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Destroying *Mobile Ground Targets* In An Anti-Access Environment

by
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In Brief

Maintaining an effective power projection capability in the face of enemy anti-access threats will require an effective means of striking mobile ground targets. Employing a systems approach is critical to achieve this capability. Enemy mobile targets must be found, identified, and tracked using intelligence, surveillance, and reconnaissance (ISR) assets. This information must then be passed to a platform that can move to an appropriate location and deliver a weapon capable of destroying the target.

To make such a system effective will require renewed focus on acquiring sufficient numbers of ISR platforms to maximize search areas. Gathered data must be integrated and distributed to theater commanders and forces. Weapons technology for striking mobile targets is reaching fruition, but these munitions and submunitions need to be fielded. In looking at platforms, the analysis illustrates that large stealthy aircraft offer the most attractive combination of capabilities for killing mobile ground targets in the anti-access environment anticipated by Department of Defense planners.

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I. Introduction

Having conclusively demonstrated their ability to strike fixed targets in recent combat engagements, the United States military is now focusing increased attention on destroying mobile ground targets. Striking mobile ground targets, particularly at night and in bad weather, has proven more difficult. US and coalition forces were unable to locate and strike mobile Scud missile launchers in the 1991 Gulf War. US and NATO forces encountered similar difficulties when attempting to destroy Serbian mobile units in *Operation Allied Force* in 1999 and the US military is confronting the same sorts of challenges in ongoing operations in Afghanistan.

This task is likely to become more challenging, but much more critical. Potential adversaries are developing and deploying mobile ballistic and cruise missiles on a widening scale to attack the theater bases, ports, and airfields used by US power projection forces. Potential foes are also investing in advanced mobile air defense systems to protect their air space. Destroying these mobile targets is thus a critical component to countering what the Department of Defense (DoD) refers to as the anti-access threat—the mix of political, geographic, and military problems that could prevent the United States from being able to project decisive power overseas. Essentially, Pentagon planners believe future conflicts could feature the political and geographic problems raised by operations in Afghanistan, complicated by adversaries armed with advanced mobile air defenses and deep strike threats to regional bases and forces. As the recent Quadrennial Defense Review report issued in 2001 laid out: "developing the capability to continuously locate and track mobile targets at any range and rapidly attack them with precision" and "projecting and sustaining US forces in distant anti-access or area-denial environments and defeating anti-access and area-denial threats" are two of the highest priority operational goals of DoD's transformation efforts.[2]

This paper outlines the challenges that mobile ground targets pose in future conflict environments and analyzes key trends and developments in the emerging systems needed to locate and strike these targets. Land-based systems offer powerful mobile ground target kill capability. M-1s, for example, can kill tanks on the move and the Army Tactical Missile System and Multiple Launch Rocket System can strike quickly when targets are located. But to bring these capabilities to bear in signficant numbers, the anti-access military threat (largely composed of mobile ground systems) must be degraded. Accordingly, this analysis focuses on land-based and sea-based air power systems because of their prominent role in the critical early phases of power projection operations in an anti-access environment.

II. Mobile Ground Targets: Classification, Characteristics, and Challenges

Mobile ground targets include the whole set which are capable of being moved (relocatable targets) and in motion (moving targets). In general, all mobile targets could be classified as relocatable, since even systems which can operate on the move (such as modern battle tanks) stop frequently for refueling, rearming, repair, and rest. However, in certain scenarios, such as the case of a ballistic missile launcher carrying a WMD warhead moving from a "hide" to a launch location, the US may need the capability to strike quickly a target actually on the move.

History suggests the targeting challenges posed to air forces by mobile targets. Air forces have successfully engaged mobile ground targets such as tank columns, supply convoys, trains, and the like in previous conflicts. These operations typically involved armed reconnaissance sorties flying at low altitude in clear weather combined with visual acquisition and target engagement (at times with assistance from forward air controllers in the air or on the ground). Relatively high attrition rates also typically characterized these operations. The famous Stuka pilot Hans-Ulrich Rudel, for example, destroyed 519 Soviet tanks during World War II, but was shot down 30 times. Striking discrete mobile force elements, particularly at night and/or bad weather, has proven extremely difficult. In the 1991 Desert Storm campaign, US forces focused considerable time and effort on attempting to kill mobile Iraqi Scud launchers to reduce the threat posed by

[2] Donald Rumsfeld, *Quadrennial Defense Review Report*, September 30, 2001.

Mobile targets must be found, fixed, targeted, and tracked using ISR assets.

these deep strike systems. Coalition air forces flew 2400 Scud strike and Scud patrol sorties. On 42 occasions, patrolling aircraft spotted a launch plume, leading to eight attacks. But overall, coalition forces failed to destroy any Scud launchers, which fired 88 missiles at targets in Saudi Arabia and Israel.[3]

The reasons for the failure of coalition efforts were revealed in the recently published memoirs of Lieutenant General Hazim 'Abd-al-Rassaq, the commander of Iraqi missile forces.[4] As Razzaq's memoirs illustrate, Iraq built up its missile forces following their successful use in the Iran-Iraq War to minimize vulnerability and maximize effectiveness. Iraqi forces indigenously developed mobile launchers and longer-range weapons, used deception and camouflage extensively, conducted continual exercises to minimize launch preparation times for firing mass volleys, developed secure communications, and coordinated operations with air defense and security forces. This careful preparation played a key role in frustrating coalition attempts to destroy the Iraqi missile force. Razzaq claims that he lost not a single launcher or crewman from his rocket brigades during the conflict and was sufficiently confident that he allowed his 10 year-old son to stand near the launching site and press the firing button during two of the launches.[5]

Iraqi forces in *Operations Northern and Southern Watch* over the past decade have employed similar tactics using mobility to limit the effectiveness of US retaliatory strikes against air defense systems. As one USAF pilot noted about the Iraqis: "They're getting really smooth. They can pick up and move in an hour or so. They can fire a missile, break down and leave before we can get in and drop a bomb."[6] Other potential adversaries observed the success of these tactics and many suspect that the Serbs learned a great deal from Iraqi missile launch procedures.

During *Operation Allied Force* in 1999, Serbian forces exploited mobility and deception to reduce vulnerability. Elements of the Serbian air defense system, such as radars and surface-to-air missile (SAM) launchers, moved routinely to frustrate allied targeting, allowing the Serbs to maintain a significant air defense threat that complicated allied air operations. For example, the Serbs would typically move their SA-3 batteries every few hours to prevent being struck by Tomahawk Land Attack Missiles (TLAMs).[7] The Serbs also made good use of decoys and camouflage. Poor weather conditions made matters more difficult by significantly reducing the ability of allied strike aircraft to visually locate and target enemy weapons. Worst case estimates suggest that coalition air power may have only destroyed 58 pieces of equipment in contrast to the 744 pieces NATO claimed soon after the conflict.[8] Of Serbia's 25 known mobile SA-6 batteries, NATO spokesmen stated that only 3 had been destroyed.[9] As the official USAF account of the air war over Serbia concluded: "The Air Force must continue to investigate new technologies and techniques for locating hidden or dispersed ground force elements with targeting quality accuracy, and rapidly passing that data to the 'shooters.'"[10]

US power projection operations rely primarily upon the rapid deployment of forces to threatened regions. What has galvanized US concern is that some mobile ground systems have emerged as extremely potent threats to US forces and regional ports, bases, and airfields. Air defenses can threaten US combat aircraft and airborne surveillance systems, and modern mobile SAM systems, such as the SA-10, have become far more lethal. Compared to previous generation SAMs, the SA-10's radar suite is much more powerful and resistant to jamming, launchers pack more firepower by carrying multiple

[3] Barry Watts, "Effects and Effectivness," *Gulf War Air Power Survey, Volume II*, Washington D.C., 1993, p. 335.

[4] LTG Hazim 'Abd-al-Razzaq, *Forty Three Missiles on the Zionist Entity*, FBIS Translation, October-November, 1998.

[5] *Ibid*.

[6] John Diamond, "Iraqis Put Air Defenses in Areas Off-Limits to Jets," *Pittsburgh Post-Gazette*, July 17, 1999.

[7] Rebecca Grant, *The B-2 Goes to War*, IRIS Press, 2000, p. 82.

[8] See "The Kosovo Coverup," *Newsweek*, May 15, 2000. The effectiveness of air power in Serbia continues to generate controversy and debate.

[9] Ben Lambeth, *NATO's Air War for Kosovo: A Strategic and Operational Perspective*, The RAND Corporation, 2001, p 111.

[10] *The Air War Over Serbia*, HQ: USAF, 2000, p. 49.

missiles, and the missiles themselves feature longer-range, higher speed, and much greater agility. As General Michael Short, *Operation Allied Force's* air component commander, stated:

> *I can tell you what I worry about every day and I can tell you what General Clark worried about every day—that somehow Mr. Milosevic would find a way to float an SA-10 or SA-12 up the Danube River, put it together and bring it to bear as a part of this conflict. If that had happened, it would have profoundly changed the balance of the threat and our ability to maintain air superiority.*[11]

To put this in perspective, the commander of Air Combat Command during the Serbian operation noted that B-1Bs (and other non-stealthy aircraft) could not operate survivably in the face of "double digit SAMs", even when employing advanced decoys and other countermeasures.[12]

Adversaries are also investing in ballistic and cruise missiles mounted on mobile transporter erector launchers (TELs) to threaten forward forces, bases, and ports. For example, some evidence suggests that the Iraqis targeted a Scud against the port of Al Jubayl. Had the missile struck ammunition stores stockpiled there, it could have closed the harbor and killed large numbers of US personnel and local port employees.[13] Although Scud effectiveness during Desert Storm was limited—owing to poor accuracy—the proliferation of satellite navigation systems, re-entry vehicle guidance systems, and more advanced submunitions has the potential to dramatically increase ballistic missile lethality. A recent RAND study indicates that upgraded ballistic missiles would pose a potent threat to forward-based US combat aircraft. As the authors observed, "The combination of increased accuracy from GPS guidance and increased warhead efficiency is what decreases the number of missiles required to attack USAF airbases from hundreds to dozens."[14]

The ballistic missile threat, however, may pale in comparison to the deep strike threat posed by land-attack cruise missiles, which could be derived from current naval anti-ship missiles or from "kit" aircraft.[15] By exploiting GPS technology, cruise missiles can strike with much greater accuracy than ballistic missiles, and are less expensive and easier to field. To complicate the task of a defender, these small radar cross section weapons can fly low and employ multiple azimuths of attack.

Finally, adversaries are attempting to reduce the vulnerability of these mobile systems through several means. In Serbia, post-war surveys found extensive use of decoys (mock tanks made of tetra-pak cartons, wood burning stoves angled to resemble artillery pieces), smoke to obscure vision, and camouflage (buried missile launchers and tanks disguised as haystacks).[16] In Iraq, Serbia, and Afghanistan, opposing forces moved into cities and took shelter in schools, mosques, and churches to exploit US concern over inflicting collateral damage. We can expect these and additional countermeasures (e.g., more sophisticated decoys, hard and deeply buried bunkers) to further complicate the mobile target problem.

In summary, developments in enemy capabilities and concepts of operations have increased the US requirement to field a capability to kill mobile targets—even when confronted by bad weather, darkness, and enemy countermeasures. The most stressing period is in the early phases of a conflict; fewer US forces would be available and an enemy could use advanced air defense systems to counter US air capabilities and employ deep strike systems against critical ports, bases, and airfields to disrupt US force deployments.

III. The Mobile Target Kill Chain

To effectively strike mobile targets, the US must employ a systems approach. Mobile targets must be detected, identified, and tracked using intelligence, surveillance, and reconnaissance (ISR)

[11] Comments by LTG Michael Short at the Eaker Institute for Aerospace Concepts, "Operation Allied Force: Strategy, Execution, Implications," August 16, 1999.

[12] "Former ACC Chief Says USAF Should Move to Larger, All B-2 Bomber Fleet," *InsideDefense.com*, October 17, 2001.

[13] See Adam Siegel, *The Scud Against Al-Jubayl: An Anti-Access Case Study*, Washington D.C.: Northrop Grumman Analysis Center, 2001.

[14] John Stillion and David Orletsky, *Airbase Vulnerability to Conventional Cruise-Missile and Ballistic-Missile Attacks: Technology, Scenarios, and US Air Force Responses*, Santa Monica: The RAND Corporation, MR-1028, 1999.

[15] The best overview of the cruise missile threat can be found in Dennis Gormley, *Dealing With the Threat of Cruise Missiles*, Adelphi Paper 339, London: International Institute for Strategic Studies, 2000.

[16] Ben Lambeth, *NATO's Air War for Kosovo: A Strategic and Operational Perspective*, The RAND Corporation, 2001, pp. 130-131.

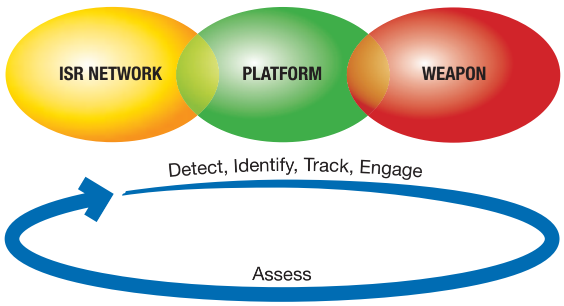


Figure 1. The Mobile Target Kill Chain

assets. This information must then be passed to a platform that can move to an appropriate location and deliver a weapon capable of destroying the target.

A. Intelligence Surveillance, and Reconnaissance

In previous wars, the primary means of acquiring and attacking a mobile target using air power assets involved aircraft flying at low and medium altitudes, such as P-47 fighter-bomber operations against trains in the buildup to the Normandy landings, F-4 road and river reconnaissance/strike operations against North Vietnamese forces during the Vietnam conflict, A-10 attacks against Iraqi armor during Desert Storm, or F-15E attacks against Serbian forces. The aircraft's pilot/aircrew played a central role in locating, identifying, and striking the target. Signals and imagery intelligence might provide cueing that enemy forces would be active in a certain area of the theater, but the final location and engagement typically depended upon the pilot's eyeballs. Night would often offer a sanctuary to enemy operations. Employing illumination flares has historically provided little success,[17] but night vision devices have improved the situation.

Bad weather has proven even more problematic. In the Gulf War in 1991 and Serbia in 1999, the Joint Surveillance Target Attack Radar System (JSTARS) would detect moving forces, but attack pilots could not visually find the target through the weather to employ their weapons. In addition, recent operations have emphasized flying strike aircraft at medium and higher altitudes to minimize the widespread threat posed by man-portable SAMs and anti-aircraft guns. This has made visual location and identification much more difficult than in the past.

Although battlefield ISR steadily improved over the decades, it remained episodic, placing the heaviest responsibility on the aircrew for target acquisition and engagement. Significant lag times occurred in updating the battlespace picture (such as processing film from reconnaissance sorties and then getting this information into the intelligence system). Target cueing and tracking has suffered similar delays in transferring data from sensor to "shooter."

Over the past decade, however, a growing variety of sensors are generating information in the form of digital data, which, when combined with data links, opens the door to near-real time integration.[18] ISR platforms, such as the JSTARS and Global Hawk, can stare at large areas using synthetic aperture and Moving Target Indicator radars to provide continuous near-real time information for long periods of time, regardless of weather. High-speed processors and digital storage can allow analysts to play back movements to detect patterns (such as locations from which threat systems deployed or unusual increases in vehicle traffic) and display a wide array of data from off-board sensors. The advent of higher resolution radar systems (such as the Multi-Platform Radar Technology Improvement Program for the Global Hawk and future JSTARS and the Radar Modernization Program on the E-2C) will allow operators to characterize specific targets (such as TELs or SAM launchers) and track these targets continuously.

Combat assets will carry high quality sensors as well, such as the electronically scanned radar arrays on the Joint Strike Fighter and F/A-18E/F, whose data can also be integrated into the overall battle picture. Combat operations in Afghanistan have demonstrated the enormous utility of Special Forces' sensors in providing intelligence and targeting data. Data provided by other intelligence systems, such as surveillance satellites, the RC-135 Rivet Joint, U-2, E-2C, Predator, and other systems, can—at least in theory—be added quickly and seamlessly using military data links.

[17] See Wayne Thompson, *To Hanoi and Back: The USAF and North Vietnam, 1966-1973*, Washington D.C.: Air Force History and Museums Program, 2000, pp. 71 and 75.

[18] See "Air Force Chief Launches Major Effort to Improve Targeting Speed," *Inside the Pentagon*, November 8, 2001.

We have not yet achieved the desired end-state in ISR integration, but we are making substantial progress.

The larger the number and the wider the distribution of such assets, the greater the knowledge of enemy dispositions and forces. For example, individual signals intelligence (SIGINT) platforms typically cannot provide sufficiently precise location data for weapons targeting. But multiple SIGINT platforms networked together and interwoven with radar and optical imagery can.[19]

The goal of the future ISR system is to update the battlespace picture in near real time and distribute that information over data links to theater commanders and forces. One analogy is the Navy's Cooperative Engagement System, which permits individual platforms to share sensor data, providing a more complete battle picture and allowing individual ships or aircraft to target using another platform's data. Overall, the trend using rapid digital search and analysis will increase commander knowledge of the battle area in near-real time and allow timely sharing with other battle force elements. As the Air Force Chief of Staff, General John Jumper noted recently, "if we let machines talk at the digital level" useful information can be passed more quickly and reliably.[20] These changes will reduce the current reliance on visual detection, identification, and targeting. Initial reports from operations in Afghanistan indicate substantial progress in linking the discrete elements of the "kill chain" to strike fleeting targets.[21] To be sure, we have not yet achieved the desired end-state in ISR integration (and should not underestimate the technical and institutional challenges), but we are making substantial progress.[22]

B. Weapons

In previous conflicts, aircraft would attack mobile targets by using cannon and rocket fire or delivering area weapons such as cluster bombs against enemy formations (such as the strikes against fleeing Iraqi forces on the "Highway of Death" in 1991). But future operations envision greater reliance on more "intelligent" weapons that can target individual mobile targets autonomously, such the Sensor Fused Weapon (SFW), which can be dispensed from a Tactical Munitions Dispenser or a Joint Standoff Weapon.[23]

SFW was primarily designed to strike large formations of armored forces and the canister containing the submunitions must be delivered close to the target in question. Other submunitions have greater on-board processing power to search, locate, and strike individual vehicles. The Brilliant Anti-Tank submunition, which uses acoustic and infrared sensors for detection, is currently planned for use on Army Tactical Missile System. It could also be carried in air-delivered canisters.

The Air Force is also developing small self-contained munitions that can search large areas for mobile targets and then home in autonomously. These weapons include the Low Cost Autonomous Anti-Armor System (LOCAAS), which employs a laser radar for target acquisition and terminal guidance, and the Phase II Small Diameter Bomb (SDB), which is planned to have an autonomous seeker for target acquisition and terminal guidance.

The munitions and submunitions discussed above rely on on-board processors and sensors to find and strike targets. DoD is also exploring another approach under a technology demonstration program known as the Affordable Moving Surface Target Engagement System (AMSTE). AMSTE turns fixed target Joint Direct Attack Munitions into mobile target killers. To do this, two individual radar platforms (which could be a JSTARS, Global Hawk, or a strike aircraft) provide radar location data on the target in question.

[19] "Defense Department Accelerates Several ACTD Programs: Focus on Hard Targets," *Aerospace Daily*, October 21, 2001.

[20] "Air Force Chief Launches Major Effort to Improve Targeting Speed," *Inside the Pentagon*, November 8, 2001.

[21] Thomas Ricks, "Bull's-Eye War: Pinpoint Bombing Shifts Role Of GI Joe," *Washington Post*, December 2, 2001.

[22] A related issue is the time required to get approval to strike targets, which can be particularly critical in the case of mobile targets. In operations, concern over inflicting civilian casualties and collateral damage has resulted in substantial decision-making delays.

[23] SFW consists of large numbers of hockey-puck-sized munitions over an area containing moving vehicles. Sensors on each submunition locates the engine heat from the targeted vehicle and trigger a small explosive charge, which drives a molten jet of copper at hypersonic speed into the top of the vehicle's engine compartment to destroy or disable the target.

Software and platform data links reduce the location error and provide the JDAM with a continuously recomputed location of the target. In an August 2001 test, the AMSTE system scored a direct hit on a moving van, illustrating the promise of this technological approach.

Finally, an ISR system capable of detecting and tracking enemy movements can be used to make other weapons effective against mobile targets. For example, if JSTARS detected a moving convoy, strike aircraft could crater a road, fill a canyon with rubble, or drop a bridge to force the enemy force to stop, after which it could be struck by a variety of munitions.

C. Strike Platforms

Clearly, we are seeing progress in the elements of ISR and munitions in the kill chain. By fusing advanced radar, electro-optical, infrared, and signals intelligence data in near-real time, US forces will increasingly have the potential to locate and identify critical mobile targets at night and in bad weather. Munitions are becoming more capable and autonomous. To take advantage of the progress made in ISR and munitions, what type of platforms would be most useful to attack mobile targets?

A complex mix of platform attributes is required to effectively engage mobile targets:

- *Range:* One of the reasons the United States is so concerned about mobile systems is their potential employment against deploying and forward-based US theater forces. Accordingly, the ideal mobile target killer would be able to operate at long range from bases or ships free of political constraints and outside the range of enemy ballistic and cruise missiles. Once the latter threats are negated, the US can deploy shorter-range forces to the theater at reduced risk.

- *Loiter/Endurance:* Long range also equates to loiter and endurance. Mobile targets may only present themselves at fleeting opportunities and may only be vulnerable for short periods. Accordingly, strike platforms must be capable of orbiting for lengthy periods of time to be airborne and available to strike when the target is located and tracked. During the Vietnam conflict, *Operation Desert Storm*, and *Operation Allied Force*, US fighters using multiple refuelings from tankers would often orbit for hours waiting for a suitable target to appear. Bombers armed with JDAMs did the same in *Operation Enduring Freedom* to strike fleeting targets in Afghanistan.[24] In Allied Force, during the decision time required to identify and get approval to attack a fleeting target, NATO fighters often ran low on fuel and had to leave the area to search for a tanker.[25]

- *Survivability:* Effective strike platforms must be capable of surviving both while loitering and when penetrating to deliver weapons. Stealth appears as a prerequisite against any capable opponent, particularly if facing an air defense equipped with advanced SAMs. Non-stealthy platforms might be capable of surviving in orbits if armed with standoff weapons of sufficient range to keep the platform outside the range of enemy defenses.

- *Short Reaction Time:* Once a target is located, the strike platform must be capable of rapidly reacting to reach the fleeting target (or reaching a location to fire a high speed weapon at the target).

- *Flexible Mix of Weapons:* The larger the aircraft's payload, the more the flexibility in weapons availability. This is important because different types of mobile targets could require a wide array of weapons. Some mobile targets may disappear into hardened underground bunkers, which would require a large penetrating weapon to destroy the target. Stopping a large scale armored advance could require hundreds of weapons, as could decisive strikes against an adversary's mobile air defense network. Against a time critical mobile target, a high speed, powered weapon could prove useful (and such weapons, which need to carry both fuel and a propulsion system, would be larger than unpowered glide weapons).

- *Connectivity:* Links to the ISR network are critical to provide the platform with situation

[24] "Attacks from Out of the Blue: US Airstrikes Hit Taliban Military Targets and Morale," *Washington Post*, November 18, 2001.

[25] Ben Lambeth, *NATO's Air War for Kosovo: A Strategic and Operational Perspective*, The RAND Corporation, 2001.

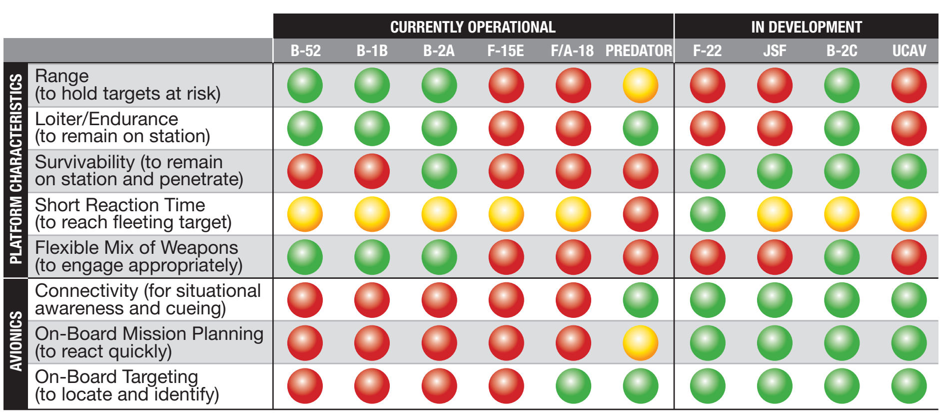
awareness and cueing. Secure data links, such as Link 16, are essential to provide strike platforms with updates on the threat environment, friendly forces, and locations of mobile targets. In recent operations in Afghanistan, for example, Predator unmanned air vehicles used data links to feed live video of enemy targets to Air Force gunships.[26]

- *On-Board Mission Planning:* Even stealth aircraft need to plan their routes through defenses to avoid being targeted by enemy air defenses. Currently, this planning is done before the aircraft launches. The advent of small powerful processors combined with data links has resulted in the development of onboard auto-routers. These can help aircrew rapidly plan penetration routes while airborne using up-to-date threat data to enable quick reaction to pop-up targets.

- *On-Board Targeting:* A powerful sensor onboard the platform allows the crew to conduct a final check before weapons release. For example, during successful B-2 strikes against relocatable Serbian air defenses, the general location information ISR systems provided was not precise enough to target weapons. Accordingly, the crews used the aircraft radar to locate the target and aim their weapons. Over the long-term, improvements in ISR capabilities and autonomous weapons may make on-board targeting less critical (that is, using advanced sensors and data fusion, targets can be more definitively identified).[27]

Figure 2 compares current and potential strike platforms, both manned and unmanned, in each category using "stoplight" evaluations (green is good, yellow is mixed, red is limited capability). These ratings are subjective (the reader is encouraged to do his/her evalution) but do provide some useful insights into which platforms offer the best combination of attributes for striking mobile ground targets.

The degree of difficulty (and cost) involved in improving individual attributes depends on whether they are related to the platform or the internal electronic systems (avionics). Avionics are routinely upgraded without typically affecting the aircraft's shape. Over the near to mid-term, plans envision fitting most platforms with advanced processing capability, data links, and sensors to take advantage of the ongoing "information revolution." This should move most systems toward a "green" rating in avionics attributes. Attributes that are a function of the aircraft platform are much more difficult and expensive to change. For example, to increase the range and payload of the F/A-18C/D required the $7 billion F/A-18E/F development program and tens of billions to procure the new platform. More radical changes in platform attributes require even more resources. Adding stealth to bombers required the $32 billion B-2



- *Ratings for the B-2A reflect current capability.*
- *The B-2C (C for conventional) is a proposed restart of the B-2 line that utilizes a B-2A airframe equipped with commercially-based processors and an advanced radar.*
- *Ratings for the F-22 assume incorporation of the modifications required (radar, avionics, etc.) to locate and strike mobile targets.*

Figure 2. Evaluating Platform Characteristics

[26] "Technology Changes Air War Tactics," *Washington Post*, November 28, 2001.

[27] For targets where a visual identification is deemed critical, the RAND Corporation has proposed development of expendable UAVs that strike aircraft could launch over the target area to provide a visual picture to the aircrew before weapons delivery (reducing the need for the combat aircraft to descend to more dangerous lower altitudes). See Alan Vick, et. al, *Aerospace Operations in Urban Environments*, The RAND Corporation, 2000.

development program, while adding stealth and supercruise characteristics to the F-15A/C required the $26 billion F-22 development program.[28]

In terms of airframe, an upgraded B-2A or a new start B-2C (C for 'conventional')[29] appears to offer the most utility when looking for the optimal mix of capabilities. The older bombers fare poorly in the vital area of survivability, as do the non-stealthy fighters.[30] The most advanced new fighters, the F-22 and JSF, do not possess the range, loiter/ endurance, or weapons mix to effectively prosecute deeper mobile ground targets or operate from rear area bases outside the range of enemy anti-access threats or political constraints imposed by local governments. This reduces the utility of these aircraft when conducting operations in the future anti-access environment anticipated by the Department of Defense. The proposed UCAV under development is related closer to modern fighters than long-range bombers. It features high survivability through stealth, but has limited payload and range. The Predator, an armed version of which has been recently used in combat in Afghanistan, offers excellent loiter, but is limited by slow speed, survivability concerns, and a small payload.

In looking at reaction time, the bombers and fighters are rated similarly except for the F-22. The F-15, F/A-18, and Joint Strike Fighter (JSF) have the capability to fly at supersonic speeds, but can only do this for very short periods because the use of afterburners uses fuel at a very high rate. Thus these aircraft are similar in terms of realistic penetration speeds to the bombers. The F-22 can "supercruise" without using afterburner like the other fighters and thus is given a "green" rating (though it still burns fuel at a much higher rate in supercruise, thus limiting its endurance). In sum, the fighters may be able to penetrate more quickly, but cannot go very deep into enemy territory unless accompanied by refueling tankers. And an anti-access environment may prevent the short-range fighters from being available to conduct operations in the first place.

Figure 3 provides a perspective on these three key characteristics (range, endurance, and payload) comparing the two most advanced stealthy strike systems: an upgraded B-2 and the planned JSF. Large bombers feature much greater endurance than fighter aircraft because the crew can get up and take breaks (and even naps as demonstrated by years of bomber operations and recent B-2 combat operations). Bombers also feature substantially longer range (which can be converted into endurance) and larger weapons payload, which allow them to carry a flexible mix of weapons and threaten multiple strikes against a much wider area. For example, assuming both the B-2 and JSF had full tanks at an orbit point and a tanker was available for post-strike refueling,

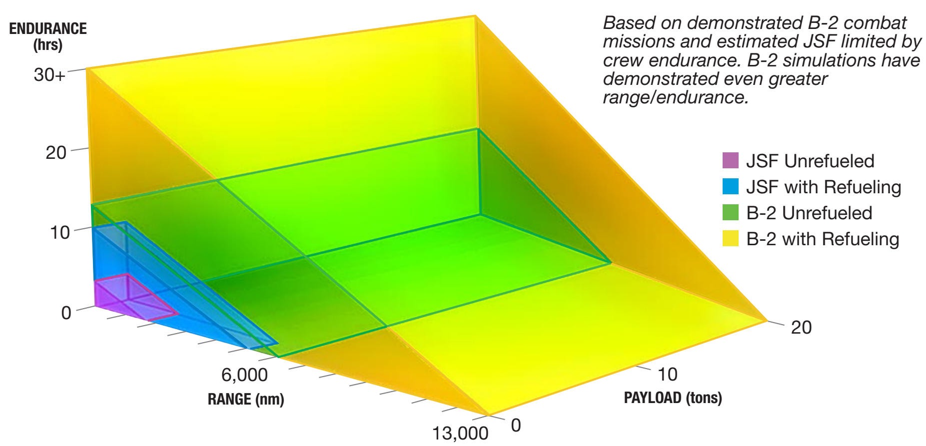


Figure 3. B-2C and Joint Strike Fighter Comparison

[28] All costs are in $FY02. Program totals are from *US Military Aircraft Data Book*, Data Research Associates, 2001.

[29] The B-2C proposal envisions restarting the B-2 production line (using the saved tooling) and building the current airframe (including the new low observable coatings currently being applied to the B-2A force to reduce maintenance requirements, modern data links, and advanced bomb racks). B-2Cs would be fitted with commercially-based processors to enable on-board mission planning and an electonically-scanned array radar (based on the Joint Strike Fighter radar) for increased resolution.

[30] Conducting operations during the day have been raised as an area of concern regarding B-2 combat employment, but any increased vulnerability relates to a fairly narrow area: enemy interceptors operating deep in their territory beyond the range of US interceptors during the day in clear weather. Enemy fighter bases would be the focus of intense attacks in the early stages of a conflict, which could significantly reduce numbers available. Remaining interceptors operating within the range of F-22s (or other US fighters) would have great difficult surviving. This leaves enemy interceptors operating in the day beyond the range of US fighers to engage penetrating B-2s. The stealth characteristics of the B-2 would make a successful enemy interception quite difficult: the interceptor would typically not receive any radar tracking data to position itself, the B-2's aircrew could use updates on enemy threats to evade the interceptor, and adverse weather and clouds could prevent a visual sighting. With all that in mind, US theater commanders would have to assess whether destroying the mobile target in question was worth the increased risk to the B-2. In some cases (a nuclear-tipped ballistic missile), it might be. In other cases, the commander might elect to wait until dark.

a JSF could penetrate approximately 650 nm, while a B-2 could penetrate almost four times further (2700 nm). This enables bombers to threaten mobile targets located in the rear of a theater, such as extended range ballistic and cruise missiles, and operate from bases outside the reach of enemy anti-access threats. Operations in Afghanistan demonstrated the value of long-range bombers in anti-access environment, since the land-based fighter force's potential combat contribution was severely constrained by political problems surrounding use of nearby bases and geography. Concerns over striking appropriate military targets also provide advantages to bombers. During Operation Allied Force, for example, the time required to gain approval to strike a fleeting target often resulted in fighter aircraft being forced to leave the area to seek an aerial refueling.[31]

Command and control issues provide additional advantages to large aircraft in the dynamic battle environment. If a commander has a number of smaller strike aircraft operating in orbits, determining which aircraft is in the right location with the right fuel state and armed with the right weapons can be difficult. In some cases, the right solution might not be available. In contrast, a larger aircraft, with its much greater internal volume for fuel and weapons, has a much greater chance of being available on orbit in the right fuel state with the right weapons.

Penetration speed has been raised by some as an important attribute for mobile target killers. For example, the Air Force has emphasized the F-22's supercruise capability, which should allow it to reach detected mobile targets quickly (though the reduction in range when flying at "supercruise" should not be forgotten). Analysis indicates, however, that high penetration speed can be useful, but must be considered within the context of such issues as range and availability on station. The Army Tactical Missile System (ATACMS), for example, fires Mach 3 missiles, but has a fairly short range and would need to be deployed into theater to conduct strikes (which may be difficult in an anti-access environment). The F-22 at Mach 1.4 is slower than the ATACMS, but has greater range and hence increased potential availability. The B-2 at an assumed Mach .85 is slower than the F-22, but has substantially greater range and hence potential availability (as highlighted by the bomber contribution in the face of political and geographic access constraints facing US forces in Afghanistan).

High penetration speeds would also appear useful in only very limited circumstances. Ground mobile targets do not move very fast compared to aircraft—30 miles per hour is probably a useful rule of thumb for missile TELs and SAM launchers. Consider the case of a mobile target traveling at 30 miles per hour 100 nautical miles from an orbit location (or a penetration route inside the theater). It would take an F-22 8.6 minutes to travel this distance at supercruise, a JSF 13.6 minutes using military power (since its penetration depth would be very limited if it used afterburner to go supersonic), and a B-2 14 minutes. During this time, the target would have traveled 4.3 nautical miles in the case of the F-22, 6.8 nautical miles for a JSF, and 7.0 nautical miles for B-2.

Is the extra 2.7 nautical miles the target traveled significant?[32] Is it more significant than the shorter range of the F-22 compared to the B-2? Fast reaction times would not be required for

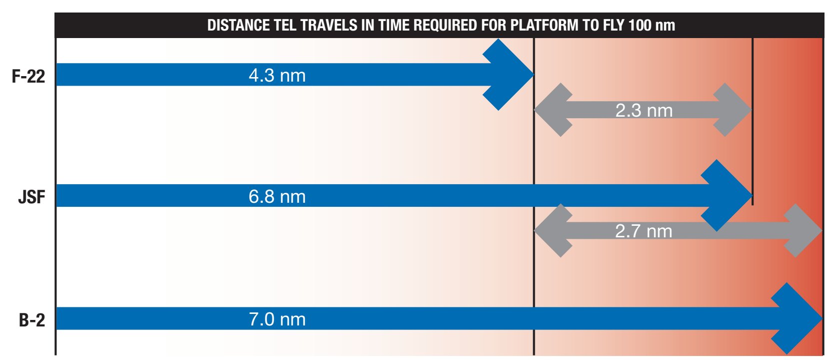


Figure 4. Potential Distances a TEL Can Travel in Time Strike Aircraft Fly to Location

[31] Ben Lambeth, *NATO's Air War for Kosovo: A Strategic and Operational Perspective*, The RAND Corporation, 2001, p. 126.

[32] Assumes a B-2 at .85 Mach (420 nmph true ground speed), a JSF at 0.9 Mach (440 nmph true ground speed), and an F-22 at 1.4 Mach using supercruise (691 nmph true ground speed).

such targets as armored columns, SAM systems, mobile command and control units, supply convoys, helicopter forward operating locations, or missile TELs moving from hide to hide, particularly if the ISR system evolves to provide continuous target tracking. The cases where fast reaction time could matter would be TELs moving from a hide to a launch location, or if the ISR system was not able to maintain a continuous track on the target. In the latter case, the shorter the time, the smaller the area the strike aircraft would need to search.

In those few cases where rapid response does matter, the best solution in the long run might be a bomber platform (with long-range and endurance, hence reliable availability) carrying a directed energy weapon or a hypersonic missile. The power generation requirements for directed energy weapons will require substantial internal volume (for example, the airborne laser under development is carried in a B-747) and thus favor deployment on larger aircraft. Hypersonic missiles would also be larger than current weapons in order to hold the engines capable of generating sufficient thrust (and thus might be too large to fit in the internal weapons bays of stealthy fighters).

A stealthy bomber would offer important advantages over non-stealthy bombers in employing these advanced weapons. A stealthy aircraft could operate closer to the threat area, thus reducing the power requirements of directed energy weapons or the size of hypersonic weapons. In addition, a stealthy bomber could penetrate air defenses to strike at mobile ground targets located in the rear of the theater. Directed energy and hypersonic weapons will not be available any time soon. In the near and mid-term, the ability of the B-2 to penetrate and then employ a variety of weapons, including the JSOW and Joint Air-to-Surface Standoff Missile (JASM), would provide a useful surrogate capability.

Conclusion

Maintaining an effective power projection capability in the face of enemy anti-access threats will require an effective means of striking mobile ground targets. The Department of Defense is now debating a range of solutions to meet this critical operational goal. To do so will require renewed focus on acquiring sufficient numbers of ISR platforms to maximize search areas, integrating the collected data, and distributing it to theater commanders and forces. Weapons technology for striking mobile targets is reaching fruition, but these munitions and submunitions need to be fielded. In looking at platform characteristics to take advantage of the developing ISR system and deliver weapons, the current range of manned and unmanned systems either in service or in development offer advantages in individual areas. Overall, large stealthy aircraft appear to offer the most attractive combination of capabilities, particularly when operating in the constraints imposed by anti-access environments.

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