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Aviation Security Research and Development at the Department of Homeland Security

Comments by Jimmie C. Oxley; Professor of Chemistry, University of Rhode Island
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What is the current state-of-art in explosives research, especially as relates to homemade and liquid explosives? What are the key knowledge and capability gaps, and what types of research projects are needed to fill these gaps?

Little explosives research in the United States (U.S.) is focused on making new explosives, i.e., new chemicals. A 2004 National Research Council (NRC) report (Advanced Energetic Materials) wrote: *"The U.S. effort in the synthesis of energetic materials at present involves approximately 24 chemists, several of whom are approaching retirement."* In the National Labs or Military Labs new formulations and new devices may be sought with goals of safer, more destructive, longer or shorter shelf-life. Device-centered research undoubtedly proceeds under government contract labs, as well.

Despite the fact that responsible governing bodies have emplaced various administrative controls to keep military explosives out of the hands of terrorists and criminals, international terrorism has relied heavily on these. Interestingly, military, rather than commercial, explosives have generally been their tool. This fact either speaks well of industrial safe guards or points the finger at state-sponsored terrorism.

The military has few applications for liquid explosives. Solid explosives perform equally well and have less handling and storage issues. For this reason, little new research in liquid explosives is performed. However, the old literature is rife with descriptions of liquid explosives, many of which are readily prepared and some of which, e.g. hydrogen peroxide and nitromethane, are commercially available. Liquid explosives are a detection challenge only because, in the past, detection equipment manufacturers had not been asked to detect them and because U.S. policy is not to open bottles. This does not mean liquids cannot be detected; the difficulty is the same as with any number of military or homemade explosives under these conditions. **Research in all areas of detection is required.**

The U.S. began to focus on homemade explosives after the bombing of the Murrah Federal building (April 19, 1995). One tangible result was a 1998 NRC book "Containing the Threat from Illegal Bombings." In 2006 various governments began to use that report as guidance on explosive precursors. What has not been done is to follow the report recommendations for testing of materials to identify actual explosive precursors.

A methodical study is needed to identify the likely explosive precursors. We must probe the fundamentals of detonation to identify the energetic materials which could be made detonable with modest effort.

My criteria for homemade explosive threats are simple: (1) the required synthesis must be minimal—mix and use or mix and separate; and (2) large amounts of the precursor must be available and readily acquired so that large a bomb can be assembled. [“Large” bomb is part of the criteria with the rational that the bomb should be more of a threat than a gun or rifle.]

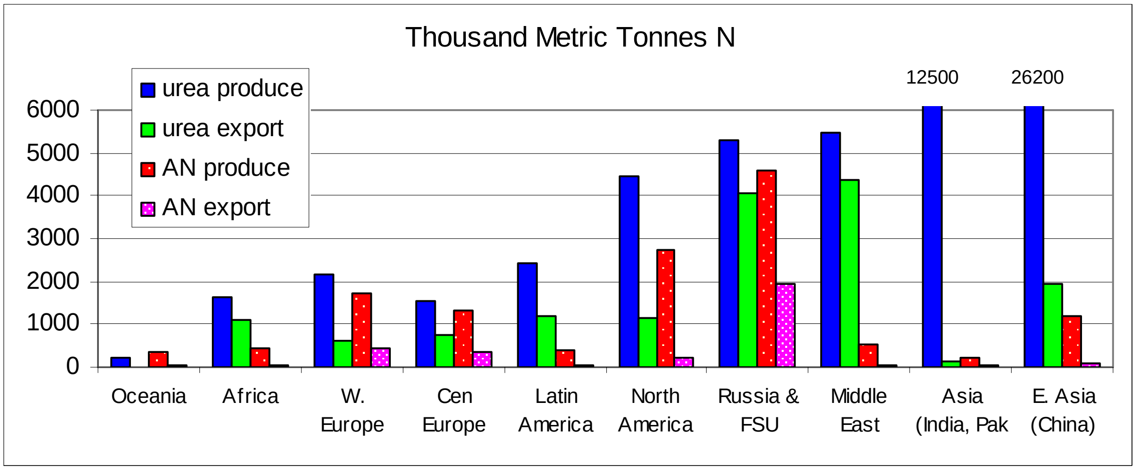
First on my list of homemade explosive are ammonium nitrate (AN) formulations and urea nitrate.

year	location	type of explosive	injured	dead	
1983	Beirut Marine & French Barracks	2 trucks, 12K lb C4?		300	
1988	Pan Am 103, Lockerbie Scotland	Semtex RDX/PETN		269	
1992	St Mary's Axe/Docklands, London	**1000's lb AN icing sugar**		3	*
1993	World Trade Center, NY	**1200 lb, urea nitrate**	~1000	6	
1993	Bombay 13 car & scooter bombs	RDX?	~1200	317	
1993,	Bishops Gate, London	**3000 lb AN/icing sugar**	40	1	*
1995	Oklahoma City Federal building	**5000 lb ANFO**	~1000	168	
1996	Canary Wharf/Docklands London	**3000 lb AN/icing sugar**	39	0	*
1996	Manchester, UK	**1000's lb AN/icing sugar**	~200	0	*
1996	Khobar Towers, Saudi Arabia	0.5-30 K lb C4?	372	19	
1998	Kenya & Tanzania	2000 lb TNT & PETN	1000s	224	
2000	U.S.S. Cole, Yeman	1000 lb TNT & RDX	39	17	
2002	Limburg oil tanker	TNT?	12	1	
2002	Bali nightclub bombs	**chlorate**	**209**	**202**	
rob	Marriot Hotel, Jakarta	**chlorate**			
2003	Istanbul, Turkey	2 bombs	450	28	
2004	Madrid subway, 10 suicide bombs	gelignite in 4 locations	~600	191	
2005	London subway, 4 suicide bombs	**peroxide explosive**	~700	56	
2006	Mumbai, India railroad	7 explosions	625	190	

*PIRA bombs targeted economic loss rather than human loss; warnings were issued

The Provisional Irish Republican Army (PIRA) made kilogram-scale bombs mixing AN with icing sugar. Timothy McVey used AN with the traditional industrial fuel—diesel. In 2006 the U.S. manufactured ~6.4 million metric tons AN, its usage split between agricultural and industrial applications. Indeed, most commercial explosives are AN based. Worldwide about 39 million tons of AN are manufactured annually at about 200 chemical plants and about 9 million tons of AN end up on the export market.

Worldwide urea production is significantly greater than AN—133 million metric tons annually and 31 million tons in export. Urea is used in agriculture, pharmaceuticals, NO_x abatement, and melamine synthesis (which with formaldehyde, forms resins used in adhesives, laminates, coatings and textile finishes). Urea is made from ammonia and carbon dioxide; typically plants producing ammonia produce urea as well. Ammonia is produced using natural gas and nitrogen from air; thus, areas with cheap natural gas make ammonia: China, Russia, Ukraine, the Middle East and Latin America. Urea plus nitric acid form urea nitrate; therefore, it is not surprising that urea nitrate, rather than AN, is frequently used by terrorists in the Middle East.



In investigating all avenues of preventing terrorist bombings, we should consider administrative controls on the most likely to be used homemade explosive precursors. **We should consider administrative tracking of a small number of precursor chemicals** (e.g. AN, urea, nitric acid, hydrogen peroxide, chlorates) **from manufacturer to end user.** Such a program would involve identification of potential precursors and their legitimate place in society. It would require the cooperation of the manufacturers from the time the product left the factory through distributors, traders, and transporters to end users. Such a system would not evolve overnight, but it should be possible with modern computer technology and international cooperation. Of course, it will not stop all diversions, any more than our present controls stop illicit use of military explosives. A 2007 NRC report "Countering the Threat of Improvised Explosive Devices" recommends among other areas of research: "*Perform case studies of actual IED construction and events to determine whether and how resource control might be implemented, with the eventual goal of developing the ability to model the connection between resources and the IED threat chain.*"

How does current university research in the field of explosives and explosives detection contribute to technology development for aviation security? How is university research coordinated between institutions and with the Federal government?

Failing to prevent a bomb from being made, we must consider detection of the bomb. Detection methodologies can be divided into those which require the actual explosive molecule to enter the instrument—these are called particle or vapor detection—and those which can detect characteristic emissions from the bulk explosive. Emission detection techniques can be passive, relying on a natural emission from the chemical, or active, probing the chemical with some sort of radiation to cause emission. Emission detectors can be differentiated as those having the potential to see, (1) with special detail, through sealed containers—check luggage or cargo—"bulk" detection; or (2) through the atmosphere at distances—"standoff" detection.

Trace techniques are at various levels of development. Even the commonly fielded ion mobility spectrometer (IMS) faces many operational challenges. For all trace techniques probably the toughest problem is getting the sample, the explosive molecule, into the detector. Solid explosives, generally, have low vapor pressure. Therefore, detection equipment attempts to sample microscopic particles, rather than vapor. To get a "detect" particles of explosive must be present; harvesting techniques must remove the particles from the surface; and the transfer technique must get the particles into the business end of the detector. Basic surface-particle interactions need to be studied. I understand the National Institute of Standards and Technology is working in this area and the Transportation Security Lab is funding further work.

Among emission detection techniques we find some of the most significant successes and the biggest gaps. As you know standoff detection and cargo screening need further research. As with other detection technologies we can expect to see imperfect systems fielded, but they can only improve with time, funding, and experience. One of the recommendations of the NRC report ("Countering the Threat of Improvised Explosive Devices" 2007) I would like to emphasize: ***"Determine the fundamental physical limits on the active and passive detection of arming and firing systems, as well as the physical and chemical limitations for trace and standoff detection."***

One last gap I wish to highlight. If Universities are to significantly contribute their vast research skills to the National needs, we need a more open access to information in this area of threats and detection. I fully understand the need not to give terrorists information, but in many cases it is those who would help us whom we are keeping in the dark. Uniformly the technologies providers have asked: ***"Increase communication to technology suppliers with respect to emerging threats, scenarios and threat levels."*** ***"Provide threat and precursor information to enable development of broad detection strategies."***

Dr. Jimmie Carol Oxley is Professor of Chemistry at the University of Rhode Island (URI) and co-director of the URI Forensic Science Partnership and co-director of the recently announced DHS Center of Excellence in Explosive Detection, Mitigation and Response. Dr. Oxley has authored 80 papers on energetic materials. She worked with the FBI simulating the World Trade Center bombing, with Forensic Explosive Lab of the Defense Science and Technology Lab (UK) examining large fertilizer bombs, and with ATF/TSWG studying the behavior of pipe bombs. Dr. Oxley has taught over two dozen explosive short courses for various government labs and agencies and has served on five National Research Council panels: Commercial Aviation Security (1995-98); Marking, Rendering Inert, & Licensing of Explosive Material (1997-98); Chemical Weapon Destruction (1998-99); Advanced Energetic Materials (2001-02); Basic Research Needs to Interrupt the Improvised Explosive Device Delivery Chain (2005-08).