The Use of Unmanned Aircraft Systems in Response to Nuclear and Radiological Terrorism

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Abstract

Much of today's nuclear terrorism literature centers on policy-based obstacles to the detonation of a nuclear or radiological device. Though this preventative analysis is essential, equal consideration should be given to responding to the devastating aftermath of a nuclear detonation. Local and state assets will most likely be overwhelmed, the federal response will initially be slow, and decision-makers at every level will be called upon to execute response plans based on real-time information from the disaster site. Unmanned aircraft systems stationed around the United States can quickly provide massive amounts of information to disaster stakeholders in an unprecedented manner. These aircraft have the ability to carry numerous sensors, imagers and communication relays all on a single platform, thus warranting the investigation of a national unmanned aircraft system (UAS) nuclear and radiological response capability. It is essential that the federal government consider this capability to ensure these federal assets are not only available, but fully exercised and utilized before the moment of domestic necessity arises.

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Introduction

The existential threat of nuclear terrorism has seen a significant increase in popularity over the last decade. Many authors focus on concepts to secure nuclear materials, strategies to thwart nuclear proliferators, or other obstacles to the detonation of a nuclear or radiological device. Though this preventative analysis is essential, equal consideration should be given to responding to the devastating aftermath of a nuclear detonation. One need only recall recent domestic disasters—all of which have fortunately been confined to a single city or region of the United States—to realize the challenge this event will present. Local and state assets will most likely be overwhelmed, the federal response will initially be slow, and decision-makers at every level will be called upon to execute response plans based on real-time information from the disaster site. Unmanned aircraft systems stationed around the United States can quickly provide massive amounts of information to disaster stakeholders in an unprecedented manner, thus warranting the investigation of a national unmanned aircraft system (UAS) rapid response capability.

As the first section of this analysis will show, these aircraft provide the carriage of numerous sensors, imagers and communication relays all on a single aircraft. The ensuing discussion of a 10-kiloton nuclear detonation in a metropolitan environment will demonstrate how a singular unmanned aerial vehicle can provide a unique assistance capability unmatched by any single manned aircraft. The UAS has the potential to become an integral component of nuclear and radiological consequence management, and it is critical that the federal government begin developing the necessary memoranda of understanding to ensure these federal assets are not only available, but fully exercised and utilized before the moment of domestic necessity arises.

UAS: State of the Art

Although there are numerous types of UAS, all UAS are comprised of two main components: (1) an unmanned aerial vehicle (UAV) and (2) a ground control station (GCS). Unmanned aerial vehicles range in size from only a few inches across to aircraft such as the Global Hawk B with a wingspan of 131 feet. The UAVs investigated here have wingspans ranging from 55 to 131 feet, fuselage lengths of over 48 feet, and total heights of approximately 15 feet. Similarly, these aircraft can

range in weight from ounces to metric tons. The size and weight are largely defined by the mission space in which the aircraft will operate. For the post-detonation scenario considered here, it is assumed that the aircraft will be required to operate from 500 to 50,000 feet for approximately 15 – 20 hours of continuous flight. This extreme altitude range reflects the operational altitudes required of manned aircraft to perform consequence management missions such as imagery gathering and other sensing.[2] The time span is chosen to demonstrate the vastly superior UAV loitering capability of roughly four to five times that of a manned-equivalent, thus elucidating the significant advantages of UAV utilization in this environment.

The above UAV flight parameters are a result of significant advances made in UAV manufacturing over the last two decades, specifically the mass production of components specifically for the UAV industry rather than assembling UAVs from traditional manned aircraft parts. This is particularly true for carbon fiber members of the airframe that can be crafted and shaped to meet specific design requirements while simultaneously contributing to considerable weight and strength benefits. It could be argued that the utilization of composite materials is one of the greatest contributors to UAS success.

Another key design requirement for unmanned aircraft systems is ease of transportation. For example, the Predator family of aircraft has removable wings, tails, landing gear, and propellers, all of which can be placed in their respective shipping containers and packed into the cargo area of relatively small military transport aircraft (e.g. – C-130). This type of unmanned aircraft can be transported to any part of the world in less than 24 hours and can be ready for flight in less than 12 hours. Some unmanned aircraft, such as the Global Hawk, are able to "self-ferry" due to their remarkable endurance. The Global Hawk made such a self-ferry flight from California to Australia (8,600 miles) in just over 23 hours with no mid-air

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[2] David R. Bowman and Donald M. Daigler. "NNSA/NV Consequence Management Capabilities for Radiological
Emergency Response," *DOE Scientific and Technical Information* (2002),
http://www.osti.gov/bridge/servlets/purl/804083-m1aTun/native/804083.pdf (accessed February 11, 2010).
Raytheon Company. "AN/ASQ-228 ATFLIR - Advanced Targeting Forward-Looking Infrared Pod," (2009),
http://www.raytheon.com/businesses/rtnwcm/groups/sas/documents/content/rtn_sas_ds_atflir.pdf (accessed February 11, 2010).

refueling. Similarly, the Global Hawk broke an unmanned record by flying continuously for just over 31 hours.[3]

Advances in avionics, engine design, and sensor integration have also allowed the capabilities of these aircraft to blossom. Sensor integration is of particular importance because it is this ability that makes the UAV such an adept and versatile tool in the post-detonation mission space. Most UAVs currently fielded feature some form of near real-time video and still-image capturing. These capabilities include a day/night television system, which uses cutting-edge video technology for day viewing and low-light charged-coupled device (CCD) imagers for night vision. Additionally, many platforms are also fitted with a forward-looking infrared (FLIR) camera that allows the UAV operators to see images based on heat signatures. The latter is particularly useful in distinguishing humans from inanimate objects as humans generally produce a unique heat signature even when surrounded by a relatively warm thermal environment.

Many larger UAVs also carry synthetic aperture radar (SAR), which is designed to provide high-resolution radar images from miles above the ground in all weather conditions. Synthetic aperture radar is novel in its ability to generate radar pulses from different angles beneath the aircraft, aggregate the numerous radar "echoes" from the various angles and pulses, and produce a high-resolution, potentially three-dimensional, interpretation of the terrain below. This type of imagery is particularly useful for observing changes in the terrain and metallic objects which will be noted later as a crucial capability in the urban, post-detonation environment.

UAS Command and Control

All sensor and aircraft system data is relayed to and from the aircraft via the UAS radio-frequency datalink. The datalink is comprised of two arteries: the uplink and the downlink. The uplink contains all flight system instructions, sensor/payload commands, and audio communications that emanate from the air vehicle. The downlink from the aircraft provides the operators with audio, video, and systems information. The datalink can be established by either line-of-sight (LOS) antennas, one on the aircraft and the other on the ground, or by satellite in which a small

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[3] Northrop Grumman. "Global Hawk," (2010), http://www.as.northropgrumman.com/products/globalhawk (accessed February 2, 2010).

satellite dish inside the UAV sends the datalink through a satellite to a distant ground control station where all command and communication operations are conducted (see Figure 1 below). The LOS datalink has a maximum range of 150 nautical miles while the satellite relay limitations are mainly satellite availability, footprint on the Earth, and data transmission rates. It is through this satellite communication that unmanned aircraft are routinely commanded from within the United States while the aircraft themselves fly on the opposite side of the planet.

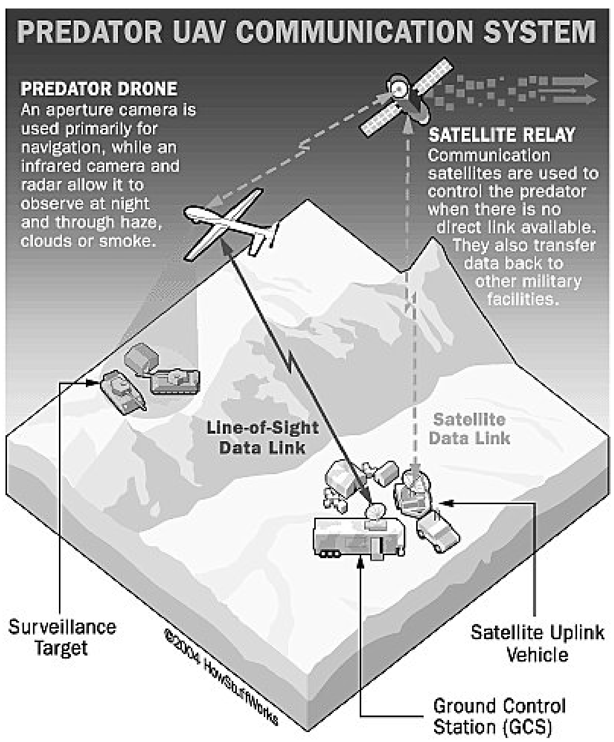

Figure 1 - UAS Datalink
(photo: http://www.hooked-on-rc-airplanes.com)

The ground control station is another integral component of the unmanned aircraft system. It is within the GCS that all command and control, as well as data collection and processing, is conducted. The pilot and payload operator (PPO) station within the GCS is the command and control interface between the air vehicle and its human controllers. All aircraft flight control and payload systems can be monitored and adjusted from the PPO stations. There are typically two PPO stations, one beside

the other, establishing a UAV "cockpit" which allows the pilot and sensor operator to easily communicate as well as take command of the other's duties should the need arise. The processing of payload data can also be performed at Payload Operator Workstations (POW), which sit behind the PPO stations and allow additional personnel in the GCS to conduct more detailed analysis of payload information, video, and other data products (see Figure 2 below). PPOs and POWs can fill a large office space or be compact enough to fit in the back of a small utility vehicle.

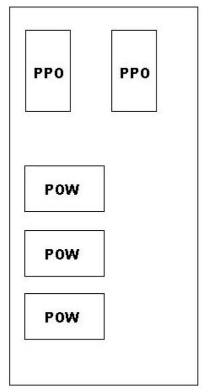

Figure 2 – Ground Control Station (GCS)

The GCS provides one of the most tangible examples of UAS superiority over manned equivalents; namely, the real-time operation of an aircraft without exposing the operator to bodily harm. By utilizing the satellite-based datalink, a growing corps of highly experienced UAV pilots and sensor operators have emerged over the last two decades despite the loss of numerous unmanned aircraft. These individuals have learned from mistakes over the years, honing their UAV command and control skills without losing pilot personnel during flight operations. This ability to continually develop a skilled workforce and simultaneously obtain an unprecedented return on U.S. government investment makes unmanned aircraft systems more valuable than their manned counterparts that perform in the same mission space.[4]

[4] U.S. General Accounting Office, *DOD's Use of Remotely Piloted Vehicle Technology Offers Opportunities for Saving Lives and Dollars, MASAD-81-20,* Washington, DC: General Accounting Office, 1981, http://archive.gao.gov/d41t14/117728.pdf (accessed February 6, 2010).

Costs and Challenges of Unmanned Aircraft Systems

With such benefits, it would be amiss to glaze over the costs of these systems, financial or otherwise. It can be objectively stated that UAS are an order of magnitude less expensive than various manned counterparts that perform similar missions.[5] This savings is due to a number of factors, some of the most central being that UAS can be manufactured at significantly higher production rates and economies of scale, are markedly less complex, and have decidedly lower life-cycle costs.[6] The generally lower cost of an unmanned aircraft also makes it far more palatable to stakeholders and observers when a vehicle is lost. The loss of an unmanned aircraft does not result in the loss of the pilot, the loss in educational/training investment on the part of the United States, nor the cost to backfill said position with an equally trained individual, thereby increasing the cost differential between manned and unmanned vehicles.[7] This cost differential and the potential disposal of UAVs is particularly relevant in the nuclear post-detonation discussion should the aircraft become contaminated with radiation.

Just as it would be wrong to avoid a UAS cost discussion, so would it be to skirt the inherent challenges in the UAS realm. Unmanned aircraft systems have four broad fault categories that can diminish a UAS role or lead to a catastrophic failure: (1) severed datalinks, (2) software or hardware failures, (3) human errors, and (4) the laws of physics. A severed datalink is a well-understood annoyance for UAS manufacturers. This issue has led to the development of elaborate mitigation schemes such as pre-programming the UAV to vary its altitude and direction when the link is broken, to deploying a parachute if the aircraft runs out of fuel while attempting to regain the datalink. Though these efforts may sound effective, a lost link "event" can easily end with the loss of an aircraft.

Lost-link and standard flight operations alike have little tolerance for software or hardware malfunctions. Though mechanical failures are exceedingly rare in unmanned aerial vehicles, software glitches can be quite prolific. The latter is due to the iterative process of modifying one branch of software code in one aircraft

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[5] Sqn Ldr Rajesh Kumar. "Tactical Reconnaissance: UAVs Versus Manned Aircraft," (March 1997): 24-26, http://www.fas.org/irp/program/collect/docs/97-0349.pdf (accessed February 11, 2010).
[6] Ibid.
[7] U.S. General Accounting Office, *DOD's Use of Remotely Piloted Vehicle Technology Offers Opportunities for Saving Lives and Dollars, MASAD-81-20,* Washington, DC: General Accounting Office, 1981, http://archive.gao.gov/d41t14/117728.pdf (accessed February 6, 2010).

configuration that can easily conflict with programming instructions for other aircraft configurations. This process of ensuring that new versions of aircraft code do not conflict with previous and simultaneous versions becomes increasingly challenging when one considers that the GCS software is also undergoing modification. As such, the evolution of aircraft software must be synchronous with that of the GCS software to ensure in-flight errors are abated. UAS manufactures employ small armies of software programmers, software configuration managers, hardware component designers, and experimental aerospace engineers, all of whom are solely focused on ensuring a harmony exists among the various software configurations. For companies like General Atomics that currently field five types of aircraft and no less than four GCS configurations, this is a daunting task with little praise upon success, but massive scrutiny upon failure.

The level of expertise required to pilot and operate a UAV is another topic often taken for granted. Many UAV pilots come from the ranks of manned aircraft test pilot programs or have thousands of manned aircraft flight hours. In addition to these pre-requisites, most UAV manufactures and government agencies require additional extensive UAS training and generally put recent UAV-graduates in the sensor operator seat many hours before allowing them to command their own aircraft. Despite this tremendous amount of training, human errors still occur. The mitigation of these mistakes requires an in-depth knowledge of the entire UAS, the interaction of system components, responses to commanded inputs, and the innate ability to rapidly analyze a deteriorating situation and execute a coherent remediation plan in a matter of seconds. Even with these instinctive piloting skills and a deep learned understanding, unmanned aircraft are lost annually due to human error. The suggestion that piloting a UAV is similar to playing a video game is at best uninformed.

Assuming the above risks are sufficiently mitigated through policy and engineering controls, unmanned aerial vehicles must still contend with fundamental laws of physics. Many of these conventions are programmed into the UAS software to create an operational flight "envelope," but this operational space may not intersect with the required mission space. An example of this is the nuclear/radiological post-detonation environment. Payloads such as day/night television and SAR have stand-off distance limitations that are largely defined by laws of optical physics as well as the operational environment. It is conceivable that the radiological plume, prevailing winds, or man-made structures may preclude the

aircraft from flying close enough to effectively utilize some on-board sensors. As such, these inevitabilities must be well understood by mission planners as well as other stakeholders.

The Urban Post-Detonation Environment

The detonation of a single nuclear device in an urban environment will likely overwhelm most local, state, and federal resources in the near-term and even more so in the case of multiple, simultaneous attacks across the United States. It is for this reason that all capabilities in the U.S. arsenal must be brought to bear on this catastrophic event. The analysis here is based on a single, densely populated city of approximately one million people. This city has a large downtown area in which the locus of buildings has an average height of 12 stories. The fateful day is one of clear skies with moderate humidity and temperature.

The improvised nuclear device (IND) detonates releasing 10 kilotons of total explosive energy on a surface street in the center of the downtown area during rush hour. The cataclysmic smashing of atomic particles causes fissioning atoms to produce neutron, x-ray, gamma, and thermal radiation as well as an electromagnetic pulse. A barrage of explosive, atmospheric, radioactive, and electromagnetic forces are released on this city center. All this occurs within the first fraction of a second after detonation.

The environment surrounding the device absorbs the destructive energy in many ways. The two immediate sources of destruction are the thermal radiation and pressure wave. As the nuclear chain reaction consumes the uranium or plutonium fuel, it releases energy in the form of thermal radiation. This fission-driven thermal radiation feeds off the chain reaction energy to rapidly expand outward, vaporizing matter within a few thousand feet of ground zero and causing the formation of a supersonic pressure wave that accelerates well ahead of the fireball at a rate of hundreds of miles per hour. As the fireball consumes its surroundings, it loses the energy needed to maintain its outward velocity and extreme temperature. By the end of the first minute, the fireball has expended its energy and begun cooling, causing the now vaporized matter to condense into a cloud. This cloud remains significantly hotter than its surroundings causing it to rise quickly and drawing with it particulates from around the detonation site. If not radioactively activated during the initial

detonation, these particles are heavily contaminated as they are whisked into the sky and violently mix with neutron and gamma contaminated particles. Relatively warmer air and particles rush to the central top of the cloud drawing cooler air and dust into the bottom, thereby creating the familiar shape of a "mushroom cloud." By the end of the second minute, the vicious power of the fireball and shockwave has been reduced to a mere warm breeze and rising cloud.[8]

After approximately five to ten minutes, the mushroom cloud is stabilized and becoming a "plume" meaning it has reached its maximum height and is now subject to local winds. The 10-kiloton detonation analyzed here would have a cloud apex of no more than 30,000 feet,[9] which is well below the maximum ceiling of most large UAVs. Large particles that were sucked into the cloud, some of which are roughly the size of toy marbles, have already begun falling out of the cloud and back to the earth near the detonation site while lighter particles the size of sand grains can travel for hundreds of miles with the wind. The falling of these particles from the radioactive cloud back to the earth is what earns them the name "fallout." With the fissionable nuclear fuel in the bomb consumed, the "initial" neutron and gamma radiation has long since dissipated at this point in time, leaving primarily "residual" radiation from the fallout. It is important to note that a surface burst IND such as that posited here would create blast and fire damage over a smaller area than its air-burst counterpart, though the amount of fallout associated with the surface burst IND would be significantly higher due to the amount of material available for fireball consumption and plume deposition.[10]

Note too that the event discussed here involves an IND, which is significantly more technologically sophisticated than the detonation of a radiological dispersal device (RDD) or "dirty bomb." Because of this disparity in sophistication, it is far more likely that a terrorist would choose an RDD over an IND. Nevertheless, the

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[8] Alexander Glaser. "Effects of Nuclear Weapons," *Princeton University: Nuclear Futures Laboratory* (February 12, 2007), http://www.princeton.edu/~aglaser/lecture2007_weaponeffects.pdf (accessed February 6, 2010).

[9] Based on calculations from Samuel Glasstone and Philip J. Dolan, *The Effects of Nuclear Weapons,* Washington, DC: U.S. Government Printing Office, 1977, http://www.princeton.edu/sgs/publications/articles/effects/effects-3.pdf (accessed February 11, 2010).

[10] Ashton B. Carter, Michael M. May and William J. Perry. "The Day After: Action Following a Nuclear Blast in a U.S. City." *Washington Quarterly* vol. 30, no. 4 (Autumn 2007): 19-32, http://belfercenter.ksg.harvard.edu/files/The%20Day%20After-%20Action%20Following%20a%20Nuclear%20Blast%20in%20a%20U.S.%20City.pdf (accessed February 6, 2010).

IND would cause considerably more death and destruction and is therefore discussed here as the "worst case" scenario. Though the detonation effects of the two devices would be different by orders of magnitude, the utilization of unmanned aircraft systems would be nearly identical in both scenarios.

UAS and Nuclear Blast Effects

Traditionally, this point of the analysis would review the mid- and long-term biological effects of radiation, but as these do not affect unmanned aircraft and the human operators will most likely be hundreds of miles from the detonation site, biological radiation effects will be left to other authorities. It is far more relevant for this discussion to conduct a critical and focused review of the myths and facts surrounding those blast effects that may impact a UAS, such as the electromagnetic pulse (EMP) generated by the nuclear detonation.

The EMP is caused by the sudden separation of electrons from their parent nucleus. The energy released from nuclear fission at detonation is so powerful that it tears relatively lighter electrons from the relatively heavier nucleus that the electrons orbit. This separation of negatively charged electrons from their positively charged atomic nucleus, or ion, causes the generation of a massive electric field between the two charged particles. This instantaneous electric field in turn generates an equally massive magnetic field, both of which radiate outward from the detonation site. This combined electro-magnetic wave front, or pulse, emanating from the detonation site is the EMP. The longer the electrons remain detached from a positively charged ion, the longer and greater distance the EMP will travel. With a surface detonation in a densely built city center, there are many opportunities for the electrons to be re-captured in the atoms of surrounding materials such as buildings. This has a great attenuation effect on the damage an EMP can cause in such a scenario. Unfortunately, the earth is also a good electric field conductor suggesting the EMP is given relatively more "paths of least resistance" than if the detonation was an air-burst. This ease of electric field transport is further enhanced by the large electric cable infrastructure most cities maintain above and below ground.

The "strength" of an electro-magnetic pulse depends on the yield of the weapon and the detonation height above ground, with the peak of the EMP occurring

microseconds after the detonation.[11] A 10-kiloton surface burst would emit an EMP that dissipated in a fraction of a second and would most likely affect electronics within one to three miles of the detonation site.[12] Electro-magnetic pulses are similar to radio waves, but have orders of magnitude greater amplitude, frequency ranges, and field strength. As such, no antenna is required to "enhance reception" of an EMP; the conductors inside a device are sufficient. The EMP propagates across a device instantaneously and does not linger. Electronics in the path of the EMP experience impairment ranging from disruption to destruction, depending on the amount of energy absorbed by the equipment and the sensitivity of that equipment. It is crucial to understand that an EMP only affects those electronics that are in the path of the EMP in the fraction of a second that the EMP exists. As such, the telecommunications and power infrastructure in the city will be affected, but unmanned aircraft outside the path of the EMP will be wholly unaffected as they arrive on the scene hours after detonation.

There are two other phenomena that need mentioning as they could potentially affect the performance of unmanned aircraft in a post-nuclear detonation environment. The first is local meteorology. After the fireball has consumed its immediate vicinity, there will undoubtedly be a large number of ground fires as well as immense heat which will rise into the surrounding atmosphere potentially causing turbulence, severe cross-winds, and generally decreased air density. The latter will negatively affect the UAV lift, which will in turn lead to decreased fuel efficiency and payload capacity. Nevertheless, this meteorological environment would not be expected to persist, and certainly not after 24 hours.

There is also the issue of ionization. Ionization could be considered a "persistent form" of an EMP, such that some electrons that have been stripped from their nuclei are at a high enough altitude that they are not absorbed by materials on the ground. These disassociated electrons effectively become a thick "electron cloud" that has the potential to attenuate radio waves by absorbing the radio wave energy, or refracting the radio wave as it crosses the electron cloud and reflecting the wave in a random direction. In the 10-kiloton surface discussed here, this electron cloud is short-lived and localized to a relatively small space compared to that of an

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[11] Samuel Glasstone and Philip J. Dolan, *The Effects of Nuclear Weapons,* Washington, DC: U.S. Government Printing Office, 1977, http://www.princeton.edu/sgs/publications/articles/effects/effects-3.pdf (accessed February 11, 2010).
[12] Based on calculations from ibid.

air-burst detonation.[13] Therefore, attenuation of the UAV line-of-sight datalink is unlikely, especially hours after the nuclear device has detonated. Refraction, or radio "static," is far more likely to affect the UAV because refraction requires a smaller amount of free electrons to affect a radio wave. This said, the sparse electron cloud from the detonation discussed here will not exist at a magnitude that would sever the powerful line-of-sight datalink. If controlled by satellite, the UAV satellite datalink will most likely be affected for a few minutes immediately after the detonation, but again, it is not expected the aircraft will be in the vicinity of the detonation site at this time.

The Utilization of Unmanned Aircraft in an Urban, Post-Detonation Environment

There is a tacit understanding between federal and state governments that most federal consequence management assets will not significantly bolster rescue efforts until 24 – 48 hours after the detonation. This is largely due to unavoidable logistical, organizational, and bureaucratic challenges at both the state and federal levels despite numerous annual exercises, interagency emergency planning activities, and extensive resource staging. The few manned air response assets that could assist would be in an emergency response procedural and logistical queue, yet the large number of UAVs stationed around the United States could quickly provide initial coverage of the detonation due to their geographic dispersion and thus proximity to most large metropolitan areas. There are UAVs (i.e. – Predators and Global Hawks) stationed at approximately ten airfields around the U.S. on any given day. The Navy, Air Force, Army, and various Air National Guard units, as well as the Customs and Border Patrol, U.S. Coast Guard, and others government agencies operate these aircraft domestically and could be called upon to assist in the nuclear response mission. If armed, these aircraft can be stripped of their weapons in minutes to mitigate safety and *posse comitatus* concerns, then self-ferry to the incident site. With this large compliment of domestically stationed aircraft, there would be no shortage of rapid response unmanned aerial vehicles ready to provide situational awareness to first responders and decision-makers on a far more contracted timeline than the manned equivalent.

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[13] Ibid.

Most larger UAVs could arrive in the affected zone within six hours of detonation and remain on-station for over 12 hours, the first 12 – 24 hours being some of the most crucial to the response effort. Day/night and thermal video cameras on-board the UAV would send near real-time video information back to the GCS where that information would then be passed to incoming first responders from neighboring areas while simultaneously being provided to national decision-makers across the United States. At the same moment, synthetic aperture radar could begin taking large, high resolution images of the city to provide emergency response planners with a "lay of the land," elucidating the most clear and direct ingress and egress arteries for response personnel once they arrive on-scene.

In addition to providing a rapid response capability, the long endurance of these aircraft provides a solution to the expected information lag emanating from the affected city. Most media sources within the city center cannot be expected to operate within the first few hours after an IND detonation due to a combination of destruction and congestion. With some forethought and testing, UAVs can be fitted with communication relay pods currently used on manned military aircraft. These communication pods could provide first responders with an independent and unaffected communications network, survivors with limited cellular phone text and email service, or AM/FM radio broadcasts containing protective action guidelines for the public as performed by a U.S. Army EC-130 after the devastating January 2010 earthquake in Haiti.[14] Payload sensor operators could also establish communication links with the U.S. Department of Energy radiological reach-back assets to ensure open lines of communication exist between the nation's radiological subject matter experts and first responders via the UAS. To facilitate communication flow, first responders permitted to enter the "hot zone" could be given ROVERS—handheld computers that allow responders in the affected city to see video footage being recorded by the UAV above. With the combination of communication relays and ROVER computers, first responders could become greatly more effective in avoiding mass exodus congestion and locating survivors due to the real-time aerial situational awareness and direct communications with the UAV sensor operators and response subject matter experts.

[14] Staff Sgt. John Seth Laughter. "Behind the Food Surge." *Digital Video and Imagery Distribution System* (February 2, 2010), http://www.dvidshub.net/?script=news/news_show.php&id=44787 (accessed February 9, 2010).

In addition to imagery and communication capabilities, UAVs could be fitted with atmospheric analysis tools to obtain real-time meteorological data. This empirical data would be fed into plume modeling software to generate more accurate plume maps. These maps help planners decide what areas of the populace must be alerted, evacuated, or told to shelter-in-place over the short, medium, and long-term. It is possible for larger UAVs to avoid the plume entirely, though the fact that it is unmanned provides the unique opportunity to fly a sensing aircraft directly through the plume to collect meteorological data. Before this is performed, it would behoove planners and UAV operators to not only certify that the UAV equipment is radiation hardened, but to also agree on an area within the contaminated city to land or crash the aircraft, as flying a now-contaminated aircraft out of a "hot zone" creates the need for at least one additional decontamination location (i.e. – the landing airfield) and more should pieces begin to fall off the aircraft or it crash before returning to base.

Nevertheless, opportunities abound for the use of a single unmanned aerial vehicle in response to a nuclear detonation. One can expand this line of thinking to include the use of multiple choreographed UAVs over an afflicted city providing a mesh of imagery, data, and communications while flying distinct, de-conflicted flight patterns at various altitudes. The Predator UAV manufacturer, General Atomics Aeronautical Systems, Inc., currently fields the "Multi-Aircraft Control" system in which one pilot commands four aircraft simultaneously by defining pre-planned flight patterns and altitudes that will ensure de-confliction. In this way, the pilot can focus on flying the aircraft while four sensor operators sit behind the pilot in the GCS operating the sensors on their respective aircraft. The number of potential concepts of operation grows significantly when one now considers this multi-aircraft system in an urban, post-detonation environment.

This discussion has, to this point, assumed that terrorists would perform a singular attack against the United States, though this assumption is inherently dangerous. As domestic points of entry/exit are shut, the federal government will most likely act quickly to search and secure other large cities and national landmarks to prevent follow-on detonations. This mission will inevitably require additional radiological search personnel, vehicles, and equipment to fan out across the nation in an abbreviated timeframe. A weighty decision will emerge with regard to which experts and vehicles should be allocated to recovery efforts in the affected city versus searching for additional devices in other cities. It is here that UAVs provide a

force-multiplying effect. Most major U.S. cities are within a relatively short flight of bases currently operating UAVs within the United States. If the appropriate planning and staging is performed today, these bases will contain all necessary infrastructure and personnel to scramble UAVs in support of a radiological search mission. Unmanned aerial vehicles could begin preliminary sweeps of major metropolitan cities at the “slow and low” speeds and altitudes required by the airborne radiological sensors. This activity would both actively search for nuclear devices and establish a radiological baseline to determine if a device is introduced into the city at a later time. This massive rapid response, search-and-secure UAV mission may not have a particularly high probability of locating follow-on devices for a number of reasons, but the shear fact the mission is performed poses a significant risk to terrorist planning a follow-on attack.[15] No such domestic deterrent exists in the United States today.

The most powerful capability unmanned aircraft can provide during this scenario is ground truth. First responders, law enforcement, utility repair personnel and others can receive near real-time information from the UAVs in the form of video, still imagery, audio, and other data formats well before and after arriving on-scene. This dissemination will allow planners and operators to more effectively and efficiently allocate response resources to specific areas within the affected city, thus optimizing resource utilization, decreasing first responder exposure time, and increasing the number of survivors. Resources arriving from other states and the federal government can also use the UAS-disseminated information to fine-tune their response plan as they transit to the affected city. The ability to immediately place highly sophisticated sensors into an affected area and relay that information across the nation to a diverse set of stakeholders is an unprecedented capability and one the United States is currently not prepared to leverage.

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[15] Ashton B. Carter, Michael M. May and William J. Perry. "The Day After: Action Following a Nuclear Blast in a U.S. City." *Washington Quarterly* vol. 30, no. 4 (Autumn 2007): 19-32, http://belfercenter.ksg.harvard.edu/files/The%20Day%20After-%20Action%20Following%20a%20Nuclear%20Blast%20in%20a%20U.S.%20City.pdf (accessed February 6, 2010).

Today

The argument for the use of unmanned aircraft systems in response to nuclear or radiological terrorism is compelling. A UAS can theoretically provide operators, responders, and decision-makers still and motion imagery, high resolution radar, communication relay, and atmospheric sensing all on a single platform for 12-15 hours. There is no manned equivalent in the United States arsenal that has a fleet as geographically dispersed and can perform the same breath of missions while remaining aloft without refueling.

This then begs the question of what the current operational plan is for deploying these unmanned systems during a domestic nuclear or radiological attack. Unfortunately, there is no evidence to suggest that such a plan exists. Some point to the National Response Framework (NRF) as the panacea document that would fold-in the use of UAS, but the operational integration of these assets cannot begin once a detonation has taken place. Local, state and federal responders must actively develop concepts of operation and exercise the systems and capabilities that unmanned aerial vehicles provide if the full potential of these aircraft is to be leveraged. Equipment must be developed, tested, validated, and fielded to ensure that operators are trained in this new mission space. The planning, procuring, and exercising should begin with the government departments and agencies that currently operate these aircraft (e.g. – the U.S. military, border patrol, NASA) with the intent of graduating intra-agency UAS response exercises to national interagency activities. There have been a limited number of internal exercises conducted by two agencies, but these exercises had little to no relevance on the consequence management mission defined here. The ideal interagency venue to exercise the domestic use of UAS in nuclear response is the National Level Exercise (NLE) conducted annually by the Department of Homeland Security (DHS). This exercise is designed to "build an integrated federal, state, tribal, local and private sector capability to…rapidly and effectively respond to, and recover from, any terrorist attack or major disaster that occurs."[16] Here, a UAS concept of operations can be tested and evaluated for effectiveness at the national level after having previously taken part in smaller exercises.

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[16] U.S. Department of Homeland Security. *National Level Exercise 2009 (NLE 09)*, Washington, DC: Federal Emergency Management Agency, December 1, 2009, http://www.fema.gov/media/fact_sheets/nle09.shtm (accessed February 6, 2010).

Perhaps the largest hindrance to utilizing unmanned aerial vehicles is domestic airspace regulation. The Federal Aviation Administration (FAA) maintains a skeptical view of UAVs and has only recently begun to loosen restrictions on UAV flights in the National Airspace System (NAS). This "loosening" shifted the policy of little tolerance to one of performing a case-by-case safety analysis for each UAV operational area. If granted, these FAA Certificates of Authorization (COA) often restrict the aircraft to Line-of-Sight operation (approximately 150 nautical miles) within a strictly defined airspace, as noted in a 2008 Government Accountability Office (GAO) study entitled "Unmanned Aircraft Systems: Federal Actions Needed to Ensure Safety and Expand Their Potential Uses within the National Airspace System."[17] It is important to note that many of the useful recommendations made in this study that would promote the use of UAVs within the NAS have not been implemented or have been rejected by the FAA. Fortunately, the heavy FAA restrictions on UAV usage only impact the exercising of UAS nuclear response capabilities, as these limits would most likely be trumped after a nuclear detonation by authorities provided to the Department of Homeland Security in statutes such as the Homeland Security Act or simply on the basis of national priorities and the protection of the U.S. public. Nevertheless, the utility of a UAS in an urban, nuclear or radiological post-detonation environment will not be fully realized until it can be exercised over an actual city within the NAS.

Conclusion

The use of unmanned aircraft systems in response to nuclear or radiological terrorism must become a national priority. This should not be a notional discussion, but instead a national effort undertaken by those emergency response communities that would benefit from such capabilities. To become a national priority will require three main pillars: a leader, a funding stream, and political will. The latter can be easily obtained based on public statements by national leaders on the utility of

[17] U.S. General Accounting Office, *Unmanned Aircraft Systems: Federal Actions Needed to Ensure Safety and Expand Their Potential Uses within the National Airspace System, GAO-08-511*, Washington, DC: General Accounting Office, May 15, 2008, http://gao.gov/products/GAO-08-511 (accessed February 6, 2010).

unmanned aerial vehicles.[18] Leadership should rest with the DHS as this agency is charged with coordinating domestic nuclear and radiological response efforts and already has a sizable UAS fleet currently operating domestically. Placing DHS in this leadership role does not require that DHS purchase additional aircraft for this effort, but DHS should lead the effort to draft memoranda of understanding between itself and other elements of the U.S. government that currently operate UAS domestically. These memoranda would delineate how the interagency would utilize, fund, and assess liability for unmanned aircraft systems, similar to existing agreements governing the use of other interagency equipment during a disaster. DHS should also house a coordination body through which all emergency response UAS communication and radiological sensor development efforts are weighed and evaluated to prevent duplicative activities and to ensure national priorities are synchronized with technology development. By placing this coordination body within DHS, it provides the opportunity to utilize existing radiological and nuclear response funding mechanisms to quickly begin required work with the ability to request sustainable DHS funding streams for this effort in the long-term.

Unmanned aircraft systems technology is mature and proven. The emergency operations plans exist, and it is time to add the UAS tool to the nuclear and radiological response chest. The video, radar imagery, and other payload data that can be provided to both responders and decision-makers anywhere in the United States are unprecedented capabilities that we as a nation cannot ignore. Unlike many initiatives, this effort capitalizes on the use of existing technologies, personnel, and funding from across the U.S. government and industry. Though some bureaucratic and logistical challenges exist, emergency responders, UAV operators, and executive-level managers from stakeholder organizations who were interviewed for this research agree that the effort to integrate unmanned aerial vehicles into nuclear and radiological response is achievable. It now requires the whole of the federal government to begin developing this capability in cooperation with state governments and industry to ensure these federal assets are not only available, but are fully exercised and utilized before the moment of domestic necessity arises.

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[18] John Dougherty. “Napolitano tapped as Obama’s Homeland Security chief.” *The Colorado Independent* (December 1, 2008), http://coloradoindependent.com/16240/napolitano-likely-choice-for-obamas-homeland-security-chief (accessed February 11, 2010).