MQ-9 Reaper Drone: Not a Revolution in Warfare

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In a surprise move this year, the Pentagon has reduced spending for two aerial drones. A version of the RQ-4 Global Hawk will be relegated to storage to be superseded by more capable versions, and future production of the MQ-9 Reaper is to be reduced from 48 per year to 24. The decisions were surprising. Drones are widely touted as the future of warfare. How can it be that the 40 year old, manned U-2 reconnaissance aircraft can do the mission better than even an early generation drone? The Reaper decision was not attached to any admission of disappointment; it was just a matter of budget constraints and skilled manpower shortages. The minor setback with Global Hawk notwithstanding, the aura of a leap ahead in war fighting technology is left intact, or so it is to be believed.

Much has been written about unmanned aerial drones. [1] Some of it has questioned the morality of how they are being used, and in a few cases, some aspects of technical performance is questioned. [2] Much more of the writing and the vast majority of expert opinion is that drones are cheaper to buy and operate than manned aircraft, can do things aircraft cannot do, and when they perform aircraft-type missions, they often do them at least as well, if not better-all without endangering an American pilot. Some even proclaim the F-35 Joint Strike Fighter to be the Air Force's last manned tactical aircraft, and the Air Force is seriously contemplating an "optionally manned" long range, nuclear bomber.

For example, Peter Singer of the Brookings Institution argues that "an amazing revolution is taking place on the battlefield;"[3] drones "will increasingly be available as autonomous force multipliers."[4] Singer's colleague at Brookings, Michael O'Hanlon, argues that "The era of manned airplanes should be seen as over,"[5] and they both argue that those who persist in supporting manned systems are standing in the way of progress in defense technology, if not history. Even some promoters of manned systems tend to agree for the long term; one advocate of all things Air Force, John A. Tirpak, executive editor of Air Force Magazine, favorably compares the Reaper drone to the F-16 as a bomber,[6] and retired Air Force General David Deptula, often quoted by the media on drone topics, has argued that the next step is to reduce, if not eliminate, the role of humans in operating drones, even from the ground.[7]

The defense trade press assiduously reports advances in drone technology;[8] Congress has called for "one-third of the aircraft in the operational deep strike force aircraft fleet" to be unmanned,[9] and there is a bipartisan Unmanned Systems Caucus in Congress, co-chaired by the ubiquitous Chairman of the House Armed Services Committee, Cong. Buck McKeon (R-CA).[10]

All of it gives the aura of inevitability to the future of drones and an impression of cutting edge insight to those who opine on what should seem obvious to thinking, informed analysts and commentators.

The rhetoric harks back to the "revolution in military affairs" proclaimed shortly before the first Gulf War (Operation Desert Storm) in 1991, the "one bomb one target" precision affirmed after that war, and the "shock and awe" that experts predicted would implode Saddam Hussein's regime in a matter of hours at the start of the 2003 war.

This author has some experience with such prognostications. From 1992 to 1996, I worked with a team in the Government Accountability Office (GAO) to assess the effectiveness of the air war in Operation Desert Storm. It was not "one bomb one target;" for bridges, for example, it was an average of eleven laser guided bombs to make any bridge un-useable; for other targets it was more.[11] Other data show that "precision" attacks on Saddam Hussein's air defenses on the first night of Operation Desert Storm and on Saddam Hussein himself in Operation Iraqi Freedom in 2003 definitively failed to achieve the intended objectives and frequently missed their aim points. [12]

Today's augury on drones makes the same facile predictions and uses the same rhetoric. It has meant more money. In the twelve years before the 9/11 attacks (1988-2000), DOD spent just $3.9 billion for drones. After 9/11, spending increased dramatically, from $667 million in 2001[13] to $5.1 billion in 2011[14] in known[15] drone costs, totaling $30 billion. CBO estimates that spending will increase again in the next decade, to $37 billion.[16] But even that estimate will probably turn out to be low, the new downturns announced for Global Hawk and Reaper notwithstanding.

Amidst the enthusiasm for drones and the increasing money, there has been little public diagnostic analysis of what a specific drone can and cannot do, how well or poorly, the cost, and how it all compares to relevant comparison manned aircraft. A recent and very informative report from the Congressional Research Service (CRS) suggests at least three areas of comparison: unmanned aerial systems "eliminate the risk to a pilot's life, and their aeronautical capabilities, such as endurance, are not bound by human limitations.. [They] may also be cheaper to procure and operate than manned aircraft."[17]

Selection of Reaper; Basics

The Air Force's MQ-9 Reaper is selected for analysis. In combat since October 2007, it has been employed long enough to have an operational record for a reality-based analysis, and as a successor to the earlier MQ-1B Predator (deployed in 2002 as the first U.S. armed aerial drone in the modern age[18]), it is not so new to be dismissed, or defended, as too embryonic for meaningful analysis.

Various websites provide a physical description of Reaper. These include sites that convey some useful basic information but also tend to describe performance as uncompromised by limitations and planned upgrades as fully in hand; sometimes important data is completely missing. Such sites include those of the producer, General Atomics, GlobalSecurity.org, and the Air Force.[19] The Wikipedia entry for Reaper provides more details and links, but it also gives the impression of being written by advocates.[20] Others, such as the Government Accountability Office (GAO) and the

Defense Department's Director of Operational Test and Evaluation (DOT&E), are more objective, but they are also cryptic.[21] More complete descriptions and analysis are provided by the Congressional Research Service[22] and the Congressional Budget Office (CBO);[23] however, even the more informative of these (CRS's) only touches on issues that when scratched can be quite revealing.

The first point that almost all descriptions make about Reaper is that it is not a stand-alone, pilot-less aircraft. It is a system with elements that go beyond what piloted aircraft require. A Reaper unit does not consist of one "aircraft;" it consists of four (more on why is so later), and it requires a manned ground control station (GCS) that is typically remotely located, often in the US.[24] It also requires a dedicated Primary Satellite Link (PSL)[25] and a local control unit for landings and take-offs where the air vehicles are based. In comparing drones to manned aircraft, CRS points out, for example, it is necessary to include these components that are essential for flight.[26]

Unclassified DOD records show Reaper spending to have started in 2002. Congress quickly became a major advocate and increased the purchase by 58 air vehicles.[27] Production had been planned to terminate at the end of 2016 at 399 individual air vehicles, and total Reaper spending had been projected at $12.497 billion in nominal ("then year") dollars.[28] The 2013 budget request included the reduction in Reaper's production rate from 48 to 24 per year for the years 2013-2017,[29] which would imply a reduction in the total buy by either 96 or 72 air vehicles.[30] It is also not clear how much this change would reduce the cost of the total buy; unit costs will go up with the rate change, and one budget document addressed buying more ground control stations with the money that is saved from the reduced production.

In any case, the total amount for Reaper costs is not borne by the Reaper program alone: Reaper uses the same ground equipment as Predator B; there may be GCS and other ground equipment paid for by the Predator B program but employed by Reapers, and more than one DOD official informally speculated that other Reaper costs may be buried in other programs, such as Gorgon Stare.

Distinguishing Reaper, Predator and Predator B

Important to appreciate about Reaper is that it is not a Predator, nor a minor modification of it as the producer's moniker, "Predator B,"[31] might lead one to believe. The Air Force makes the distinction between them clear in its "factsheets."[32] While they dissemble on issues like cost and performance, they can at least be taken at face value on some basics. See the table below:

Characteristic	MQ-1B Predator	MQ-9 Reaper
Wingspan	55 ft.	66 ft. or 86 ft.
Empty Weight	1,130 lbs.	4,900 lbs. for 66 ft. wingspan variant
Maximum Take Off Weight	2,250 lbs. with up to 665 lbs. of fuel and 450 lbs. of weapons	10,500 lbs. with up to 4,000 lbs. of fuel and up to 3,000 lbs. of external wing stores (fuel and/or weapons) and a 750 lb. internal sensor payload. Any payload combination may not exceed 5,600 lbs.
Sensor Package	Multi-spectral Targeting System (MTS-A) with infrared sensor, daylight TV camera with image-intensifier & laser illuminator/designator	MTS-B with basically same sensors, plus synthetic aperture radar (SAR) to enable GBU-38 JDAM targeting. (See SAR/JDAM discussion below.)
Armament	2 laser-guided AGM-114 Hellfirei[33] missiles	Hellfire and/or 500 lb. GBU-12 laser guided bombs up to a total of 3,000 lbs.ii[34]
Speed (kt)	70 (cruise/loiter); 118 (max.)iii[35]	120 (cruise/loiter); 240 (max.)iv[36]
Range	Up to 770 miles	Up to 1,150 miles
Ceiling	Up to 25,000 ft. depending on payload	Up to 50,000 ft. depending on variant and payload
Endurance	Up to 40 hours; 14-16 hours with wing storesv[37]	Up to 24 to 30 hours with no external stores; 14 hours with typical munitions; up to 42 hours with 2 wing fuel tanks and 1,000 lbs. of weaponsvi[38]
Initially Deployed	March 2005	October 2007

Note that, despite some similarity in appearance, Reaper is an entirely different air vehicle from the MQ-1B Predator (or the original, unarmed RQ-1A Predator). At 4,900 pounds, Reaper is four times the weight of Predator, and its wingspan is 20 to 56 percent wider. Reaper is has loiter and maximum speeds that are roughly twice Predator's, but both are slow compared, for example, to modern combat aircraft. (The slow speed is a real advantage for finding and identifying targets.) Perhaps the most noticeable difference in the table above is the much larger payload of weapons that Reaper can carry, up to 3,000 pounds rather than Predator B's very modest 450 pounds.

There are also important similarities. Both can loiter above the battlefield searching for targets for long periods (up to 40 hours), much longer than manned aircraft-even when

the latter can be refueled in the air. Similarly, loiter endurance is significantly reduced depending on the weight and drag of munitions, down to 14-16 hours, perhaps less. The two may differ little in their maximum ceiling with no or light payloads, but there is a high altitude, longer wingspan version of Reaper for as high as 50,000 feet claimed.

Specific Issues

Cost: Because of Reaper's nature, unit cost estimates can be tricky. Various media reports cite a per-unit cost from $4 to $5 million. They are quite incorrect. Because they are integral to Reaper's ability to operate, the ground components for it must be included, and a Combat Air Patrol, or "CAP" (i.e. the specified Reaper operating unit), consists of four air vehicles, not one. Accordingly, the Air Force factsheet cites a unit cost not for one air vehicle but for a Reaper CAP ("four aircraft with sensors") at $53.5 million in FY 2006 dollars (which would be $60.3 million in 2012 dollars).[39]

The Air Force fact sheet calculation is, however, incomplete; it does not include development and other costs that are included in DOD's summary Selected Acquisition Reports (SARs). The latest SAR available (from December 2010) shows a cost of $11.3 billion (in 2008 dollars) for the then-planned total purchase of 399[40] individual Reaper air vehicles and associated ground equipment.[41] In contemporary 2012 dollars that comes to $12.1 billion, which calculates to $30.2 million for each individual Reaper and its share of ground equipment, or $120.8 million for a complete, operable CAP of four.[42] (Given the infrequency at which Reaper flies in comparison to typical combat aircraft, the four Reaper calculation is apt for comparing to manned aircraft. This issue is discussed more below.) The appropriate cost for a Reaper unit is $120.8 million in 2012 dollars. Given the newly announced reduction in Reaper production rates and the statement that some additional ground control stations may be bought, the $120.8 million unit cost is an underestimate; however, the data are unavailable to know by how much.

Reaper unit cost is well above that of the aircraft frequently compared to it: the F-16 and the A-10. The Air Force's "factsheet" on the F-16C cites an $18.8 million unit cost in 1998 dollars (or $27.2 million in 2012 dollars);[43] GAO cites F-16C unit procurement cost, not including R&D which is not available for inclusion, at $55 million per copy.[44] For the A-10, the Air Force factsheet cites no estimate for the unit cost,[45] but GAO cited a total program unit cost (including R&D) at $11.8 million in 1994 dollars (or $18.8 million in 2012 dollars). There have been modifications to the A-10 since that GAO estimate, even if they were to double the cost of the aircraft, it would remain a fraction of the cost to buy a Reaper unit.

Reaper is not cheaper to buy than aircraft it is compared to; it is multiples more expensive: from two to six times more expensive.[46]

Nor is Reaper cheaper to operate, despite initial appearances. Air Force flying hour cost data shows Reaper to cost only $3,624 per hour to fly in 2011 for what the Air Force terms "operational" flying hour costs.[47] That compares to the much higher hourly cost

to fly A-10s or F-16s: $17,780 per hour for the newly modified A-10C and $20,809 for an F-16C. However, because each Reaper flies a large number of hours in the air, the math suppresses the per-hour Reaper number. If the calculation is for total maintenance costs over the course of a year for a Reaper unit, the relationship changes: at a per year cost of $5.1 million, per individual Reaper, and at $20.4 million per CAP, the Reaper shows itself to be well above the cost to maintain and operate over a year for an individual A-10C (at $5.5 million) or an F-16C (at $4.8 million).[48] Annual operating unit cost for a Reaper unit is about four times the annual cost to operate an F-16 or an A-10.

Infrastructure: Much of those higher costs are driven by the infrastructure needed to operate Reaper, which has an extensive infrastructure on the ground: the GCS, satellite link, and the local control unit for take offs and landings. Most of this support is not analogous to manned aircraft. For example, without a control tower and its personnel, a manned aircraft remains capable of landing, and without centralized mission control, they are able to perform their missions quite effectively. (Indeed, many argue convincingly that micro-management of manned aircraft by a central command seriously degrades effectiveness.)

Reaper's infrastructure necessitates at least 171 personnel for each CAP: these include 43 mission control personnel, including seven pilots and seven sensor operators, 59 launch, recovery and maintenance personnel (including six more pilots and sensor operators), 66 Processing Exploitation Dissemination personnel for intelligence and its support (including 14 more maintenance personnel) and three "other equipment" personnel.[49]

As some say, drones like Reaper are not "unmanned;" hence the term "remotely piloted vehicle."

Endurance: Reaper's ability to loiter over the battlefield for long periods (attempting to collect intelligence, find targets, and engage them) is much longer than manned combat aircraft; however, there are some limitations. Reaper, like many aircraft, must trade off gas (and loiter time) for munitions and cannot take off with a full load of both. General Atomics, and many media reports, assert day long endurance, even 30 hours,[50] but that is with no munitions adding weight and drag. Others, such as DOT&E and Global Security note the trade-off between fuel and weapons and that actual endurance is "approximately" [51] 14 hours (or "up to" 14 hours[52]) for a Reaper carrying weapons. Nonetheless, this lesser loiter time is a multiple of what manned aircraft perform, even with mid-mission aerial refueling. An A-10 might have a prolonged mission of four hours, usually less. (CBO reports an Air Force assessment of a limit of 12 hours for the pilot of a single seat aircraft;[53] however, that is very uncommon and may only realistically pertain to U-2 reconnaissance aircraft.)

Survivability: Reaper (like Predator) is fundamentally incapable of defending itself. It lacks any ability to sense threats 360 degrees around itself; while it can "see" below and somewhat to the sides, it is through a "soda straw" (depending on the setting of the sensors). If it does observe a threat, it is incapable of doing anything effective about it;

not only is it quite slow, but with a high aspect ratio wing varying from 55 to 86 feet and a frail airframe unable to withstand more than a mild two "G" maneuver,[54] it is incapable of agile movement to get out of the way of immediate threats. If it attempts high angle maneuvers, it may lose its link to satellite or ground control, which has in the past caused crashes. It is also unarmored to survive a hit. Reapers (and Predator) have been equipped with Stinger air to air missiles for a theoretical air-to-air capability, but with so little external awareness and no ability to maneuver, it is a meaningless "capability" adding little more than weight and drag. (A Predator has been reported to have attempted, unsuccessfully, to engage an Iraqi aircraft in 2003 with a Stinger missile; the Predator was destroyed by the aircraft it attempted to engage.[55]) As analysts have commented, Reaper is survivable only in a "permissive" environment, which in truth means an absence of air defenses. (This problem also explains why Reaper and Predator are reluctant to venture below 10,000 feet where they can become vulnerable to man portable guns and early vintage man portable air defense missiles.)

Reaper compares poorly to manned combat aircraft on survivability. The A-10, for example, was thought by some to be vulnerable to modern air defenses of the sort above Iraq and Kosovo that it successfully engaged and survived. In operation Desert Storm in 1991, A-10s were highly survivable, even in the presence of Iraq's densest and more effective defenses; there, the A-10 had an attrition rate of 0.5 aircraft for every 1,000 sorties,[56] a rate that GAO found to be a statistically insignificant difference from the higher survivability rate of the F-117 stealth attack bomber.[57] In the Kosovo air war, the A-10 had a higher survivability rate than the F-117.

Payload: One of the biggest improvements of Reaper over Predator is increased payload: 450 pounds for the Predator (specifically two Hellfire missiles), compared to an internal payload of 750 pounds (for sensors) and an external (wing mounted) payload of 3,000 pounds for Reaper (for weapons and/or fuel tanks).[58] However, the weight carrying ability of the individual wing hard points limits what is in fact carried.[59] While the Reaper is credited to be able to carry as many as 16 Hellfires[60] or four 500 pound laser guided bombs, CBO notes that a typical payload "varies up to" four Hellfire missiles and two 500 pound bombs.[61]

Despite being credited by many as also employing 500 pound GPS guided Joint Direct Attack Munition (JDAM) bombs, DOT&E reports that "ongoing developmental challenges precluded operational testing and fielding" Reaper with JDAMs.[62]

Reaper's maximum payload is a fraction of what A-10s can and do carry. Rather than the Reaper's maximum 3,000 pound payload (or a typical payload of two Hellfires and two 500 pound laser guided bombs), the A-10 has a maximum payload of 16,000 pounds and is credited with carrying up to eighteen 500 pound bombs (guided or unguided).[63] F-16's, as bombers, typically carry two 2,000 pound bombs and additional fuel.[64] (Some asses F-16's at four 2,000 pound bombs or eight 500 pound bombs.[65]) However, this crude analysis of simple weight does not adequately measure the difference between Reaper and an aircraft such as the A-10, or even lesser aircraft. This analysis ignores other very important issues, such as the nature, variety and delivery methods the A-10

can employ. And, it ignores what many credit at the A-10's most effective weapon, the GAU-8 cannon for which Reaper has no counterpart. With its lesser weapons payload, Reaper is unable to loiter over the battlefield and employ weapons for more than a very limited number of targets.

However, one must also consider the relative ability to collect intelligence and find a target (and to distinguish if it should be attacked). This is an area where drone advocates assert real superiority over manned aircraft.

Sensors/Ability to Find Targets: Many argue the most critical payload Reaper carries is sensors for finding targets and collecting information that is made available to operators on the ground. The current version of the Reaper has a "Multi-Spectral Targeting System" that combines infrared and optical sensors and a laser designator/range finder to employ Hellfire missiles and laser guided bombs.

The ability of these sensors to identify targets-to discern just what they are, based on the clarity and resolution of the imagery received on the ground-has serious limitations. According to test reports, these sensors have had difficulty finding and tracking targets as large as "vehicles," and they have even more difficulty with "dismounts" (people).[66] To improve the resolution of these sensors, Reaper operates at altitudes well below its nominal 25,000 to 50,000 foot ceiling; they typically operate at 10,000 to 15,000 feet[67] to enable better image resolution, and they may operate lower than that, if severe terrain and vulnerability to hand held air defenses is not a problem.

Some Reaper and Predator imagery has appeared on the internet. One should assume that the quality of these images is degraded by the reproduction on the internet; however, even assuming that as an analytical precaution, the quality of the imagery-specifically the ability to discern the nature of "dismounts" (people) and whether they are or are not legitimate targets-is very clearly very limited.[68]

The failure to be able to discriminate valid human targets was vividly and tragically displayed in a combat engagement in April 2011 involving Marines and the Taliban in Afghanistan. A Predator was unable to discriminate the highly distinctive combat outline of friendly forces (Marines with full battle equipment) from the irregular enemy. Based simply on detecting muzzle flashes and making a poorly informed assessment from their geographic location in the middle of a fluid firefight, a Predator with Hellfires killed two Marines, mistaking them for the enemy.[69] As the internet video cited above makes abundantly clear, the quality of the imagery transmitted to screens on the ground from operational altitudes is so poor it cannot make critically important distinctions.

Reaper is commonly described to have a Synthetic Aperture Radar (SAR) for finding and identifying targets through weather (which the other sensors are unable to attempt). However, according to DOD's Director of Operational Test and Evaluation (DOT&E), the SAR has been problematic,[70] in part due to power and payload limitations: Reaper "remains unable to execute all-weather Hunter-Killer operations. The SAR is the only MQ-9 system capable of providing MQ-9 UAS with the capability to find, fix, track, and

engage targets through the weather."[71] If the SAR were to be available, several experts cautioned the author that it remains quite controversial whether SAR imagery would materially assist the ability to actually find and identify targets.

According to GAO, Reaper's Block 5 upgrade will attempt to address these and other deficiencies, by attempting to remediate poor performance in area surveillance and the ability to detect "dismounted soldiers."[72] These improvements are not expected to be available until 2014 to 2015.[73] The extent to which they will be effective is unknown, but it is notable that problems in Predator's (and by implication Reaper's) sensors have been an issue for a long time. A report as early as 2001 from DOT&E noted them; [74] the problems are persistent, and assuming a new technological development will eliminate them has proven to be a false hope in the past.

Reaper's sensors and endurance might seem tailor made for the task of border surveillance and assisting in the apprehension of illegal aliens and drug smugglers crossing the border. The terrain in the US southwest would seem near-ideal for such operations-being relatively flat, barren and arid, especially compared to the extremely rugged terrain in much of Afghanistan. And, there is no air defense to worry about or to limit low altitude searching. Thus, one would expect Reaper and other drones to excel. Indeed, drones were declared a "force multiplier" by Customs and Border Enforcement in the Department of Homeland Security (DHS).[75]

Customs and Border Protection (CBP) in DHS has attempted to employ drones for border surveillance for several years. The simpler and cheaper Hermes and Hunter drones were initially employed, and the experiment was assessed in a December 2005 report from DHS's Office of Inspections and Special Reviews. The report found that those drones cost $1,351 and $923 per hour to operate (considerably less than Predator), but those costs were double the cost of manned aircraft to operate. More importantly, those drones were found to be significantly less effective than manned aircraft in finding and helping to seize immigrants or marijuana crossing the border illegally.[76] The report also found that when the drones did play a role in seizures, the role was secondary in that they simply assisted in the seizure of illegals already detected by other means.[77] The drones' sensors were impeded by "weather" in the mild form of clouds and humidity, and finally the drone's high accident rate impeded operations.[78]

CBP subsequently purchased six Reapers[79] (reported as "Predator Bs") for southwest border enforcement. As of June, 2011, they had flown 10,000 hours, which led to the apprehension of 4,865 undocumented aliens and 238 drug smugglers.[80] This was 1.5 percent of the total reported number of 327,577 illegal immigrants caught in the same time frame, and based on an operating cost estimate of $3,600 per hour, Reaper's cost-effectiveness calculated to $7,054 for each illegal immigrant or drug smuggler caught.

In assessing these Reaper operations, GAO also considered a program dubbed "Big Miguel" that consisted of a manned Cessna aircraft with a forward looking infrared (FLIR) sensor acquired and operated for $1.2 million for a year-i.e. one quarter the cost of acquiring one Reaper air vehicle without its support infrastructure and without the cost

of operations. According to GAO, the Cessna/FLIR program found and assisted in the apprehension of 6,500 to 8,000 undocumented aliens and the seizure of $54 million in marijuana.[81] Those numbers calculate to a cost per illegal alien for the Cessna at $230 per alien, or 3 percent of the Reaper's per alien cost.[82]

The manned Cessna was far cheaper to both buy and operate than the Reapers bought by CBP, and the Cessna was more effective. The experience was summed up by an official of the Border Patrol Union: "Unmanned aircraft .are not economical or efficient in civilian law enforcement applications..there are a number of other [manned] technologies that are capable of providing a greater level of usefulness at far lower cost. It appears that the contractors have once again managed to sell a bill of goods to the politicians and bureaucrats who oversee the procurement of technology designed to secure our borders."[83]

These awkwardly costly and ineffective results notwithstanding, Congress has called for still more domestic drone use. In February 2012, a new authorization statute for the Federal Aviation Administration called for "a comprehensive plan to safely accelerate the integration of civil unmanned aircraft systems into the national airspace system .. as soon as practicable, but not later than September 30, 2015."[84]

Numbers: Predator purchases were terminated in 2009, a total of 248 being bought by the Air Force.[85] Reaper purchases started in 2002, rose from four per year in 2004 to 48 per year in 2011, making a total of 108 Reapers authorized to be bought by the end of 2010, with 48 more to be bought in both 2011 and 2012.[86]

Previous plans for combined Predator and Reaper production had been to support 65 CAPs (four air vehicles each) by 2013.[87] However, 2013 budget materials clarified that the 65 CAPs would not be complete until later, variously stated to be either 2014[88] or 2017.[89] 2013 Air Force budget documents assert that by the end of 2011 there were 60 Predator/Reaper CAPs,[90] implying a total count of Predators and Reapers of 240.

Assuming a two year delay between purchase authorization and delivery, a combined total of 248 Predators and 108 Reapers (356 of both) should be available at the start of 2012.[91] (If one assumes a one year delivery delay, that number would be 404 in 2012.) With almost all Predators and Reapers operationally deployed,[92] there would seem an excess of up to 116 Predators and/or Reapers (or an excess of 164 if one assumes only a one year delivery delay.)[93]

There are two potential explanations: either there are significantly more than four air vehicles per CAP (to address the infrequency with which they fly, an issue addressed below) or there have been an extraordinary number of Predator and Reaper crashes. The latter appears to be the more complete explanation.

Crashes: While it is conventional wisdom that drones are prone to crashes, that wisdom seems to understate the dimension of the problem.

As a gross indicator of the seriousness of the problem, DOD had expected the Reaper inventory to be 256 air vehicles in 2017, a year after the previously planned buy of 396 was to be complete.[94] Assuming the last purchase is delivered within a year, losses as high as 140 air vehicles appear to have been anticipated. If the delivery lag is two years, not one, 92 air vehicles would seem to have been anticipated as losses.

The Air Force claims that it has reduced the loss rate for Predator from 28 mishaps per 100,000 hours to 7.6 and that Reaper can or will share this reduction in losses by virtue of its triple redundant flight controls, back up communications and other characteristics.[95] The available data do not appear to support this claim.

While Air Force "mishap" reports[96] show only three Reaper crashes since 2006; that data base is incomplete. A larger number has been publically reported, as well as an extremely high crash rate of 16.4 for every 100,000 flying hours. [97] A different public data base, at Drone Wars UK, appears to be a little more complete.[98] It reported four Reaper crashes in 2011 and six more in the preceding three years. While the data show some evidence of a declining crash rate per flying hour as operators become more familiar with the Reaper's characteristics, the data also show an increase in crashes, and the crash rate, from 2010 to 2011. However, the Drone Wars UK data base, being reliant on public reports, asserts "This list is almost certainly not complete." The data here is clearly an undercount of Reaper crashes; an audit of each Reaper produced and its status and history is clearly needed to resolve this critical, possibly crippling, issue.

A high Predator crash rate tends to validate these data. CRS reported 20 Predator mishaps for every 100,000 flying hours in 2005.[99] The Air Force claims that contemporary mishap rates have fallen as the system matures. Air Force class A mishap reports show 12 Predator MQ-1B crashes in 2011, and a calculation of the crash rate per flying hour does not support the Air Force contention of lowering rates. Both the total number of Predator crashes and the rate per 100,000 hours of flying increased, for example, from 2010 to 2011. The Predator crash data at the UK Drone Wars website also shows a continuing and severe Predator crash problem.[100] And the gross numbers of Predators and Reapers produced compared to those operating in the inventory suggests that the number of Predator/Reaper crashes could be as many as 100 air vehicles, possibly more. Clearly, a full and independent audit of the fate of each tail number is called for to measure-accurately-the precise dimension of this problem.

Operational Availability: DOT&E found that Reaper has failed to meet its own criteria for system failures sufficiently seriously that it is not ready, several years after its operational deployment, for resumed operational testing. (The system continues to be deployed under an extended "Interim Authority to Operate.")[101] The system's unreliability surely exacerbates the system's high crash rate, and it is one of several factors impacting the system's operational availability.

In 2011, the declared operational inventory of 69 Reaper air vehicles flew a total of 97,727 hours. That calculates to 1,416 hours per air vehicle per year, or 118 hours per month, or 29.5 hours per week.[102] For a Reaper that flies the maximum 42 hour sortie

(using two wing fuel tanks and two munitions), the air vehicle gets into the air less than once a week. If a Reaper flies what is described as a more typical 14 hour mission, it will be in the air twice a week, on average. Thus, individual Reaper air vehicles fly from less than once a week to as much as twice a week.[103]

Some unofficial websites describe Predator and Reaper CAPs providing 24 hour per day seven days per week coverage of the battlefield.[104] With four air vehicles, as defined by DOD, a Reaper CAP is incapable of providing that coverage: there are 168 hours in a week; any four Reapers flew, on average, 118 hours in any week in 2011. A six Reaper "CAP" could provide the 168 hours needed per week, providing a slim additional margin of nine hours, but if two hours of flying are required for transit to the operational area and back for each sortie, seven Reaper air vehicles would be required for a 24/7 CAP.

These sortie rates are a small fraction of what manned aircraft have flown in historically relevant combat. In Operation Desert Storm in 1991, GAO found that throughout the course of the 41 day air war, F-16s flew more than one sortie per day, not two sorties, or less, per week. The A-10 flew significantly more often than F-16s in Desert Storm. The notoriously unreliable F-111Fs flew almost one sortie per day (0.9), and the even more difficult to support F-117 had a rate of .7 sorties per day.[105] In 2011, the average Reaper air vehicle flew somewhere between 0.1 and 0.3 sorties per day, a rate that for a single manned aircraft in sustained combat would surely be deemed catastrophically low.

An astute reader will observe that this analysis ignores Reaper's much longer endurance (from up to 14 hours to as long as 42 hours) which enables it to search for targets and intelligence. To make the argument that Reaper's (and other drones') ability to loiter and search for and find targets proves superiority over manned aircraft in a critically important dimension assumes that the drones are effective at finding targets and collecting intelligence and at prosecuting the targets once detected and identified. The available evidence, discussed above, shows that, as a practical matter, Reapers (and other drones) are less effective than simple, even primitive, manned Cessnas at finding and identifying targets.

In sum, the proclamation of Reaper (and, by implication similar drones) as the future of warfare, a revolutionary transformation, would appear to be as empty a description as we have heard proclaimed in the past. The data support no such thing in the case of Reaper.

Summary Findings

In acquisition since 2002 and in combat operations since 2007, the Reaper (MQ-9) is a prominent example of drone technology that can be assessed for cost effectiveness using publically available empirical data.

Based on Defense Department data on the cost to acquire and operate, a Reaper unit costs at least $120.8 million to buy and $25.6 million per year to operate (in 2012 dollars). As such, Reaper is more expensive to both acquire and operate than manned aircraft it is

commonly compared to. The margins are not close; Reaper is approximately twice the cost to acquire compared to a contemporary F-16 fighter bomber and up to six times the cost to acquire A-10 close support aircraft. Reaper's annual operating costs are roughly four times the cost to operate an F-16 or an A-10.

A substantial part of the high cost to acquire and operate a Reaper "CAP" is the considerable material and human infrastructure it requires, including ground control stations, satellite links and at least 171 human operators and support personnel.

While Reaper possesses the ability to loiter in the air far longer than manned aircraft on a typical mission, the ability of Reaper to find targets is limited and problematic. Empirical comparisons to simple, even primitive, manned aircraft used in border surveillance with FLIR technology demonstrates that Reaper is, again, more expensive to operate and, importantly, less effective in finding and identifying targets. The quality of the imagery received on the ground from drone sensors is too poor even to reliably make distinctions between friendly combat loaded Marines from irregulars with a quite different profile.

Reaper's limited weapons payload, compared to manned combat aircraft, seriously restrict its ability to attack targets, when they are successfully located and identified.

Defense Department usage data verify that individual Reaper air vehicles are not available for use more than once or twice a week: An operational availability rate that for a manned aircraft would be deemed unacceptable.

While many understand that drones, such as Reaper, have a high crash rate, the actual rate may be significantly higher than is commonly understood. While public and DOD data are incomplete and an audit of each tail number produced is called for, the total number of Predator and Reaper crashes may already be as many as 100, possibly more.

Reaper is not survivable in the presence of even minimal air defenses; it is far less survivable than manned aircraft, such as the A-10 which has demonstrated high survivability in air combat since 1991. In the presence of air defenses, Reaper would require manned escort aircraft, thereby removing the assumed advantage of being unmanned.

Conclusion

The wide and enthusiastic popularity for Reaper, and other drones, in the Defense Department, the Executive branch, Congress, the mainstream media and think tanks is not rationally explained by Reaper's poor to mediocre performance on the operating dimensions measured here.

Instead, the drone's most unique characteristic, that it is manned from the ground not in the air, gives it an operating characteristic that seems to intrigue policy makers, giving them self-perceived license to employ the system over ambiguous or hostile territory

(such as Pakistan and Iran) . The consequences of that use, while not addressed here, appear highly significant and controversial. Like much else with drones such as Reaper, an empirical study of the relevant data, including all classified data, is clearly in order.

The unique unmanned nature of Reaper (and other drones) has also intrigued technology enthusiasts, who proclaim-not for the first time-a "revolution" in warfare that the actual data refute, rather than support.

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Endnotes:

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[1] Several titles have been applied to drones: unmanned aerial systems (UASs), unmanned aerial vehicles (UAVs), and remotely piloted vehicles (RPAs) are the most common.

[2] For example, see David Cortright's "License to Kill" at http://www.cato-unbound.org/2012/01/09/david-cortright/license-to-kill/, the work of David S. Cloud at the LA Times, such as at http://articles.latimes.com/2011/dec/29/world/la-fg-drones-civilians-20111230, work at the U.K.'s The Guardian, such as at http://www.guardian.co.uk/commentisfree/cifamerica/2011/nov/07/cia-unaccountable-drone-war or at http://www.guardian.co.uk/world/2011/jul/17/us-drone-strikes-pakistan-waziristan. There is also an excellent summary of the aftereffects of drones and occupation in Iraq at Salon.com at http://www.salon.com/2012/01/30/lessons_from_iraqi_outrage_over_us_drones/singleton/. See also Nick Turse's work at TomDispath.com at http://www.tomdispatch.com/post/175489/tomgram%3A_nick_turse%2C_drone_disasters_/ and http://www.tomdispatch.com/post/175482/tomgram%3A_nick_turse%2C_the_life_and_death_of_american_drones/

[3] See the website for P.W. Singer's Wired for War at http://wiredforwar.pwsinger.com/.

[4] See "With more details coming, analysts split on new DOD strategy," Chris Carroll & Leo Shane III, Stars and Stripes, January 25, 2012 at http://www.stripes.com/news/with-more-details-coming-analysts-split-on-new-dod-strategy-1.166755.

[5] See "Rest in Peace, Manned Aircraft," Air Force Times, April 16, 2011, posted by David Larter at http://militarytimes.com/blogs/flightlines/2011/08/16/rest-in-peace-manned-aircraft/.

[6] See "The RPA Boom," Air Force Magazine, John A. Tirpak, August 2010 at http://www.airforce-magazine.com/MagazineArchive/Pages/2010/August%202010/0810RPA.aspx.

[7] See "Former ISR Chief Calls for More Autonomy in UAVs," Areas A Technology Blog, by Paul McLeary, Aviation Week, January 25, 2012 at http://www.aviationweek.com/aw/blogs/defense/index.jsp?plckController=Blog&plckScript=blogScript&plckElementId=blogDest&plckBlogPage=BlogViewPost&plckPostId=Blog%3A27ec4a53-dcc8-42d0-bd3a-01329aef79a7Post%3Aca1e0ff0-837f-4b24-8e09-acb9eebe7bb9.

[8] See "MQ-9 to Provide Full HD Video by 2015 after Two-Phased MTS Upgrade," Inside the Air Force, 1/20/12 at http://defensenewsstand.com/Inside-the-Air-Force/Inside-the-Air-Force-01/20/2012/menu-id-290.html.

[9] See section 220 of PL 106-398.

[10] Find the website at http://unmannedsystemscaucus.mckeon.house.gov/.

[11] P. 189 ff., Operation Desert Storm: Evaluation of the Air Campaign," General Accounting Office, June 1997, GAO/NSIAD-97-134 at http://www.gao.gov/archive/1997/ns97134.pdf.

[12] Pp. 135-139, GAO, Operation Desert Storm: Evaluation of the Air Campaign, at http://www.gao.gov/archive/1997/ns97134.pdf.

[13] P. 13 of "U.S. Unmanned Aerial Systems," Jeremiah Gertler, Congressional Research Service, R42136 at http://www.fas.org/sgp/crs/natsec/R42136.pdf.

[14] P. ix of "Summary" of "Policy Options for Unmanned Aircraft Systems, Congressional Budget Office, June 2011 at http://www.cbo.gov/ftpdocs/121xx/doc12163/06-08-UAS.pdf.

[15] There are additional drone costs in the DOD budget, but they are classified and for the Central Intelligence Agency.

[16] P. vii of "Summary" of CBO, "Policy Options," at http://www.cbo.gov/ftpdocs/121xx/doc12163/06-08-UAS.pdf.

[17] P. 1, CRS, "U.S. Unmanned Aerial Systems,"at http://www.fas.org/sgp/crs/natsec/R42136.pdf.

[18] For a discussion of unmanned systems in the previous century, see "Air Force UAVs: The Secret History," Thomas Erhardt, July 2010, A Mitchell Institute Study, at http://www.afa.org/mitchell/reports/MS_UAV_0710.pdf.

[19] See, for example, the descriptions of Reaper at the General Atomics website at http://www.ga-asi.com/products/aircraft/predator_b.php, which describes endurance as 30 hours without caveat (discussed below in text) and the description by GlobalSecurity.org at http://www.globalsecurity.org/military/systems/aircraft/mq-9.htm, which, for example, describes the performance of Reaper's Synthetic Aperture Radar without any issues and available munitions to include GPS-guided Joint Direct Attack Munitions without the issues pointed out by others. The Air Force's "factsheet" is at http://www.af.mil/information/factsheets/factsheet.asp?id=6405.

[20] For example, see the Wikipedia entry for Reaper, as of February 2012, at http://en.wikipedia.org/wiki/MQ-9_Reaper.

[21] See the system descriptions by GAO (at p. 113 of "Defense Acquisitions: Assessments of Selected Weapons Programs," Government Accountability Office, March 2011, GAO-11-233SP, at http://www.gao.gov/new.items/d11233sp.pdf) or by DOD's DOT&E at http://www.dote.osd.mil/pub/reports/FY2011/.

[22] See CRS' "U.S. Unmanned Aerial Systems." An informative and useful report, it is at http://www.fas.org/sgp/crs/natsec/R42136.pdf.

[23] See CBO's "Policy Options" volume at http://www.cbo.gov/ftpdocs/121xx/doc12163/06-08-UAS.pdf. This report contains some basic system information, but is mostly devoted to "policy options" which are limited to only a mix of current and planned drones, not other platforms that in some cases are clearly cheaper and more effective-see following text in main body.

[24] At Cannon and Holloman AFBs, NM; Creech AFB, NV, and Syracuse NY plus "several locations in CENTCOM and AFRICOM." The Air Force will start MQ-9 operations at Ellsworth AFB SD in 20012. P. 7 & 11 of United States Air Force, Report to Congressional Committees , "Report on Future Unmanned Aerial Systems Training, Operations, and Sustainability," September 2011, submitted to Congress pursuant to House Report 111-491, page 509.

[25] See the Air Force fact sheet at http://www.af.mil/information/factsheets/factsheet.asp?id=6405.

[26] P. 13 of CRS's "U.S. Unmanned Aerial Systems," at http://www.fas.org/sgp/crs/natsec/R42136.pdf.

[27] P. 4, "Selected Acquisition Report (SAR) RCS: DD-A&T (Q&A) 823-424; MQ-9 UAS Predator, as of June 30, 2010." Not available on line but available from the author.

[28] Pp. 14-18 of the DOD SAR for Reaper.

[29] See "Service Scales Back MQ-9 Purchases: Lt. Gen. James: Air Force Could Provide More Than 65 CAPs If Needed," Maggie Ybarra, Inside the Air Force, 2/17/12.

[30] The previous production plan was scheduled to end after 2016; if it is extended to 2017 with the additional 24 air vehicles, the reduction would be 72 rather than 96.

[31] See the General Atomics advert for "Predator B," rather Reaper, at http://www.ga-asi.com/products/aircraft/predator_b.php.

[32] Find the Air Force Fact sheet on MQ-1B Predator at http://www.af.mil/information/factsheets/factsheet.asp?fsID=122; on Reaper at http://www.af.mil/information/factsheets/factsheet.asp?fsID=6405.

[33] Hellfire is a short range 100 pound missile with a 20 pound warhead; find a discussion of it at the Wikipedia website at http://en.wikipedia.org/wiki/AGM-114_Hellfire. There is also a useful system description of Hellfire at the Federation of American Scientists website at http://www.fas.org/man/dod-101/sys/missile/agm-114.htm.

[34] See text in main body below; while the fact sheet asserts Reaper can employ GPS-guided JDAM GBU-38, that appears not to be the case.

[35] See p. 63 of "FY 2009-2034 Unmanned Systems Integrated Roadmap," Department of Defense, 2009, at http://www.acq.osd.mil/psa/docs/UMSIntegratedRoadmap2009.pdf.

[36] See p. 67 of "FY 2009-2034 Unmanned Systems Integrated Roadmap," at http://www.acq.osd.mil/psa/docs/UMSIntegratedRoadmap2009.pdf.

[37] This data not from USAF Fact Sheet; see instead General Atomics brochure at http://www.ga-asi.com/products/aircraft/predator.php. CBO limits the endurance to 24 hours with no weapons payload; 20 hours with weapons; see p. 4 of http://www.cbo.gov/ftpdocs/121xx/doc12163/06-08-UAS.pdf. A different DOD source limits loiter to 16 hours with external stores; see http://www.acq.osd.mil/psa/docs/UMSIntegratedRoadmap2009.pdf.

[38] These data not from USAF Fact Sheet; see instead General Atomics brochure at http://www.ga-asi.com/products/aircraft/predator_b.php, and Global Security at http://www.globalsecurity.org/military/systems/aircraft/mq-9.htm. CBO cites 21 and 17 hours for with and without weapons; see p. 4 of http://www.cbo.gov/ftpdocs/121xx/doc12163/06-08-UAS.pdf. DOD cites 24 hours with no external stores at http://www.acq.osd.mil/psa/docs/UMSIntegratedRoadmap2009.pdf.

[39] See p. 2 of http://www.af.mil/information/factsheets/factsheet.asp?fsID=6405.

[40] The 399 count includes the 396 bought under procurement account funding and three bought under research and development funding.

[41] See p. 11 of the DOD Summary SAR for all Major Defense Acquisition Programs for December 2010 at http://www.acq.osd.mil/ara/am/sar/SST-2010-12.pdf.

[42] In the- year dollars, the program is $12.496 billion for 399 air vehicles, or $31.3 million each, or $125.3 million for a CAP.

[43] See the Air Force's "factsheet" at http://www.af.mil/information/factsheets/factsheet.asp?id=103.

[44] See p. 9 of February 24, 2011 letter to Senator Carl Levin and Congressman Howard McKeon, Government Accountability Office, "Tactical Aircraft: Air Force Fighter Reports Generally Addressed Congressional Mandates, but Reflected Dated Plans and Guidance, and Limited Analyses," GAO-11-323R, at http://www.gao.gov/new.items/d11323r.pdf.

[45] See the Air Force fact sheet at http://www.af.mil/information/factsheets/factsheet.asp?fsID=70.

[46] Reaper, like virtually any DOD acquisition system, has also its cost overruns: GAO estimates that, as of 2010, Reaper unit cost increased 32 percent (from $508.7 million for 33 aircraft to $2,406 million for 118 aircraft). See p. 6 of "Defense Acquisitions: DOD Could Achieve Greater Commonality and Efficiencies among Its Unmanned Aircraft Systems," Government Accountability Office, March 23, 2010, GAO-10-508T, at http://www.gao.gov/assets/130/124311.pdf.

[47] The flying hour cost data is from Air Force flying hour cost spread sheets available from the author on request.

[48] Some will find it strange that an A-10 costs more to operate per year than an F-16, but the A-10 has been flying significantly more hours per aircraft, and the conversion to the new "C" model has also increased costs.

[49] See slide 4 of "The Way Ahead: Remotely Piloted Aircraft in the United States Air Force," briefing slides presented by Lt Gen Dave Deptula, Deputy Chief of Staff, Intelligence, Surveillance and Reconnaissance, undated, at http://www.daytonregion.com/pdf/UAV_Rountable_5.pdf. The slide cites 168 people but the data on the slide indicate 171; 177 for surge purposes.

[50] See General Atomics fact sheet at http://www.ga-asi.com/products/aircraft/predator_b.php.

[51] P. 245, "FY 2011 Annual Report," Director of Operational Test & Evaluation, December 2011, Department of Defense, at http://www.dote.osd.mil/pub/reports/FY2011/.

[52] See Global Security website at http://www.globalsecurity.org/military/systems/aircraft/mq-9.htm.

[53] P. 29 of CBO's "Policy Options" at http://www.cbo.gov/ftpdocs/121xx/doc12163/06-08-UAS.pdf.

[54] See Table 4 of Integration of UAS in the Civil Airworthiness Regulatory System: Present and Future, C. Cuerno-Rejado, R. Martinez-Val, E. Garcia-Julia, Universidad Politecnica de Madrid, Spanish Civil Aviation Authority, at http://oa.upm.es/9504/1/INVE_MEM_2010_88111.pdf. Note that A-10 and F-16s are stressed well above the MQ-9 to 7Gs.

[55] P. 5, CRS, "U.S. Unmanned Aerial Systems," at http://www.fas.org/sgp/crs/natsec/R42136.pdf.

[56] P. 651, Gulf War Air Power Survey, Volume V, A Statistical Compendium and Chronology, Washington D.C. 1993.

[57] See pp. 99-102 of "Operation Desert Storm: Evaluation of the Air campaign," General Accounting Office, July 1997, GAO-97-134, at http://www.gao.gov/archive/1997/ns97134.pdf.

[58] P. 219, DOT&E 2010 Annual Report, at http://www.dote.osd.mil/pub/reports/FY2010/.

[59] See discussion of the wing hard points at http://www.globalsecurity.org/military/systems/aircraft/mq-9.htm or at the Wikipedia entry for MQ-9.

[60] P. 35, CRS, "U.S. Unmanned Aerial Systems," at http://www.fas.org/sgp/crs/natsec/R42136.pdf.

[61] Pp. 4 & 16 (footnote #5), CBO, "Policy Options" at http://www.cbo.gov/ftpdocs/121xx/doc12163/06-08-UAS.pdf.

[62] P. 245 of DOT&E 2011 Annual Report, at http://www.dote.osd.mil/pub/reports/FY2011/

[63] Air Force fact sheet at http://www.af.mil/information/factsheets/factsheet.asp?id=70.

[64] Air Force fact sheet at http://www.af.mil/information/factsheets/factsheet.asp?fsID=103.

[65] P. 1, CBO, "Policy Options" at http://www.cbo.gov/ftpdocs/121xx/doc12163/06-08-UAS.pdf.

[66] See a longer discussion of these limitations in an analysis of the Gorgon Stare equipment that has been added to some Reapers; find it at "Gorgon State Is 'Not Operationally Effective' and 'Not Operationally Suitable,'" Winslow T. Wheeler, January 27, 2011 at http://www.cdi.org/friendlyversion/printversion.cfm?documentID=4637.

[67] P. 34, CRS, "U.S. Unmanned Aerial Systems," at http://www.fas.org/sgp/crs/natsec/R42136.pdf.

[68] Find samples of these videos at http://www.youtube.com/watch?v=GShSMMLooJg&feature=related, http://www.dvidshub.net/video/133189/last-convoy-out-iraq, and http://www.youtube.com/watch?v=Smh-HwtDHI8&feature=related.

[69] See the unclassified summary of the USMC report on this incident at http://cryptome.org/2012/01/drone-heroes.pdf.

[70] P. 219, DOT&E 2010 Annual Report, at http://www.dote.osd.mil/pub/reports/FY2010/.

[71] P. 246, DOT&E 2011 Annual Report, at http://www.dote.osd.mil/pub/reports/FY2011/.

[72] See p. 114 GAO "Defense Acquisitions" at http://www.gao.gov/new.items/d11233sp.pdf.

[73] See "MQ-9 to Provide Full HD Video by 2015 after Two-phased MTS Upgrade," Inside the Air Force, 1/20/12, Gabe Starosta.

[74] Pp. 21 ff, "Operational Test & Evaluation Report on the Predator Medium-Altitude Endurance Unmanned Aerial Vehicle (UAV)," September 2001, Director of Operational Test and Evaluation, Department of Defense.

[75] P. 10, "Fallacies of High-Tech Fixes for Border Security," Tom Barry, International Security Report, Center for International Security, April 2010, at http://www.ciponline.org/images/uploads/1004_TBP.pdf.

[76]P. 16, "A Review of Remote Surveillance Technology Along US Land Borders," Department of Homeland Security, Office of Inspector General, Office of Inspections and Special Reviews, OIG-06-15, December 20005, at http://www.oig.dhs.gov/assets/Mgmt/OIG_06-15_Dec05.pdf.

[77]P. 10, "Fallacies of High-Tech Fixes for Border Security," Tom Barry, at http://www.ciponline.org/images/uploads/1004_TBP.pdf.

[78] P. 4, "Homeland Security: Unmanned Aerial Vehicles and Border Surveillance," Chad C. Haddal, Jeremiah Gertler, Congressional Research Service, July 8,2010, RS21698, at http://www.fas.org/sgp/crs/homesec/RS21698.pdf.

[79]P. 1, CRS, "Homeland Security: Unmanned Aerial Vehicles and Border Surveillance," at http://www.fas.org/sgp/crs/homesec/RS21698.pdf.

[80] See "More Predator Drones Fly US-Mexico Border," William Booth, Washington Post, December 21, 2011, at http://www.washingtonpost.com/world/more-predator-drones-fly-us-mexico-border/2011/12/01/gIQANSZz8O_story.html.

[81] P. 32, "Observations on the Costs and Benefits of an Increased Department of Defense Role in Helping to Secure the Southwest Land Border," Government Accountability Office, September 12, 2011, GAO-11-856R, at http://www.gao.gov/assets/100/97733.pdf.

[82] "More Predator Drones Fly US-Mexico Border," William Booth, at http://www.washingtonpost.com/world/more-predator-drones-fly-us-mexico-border/2011/12/01/gIQANSZz8O_story.html

[83] "US Adds Drones to Fight Smuggling," Randall C. Archibald, New York Times, December 7, 2009, at http://www.nytimes.com/2009/12/08/us/08drone.html.

[84] See the conference report at http://www.fas.org/sgp/news/2012/02/faa-uas.html.

[85] P. 16, "Selected Acquisition Report (SAR) RCS: DD-A&T (Q&A) 823-271; MQ-1B UAS Predator, as of June 30, 2010."

[86] Pp. 15 & 18, DOD Predator SAR.

[87] P. 5, DOD Reaper, SAR. See also p. 4 of DOD's 2012-2041 Aircraft Procurement Plan at http://www.airforce-magazine.com/SiteCollectionDocuments/Reports/2011/May%202011/Day25/AircraftProctPlan2012-2041_052511.pdf.

[88] P. 58, United States Air Force, FY2013 Budget Overview, SAF/FMB February 2012 at http://www.saffm.hq.af.mil/shared/media/document/AFD-120209-052.pdf.

[89] P. 1-2 of Program Acquisition Costs by Weapon System, February 2012, Office of the Under Secretary of Defense (Comptroller) at http://comptroller.defense.gov/defbudget/fy2013/FY2013_Weapons.pdf.

[90] P. 57, United States Air Force, FY2013 Budget Overview, SAF/FMB February 2012 at http://www.saffm.hq.af.mil/shared/media/document/AFD-120209-052.pdf.

[91] That would be 248 Predators purchased through 2009, 108 Reapers purchased through 2010, and 48 more Reapers purchased in 2011.

[92] In 2011 only 10 Predators and 5 Reapers in the total available inventory of both were not operationally deployed, according to operating cost data provided by the Air Force and available from the author.

[93] There is also confusion about the total number of Reapers actually existing in 2011 according to Air Force records. Four different DOD reports give four different Reaper inventory counts varying from 63 to 74. See p. 4 of "Selected Acquisition Report (SAR) RCS: DD-A&T (Q&A)823-424; MQ-9 UAS Predator, as of June 30, 2010;" p. 5 of "Report on Future Unmanned Aerial Systems Training, Operations, and Sustainability," Report to Congressional Committee, United States Air Force, September 2011; p. 21 of http://www.defenseinnovationmarketplace.mil/resources/UnmannedSystemsIntegratedRoadmapFY2011.pdf , and Air Force inventory, flying hour and cost data in the files of the author. Reapers are also being produced for the CIA; their numbers are classified and are publically unknown.

[94] See p. 5 of United States Air Force, Report to Congressional Committees, "Report on Future Unmanned Aerial Systems Training, Operations, and Sustainability," September 2011, submitted to Congress pursuant to House Report 111-491, page 509.

[95] P. 32, CBO, "Policy Options," at http://www.cbo.gov/ftpdocs/121xx/doc12163/06-08-UAS.pdf.

[96] See the Air Force's official mishap data at http://usaf.aib.law.af.mil/index.html.

[97] For example, see "War Zone Drone Crashes Add Up," David Zuccino, Los Angeles Times, July 6, 2010, at http://articles.latimes.com/2010/jul/06/world/la-fg-drone-crashes-20100706.

[98] See Drone Wars UK, Drone Crash Database, at http://dronewarsuk.wordpress.com/drone-crash-database/.

[99] P. 18, CRS, "U.S. Unmanned Aerial Systems," at http://www.fas.org/sgp/crs/natsec/R42136.pdf.

[100] The Air Force claims that contemporary drone mishap rates have fallen to the point where they are comparable to aircraft, such as the F-16 at a similar (implied early) stage of maturity. The data available do not support that assertion. Air Force class A mishap reports show 12 Predator MQ-1B crashes in 2011 after almost 10 years of employment: Predator is not an "immature" system. While early F-16C mishap reports and flying hours are not available; in 2011 there were four F-16C class A mishaps. According to Air Force flying hour data, the two platforms flew approximately the same number of hours in 2011, just over 200,000. The Predator mishap (rather crash) rate calculates to three times that of the F-16C.

[101] P. 247, DOT&E 2011 Annual Report, at http://www.dote.osd.mil/pub/reports/FY2011/.

[102] The data is available in USAF flying hour and cost data made available to the author; these data are available on request.

[103] The 2011 data for Reaper's "sortie" rate is not an exception. The 2010 data shows Reaper in the air for 30.4 hours each week, and the 2010 data for Predator (MQ-1B) shows it in the air 26.4 hours per week.

[104] For example, see "Predator Patrols to Nearly Double by 2010," Defense Update, Undated, at http://defense-update.com/newscast/0707/news/200707_predator.htm.

[105]P. 166, GAO, Evaluation of the Air Campaign,: at http://gao.gov/assets/230/224366.pdf.