facilities within the United States, excluding foreign-based operations and military installations (discussed in the *Military Market* section of this report). Thus, in addition to hospitals, blood collection centers may also have relevance for the IMS as the device could be used to test bioaerosol sampler systems at these facilities.

However, hospitals and other medical facilities within the U.S. are probably more relevant than those in foreign countries. The U.S. spends roughly $7,681 per resident (2008 dollars) on health care services annually, accounting for nearly 17% of the gross domestic product (GDP).[106] By far, the U.S. is the world's leader in health care expenditures. In general, this provides decent medical treatment to those living within the U.S. for nearly all potential injuries and diseases.

4.4.2.2 Market Drivers & Influences

As the IMS may serve hospitals, blood collection centers, and medical treatment facilities, in terms of the market drivers and influences for the IMS, there is one that may provide the most relevance:

- Population growth

Population Growth

Population growth is also a potential driver for the hospital, blood collection centers, and medical treatment facilities markets. As the population grows, the need for these medical facilities should increase, which would drive the need for bioaerosol sampler detector systems and their testing. According to the 2012 U.S. Demographics Profile, the predicted U.S. population growth is 0.963% per year.[107]

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[105] Whitaker, Barbee I., et al. "The 2007 National Blood Collection and Utilization Survey." *2007nbcus_survey.pdf*. Department of Health and Human Services, 2008. Web. Jun 2010. <http://www.hhs.gov/ophs/bloodsafety/2007nbcus_survey.pdf>.

[106] "U.S. Health Care Costs: Background Brief - KaiserEDU.org, Health Policy Education from the Henry J. Kaiser Family Foundation." *Home - KaiserEDU.org, Health Policy Education from the Henry J. Kaiser Family Foundation*. Mar. 2010. Web. 30 June 2011. <http://www.kaiseredu.org/Issue-Modules/US-Health-Care-Costs/Background-Brief.aspx>.

[107] U.S. Demographics Profile 2012 http://www.indexmundi.com/united_states/demographics_profile.html viewed February 1, 2012.

4.4.3 Pharmaceutical Industry

4.4.3.1 Definition and Quantification

IMS is also used in the pharmaceutical industry as a quality control mechanism to measure the composition of drugs produced. Any situation where an organic compound is supposed to be present or not present can be considered a candidate.

The global industry revenue for the pharmaceutical industry in 2011 was expected to grow 5 to 7% to $880 billion and is expected to grow at a 4 to 5% pace this year.[108,109] This revenue is concentrated in the hands of the top fifty pharmaceutical firms which account for almost all of the manufacturing that goes on in the industry. The figure below shows the revenue distribution of the top fifty pharmaceutical manufacturing firms in 2010.[110] Note that the top ten accounted for nearly 60% of the sales, while the top twenty accounted for just over 80% of the sales for 2010.[111] The top ten pharmaceutical manufacturing firms were Pfizer, Novartis, Sanofi-Aventis, Merck, Roche, GlaxoSmithKline, AstraZeneca, Johnson & Johnson, Eli Lilly, and Abbott.[112]

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[108]Rosenberg, R., "IMS Health Forecast: Global Pharmaceutical Market Poised for Growth in 2011 to $880 Billion," CenterWatch News Online, October 25, 2010 http://www.centerwatch.com/news-online/article/1001/ims-health-forecast-global-pharmaceutical-market-poised-for-growth-in-2011-to-880-billion viewed May 2, 2012.

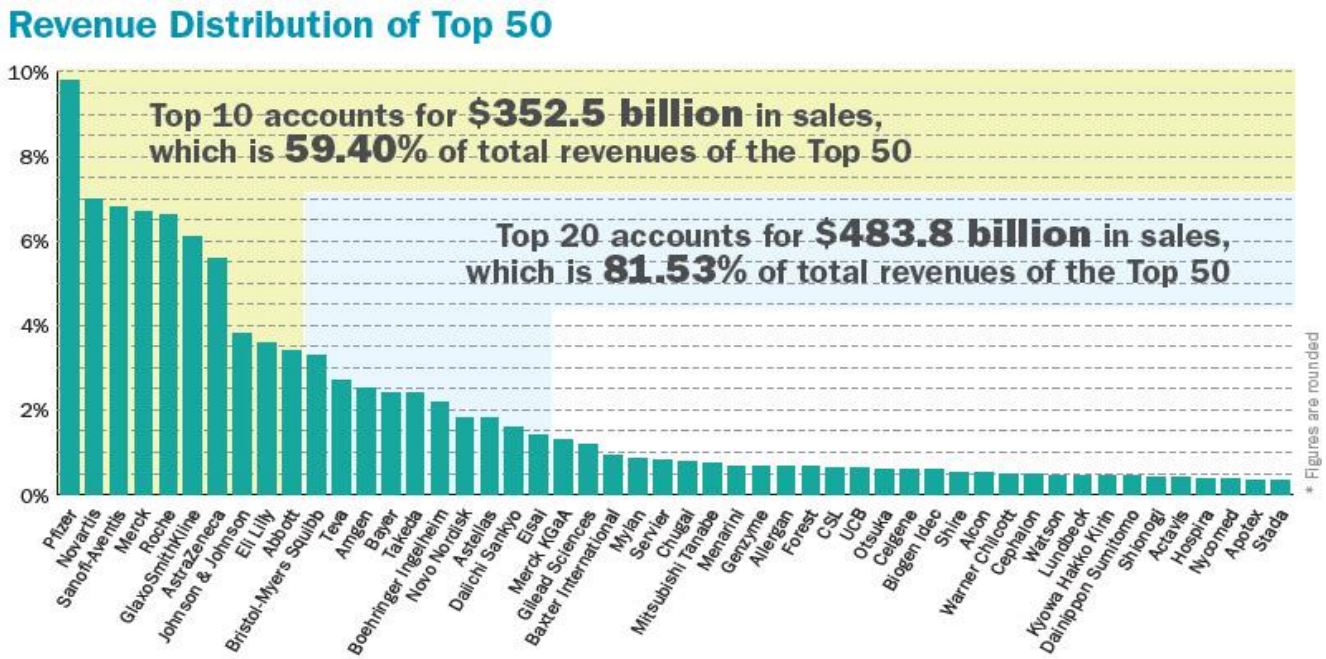
[109]Gatyas, G., "Value of the Global Pharmaceutical Market," IMS Health, October 6, 2010 http://www.imshealth.com/portal/site/imshealth/menuitem.a46c6d4df3db4b3d88f611019418c22a/?vgnextoid=119717f27128b210VgnVCM100000ed152ca2RCRD viewed May 2, 2012.

[110]Cacciotti, J. and P. Clinton, "12th Annual Pharm Exec 50," PharmExec.com, May 1, 2011http://www.pharmexec.com/pharmexec/Global+Report/12th-Annual-Pharm-Exec-50/ArticleStandard/Article/detail/719596 viewed May 2, 2012.

[111]*Ibid.*

[112]*Ibid.*

Figure 3: Revenue Distribution of the Top Fifty Pharmaceutical Companies



Revenue Distribution of Top 50

There are approximately 2,500 pharmaceutical manufacturing plants in the U.S. These plants are involved in the manufacture of both pharmaceutical preparations and finished drugs. Other products that are made in these plants include tranquilizers, antiseptics, antibiotics and biological products like serum and vaccines. Bulk medicines that include diagnostic products are also made at these plants. These plants employ upwards of 315,000 workers. Approximately half of those workers are in the production and manufacturing end of the spectrum. These plants are clustered in the states of California, Illinois, Indiana, New Jersey, New York, North Carolina and Pennsylvania.[113]

These facilities are very high tech and clean facilities atypical of what one would think of when thoughts of a manufacturing facility come to mind. Because the products that these facilities are producing cost so much to develop and bring to market, it is critical that these facilities operate at the highest possible level of efficiency. One critical aspect of operation is the checking of cleanliness of these machines in between production runs. This process was at one time a long tedious process that could literally take days at a cost to the facility of about $1,000,000 per day. This process was dramatically streamlined in recent years with the use of IMS technology to

[113] *Ibid.*

check for cleanliness. Costs and downtime were reduced by as much as 75-80%. It also reduced the length of time to check for cleanliness from days to hours.[114]

4.4.3.2 Drivers and Influences

Key drivers and influences in the pharmaceutical industry include the following:

- Safety and quality regulations
- Regulatory compliance
- New product innovation

Each of these factors will be discussed in turn in the following paragraphs.

Safety and Quality Regulations

Assurance and monitoring in the pharmaceutical industry enforce a high degree of quality control by complying with health and safety regulations to reduce risk of product recall. In order to ensure safety and quality, monitoring, testing, and inspection are carried out on all materials and products at numerous stages.[115] Using IMS for cleaning verification processes reduces preparation and process time because surface materials in question can be analyzed in less than 30 seconds. This reduction in analysis time versus competitive techniques such as high performance liquid chromatography (HPLC), can lead to a reduction in cycle time and increased utilization of production equipment and reduce the lead time for the drug development process.[116]

Regulatory Compliance

Regulatory compliance is a significant driver because regulations are enacted by government to ensure public health and safety. The focus of regulation is on quality assurance and control in all areas including receiving, manufacturing, storage, packaging, dispatching, and delivery. These areas provide opportunities for quality checks using IMS. These regulations require extensive record keeping of procedures, processes, and systems. For this reason, records management is

[114]DeBono, R., "Ion Mobility Spectrometry: A Fast, Sensitive, and Robust HPLC Alternative," Applications in Chromatography, March 2002 http://trace.smithsdetection.com/Documents/LifeSciences/LE203sBarringer.pdf viewed May 2, 2012.

[115]Syspro, "Pharmaceutical Industry Positioning White Paper," http://www.k3scs.com/_files/8-Pharmaceutical%20white%20paper.pdf viewed May 2, 2012.

[116]DeBono, R., "Ion Mobility Spectrometry: A Fast, Sensitive, and Robust HPLC Alternative," Applications in Chromatography, March 2002 http://trace.smithsdetection.com/Documents/LifeSciences/LE203sBarringer.pdf viewed May 2, 2012.

becoming increasingly important. Compliance legislation has been increasing since the 1990's and the trend looks likely to continue.[117]

New Product Innovation

The drive for new product innovation has both an external and internal component in the pharmaceutical industry. The external component includes both scientific advances that can have a break-through impact and create upheavals in established sectors, and healthcare changes can require changes in business practices. The internal component can require improvements in manufacturing, packaging, and other areas to lower costs. IMS can help to reduce the lead times for new product innovation, by reducing the lead time for the drug development process and providing quality checks.[118]

4.4.4 Petroleum Industry

4.4.4.1 Definition and Quantification

The petroleum industry is another market that holds potential for IMS technology. In 2007, the oil industry recorded revenues of $1.9 trillion, of which 78% was accounted for by the five major oil companies-ExxonMobil, Royal Dutch Shell, BP, Chevron, and ConocoPhillips.[119] Profits for industry totaled over $155 billion, with the largest, ExxonMobil, earning over 25% of the total profit.[120]

The oil companies own millions of miles of pipeline that must be maintained. According to 2009 statistics, there are nearly 1,700,000 miles of oil and gas pipeline in the U.S.[121] These pipelines have to be constantly monitored and checked to ensure that they are not leaking or being contaminated. Yet another application for IMS technology would be the testing of these pipelines for leaks and integrity. IMS can detect for byproducts such as hydrogen fluoride which is produced by processes such as petroleum refining, aluminum refining, semiconductor

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[117] Syspro, "Pharmaceutical Industry Positioning White Paper," http://www.k3scs.com/_files/8-Pharmaceutical%20white%20paper.pdf viewed May 2, 2012.

[118] *Ibid.*

[119] Pirog, R., "Congressional Research Service Report for Congress Oil Industry Profit Review 2007," April 4, 2008 http://fpc.state.gov/documents/organization/103679.pdf viewed May 3, 2012.

[120] *Ibid.*

[121] Research and Innovative Technology Administration (RITA) U.S. Department of Transportation Website, "U.S. Oil and Gas Pipeline Mileage," http://www.bts.gov/publications/national_transportation_statistics/html/table_01_10.html viewed May 4, 2012.

processing, and refrigerant manufacturing.[122] The petroleum industry is exploring IMS usage for testing the composition of crude oil in order to make processing improvements in refining activities.[123]

4.4.4.2 Drivers and Influences[124]

Key drivers and influences in the petroleum industry include the following:

- Environmental concerns
- Markets and demand
- Competitive forces
- Process improvements

Each of these factors will be discussed in turn in the following paragraphs.

Environmental Concerns

There is likely to be continuing concerns about the lifecycle of petroleum fuels on the environment, particularly the impact on air pollution. Environmental regulations will continue to influence the direction of technological development and progress. Technological development will be focused on reducing air emissions, minimizing waste production, and developing technologies for in-situ remediation, potentially using IMS. Focus will be placed on ensuring that environmentally related expenditures are achieving cost-effective environmental benefits.

Markets and Demand

While there is an objective to reduce demand for petroleum fuels by replacing them with cost effective, renewable energy sources, it is likely that oil and gas will continue to fuel the U.S. and other world economies into the next century. Petroleum fuels will continue to dominate the transportation industry, and these fuels will need to continue to improve to meet environmental demands which could be assisted through use of IMS. Consumers of petroleum fuels will have a

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[122] Bacon, T., "Ion Mobility Spectroscopy Applications for Continuous Emission Monitoring," Molecular Analytics Publication Date Unknown http://www.jusun.com.tw/IMS%20Application%20for%20CEM.pdf viewed April 18, 2012.

[123]Ferandez-Lima, F.A., "Ion Mobility Mass Spectrometry: A Tool for Characterizing the Petroleome," Academia.edu, July 30, 2009 http://tamu.academia.edu/FranciscoAFernandezLima/Papers/413311/Ion_Mobility_Mass_Spectrometry_A_Tool_for_Characterizing_the_Petroleome viewed May 4, 2012.

[124]American Petroleum Institute, "Technology Vision 2020 A Report on Technology and the Future of the U.S. Petroleum Industry," http://www1.eere.energy.gov/manufacturing/industries_technologies/petroleum_refining/pdfs/techvision.pdf viewed May 4, 2012.

key influence on markets and demand, and their expectations for refueling their vehicles with safe, low-polluting, and inexpensive high performance petroleum products will continue into the next century.

Competitive Forces

Global competition has led to many joint ventures and mergers combining the assets of two or more companies. This has led to both refinery shutdowns and the shutdown of inefficient processing units. In 1982, there were 301 operable refineries producing 17.9 million barrels of oil per day, compared to 148 in 2011 which produce about 17.4 million barrels of oil per day, which is just over a 50% reduction in refineries (and not enough to meet the demand of U.S. consumption of 20.7 million barrels of oil per day).[125,126] Meanwhile, the crude oil feedstock has become heavier and more difficult to refine. Processing developments have led to the increase in efficiencies which have enabled the current production of barrels of oil per day. There is the potential for future processing development to be assisted by the use of IMS.

Process Improvements

Refineries will increasingly need capabilities to accommodate changes in crude oil feedstock. New technology and approaches will need to be employed as operations become more sophisticated. New chemistries and technologies for refining will provide the basis for major improvements in refinery processes. New process and modeling technologies including on-line measurement technologies will allow optimization of facilities. Similar to the discussion above, development of these processing improvements could be assisted by IMS.

Disease Detection

4.4.4.3 Definition and Quantification

Ion mobility is becoming widely used as a research tool for the analysis of biological materials, such as proteomics, which is the large scale study of proteins, and metabolomics, which is the study of the unique chemical fingerprints left behind by cellular processes. The areas of metabolomics and proteomics will continue to evolve and use IMS and mass spectrometry as a testing and diagnostic tool. In metabolomics, IMS technology is being used to detect such conditions as lung cancer, chronic obstructive pulmonary disorder (COPD), and sarcoidosis. IMS is also being used to detect bacteria in the lungs and aiding in the success of lung

[125] Hening, J., "U.S. Oil Refining Capacity," FactCheck.Org, May 12, 2008 http://www.factcheck.org/2008/05/us-oil-refining-capability/viewed May 7, 2012.

[126] Unknown, "Number and Capacity of Petroleum Refineries," U.S. Energy Information Administration, June 24, 2011, http://205.254.135.24/dnav/pet/pet_pnp_cap1_dcu_nus_a.htm viewed May 7, 2012.

transplantation surgery.[127] In addition, breath analysis is an area that will be developed and IMS technology will play a prominent role particularly for lung diseases such as tumors, airway infection, interstitial lung disease, and sleep apnea.[128] Each year, more than 400,000 Americans die of lung disease. Lung disease is the U.S.'s number three killer and it is responsible for one in six deaths. In addition, more than 35 million Americans currently live with chronic lung disease.[129]

4.4.4.4 Drivers and Influences

Key drivers and influences of lung diseases and cancer include the following:

- Smoking
- Exposure to occupational and environmental toxins
- Radiation and chemotherapy
- Each of these factors will be discussed in the paragraphs below.

Smoking

Some forms of lung disease are more likely to occur in people with a history of smoking and active smoking may worsen the disease.[130] In addition, children exposed to secondhand smoke have nearly twice the risk of developing COPD when they are adults, according to a recent study.[131] Smoking rates are slowly declining in the U.S. Between 2005 and 2010, adult smokers declined from 20.9 to 19.3 percent of the population,[132] but there are still about 1 in 5 people who are likely to develop lung disease which could necessitate the use of IMS for its diagnosis.

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[127]Unknown, "Ion-mobility Spectrometry," Wikipedia, updated February 1, 2012, http://en.wikipedia.org/wiki/Ion-mobility_spectrometry viewed May 7, 2012.

[128] Unknown, "Breath Analysis by Ion Mobility Spectrometry," ClinicalTrials.gov A Service of the U.S. National Institutes of Health, updated June 22, 2011 http://clinicaltrials.gov/ct2/show/NCT00632307 viewed May 7, 2012.

[129] Epidemiology & Statistics, American Lung Association http://www.lung.org/finding-cures/our-research/epidemiology-and-statistics-rpts.html viewed May 7, 2012.

[130]Mayo Clinic Staff, "Interstitial Lung Disease," Mayo Clinic http://www.mayoclinic.com/health/interstitial-lung-disease/ds00592/dsection=risk-factors viewed May 9, 2012.

[131]Unknown, "Secondhand Smoke in Childhood Linked to Lung Disease Years Later," U.S. News and World Report Health, March 19, 2012 http://health.usnews.com/health-news/news/articles/2012/03/19/secondhand-smoke-in-childhood-linked-to-lung-disease-years-later viewed May 9, 2012.

[132]Rettner, R., "Smoking Declines in U.S., but 1 in 5 Still Light Up," My Health News Daily September 6, 2011 http://www.myhealthnewsdaily.com/1650-smoking-prevalence-decreasing-united-states.html viewed May 9, 2012.

Exposure to Environmental and Occupational Toxins

Working in mining, farming, or construction or exposure to an excessive amount of pollutants known for lung damage, will increase risk of lung disease.[133] Other exposures such as radon gas or asbestos are a risk factor for lung cancer.[134] Indoor allergens such as dust and mold can lead to asthma or COPD. Asthma is on the rise in the U.S. and other developed countries. Factors which may contribute to this increase may include spending more time indoors exposed to indoor allergens and an increase in obesity which has been linked to asthma.[135] As the air we breathe is more polluted than that of our ancestors,[136] it is likely that incidences of lung diseases will continue, which could necessitate the use of IMS for their diagnosis.

Radiation and Chemotherapy

Having radiation treatments to the chest or use of some chemotherapy drugs increases the likelihood of developing lung disease.[137] In some cancer cases (such as brain tumors) where surgery is not an option, radiation and/or chemotherapy are often used.[138] Meanwhile, chemotherapy and radiation therapy can help patients with lung cancer live nearly 50% longer.[139] Therefore, radiation and chemotherapy may necessitate the use of IMS to diagnose lung disease, while at the same time they can help the fight against lung cancer, which also may be detected using IMS.

Other Civilian Markets Summary

With regard to the *Other Civilian Market* section overall, an examination of the potential market drivers and influences for the prospective IMS market opportunity appears favorable. IMS can be used to detect for chemical and biological agents at critical infrastructure sites, hospitals, blood

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[133]Mayo Clinic Staff, "Interstitial Lung Disease," Mayo Clinic http://www.mayoclinic.com/health/interstitial-lung-disease/ds00592/dsection=risk-factors viewed May 9, 2012.

[134]Unknown, "Lung Cancer Risk Factors," Centers for Disease Control and Prevention http://www.cdc.gov/cancer/lung/basic_info/risk_factors.htm viewed May 9, 2012.

[135]Schiffman, G., M.D. and M.C. Stoppler, M.D., "Asthma," emedicine*health* http://www.emedicinehealth.com/asthma/article_em.htm viewed May 9, 2012.

[136]*Ibid.*

[137]Mayo Clinic Staff, "Interstitial Lung Disease," Mayo Clinic http://www.mayoclinic.com/health/interstitial-lung-disease/ds00592/dsection=risk-factors viewed May 9, 2012.

[138]Treatment FAQ, National Brain Tumor Society, http://www.braintumor.org/patients-family-friends/treatment/FAQ.html viewed May 9, 2012.

[139]Unknown, "Chemotherapy and Radiation Together Extend Lung Cancer Patients' Lives,"ScienceDaily, November 9, 2007 http://www.sciencedaily.com/releases/2007/11/071109171615.htm viewed May 9, 2012.

collection centers, and other medical treatment facilities. IMS may also be able to assist the pharmaceutical industry with current and future challenges presented by safety and quality regulations, regulatory compliance, and new product regulations. Also, IMS may assist the petroleum industry with its current and future challenges presented by environmental concerns, pressure from changing markets and more stringent demands, pressures from competitive forces, and necessary process improvements. In addition, IMS can assist with lung disease detection whose prevalence is influenced by factors such as smoking, exposure to occupational and environmental toxins, and use of radiation and chemotherapy. These applications provide a multitude of avenues through which market value of the IMS may be fostered.

5 Competitive Landscape

5.1 Existing Technologies

Existing competitive technologies include vapor explosive detectors and technologies which provide explosive detection and chemical and biological agent detection. The technologies discussed below are not an exhaustive list of possibilities, but rather a list that is representative of commercially available options. These competitive solutions are reviewed below and summarized in a table at the end of this section.

The vapor explosive detector, manufactured by Kapri Corp., is an explosives detection device that can detect 2,4,6-trinitrotoluene (TNT), nitroglycerine, ethylene glycol dinitrate (EGDN), hexogen, and octogen. These detectors offer protection to banks, government buildings, civilian buildings, and means of transportation (automobile, air, rail, and water) against terrorist activities. These devices require no setup or adjustments, diminishing the possibility of user error. Also, these devices use high sensitivity, selectivity, and ergonomic form factors for detection. Furthermore, these devices operate in a wide range of environmental conditions. [140] The Kapri Corp.'s vapor explosive detector is shown in the figure below.

Figure 4: Kapri Corp.'s Vapor Explosive Detector

The EVD 3000, manufactured by Crossworld Solutions, is another competitive explosives detection device. This device does not use radioactive materials or consumables for sampling. The EVD 3000 has the ability to detect explosives by both vapor and particle sampling. Vapor sampling is done through the sampling nozzle, while particle sampling is done by swabbing suspected item(s) with a pair of cotton gloves and then transferring the samples to a screen which is inserted into the sampling port. The results are available immediately and appear on an LCD

[140] "Vapor Explosive Detectors, Mumbai." Allbiz, June 22, 2011 http://www.in.all.biz/g116670/ viewed May 9, 2012.

screen, or can be heard through an audio port.[141] Crossworld Solutions' EVD 3000 is shown in the figure below.

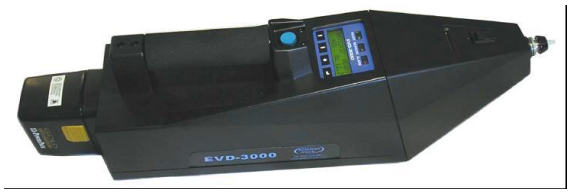

Figure 5: Crossworld Solutions' EVD 3000

The Pilot M1 is one of the Tairis explosive detection devices. It can detect traces of TNT, nitroglycerine, EGDN, hexogen, octogen, TEN and their compositions. This detector offers protection to banks, government buildings, civilian buildings, and means of transportation (automobile, air, rail, and water) against terrorist activities. This detector uses high sensitivity, selectivity and ergonomic factors to detect and store the results in the device until they are transferred to a PC. It comes with a monitor and an interface cable. The Pilot M1 uses an ionogram to display explosives, takes only one second to get results and uses a 6 V battery to set off visual and audio alarms if detection occurs. For most accurate results, it must be within 300 mm of explosive vapors.[142] Tairis' Pilot M1 is shown in the figure below.

Figure 6: Tairis' Pilot M1

[141]"Hand-Held Dual-Mode Particulate and Vapor Explosives Detector," Alibaba, January 1, 2012 http://www.alibaba.com/product-free/100296305/Hand_Held_Dual_Mode_Particulate_And.html viewed May 9, 2012.

[142]"Gas Analyzer & Explosive Vapor Detector PILOT-M1," Tairis website 2012 http://eng.tairis.ru/catalogue/7/1431/ viewed May 9, 2012.

Tairis also makes the Pilot M, which has the same qualities as the M1, but it does not require a PC, all the results can be displayed on the built-in LCD screen, as well as via an audio port.[143] Tairis' Pilot M is shown in the figure below.

Figure 7: Tairis' Pilot M

The EMAX-5200 is an explosives detection device manufactured by Electromax International. It can detect the full range of explosive vapors including taggants. This device takes 60 seconds to warm up for use and takes 15 seconds to respond to detection. It uses no radioactive materials. Explosive vapors are detected through a sampling nozzle and results are indicated on a built in LCD screen and by an audio port; This device can also store one thousand data records and has a port for remote controlling and monitoring. [144] The pricing for this unit is $18,500.[145] Electromax International's EMAX-5200 is shown in the figure below.

Figure 8: Electromax International's EMAX-5200

Electromax International has another product, the EMAX-5300 which allows for sampling of both vapors and particles. It also takes 60 seconds to warm up and 10 seconds for detection

[143]"Gas Analyzer & Explosive Vapor Detector PILOT-M," Tairis 2012, http://eng.tairis.ru/catalogue/7/1430/ viewed May 9, 2012.
[144]"EMAX-5200 for Hand-held Exposive Detection" Electromax International, Inc. website http://www.electromax.com/emax5200.html viewed May 9, 2012.
[145] Pricing provided by e-mail correspondence from Electromax International on May 10, 2012.

response. Responses are shown on the LCD screen and by an audio alarm. It can detect C-4, TNT, Dynamite, PETN, Semtex, EGDN, DMNB, RDX, and Nitroglycerine. The EMAX-5300 can store 896 data records and does not use any radioactive materials for detection.[146] The pricing for this unit is $28,500.[147] Electromax International's EMAX-5300 is shown in the figure below.

Figure 9: Electromax International's EMAX-5300

Another explosives detector is the MO-2M, manufactured by Sibel Ltd. It can detect TNT, NG, PETN, RDX, and ICAO taggants including EGDN, o-MNT, p-MNT, HMX, and TATP. It has a dual detection method, using vapors and/or particle sampling. It uses field asymmetric IMS to achieve a high sensitivity, and can respond in two seconds. It has audio and visual alarms when detection occurs, as well as storage for up to 4,000 records. It also uses ionogram measurements, and has a Bluetooth communication for signal transmission to a remote computer for oversight by security. Pricing for this unit is $25,000.[148] Sibel Ltd.'s MO-2M is shown in the figure below.

Figure 10: Sibel Ltd.'s MO-2M

[146]"EMAX-5300 for Hand-held Exposive Detection" Electromax International, Inc. website http://www.electromax.com/EMAX5300.html viewed May 9, 2012.
[147] Pricing provided by e-mail correspondence from Electromax International on May 10, 2012.

[148]"MO-2M Hand Held Explosive Detector," FEMA Responder Knowledge Base February 2012 https://www.rkb.us/contentdetail.cfm?content_id=138492 viewed May 10, 2012.

1st Detect's SwabMate uses mass spectrometry to detect explosives, pesticides, and chemical warfare agents. It can detect by a means of particle analysis and vaporization, as well as detection of vapors within compounds. It uses a novel thermal desorption sampling system that allows vaporization of difficult compounds while retaining the analysis power of a mass spectrometer.[149] 1st Detect's SwabMate is shown in the figure below.

Figure 11: 1st Detect's SwabMate

The Mini 10 is a mass spectrometry-based explosives detection device developed by Prof. R. Graham Cooks at Purdue University. It can detect traces of many different types of explosives. It is lab scale instrumentation that has been reduced to miniature size. This device uses 75 W of power, weighs 10 kg, and has a volume of 0.5 ft^3.[150] Purdue University's Mini 10 is shown in the figure below.

Figure 12: Purdue University's Mini 10

[149] SwabMate product information from 1st Detect website http://www.1stdetect.com/SwabMate.php viewed May 10, 2012.
[150] Miniature Mass Spectrometers from Purdue University http://aston.chem.purdue.edu/research/instrumentation/miniature-mass-spectrometers viewed May 10, 2012.

The Mini 11 is another mass spectrometry-based explosives detection device developed by Prof. R. Graham Cooks at Purdue University. The Mini 11 is a smaller version of the Mini 10. It has the same explosives detection capabilities of the Mini 10. The Mini 11 uses 35 W of power, weighs 4 kg, and has a volume of 0.2 ft^3.[151] Purdue University's Mini 11 is shown in the figure below.

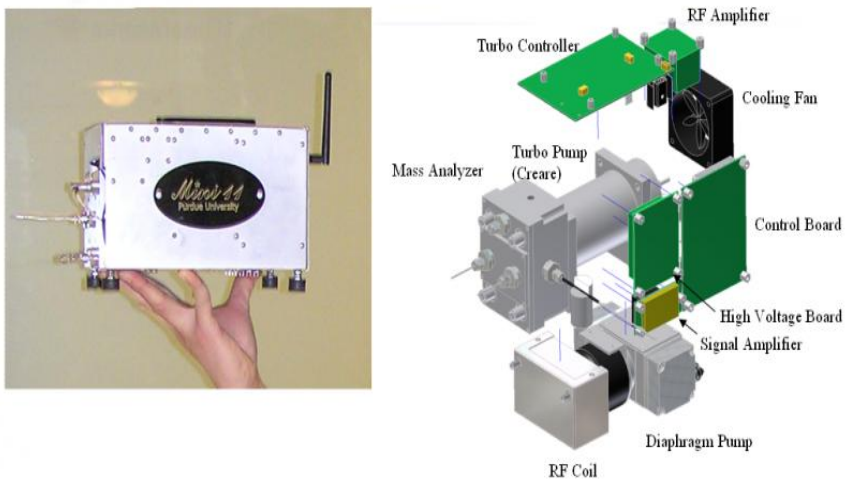

Figure 13: Purdue University's Mini 11

The Single Particle Aerosol Mass Spectrometer or "SPAMS" device developed by Lawrence Livermore National Laboratory uses mass spectrometry to identify particles as small as a single particle of any chemical, biological or explosive agents.[152] This device, once finalized, may be used one day to screen airport baggage for chemical and biological agents and explosives all at the same time.[153] Lawrence Livermore National Laboratory's "SPAMS" device is shown in the figure below.

[151] *Ibid.*

[152] Wampler, S., "One Machine for Detecting Explosives, Chemicals, Bioagents," Lawrence Livermore National Laboratory Physical and Life Sciences Directorate website https://www-pls.llnl.gov/?url=science_and_technology-life_sciences-spams viewed May 10, 2012.

[153] *Ibid.*

Figure 14: Lawrence Livermore National Laboratory's Single Particle Aerosol Mass Spectrometer or "SPAMS" Device

The CNI-06, developed by Ion Metrics, uses both mass spectrometry and IMS for detection of the full range of explosive compounds, including military, commercial, improvised, and homemade explosives, as well as precursors, binders, and stabilizers, that are used to make improvised explosive devices. This device is small enough that it can be adapted to many packaging footprints as well as many user interfaces. It can detect explosives in one to five seconds, can be remote control operated, and costs about $10,000 for high volumes. This device is also said to be low maintenance with minimal maintenance costs. [154] Ion Metrics' CNI-06 is shown in the figure below.

Figure 15: Ion Metrics' CNI-06

The Guardion, developed by Smiths Detection, is a gas chromatography/mass spectrometry device that can detect the presence of and identify chemical warfare agents and toxic industrial

[154] Ion Metrics Applications http://www.ionmetricsinc.com/applications.htm viewed May 11, 2012.

chemicals in gases, vapors, and solids for military and emergency use. This device can analyze and can store up to 30 samples in the field, is battery operated and is roughly the size of a small carry-on suitcase.[155] This device is priced at about $129,000.[156] Smiths Detection's Guardion is shown in the figure below.

Figure 16: Smiths Detection's Guardion

The Sabre 5000, which was also developed by Smiths Detection, is a small, light-weight hand-held system for detecting trace amounts of explosives, chemical warfare agents, toxic industrial chemicals, or narcotics. This system uses IMS technology to indentify 40 threat substances in approximately 20 seconds. These threats include peroxide-based, volatile, and unstable chemicals used to manufacture improvised explosive devices (IEDs) and ammonium nitrate chemicals used in homemade explosive devices.[157] This device is priced at $25,000.[158] Smiths Detection's Saber 5000 is shown in the figure below.

[155] Unknown, "Smiths Detection unveils new portable chemical detector," Homeland Security Newswire, January 30, 2012, http://www.homelandsecuritynewswire.com/dr20120130-smiths-detection-unveils-new-portable-chemical-detector viewed May 11, 2012.

[156] Pricing information provided by Nancy Otto of Smiths Detection on May 11, 2012.

[157] Smiths Detection Sabre 5000 Handheld Trace Detector for Explosives, Chemical Agents, Toxic Industrial Chemicals, or Narcotics, 2012 http://www.smithsdetection.com/sabre5000.php viewed May 14, 2012.

[158] Pricing information provided by Nancy Otto of Smiths Detection on May 11, 2012.

Figure 17: Smith's Detection Saber 5000

The following table summarizes the key features of the competitive technologies discussed above. Equipment pricing is noted where it was available from the manufacturer. These devices differ in the range of substances which can be detected; whether these substances are vapors, liquids, or solids; and whether the equipment is portable or suitable for a fixed location such as a device for airport screening. The last two table entries by Smiths Detection are of particular interest. The Sabre 5000 is a light-weight hand-held device which is based on IMS technology and can detect a range of explosives, chemical agents, toxic industrial chemicals, and narcotics.

Table 21: IMS Competitive Technologies

Product Name	Developer	Relevant Details
Vapor Explosive Detectors	Kapri Corp	This detector can detect explosives such as TNT, nitroglycerine, EGDN, hexogen, and octogen. This detector offers protection to banks, government buildings, civilian buildings, and means of transportation (automobile, air, rail, and water) against terrorist activities.[159]
EVD 3000	Crossworld Solutions	This detector does not use radioactive materials or consumables for vapor or particle sampling. For vapors, the sampling is done directly through the sampling nozzle. For particles, the suspected item is swiped and samples are transferred to the sampling port. Results occur within seconds via a LCD screen or audio.[160]
Pilot M1	Tairis	This detector can detect TNT, nitroglycerine, EGDN, hexogen, octogen, TEN and their

[159] "Vapor Explosive Detectors, Mumbai." Allbiz, June 22, 2011 http://www.in.all.biz/g116670/ viewed May 9, 2012.

[160] "Hand-Held Dual-Mode Particulate and Vapor Explosives Detector," Alibaba, January 1, 2012 http://www.alibaba.com/product-free/100296305/Hand_Held_Dual_Mode_Particulate_And.html viewed May 9, 2012.

		compositions. This detector uses high sensitivity, selectivity and ergonomic factors. It comes with a monitor and interface cable to ensue data transfer and storage to PC. It uses an ionogram to display explosives detected, and takes one second to respond, has visible and audio alarm indicators, and uses 6 V rechargeable batteries. It must be within 300 mm for vapor detection and weighs 2 kg.[161]
Pilot M	Tairis	This detector can detect TNT, nitroglycerine, EGDN, hexogen, octogen, TEN and their compositions. The Pilot M is similar in capabilities to the Pilot M1, except that it is a hand-held unit that does not require a PC.[162]
EMAX-5200	Electromax International	This detector responds to the full range of explosive vapors and taggants. It takes 60 seconds to warm up and responds in 15 seconds. It uses no radioactivity and vapors are detected by the sampling nozzle. The results are indicated on the LCD screen and by audio. It weighs 1.5 kg, can store 1000 data records, and has a port for remote control and monitoring. It uses a 12V DC rechargeable battery and has indicator lights.[163] Pricing is $18,500.[164]
EMAX-5300	Electromax International	This detector allows for sampling of both vapors and particles. It takes 60 seconds to warm up and responds in 10 seconds. It weighs 7 lbs., uses a 12V DC rechargeable battery and can detect traces of C-4, TNT, dynamite, PETN, Semtex, EGDN, DMNB, RDX, and nitroglycerine. Results are indicated on the LCD screen and by audio alarm. It does not use radioactive materials,

[161] "Gas Analyzer & Explosive Vapor Detector PILOT-M1," Tairis website 2012 http://eng.tairis.ru/catalogue/7/1431/ viewed May 9, 2012.

[162] "Gas Analyzer & Explosive Vapor Detector PILOT-M," Tairis website 2012, http://eng.tairis.ru/catalogue/7/1430/ viewed May 9, 2012.

[163] "EMAX-5200 for Hand-held Exposive Detection" Electromax International, Inc. website http://www.electromax.com/emax5200.html viewed May 9, 2012.

[164] Pricing provided by e-mail correspondence from Electromax International on May 10, 2012.

		can store 896 data records, and it only weighs 3kg.[165] Pricing is $28,500.[166]
MO-2M	Sibel Ltd.	This detector detects TNT, NG, PETN, RDX, and ICAO taggants including EGDN, o-MNT, p-MNT, HMX, and TATP. Dual detectors methods allow for both vapor and particle sampling. It relies on field asymmetric IMS to achieve a very high sensitivity. It calibrates itself and is ready for use in 10 seconds. It responds in 2 seconds, has an audio and visual alarm for detection, can store 4000 ionogram measurements, has Bluetooth communication which sends signals to a remote computer for oversight by security, and uses a 14.4 V rechargeable battery. Pricing for this unit is $25,000.[167]
SwabMate	1st Detect	This device uses mass spectrometry to detect explosives, pesticides, and chemical warfare agents. It can detect by a means of particle analysis and vaporization, as well as detect vapors within compounds. For detection and analysis of particulate and low volatility compounds, this novel thermal desorption sampling system samples vaporization of difficult compounds using mass spectrometer analyses.[168]
Mini 10	Purdue University/Aston Labs	This device uses mass spectrometry to detect traces of triacetone triperoxide, or TATP, which are used in explosives. It is lab scale instrumentation that has been miniaturized.

[165]"EMAX-5300 for Hand-held Exposive Detection" Electromax International, Inc. website http://www.electromax.com/EMAX5300.html viewed May 9, 2012.

[166] Pricing provided by e-mail correspondence from Electromax International on May 10, 2012.

[167] "MO-2M Hand Held Explosive Detector," FEMA Responder Knowledge Base February 2012 https://www.rkb.us/contentdetail.cfm?content_id=138492 viewed May 10, 2012.

[168]SwabMate product information from 1st Detect website http://www.1stdetect.com/SwabMate.php viewed May 10, 2012.

		This device uses 75 W of power, weighs 10Kg and has a volume of 0.5 ft^3.[169]
Mini 11	Purdue University/Aston Labs	This device has all the qualities and features the Mini 10, but in a smaller size. This device uses 35 W of power, weighs 4kg, and has a volume of 0.2 ft cubed.[170]
Single Particle Aerosol Mass Spectrometer "SPAMS"	Lawrence Livermore National Laboratory	This device can identify single particles of chemical, biological, and explosive agents. This device is to be put to use in airport screenings after it is finalized. Pricing will be about $10,000 for large volumes.[171]
CNI-06	Ion Metrics	This device has universal detection of known and improvised explosives. This device is small enough for most foot print requirements, can detect traces of explosives in one to five seconds, and can be remote control operated, which makes it safe and easy to use. Pricing for this device is $4800.[172]
Guardion	Smiths Detection	This device can detect the presence and identify chemical agents in gases, vapors, and solids, and is used for military and emergency use. It can analyze up to 30 samples, is battery operated, and is the size of a small suitcase.[173] This device is priced at $129,000.[174]
Sabre 5000	Smiths Detection	This device is a small, light-weight hand-held

[169] Miniature Mass Spectrometers from Purdue University http://aston.chem.purdue.edu/research/instrumentation/miniature-mass-spectrometers viewed May 10, 2012.

[170] *Ibid.*

[171] Wampler, S., "One Machine for Detecting Explosives, Chemicals, Bioagents," Lawrence Livermore National Laboratory Physical and Life Sciences Directorate website https://www-pls.llnl.gov/?url=science_and_technology-life_sciences-spams viewed May 10, 2012.

[172] Ion Metrics Applications http://www.ionmetricsinc.com/applications.htm viewed May 11, 2012.

[173] Unknown, "Smiths Detection unveils new portable chemical detector," Homeland Security Newswire, January 30, 2012, http://www.homelandsecuritynewswire.com/dr20120130-smiths-detection-unveils-new-portable-chemical-detector viewed May 11, 2012.

[174] Pricing information provided by Nancy Otto of Smiths Detection on May 11, 2012.

		system for detecting trace amounts of explosives, chemical warfare agents, toxic industrial chemicals, or narcotics. This system uses IMS technology to indentify 40 threat substances in approximately 20 seconds. These threats include peroxide-based, volatile, and unstable chemicals used to manufacture improvised explosive devices (IEDs) and ammonium nitrate chemicals used in homemade explosive devices.[175] This device is priced at $25,000.[176]

[175]Smiths Detection Sabre 5000 Handheld Trace Detector for Explosives, Chemical Agents, Toxic Industrial Chemicals, or Narcotics, 2012 http://www.smithsdetection.com/sabre5000.php viewed May 14, 2012.

[176] Pricing information provided by Nancy Otto of Smiths Detection on May 11, 2012

6 Cautions & Considerations

This assessment has worked to provide a market overview of the many existing and potential market applications of IMS technology. As prospective licensees further explore market opportunities in the various market applications, a variety of cautions and considerations may be further revealed. While by no means exhaustive, this discussion addresses only those cautions and considerations which are known at this time.

6.1 Industry Specific Requirements and Further Testing

Important for the readiness for use of IMS technology is determining what industry specific requirements may be necessary for specialized applications such as explosive detection and chemical and biological agent detection by the military, first responders, and government. In addition, the safety and quality regulations in the pharmaceutical and petroleum industries may have their own testing requirements. These specialized applications may require their own testing and validation before the technology is implemented.

It may be necessary to demonstrate through journal publications the technological background of this technology, as the burden of proof is lower for patent applications. It also may be necessary to gain the trust of the explosives detection community. One inventor of this technology estimated about two man years of effort and $500,000 in funds and supporting materials in terms of additional test data and publications.[177]

6.2 Licensee Identification

Currently, no licensing partners have been identified for the IMS patents for this market overview. Licensees could be helpful to commercialize, manufacture, market, and sell the IMS technology into the potential market applications. Licensees could expedite the process of getting the IMS technology into the hands of potential users. In determining a suitable licensee, consideration should be given to identifying an entity with existing expertise in IMS technology, manufacturing, marketing, and sales and/or who can easily obtain this expertise.

Consideration should be given to approaching existing manufacturers of devices which use IMS technology such as Smiths Detection or Sibel Ltd. They would be able to assess the commercial value of the patents versus technology which is currently on the market. They also would have established channels to market.

[177] Discussion with inventor Jack Fulton on February 6, 2012.

6.3 Competing Systems

Many (at least fourteen) competing explosive and chemical and biological agent detection systems appear to have comparable levels of sophistication, as discussed in Section 5. It is crucial to determine the relative value of the key technologies provided by these patents versus this completion. In particular, the relative value of the key advantages of the IMS technology of this market overview including software which allows the IMS technology to operate at higher efficiencies, a process and apparatus to reduce maintenance costs by reducing the need for filter changes, and technology to allow field calibration of IMS devices with less training and time should be assessed.

7 Conclusion

The IMS technology offers some prospective advantages over traditional methods for explosive and chemical and biological agent detection. The prospective advantages and detailed descriptions are summarized in the table below.

Table 22: IMS Prospective Advantages and Detail

Prospective Advantage	Detail
An increase in specificity and selectivity in IMS technology.	This which may allow the equipment to operate at higher efficiencies.
A decrease in maintenance costs.	This is accomplished by employing a closed system and a water permeable membrane comprised of Nafion (a fluoropolymer copolymer) that continuously removes water vapor and reduces the need for filter changes.
The removal of acetone that is injected in the counter-flow air stream.	This is due to the Nafion which allows the air flow not to become saturated with acetone.
While IMS systems typically require replacement scrubbers (adsorbents) such as desiccant which require replacement, this technology does not.	This technology makes use of Nafion technology which continually regenerates, thus requiring no desiccant to saturate and replace.
A two point field calibration check with versatility to get into awkward and tight locations is possible.	Field personnel can calibrate an IMS with less training and time.

The prospective advantages of the IMS technology may provide impetus to resolve the go-to-market needs which include meeting industry specific requirements, licensee identification, and proving key advantages versus the substantial competition. In particular, the relative value of the key advantages of the IMS technology of this market overview including software which allows the IMS technology to operate at higher efficiencies, a process and apparatus to reduce maintenance costs by reducing the need for filter changes, and technology to allow field calibration of IMS devices with less training and time should be assessed.

In summary, the technical feasibility of IMS technology has been proven and there appears to be a potentially favorable market opportunity. The largest hurdle at this point appears to be competitive solutions, and therefore, the technology will need to differentiate itself effectively by way of features such as higher efficiencies, processing advantages, and reduction in calibration times will need to be assessed in order to capture a share of what appears to be a potentially large market.

Appendices

Appendix A: Law Enforcement Agencies within the United States

50 Largest State and Local Law Enforcement Agencies in the U.S.

Fifty Largest State and Local Law Enforcement Agencies in the United States	
Agency	**Full-time sworn personnel**
New York (NY) Police	36,118
Chicago (IL) Police	13,129
Los Angeles (CA) Police	9,099
Los Angeles County (CA) Sheriff	8,239
California Highway Patrol	7,085
Philadelphia (PA) Police	6,832
Cook Co. (IL) Sheriff	5,555
Houston (TX) Police	5,092
New York State Police	4,667
Pennsylvania State Police	4,200
Washington (DC) Metropolitan Police	3,800
Detroit (MI) Police	3,512
Texas Department of Public Safety	3,437
Broward County (FL) Sheriff	3,190
Baltimore (MD) Police	3,160
Miami-Dade County (FL) Police	3,094
Dallas (TX) Police	2,935
Phoenix (AZ) Police	2,858
New Jersey State Police	2,768
Suffolk County (NY) Police	2,692
Las Vegas (NV) Metropolitan Police	2,674
Nassau County (NY) Police	2,574
Harris County (TX) Sheriff	2,545
Massachusetts State Police	2,200
San Francisco (CA) Police	2,167
Orange County (CA) Sheriff	2,119
San Diego (CA) Police	2,103

San Antonio (TX) Police	2,054
Memphis (TN) Police	2,017
Illinois State Police	2,008
Boston (MA) Police	1,961
Milwaukee (WI) Police	1,946
Virginia State Police	1,869
Michigan State Police	1,862
Baltimore County (MD) Police	1,798
Honolulu (HI) Police	1,795
Columbus (OH) Police	1,777
Florida Highway Patrol	1,654
New Orleans (LA) Police	1,646
Atlanta (GA) Police	1,643
Jacksonville (FL) Sheriff	1,617
Port Authority of New York-New Jersey Police	1,607
Maryland State Police	1,596
Sacramento County (CA) Sheriff	1,565
Cleveland (OH) Police	1,560
San Bernardino County (CA) Sheriff	1,542
North Carolina State Highway Patrol	1,517
Ohio State Highway Patrol	1,502
Riverside County (CA) Sheriff	1,490
Charlotte-Mecklenberg (NC) Police	1,483

Special Jurisdiction Law Enforcement Agencies

Special Jurisdiction Law Enforcement Agencies, by Type of Jurisdiction & Number of Full-Time Sworn Personnel[178]		
Type of special jurisdiction	**Agencies**	**Full-Time Sworn Personnel**
Public buildings/facilities	1,011	19,247
4-year university/college	488	10,167

[178] Reaves, Brian A. "Census of State and Local Law Enforcement Agencies, 2004." *csllea04.pdf*. Bureau of Justice Statistics, Office of Justice Programs, U.S. Department of Justice, Jun 2007. Web. Sep 2010. <http://bjs.ojp.usdoj.gov/content/pub/pdf/csllea04.pdf>.

Public school district	183	3,517
2-year college	254	2,438
State capitol/government buildings	18	1,289
Medical school/campus	22	732
Public housing	12	411
Public hospital/health facility	30	399
Courts	4	294
Natural resources/parks and recreation	205	14,332
Fish and wildlife	50	4,937
Parks and recreational areas	95	4,212
Multifunction natural resources	25	3,550
Environmental laws	6	700
Waterways and boating	17	663
Water resources	5	129
Sanitation laws	2	97
Forest resources	5	44
Transportation systems/facilities	130	9,073
Mass transit system/railroad	18	3,094
Airports	90	2,900
Transportation — multiple types	5	2,200
Port facilities	11	333
Commercial vehicles	2	285
Bridges, tunnels	4	261
Criminal investigations	103	4,739
County/city	62	1,756
State bureau	16	1,702
Fire marshal	17	454
Other	8	827
Special enforcement	32	2,007
Alcohol enforcement	17	1,219
Agricultural law enforcement	5	340
Gaming/racing law enforcement	6	225
Drug enforcement	4	223

Appendix B: NAICS Codes

Food Manufacturing

NAICS 311 Food Manufacturing, 2007 Economic Census[179], *CIKR: Agriculture and Food*		
2002 NAICS Code	**Meaning of the 2007 NAICS Code**	**Number of Establishments**
311111	Dog and cat food manufacturing	264
311119	Other animal food manufacturing	1,489
311211	Flour milling	290
311212	Rice milling	65
311213	Malt manufacturing	25
311221	Wet corn milling	64
311222	Soybean processing	124
311223	Other oilseed processing	37
311225	Fats and oils refining and blending	121
311230	Breakfast cereal manufacturing	57
311311	Sugarcane mills	21
311312	Cane sugar refining	22
311313	Beet sugar manufacturing	33
311320	Chocolate and confectionery manufacturing from cacao beans	162
311330	Confectionery manufacturing from purchased chocolate	1,176
311340	Nonchocolate confectionery manufacturing	432
311411	Frozen fruit, juice, and vegetable manufacturing	210
311412	Frozen specialty food manufacturing	417
311421	Fruit and vegetable canning	673
311422	Specialty canning	112
311423	Dried and dehydrated food manufacturing	191
311511	Fluid milk manufacturing	485
311512	Creamery butter manufacturing	28
311513	Cheese manufacturing	481
311514	Dry, condensed, and evaporated dairy product manufacturing	196
311520	Ice cream and frozen dessert manufacturing	394
311611	Animal (except poultry) slaughtering	1,597
311612	Meat processed from carcasses	1,379
311613	Rendering and meat byproduct processing	228
311615	Poultry processing	553

[179] "North American Industry Classification System (NAICS), U.S. Census Bureau, 2002, Web, September 2010, <http://www.census.gov/cgi-bin/sssd/naics/naicsrch>

311711	Seafood canning	92
311712	Fresh and frozen seafood processing	556
311811	Retail bakeries	6,249
311812	Commercial bakeries	2,578
311813	Frozen cakes, pies, and other pastries manufacturing	229
311821	Cookie and cracker manufacturing	348
311822	Flour mixes and dough manufacturing from purchased flour	291
311823	Dry pasta manufacturing	161
311830	Tortilla manufacturing	365
311911	Roasted nuts and peanut butter manufacturing	212
311919	Other snack food manufacturing	350
311920	Coffee and tea manufacturing	358
311930	Flavoring syrup and concentrate manufacturing	168
311941	Mayonnaise, dressing, and other prepared sauce manufacturing	326
311942	Spice and extract manufacturing	347
311991	Perishable prepared food manufacturing	665
311999	All other miscellaneous food manufacturing	847
311	***Agriculture and Food Totals***	***25,468***

Energy and Water

NAICS 221 Utilities[180]: 2007 Economic Census, *CIKR: Energy, Water*		
NAICS Code	**Meaning of the NAICS Code**	**Number of Establishments**
221111	Hydroelectric Power Generation	316
221112	Fossil Fuel Electric Power Generation	1,270
221113	Nuclear Electric Power Generation	74
221119	Other Electric Power Generation	322
221121	Electric Bulk Power Transmission and Control	74
221122	Electric Power Distribution	7,585
221210	Natural Gas Distribution	2,247
221310	Water Supply and Irrigation Systems	3,920
221320	Sewage Treatment Facilities	681
221330	Steam and Air-Conditioning Supply	60
221	***Utilities Totals***	***16,578***

[180] *Ibid.*