Kinetic Energy Weapons
The Beginning of an Interagency Challenge

by Daniel C. Sproull

In 1948, the UN Commission for Conventional Armaments defined weapons of mass destruction (WMD) as "…atomic explosive weapons, radioactive material weapons, lethal chemical and biological weapons, and any weapons developed in the future which have characteristics comparable in destructive effect to those of the atomic bomb or other weapons mentioned above."[1] This widely-embraced definition of WMD acknowledges the possibility of unforeseen and, indeed, unforeseeable technological advances that could lead to the development of weapon types which, for all practical purposes, constitute WMD. One such possible weapon type—the result of rapid advances in hypersonic technology—is the so-called "kinetic energy weapon" (KEW).

KEW: An Overview

A KEW travels at hypersonic velocities and converts part or all of its mass into energy on impact. The kinetic effect of objects impacting at hypersonic speeds is easy to demonstrate in nature. Hundreds of craters, the result of impacting asteroids—some small, others extraordinarily large—can be found all over the earth.[2] The U.S. has contemplated artificially creating this phenomenon ever since the RAND Corporation first proposed placing tungsten rods on intercontinental ballistic missiles (ICBMs) in the 1950s.[3] In 2002, the RAND Corporation issued a report detailing what a possible rod-based KEW weapon system would look like.[4] In 2003, the U.S. Air Force detailed the development of hypervelocity rod bundles as a future weapon system goal. The concept contemplates that a KEW would enable the U.S. to strike ground systems anywhere in the world from space, as well as work to mitigate any anti-access environment that would restrict the operation of conventional forces.[5] The propulsion science for this type of weapon is currently under development by multiple countries, with the only limitation being sufficiently advanced materials science to withstand the enormous heat

Mr. Daniel C. Sproull is an Advanced Concept Weapons analyst for the U.S. Air Force, where he evaluates impact of developing and conceptual weapon systems at the campaign level. He received a M.S. Degree in WMD Studies as a National Defense University Countering WMD Graduate Fellow.

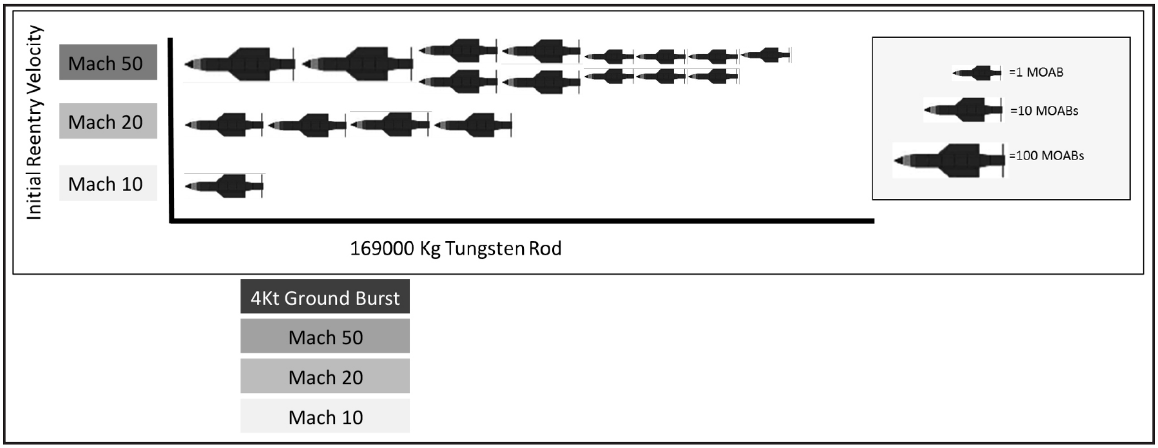

Figure 1. Tungsten Rod KEW vs. MOAB

and stress generated at hypersonic speeds. Once the materials science allows reliable hypersonic speeds to be attained, there is little to stop the development of a viable, large-scale, weapon system.

The U.S. is not waiting for hypersonic engines to become viable before developing a hypersonic weapon. The U.S. Navy railgun project is a low-yield, tactical application of hypersonic technology. The railgun uses electromagnetic force to accelerate an inert steel projectile to hypersonic speeds, currently Mach 7, with a current range of 100 miles. Energy released upon impact is equivalent to 15.5 lbs. of TNT. While 15.5 lbs. of TNT does not equate to a WMD, an immediate kinetic effect of this magnitude clearly suggests the potential for a KEW of WMD proportions.

The Defense Advanced Research Projects Agency's (DARPA) hypersonic vehicle platform has similar potential. While tests conducted to date have only been able to achieve speeds around Mach 10, present goals call for a minimum speed of Mach 20.[6] If DARPA's vehicle was loaded with its maximum payload of 5500 kg and impacted on target at Mach 20, the energy released would approximate 31 tons of TNT.[7]

While this is still miniscule compared to the energy release of a nuclear weapon, it clearly shows the lethal potential inherent in a KEW. This is a yield which certainly exceeds the kinetic yields typically associated with conventional weapons. So, even if currently contemplated KEW does not produce effects of nuclear-weapon proportion, its effects still would far exceed present conventional capabilities.

KEW as WMD

WMD, as a class, have historically been understood to possess some extraordinary combination of four characteristics: high order of destruction, wide area of effect, lingering effect, and indiscriminate effect. Although not all WMD possess all of these characteristics in extraordinary degree, the case can be made that a KEW possesses all four:

High order of destruction

Figure 1 shows the comparison between a single, tungsten, rod-based KEW and the GBU-43/B Massive Ordnance Air Blast (MOAB), the largest precision-guided conventional munition in the U.S. Air Force inventory, with a blast radius of approximately 150 meters.[8] Given a tungsten-rod KEW with a mass of 169,000 kg, 90 percent the lift capacity of an Ares V rocket, note how the impact of one such rod compares with that of the MOAB at reentry velocities of Mach 10, 20, and 50, respectively.[9]

A single rod accelerated to Mach 10 releases the energy equivalent to 10 MOABs (300,000

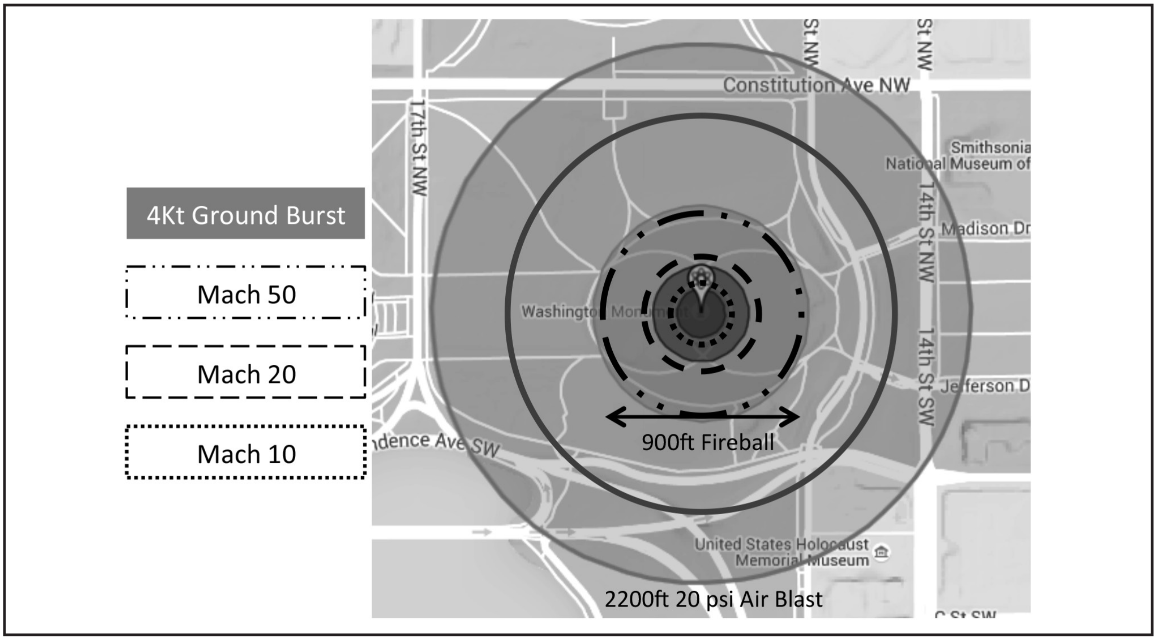

Figure 2. Comparison of Ground-Burst Effects

pounds of TNT) detonating at a single point. At Mach 50, the energy release is equivalent to 247 MOABs or approximately 4 kiloton (kT) of TNT at a single point. As the tungsten rod impacts, a significant portion of the rod vaporizes, leaving tungsten vapor or particulate to spontaneously combust at over 6,000 degrees Fahrenheit.[10] If this combustion occurs in an enclosed space, like a bunker, the resulting fireball would only add to the devastation caused by the impact.[11]

Wide area of effect

Figure 2 centers on the Washington Monument for scale and compares the immediate effects of a ground-burst 4 kT nuclear detonation (Circle 1) with those of a KEW, impacting at Mach 50 (Circle 3), Mach 20 (Circle 4), and Mach 10 (Circle 5).[12]

The Mach 10 and 20 rings either match or exceed the nuclear weapon crater. The Mach 50 ring almost meets the 4 kT nuclear fireball ring. However, a fireball is not the only nuclear weapon-like effect that the KEW illustrated above would produce. It would also produce lethal dynamic overpressure—20 pounds-per-square-inch (psi) in the case of a KEW delivered at Mach 50. Circles 1 and 2 are the 20 psi air blast ranges for the 4 kT nuclear detonation and the Mach 50 KEW impact respectively.13 At these distances, total destruction occurs simply from the air blast. Nearly equaling the Circle 1 is the 5-psi air blast range for the Mach 50 KEW. This also causes extensive damage to people as well as buildings. To place this degree of overpressure in perspective, Figure 3 summarizes the effect of dynamic overpressure on both buildings and on the human body.[13]

In terms of raw destructive capability, the Chelyabinsk meteor explosion over Russia in 2013 gives a real-world example of the possible wide area of effect of a KEW. Weighing in at over 12,000 metric tons and entering the atmosphere at around Mach 50, the meteor exploded 20–30 miles above ground. This event caused minor structural damage across six cities, with over a thousand injuries being reported. The explosion was estimated around 450 kT.[15] Had the meteor held together until impacting the ground, the area of effect would have been much smaller, but the damage done would have been significantly greater.

Peak Overpressure	Maximum Wind speed	Effect on Structures	Effect on the human body
1 psi	38 mph	Window glass shatters	Light injuries from fragments occur
2 psi	70 mph	Moderate damage to houses (windows and doors blown out and severe damage to roofs)	People injured by flying glass and debris
3 psi	102 mph	Residential structures collapse	Serious injuries are common, fatalities may occur
5 psi	163 mph	Most building collapse	Injuries are universal, fatalities are widespread
10 psi	294 mph	Reinforced concrete buildings are severely damaged or demolished	Most people are killed
20 psi	502 mph	Heavily built concrete buildings are severely damaged or demolished	Fatalities approach 100 percent

Figure 3. Effects of Dynamic Overpressure

Indiscriminate and Lingering Effect

Like WMD, KEWs possess the capacity to produce both indiscriminate and lingering effects. However, because of their cratering capability, KEWs could locally magnify these effects on subterranean infrastructure to a degree that exceeds that of WMD. Figure 4 compares the differences in cratering between the 20 kT "Fat Man" nuclear detonation over Nagasaki and Mach 10, 20 and 50 KEW impacts.

Even "Fat Man" caused unexpected subterranean damage over a wide area: the overpressure wave caused by the atomic detonation caused extensive damage to the city's subterranean public utilities, especially water mains, down to about 10 feet. In contrast, a Mach 10 KEW has the capability of cratering down to almost 100 feet. The Mach 50 depth is over 150 feet with a crater almost 800 feet wide. If a KEW attack were to take place near a large body of water, crater flooding would be catastrophic both in terms of lives lost and the time required to restore infrastructure. This effect is magnified if such flooding breached a subway system. Most modern, subterranean rail systems are not equipped to contain massive flooding. The magnitude of the problem becomes evident with today's society. Modern cities place much

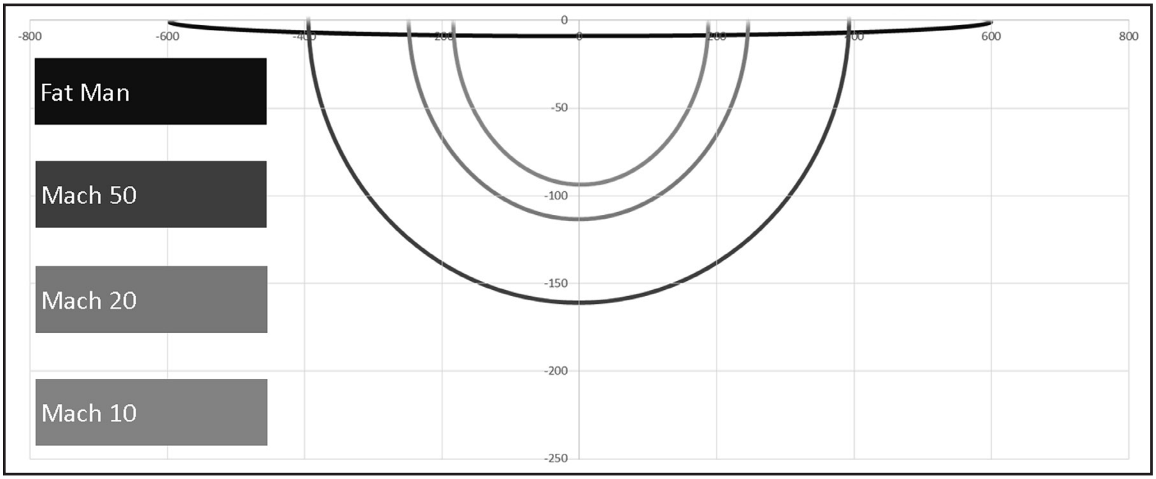

Figure 4. Comparison of Cratering Effects

of their infrastructure underground due to space and security constraints. At depths of less than 30 feet, cities typically have a labyrinth of power, water, steam and gas lines, and in some cities, a maze of subway tunnels and other structures beneath the utility lines. A KEW could easily cause catastrophic damage to this underground infrastructure.

Opportunities and Challenges for the Interagency

Hypersonic research promises a vast array of peaceful, commercial applications, such as hypersonic transportation systems. Moreover, peaceful applications of KEW-like devices for major public works projects, such as large earth-moving projects for cutting canals or creating mountain passes, can be imagined. In previous decades, this discussion was undertaken in earnest with respect to the peaceful use of nuclear weapons. KEW-like devices could conceivably accomplish the same peaceful tasks suggested for nuclear weapons use but without the inherent radiological hazards.

On the diplomatic front, a coordinated international effort will be necessary to achieve uniform understanding about the licit and illicit use of hypersonic technologies. That effort might, in fact, require the establishment of regulatory mechanisms similar to the Nuclear Nonproliferation Treaty (NPT) or the Chemical Weapons Convention (CWC). As the number of nations working to develop hypersonic flight capabilities or KEW expands, the need for such coordination will expand as well. Since the number of countries now focused on these kinds of advanced research efforts is small at present, now is the time to begin regulatory efforts. The NPT states that countries that voluntarily give up construction of KEWs could receive assistance with civilian applications enabled by new materials science. This has worked fairly well for the NPT, with many countries receiving access to technology they did not have to develop on their own.

Even so, both nuclear weapons and KEWs are, first and foremost, weapons, and the interagency must proceed with this reality foremost in mind. Looking at the history of kinetic impacts from meteors—from the older Morokweng and Sudbury impacts to the more recent Tunguska and Chelyabinsk—the unavoidable question becomes how might the U.S. be affected if an adversary were able to create similar effects with a KEW? Now is the time to begin a serious interagency exploration of the implications of hypersonic technology, particularly as that technology relates to KEW. The Department of Defense will be faced with some obvious operational questions such as: What yields will be acceptable for use on the conventional battlefield? What targets would be both viable and valid for attack using KEW? How will the U.S. detect orbital KEW systems? Can such a system be interdicted?

Diplomatic resources will be required to establish international understanding on the weaponized use of hypersonic technologies as well. The subclass of KEWs that can be used on the conventional battlefield must also be defined. Using either the BLU-82 "daisy cutter" or the GBU-43 MOAB would be an appropriate first start to establishing an acceptable conventional yield limit. Both these weapons rely on significant quantities of conventional explosive, 12,000 lbs. for the BLU-82 and 18,000 lbs. for the MOAB. However, the damage from these weapons is confined to a limited area. The BLU-82 has a maximum blast radius of approximately 900 ft., while the MOAB radius is slightly larger due to is greater explosive weight. These are the largest conventional weapons in the U.S. inventory, and both are used sparingly if at all.[16]

They must also decide on a minimum and maximum strategic yield of a KEW. For a time, the upper bound of a KEW yield will be limited by the lift capability of current rocket technology, as well as limitations in materials science, yet these restrictions may not remain in effect forever. Fixing an upper bound on the size of an orbital KEW should be a necessity.

Additionally, countries must also decide how and on what targets KEWs can be used in conventional warfare. Current rules of engagement will suffice for most targets. However, greater care is needed when using a KEW around facilities that have the capability of causing secondary effects. For instance, dropping a 500-lb. bomb several hundred feet away from a nuclear facility might constitute a minimal risk.[17] Using a KEW near a nuclear facility runs the risk of catastrophic damage to the reactor and possibly spreading radioactive fallout. Chemical facilities are also of concern. The Bhopal India incident is a striking example of what can go wrong when dealing with toxic chemicals.[18]

The governing body will have to take decisive action on multiple issues. First, they will have to add large-scale KEWs to the existing UN WMD definition, or amend the Weaponization of Space Treaty to include whatever level of KEWs the group deems appropriate. Second, the group must tackle the issue of dual-use technology. Extensive military and commercial uses for the required high-strength materials as well as the propulsion technology will be found, and regulations must govern where, when, and to whom access to these materials and technology can be given. Finally, the governing body must decide whether or not countries that refuse to adhere to these regulations should be given access to the dual-use materials. Historically, this has been a reactionary measure when existing WMD conventions were violated. Hopefully, the lessons learned from the multiple, currently-existing, WMD regulatory bodies will be accounted for by the KEW governing body.

By and large, there is no one correct path to take concerning the future of KEW. Now is the time to be proactive. As these weapons become reality, ignoring the KEW issue could leave the U.S. and the UN in the weaker position of simply having to react once again. Hypersonic technology is not going away. The railgun is here now, and larger KEWs will follow steadily along in its wake. By declaring KEWs to be WMD, the door is kicked open to begin defining the regulations that will be required in the years to come. ***IAJ***

NOTES

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