November 2005

Command and Control Arrangements for the Attack of *Time-Sensitive Targets*

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NORTHROP GRUMMAN

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Executive Summary

Over the last decade and a half, the U.S. military has increasingly focused on improving its ability to deal with targets for which timeliness of attack is a key objective. In general, these targets are called "time-sensitive targets." To be sure, joint airpower has prosecuted missions for which timeliness has always been a component, including close air support, battlefield interdiction and offensive counter-air missions. But there are new threats emerging, and new developments in producing tools to address them.

The new threats derive from terrorists and non-state actors: the war on terrorism is predominantly a war on time-sensitive targets.

Time-sensitive targets need not be mobile, e.g., a building temporarily occupied by a terrorist combat team. If the number of time-sensitive targets grows, then the effort to service them will necessarily impinge upon the main, pre-planned air campaign. Indeed, lots of friction will be created even for small amounts of diversion. This paper takes no presumptive stand with respect to how much diversion is too much, for that judgment will truly depend upon the combat situation and the relative urgency of prosecuting the pre-planned target list. The paper will identify a number of detailed issues associated with making an informed judgment and offer some solutions that aim to mitigate the friction.

The new developments include new forms of neutralizing targets, e.g., kinetic kill using precision weapons and non-kinetic kill using information operations, and new forms of sensors, e.g., *Joint STARS* and *Global Hawk* equipped with high-resolution radars providing persistent, detailed coverage of mobile ground targets over wide areas. The new tools also include information networks that speed data to decision makers, allowing them to rapidly assess the situation and direct appropriate actions.

This paper analyzes the command and control (C2) arrangements required to support the prosecution of time-sensitive targets using a framework of *sensor-decider-shooter*. But if the framework sounds straightforward, its application is complex. Every time-sensitive target poses a somewhat different problem to the decider. For each target the decider needs to answer questions like the following: What is the relative priority of this time-sensitive target? What is the correct assignment of functions and responsibilities to an array of sensors and shooters to attack this particular target successfully? What command and control arrangement enables the assignment of those duties most efficiently? What criteria should be consulted to determine those arrangements and make those assignments? When and how can C2 be streamlined to facilitate the timeliness of this particular attack?

The paper is written as a tutorial for those who want to understand better the issues of C2 for time-sensitive targeting. The paper describes the time-sensitive targeting problem and then develops specific technical and operational challenges to solving that problem. It examines a number of specific combat situations in enough detail to point out how different combat situations need different command and control arrangements. It suggests how different command and control arrangements centering on the sensor, decider or shooter show promise for dealing with these diverse challenges. It shows how each of these specific arrangements devolves from more general "network-centric" arrangements.

The paper gives much attention to describing three fundamental issues that arise in the prosecution of time-sensitive targets. They are as follows: a) each command entity has a different perspective on any time-sensitive target, b) coordination among these command entities takes time and interferes with timely attack, c) the ability to mount timely attacks requires the persistent, often lavish allocation of both sensor assets and attack assets, as well as the proper use of the network to mitigate the first two issues.

There is no "silver bullet" solution to developing C2 that adequately supports the complex task of attacks on time-sensitive targets. Success is to be found in the careful harmonization of a large number of considerations by a large number of sensor entities, decision-making entities and action-taking entities. For example, achieving timeliness cannot come at the expense of inadvertent strikes on unauthorized, politically sensitive targets. Just this one criterion involves many information sources, analyses and decisions.

The paper goes beyond describing command and control arrangements that show promise to provide concrete advice on relevant aspects of military doctrine, technology, personnel training, systems engineering and procurement that are peculiar to success in time-sensitive targeting. This advice is summarized in the following guidelines for action:

Doctrine related guidelines:

- Recognize that the attack of time-sensitive targets is a valued combat goal that has its own particular Tactics, Techniques, Training and Procedures.

- Recognize that particular sets of technical capabilities and combat situations lead to a preference for alternative command and control arrangements such as the *Shooter*-led, *Sensor*-led and *Decider*-led cases described in the text.

- Recognize that a principal value of an overall *Network*-centric command and control arrangement is its ability to support two actions: 1) the top-level adjudication of issues set forth above and 2) the devolution to the specialized arrangements in the previous bullet.

- Recognize that the overall combat goal is to fulfill the commander's intent and to translate that into wise and effective operational choices. Those choices, in turn, rest on judgments as to the relative priority of individual time-sensitive targets and the overall priority of groups of time-sensitive targets in relation to groups of pre-planned targets.

- Remember that over time the opponents will adapt.

Training related guidelines:

- Develop special training protocols for attack of time-sensitive targets for all command entities.

- Establish Sensor Management as a specific combat skill worthy of formal training, selection and assignment monitoring.

- Exploit modern methods of training and simulation in these protocols that 1) facilitate participation by those exceptional individuals who are likely to be in combat command positions some day, 2) explore a wide variety of combat circumstances and 3) familiarize participants with a wide variety of *sensor, shooter* and *decider* equipments and applications.

- Include training modes in all command and control equipments and procedures that can support fast-track training of newly assigned personnel, in recognition that 1) modern command and control equipments will always be in a state of continuous evolution and 2) assignments too often precede formal training.

Technology related guidelines:

- Place the burden of information interoperability on translation services within the C2 infrastructure that are designed, funded and controlled by the information customer. Information sources already have legacy transmission systems that have been designed to meet demanding operational requirements. It is unreasonable to expect these diverse sources to adopt some new transmission, especially in Joint and Coalition operations. This guideline often leads to separate, valuable nodes, e.g., distributed common ground stations utilizing *ISR Manager/Tactical Exploitation System* and the *Battlefield Airborne Communications Node (BACN)*. These nodes collect and collate from diverse sources into a single data stream and publish that stream in a format readily useful to many customers.

- Strive for machine-to-machine transmittal of data. The payoffs are reduced delay, fewer errors and the ability to more easily combine and process diverse data streams into higher order, more coherent combat information. Even one-way machine-to-machine transmittal is valuable and is often a lot easier to implement.

- Provide for robust, real-time collaboration among people who can turn data into information, without regard for their geographical and organizational location.

- Curtail the propensity to "push" large volumes of data (e.g., images). Rather, post primary data in a retrievable mode and distribute small amounts of "meta-data" that describe what has been posted, who might benefit and how to retrieve it.

- Exploit the value of preparing electronic "mission packages" that are 1) tailored to specific missions, 2) sent via electronic address techniques (e.g., a secure version of IP) to designated platforms and 3) provide feedback paths for the customer's experiences.

- Pursue the development and use of platforms that combine portions of two or three of the *Sensor, Shooter* and *Decider* functions to enhance attacks on time-sensitive targets. Combined function platforms can range from a weapon (e.g., *Viper Strike*) with its own homing sensor, to an unmanned aircraft (e.g., *J-UCAS*) or ground vehicle with sensors and, perhaps, human control, to a large battle management aircraft (e.g., E-8, E-10, E2-D, and P-8) integrating sensors and command elements.

- Support the continued development of technical aids to command and control such as data and analytic techniques for 1) collateral damage estimation, 2) precise geo-location and mensuration, 3) damage assessment and combat implications thereof, 4) information warfare matters such as recognition of cyber attack and real-time measurement of network performance and 5) near-real time monitoring of the performance level of sensors in the combat environment.

System Engineering and Procurement Guidelines:

- Develop specialized System Engineering techniques and procedures for Command and Control facilities that facilitate the following needs: 1) timely configuration management, 2) rapid evaluation of the technical and combat relevant value of proposed changes and upgrades, 3) implementation of changes in ways to reduce disruption and opportunity for error and 4) diagnosis of on-going operations to evaluate the performance of functions and to identify practical performance enhancements.

- Tailor procurement arrangements for upgrades to Command and Control facilities that meet the following needs: 1) achieve timely approvals without sacrificing accountability, 2) record judgments and estimates of cost, schedule and performance in a manner to support System Engineering procedures, 3) allow for the inclusion of equipment and software derived from a variety of funding sources and physical sources, e.g. coalition partners.

- Approach true invention with humility. We cannot simply “order up” something that needs to be invented. True, history shows that we can usually find organizations that will agree to deliver an invention. But that agreement, in itself, will assuredly lead to effort and expense, but not necessarily an invention.

These guidelines are not intended to cover a comprehensive set of actions for the improvement of C2 for time-sensitive targeting. Indeed, many useful and important actions not mentioned here are being taken throughout the C2 community that will bring improvements.

The selected guidelines set forth above were chosen to highlight perspectives and approaches that we felt were particularly promising, or under appreciated, or highly dependent upon the personal efforts of individuals who are probably scheduled to leave their posts over the next few years. We do believe that following these guidelines for action will bring added improvement.

We are ever so mindful that time-sensitive targeting has only recently been recognized as a valuable and distinct combat goal. The progress to date has been significant. But there is much left to do. Only continued, thoughtful efforts, well financed, will finish the job.

I. Introduction

It is widely understood in the U.S. defense community that the overall effectiveness of joint air power has been steadily improving over the past decade. This is due, in large measure, to enhancements in sensors with which to find targets, advancements in weapons with which to attack targets, and the evolution of the command and control (C2) capabilities uniting the two. High-ranking officials in the US armed services have acknowledged that attacking fixed targets that do not present a timeliness factor has become a routine undertaking.[1]

But the emergence of new threats has increased requirements for attacking targets that are on-the-move and in conditions that rapidly change, where timeliness is of paramount concern. The new threats derive in part from terrorists and non-state actors who often act in unpredictable, unconventional ways, such as hiding among civilians or civilian facilities that would not ordinarily be military targets. Thus, the war on terrorism is predominantly a war on time-sensitive and time-critical targets. The Department of Defense (DOD) defines "time-sensitive" targets as those warranting immediate action because they present a clear and present danger to friendly forces or are considered high-value targets of opportunity. "Time-critical" targets are time-sensitive targets with an extremely limited window of vulnerability.[2]

Also contributing to the greater emphasis the U.S. military is placing on time-sensitive targeting is the fielding of new capabilities to find and neutralize time-sensitive targets (TSTs)[3]. These include kinetic kill using precision weapons and non-kinetic kill using information operations, as well as new forms of sensors. Some current examples are the *Joint STARS* aircraft and *Global Hawk* unmanned aerial vehicle (UAV), both equipped with high-resolution radars providing persistent, detailed coverage of mobile ground targets over wide areas. As even more capable platforms and sensors are developed and deployed, these new tools will enable the military to meet TST demands like never before.

But the ability to bring weapons to bear on fleeting targets in a sufficiently timely manner remains an unmet challenge.[4] By all accounts the problem is proving to be a difficult one, and fully satisfactory solutions seem agonizingly far away. While TSTs are often considered a challenge for air power, non-air assets, particularly Special Operations Forces, can certainly accomplish target discovery and destruction.[5] But their greater value, as demonstrated in combat operations in Afghanistan and Iraq, is likely to be cueing air assets to track and attack TSTs. **Section II and Appendix B contain some historical examples of the difficulties that have been encountered** by air and ground forces in attacking time-sensitive targets.

Section II notes that increasingly powerful sensors and more precise weapons have been developed and fielded, and that the deployment of unattended and uninhabited sensors and vehicles has added critical capabilities. But these new capabilities also have greatly added to the complexity of C2. Without appropriate C2 arrangements, even the best sensors and weapon systems will fail to realize their potential. As the U.S.

[1] Former Secretary of the Air Force James Roche "Roche Plots a Course," Air Force, October 2001, p. 67.

[2] See Joint Publication 3-60 (Targeting) and Aerospace C2 and ISR Center document 2000a, "Defeating Theater Time Critical Targets," Langley AFB, Virginia. 11 January 2000.

[3] In this paper we will use TST, in both singular and plural forms as a noun, and in normal government misuse as an adjective.

[4] Air Force Chief of Staff General John Jumper, AFA/AEF Air Warfare Symposium Transcripts, February 12, 2004. http://www.afa.org/media/scripts/Jumper 04aws.htm. Topping the most recent Air Force Air Combat Command's "Ten Most Wanted" list of identified innovation areas is "time sensitive targeting." This paper will focus principally on the attack of time-sensitive targets (TST) from the air, but much of the discussion is applicable to fires delivered from land or sea-based platforms, as well. And, although the paper provides examples of air power C2 capabilities, the discussion also applies to ground command and control organizations such as the Fire Support Cell.

[5] See Jonathan Jackson, "Solving the Problem of Time-Sensitive Targeting," Newport: Naval War College, February 2003.

military begins to take advantage of advances in networked C2 systems, sensors and weapon systems are being brought together to generate new time-sensitive targeting capabilities. Decision-making and organizational structure have evolved from an individual manned platform focus to service, joint, and now Coalition (or Combined) Air Operations Centers (CAOC).[6] As command and control capabilities bring the new tools to bear on the new demands, higher levels of centralized command and control, with integrated common operational depictions of the battle-space, are in the offing.

Because of the importance of the prosecution of TSTs in a global war on terrorism, these issues demand the attention of defense decision-makers. Thus, we intend this paper for readers who want to develop contributions to this new command and control task, or who are working on one part of the task and want help in seeing how their particular piece fits into a larger pattern, or who are charged with programming and budgeting actions involving C2 components and want to understand the relative value of various proposals bidding for funds.

To further that understanding, we will focus on what we will call "command and control arrangements." We chose this term to emphasize the essential human nature of command and control, albeit facilitated by technical capabilities and hobbled by technical limitations.[7]

To these ends the paper is written as a tutorial. Indeed, we might have titled it, "How to think about C2 for Time-Sensitive Targets." The paper lays out general needs and then develops specific technical and operational challenges to meeting those needs. It examines a number of specific combat situations in enough detail to point out how each situation needs some special arrangements. It develops a number of medium to large-scale command and control arrangements that show promise for dealing with the challenges. It shows how each of these specific arrangements devolves from more general "network-centric" arrangements.[8] It provides background on the challenges facing TST C2, historically as well as in present times, assuming that an understanding of these challenges is important to the discussion of solutions.

The paper gives much attention to describing three fundamental issues that arise in the prosecution of time-sensitive targets. They are as follows: a) each command entity has a different perspective on any TST, b) coordination among these command entities takes time and interferes with timely attack and c) the ability to mount timely attacks requires the persistent, often lavish allocation of both sensor assets and attack assets.

The paper will make use of the general technique of systems engineering. The paper will describe the entire process of C2 for time-sensitive targeting in a framework of three broad, but intensely interactive "functions." They are named *Sensor, Decider* and *Shooter*. Each of these functions plays several essential roles in supporting the more widely known "kill chain" as depicted in Box 1 in Section III of the paper. We need to emphasize that these functions are normally distributed across a number of platforms, organizations and personnel. **Section III describes some of the challenges that TST operations bring to each of these three functions.**

It is sometimes useful to associate a function with a specific platform or organization, but we ask the reader to adopt a broader perspective. Indeed, many of the difficulties of executing timely

6 With the disbanding of the Prince Sultan AOC in Saudi Arabia, there are presently five major AOCs: Al Udeid in Qatar, Osan in South Korea, Hickam in Hawaii, Davis-Monthan in Arizona, and Ramstein in Germany. An experimental center, CAOC-X, is in Langley AFB, Virginia. The AOC has also been designated as a weapons system, the AN/USQ-163 "Falconer," meaning that block improvements to the CAOC will be defined and scheduled, and a weapon system integrator selected to manage that process.

7 The former USJFCOM Commander viewed "command and control" as "how commanders and staffs use knowledge and the understanding it creates" to direct their forces—stressing the human and organizational aspects of knowledge superiority. Admiral Edmund Giambastiani, Remarks, AFCEA TechNet Conference, June 10, 2004 at http://www.jfcom.mil/newslink.htm. Students of the elements of command and control point out four dimensions of warfare. C2 sensors, systems, platforms and facilities exist in the *physical* dimension. Data collected, processed and stored lie in the *information* domain. Perception and understanding exist in the *cognitive* domain and C2 organizational processes belong in the *social* domain. Our analysis focuses principally in the physical and information areas, but our prescriptions spill over into the cognitive and social dimensions of C2. See "Command and Control Implications of Network-Centric Warfare", *AFRL Technology Horizons*, February 2005, also at http://www.afrlhorizons.com.

8 Two excellent brief studies on the concept of network-centric warfare are John Luddy, "The Challenge and Promise of Network-Centric Warfare," Washington, D.C.: Lexington Institute, February 2005, and the Office of Force Transformation, The Implementation of Network-Centric Warfare, Washington, D.C: USGPO, January 2005.

attacks on time-sensitive targets arise from interactions among the various platforms, organizations and personnel. On the other hand there are cases where adequate subsets of the *Sensor, Decider* and *Shooter* functions can all be carried out on one platform or even by one person. These cases do much to enhance timeliness, but for many reasons, alas, they are not always feasible. Therefore, **Section IV describes several C2 operating modes within the Network-Centric paradigm and how they facilitate TST under particular circumstances.**

Command and control for time-sensitive targets is a particularly complex task. Success is to be found in the careful harmonization of a large number of considerations by a large number of sensor entities, decision-making entities and action-taking entities—a "network-centric" approach. But in our embrace of "network-centric warfare,"[9] we caution that not just any network-centric arrangement will exploit the full promise of the genre. The nub of the problem is that all real networks have limitations: technical, operational, organizational and procedural. The imperative to make them better leads to piecemeal improvement, occasionally years in advance, often during on-going campaigns. **Section V outlines some of the infrastructure issues for networks to support TST C2.**

The paper then goes beyond describing command and control arrangements that show promise. It provides concrete advice on relevant aspects of military doctrine, technology, personnel training, systems engineering and procurement peculiar to time-sensitive targeting success. **This action-oriented advice is summarized in Section VI.**

[9] The US Department of Defense describes its strategy for implementing network-based warfare in "Network Centric Warfare: Creating a Decisive Warfighting Advantage," OSD, Office of Force Transformation, January 2004.

II. Time Sensitive Targeting: An Historical Sketch

In the 1920s, Italian General Giulio Douhet was perhaps the first to realize that the key to air power was targeting and that the choice of targets depended on a number of variables.[10] Today, we recognize that effective air power employment is inseparable from battlefield information and battlefield management. But until recently, the only way for aircraft to find targets on the move was to go out and look for them—aided by forward air controllers (FACs) in the air or on the ground—or have friendly ground forces report enemy troops in contact and request close air support. Thus, the use of modern combat aircraft against time-sensitive targets has not varied much over time in tactics, technology or procedures.

For example, Air Force Historian Dick Anderegg describes time-sensitive targeting in Vietnam as follows:

> Their [airborne forward air controllers'] mission was to find targets along the stretch of dirt highway known as Route 7…. Once they found a target, typically a truck or two, or perhaps a poorly hidden supply cache, they would rendezvous with other fighters, mark it with a white phosphorous smoke rocket, and then direct the other fighters' bombs onto the target. The scheme of fast FACs directing flights of other fighters onto small targets was the predominant interdiction tactic used in Laos along the Ho Chi Minh Trail, but it was very ineffective. Even the fast FAC familiar with his area had a difficult time finding targets, because he had to fly fast enough to survive anti-aircraft artillery and he had to fly high enough to stay out of the small arms fire… Even when the fast FAC did find a target, the fighters had a difficult time hitting it because their ordnance and delivery systems were ineffective.[11]

Not much progress was evident in the acquisition and attack of TST from Southeast Asia in the 1960s to the Persian Gulf in 1991. U.S. air campaign planners had anticipated that Iraq might launch Scud missiles against Israel in an attempt to split the coalition and provoke a wider war, and had targeted fixed Scud sites on the first night of *Desert Storm's* air campaign. The failure of these strikes prompted what came to be known as the "great Scud hunt"—the pursuit of mobile launchers capable of moving from hidden sites, firing, then scurrying away before aircraft could attack them. According to those who conducted a major after-action study of the conduct of the Gulf air war,

> The Scud hunt included continuous airborne surveillance of western and southern regions of Iraq, positioning strike aircraft within the Scud launch areas for more immediate targeting, attacks on communications links thought to be transmitting Scud launch authorization, attacks of suspected sites, and strikes against Scud protection and storage facilities. By war's end, nearly every type of strike and reconnaissance aircraft employed in the war participated in the attempt to bring this threat under control, but with scant evidence of success.[12]

U.S. air forces encountered many of the same kill-chain obstacles faced during the Gulf War during the 1999 NATO air campaign against Serbia in *Operation Allied Force*. Many camps have credited the war's victory to the use of air power, alone.[13] But in terms of efficiency, the air war against Serbia is more accurately considered a step backward when compared with Desert Storm, given that students of this conflict have concluded that the effort to attack time-sensitive targets from the air was essentially a failure.[14]

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[10] Phillip S. Meilinger, (ed.) The Paths of Heaven: The Evolution of Airpower Theory, Maxwell AFB Alabama: Air University Press, 1997, p.11.

[11] C. R. Anderegg, Sierra Hotel, Washington, D.C.: Air Force History and Museums Program, 2000. p. 3.

[12] Thomas Keaney and Eliot Cohen, Gulf War Air Power Summary Report, Air University: Maxwell AFB, Alabama, p. 17. RAND analyst Ben Lambeth has called the Scud hunt "the most frustrating and least effective aspect of the air war." Lambeth points out "despite more than 1400 strikes committed against Scud-related targets…no Scuds were proved to have been destroyed by coalition air power throughout the course of the operation…" The Transformation of American Air Power, p. 145.

[13] British historian John Keegan wrote, "Now there is a new date to fix on the calendar: June 3, 1999, when the capitulation of President Milosevic proved that a war can be won by air power alone." London Daily Telegraph, June 6, 1999.

[14] See Rebecca Grant, "True Blue: Behind the Kosovo Numbers Game," *Air Force*, August 2000, pp. 74-78.

The US and its NATO allies tried a number of approaches against pop-up ground targets, in what became known as "flex" targeting; few of them proved successful.[15] One of the reasons for this, as recorded by those inside the CAOC, was the flawed command and control arrangement. According to RAND analyst Ben Lambeth, C2 had been "hastily cobbled together at the operational and tactical levels once it became clear that NATO was committed to an air war for the long haul."[16] Although progress was made in prosecuting TST during the campaign, "those doing the 'flex' decision making during the first half of *Allied Force* did so with no apportionment or targeting guidance whatever," Lambeth writes.[17]

The weaknesses of C2 in executing TST attacks were further highlighted by the frustrations that commanders and controllers reportedly experienced even after the requisite architecture was put into place with the length of time involved in cycling critical targeting information from sensors to shooters.[18] This was primarily due to the lack of high-volume data links, resulting in delays measured in days to accurately locate Serbian air defense radars and to disseminate that information to the air planners.[19] Other obstacles to effective TST included a reliance on voice communications, rather than tactical data links, which while facilitating Allied participation, greatly slowed the kill chain.[20] Inefficient interfaces with the *Predator* unmanned air vehicle (UAV) and *Joint STARS* capabilities, and the "unsatisfactorily slow operating speed of SIPRNET," the classified internet link, further exacerbated the shortcomings.[21]

The problems of TST were multiplied in Serbia owing to requirements for minimizing collateral damage. As RAND's Lambeth put it, the commingling of Kosovar Albanian civilians with Serb military convoys and the extensive use of camouflage, concealment and deception techniques, "made air operations against both fixed and mobile targets far more difficult than they had been in *Desert Storm.*" In addition, the extended time it took to approve a target through a multitude of approving authorities and dual-redundant allied chain of command "frequently rendered operations against fleeting targets downright impossible…."[22]

Similar restrictions on combat identification (CID) and collateral damage followed the prosecution of time-sensitive targets in Afghanistan during *Operation Enduring Freedom* in 2001. But this time the process was smoothed considerably by the presence and ability of Special Operations Forces to locate and designate targets on the ground, as well as by a streamlined decision cycle. Aiding this streamlining was a permissive air environment over Afghanistan, with the speedy suppression of any air threat allowing sensor, tanker, and special operations aircraft to operate directly over the engagement zone, thereby accelerating the pace of TST operations. Given the relatively few valuable fixed targets in the country and the long distances U.S. aircraft had to traverse to operate in the region, about 80 percent of the targets struck by U.S. air forces in Afghanistan were provided to the crews after they had become airborne.[23]

A significant TST lesson drawn from Afghanistan was that the sensor-to-shooter links were now communicating faster than could be supported by a C2 process involving evaluation of targets by numerous decision levels. In several cases the *Predator* UAV with streaming real-time video was linked directly to an AC-130 gunship. But owing to the sensitive nature of some of the targets and guidance to avoid civilian casualties, commanders

[15] Ben Lambeth lists three approaches: "flex" sorties designated in the Air Tasking Order (ATO), redirecting aircraft already enroute to strike fixed targets, and dedicated sorties launched into holding orbits for on-call strikes. NATO's Air War for Kosovo, p. 122.

[16] Lambeth, NATO's Air War for Kosovo, p. 124.

[17] Ibid.

[18] Lambeth, American Air Power, p. 202.

[19] Ibid.

[20] Ibid. p. 203

[21] American Air Power, p. 203. In addition, the tight rules of engagement restrictions meant that aircrews had to get clearance for any attack from the CAOC, which often meant a second source of target verification, such as a UAV video feed, would be required. And of course, NATO aircrews were up against a wily adversary that had learned lessons from American tactics and capabilities employed in the Gulf War. See NATO's Air War for Kosovo, p. 126.

[22] Lambeth, NATO's Air War for Kosovo, pp. 212-213.

[23] See John A. Tirpak, "Enduring Freedom," Air Force, February 2002 pp. 32-39, and Rebecca Grant, "An Air War like no Other," Air Force, November 2002, pp. 30-37.

did not always provide clearance to fire in time to be most effective. One report noted that Central Command required "almost every significant target involving al Qaeda and Taliban leadership be approved by officials there, or even by more senior officials in Washington."[24]

Frequently, this delay in effective time-sensitive targeting and attacks resulted from the strict rules of engagement mandating commanders positively identify all targets before launching attacks against them. Even with the "machine-to-machine" interface of a *Predator* and a gunship, for example, a requirement remained to get a second source of data for independent verification.[25] The facts of these episodes, including an aborted attack on a building allegedly housing Mullah Omar, the top Taliban leader, are somewhat murky. But, as Air Force analyst Rebecca Grant concluded, "the coordination required for tracking and killing a time-sensitive target was not smooth."[26]

What did work in Afghanistan, and evidently in *Operation Iraqi Freedom* as well, was the deployment of Special Operations Forces (SOF) divided into small teams to facilitate the delivery of "on-call" firepower against mobile and time-sensitive targets. In one widely reported incident, a B-52 bomber attacked a Taliban military outpost "within 20 minutes of a call for assistance."[27] Clearly, the combat engagement of troops in the open did not necessitate the top-level oversight, as did targets in urban areas where collateral damage was a much greater concern. Even under these improved conditions for TST, however, serious limitations were observed. Intelligence, surveillance and reconnaissance (ISR) assets and SOF were limited in numbers and capabilities, the rugged terrain and inclement weather posed difficulties for sensors, and the CAOC itself experienced simultaneous disconnects among the people, process, system and organizations.[28]

A number of factors contributed to the increased use and effectiveness of time-sensitive targeting during *Operation Iraqi Freedom* (OIF). From June 2002 until the initiation of hostilities in March 2003, coalition aircraft increased their presence and activity in the northern and southern "No Fly Zones" to facilitate the early achievement of air superiority over much of Iraq. Similarly, a joint concept of air-ground operations had been developed and practiced with forward air controllers and unmanned battlespace awareness assets constantly airborne, with stacks of fighter and bomber aircraft available to respond to short notice requests for air power from the Coalition Land Force Component Commander.[29] To further quicken response time, the Coalition Air Component Commander established a "time-sensitive targeting cell" in the CAOC at Prince Sultan Air Base. The results were attacks on 156 time-sensitive targets, 50 of which were dedicated to strikes on Iraqi leadership. In addition, another 686 "dynamic" targets—meaning those that were mobile and of high importance—were attacked using the same command and control mechanisms, but by diverting airborne aircraft from other pre-assigned missions.[30] Despite this C2 emphasis, however, most targets took from one to two hours to strike owing to the intense scrutiny demanded to evaluate and minimize prospective collateral damage.

In most post-OIF analyses, time-sensitive targeting was categorized as a capability demonstrating improved effectiveness, but still needing enhancement. Particularly lacking were ISR planning, execution and assessment, to include a common visualization capability for all ISR and strike assets available. The requirement for positive identification before engaging a TST, (particularly of dual-use systems such as pick-up trucks and small paramilitary units mingling with civilians) proved especially demanding. Moreover, the

[24] "Target Approval Delays Cost Air Force Key Hits," Washington Post, November 18, 2001, p. 1.

[25] "Enduring Freedom Allowed 'Machine-to-Machine' Interfaces," Inside the Air Force, September 13, 2002, p. 1.

[26] "An Air War Like No Other," p. 34.

[27] Ibid. p. 36.

[28] PSAB CAOC Tiger Team Interim report. The CAOC team also noted CENTAF dissatisfaction with the ability of reachback organizations to provide near real-time support, specifically for time-critical targeting. See "Despite Complaints, USAF Declared Saudi-based CAOC "Fully Capable," Air Force, April 2003, p. 12.

[29] Group Captain Chris Finn, "Air Aspects of Operation Iraqi Freedom," Air Power Review, Winter 2003, p.6.

[30] US CENTAF Operation Iraqi Freedom briefing, "By the Numbers," 30 April 2003. See also Robert S. Dudney, "The Gulf War II Air Campaign, by the Numbers," Air Force, July 2003, pp. 36-42, and "Moseley: Time Sensitive Targeting Improved from Afghanistan to Iraq," Inside the Air Force, June 20, 2003, p. 1. A USCENTCOM "fusion cell" worked ATO-related TSTs and the CACC cell focused on non-ATO TSTs. There were at least two additional TST cells as well. The numbers documented here attest to the relative importance given to attacking TST, rather than providing any statistically significant measure of weight of effort or effectiveness when compared with other recent campaigns.

multiple TST cells developed along service lines to meet these challenges created more stove-piping than joint-service integration. Also noted as requiring improvement was all-weather geo-location to obtain targetable coordinates on a dynamic battlefield. Inadequate communications links, incomplete bomb damage assessment (BDA), and poor dynamic airspace management all contributed to shortfalls in the TST process.[31] The importance of rapid fusion of information from distinct sources to support TST operations was emphasized repeatedly in after-action reports.

There is room for improvement in the command and control of TST attacks.

This brief sketch of past efforts at time-sensitive targeting suggests some important trends that merit further examination. The U.S. has become increasingly focused on finding and attacking fleeting targets, and has developed tactics, techniques and organizations to prosecute them. Still there is room for improvement in the command and control of TST attacks. Every TST situation is different, and C2 arrangements are often fitted, temporarily, to meet a tactical need. The next section discusses the challenges facing the components of the kill chain to aid understanding of how C2 arrangements can be improved and streamlined to meet the requirements of diverse TST scenarios.[32]

[31] Mike Carpenter, "OIF Air Operations" undated briefing Langley AFB, VA.

[32] An idealized vision of what a C2 arrangement optimized for the precise engagement of TSTs is presented in Appendix B.

III. C2 for TST Challenges: Sensor, Shooter, Decider

At the top level, implications for C2 derived from the preceding Section II can be summarized as follows:

First, the action of attacking time-sensitive targets is inherently difficult and complex. It involves geographically distributed and technically advanced equipment. It requires personnel trained to perform technical, demanding tasks. An essential command function is to develop a harmonious organization of personnel and equipment to execute the commander's intent.

Second, the need to coordinate actions throughout a theater of combat is in conflict with the need to act quickly. Coordination takes time. The more inputs that are included, and the more they are dispersed, the more time is added. An essential command function is to adjudicate the conflict between timeliness and coordination.

Third, timely prosecution of time-sensitive targets demands the allocation of sensor platforms and shooter platforms to loitering modes in the vicinity of where such targets are expected to appear. This allocation of scarce resources competes with the efficient and effective prosecution of the main combat action. Moreover, these loitering platforms may well be exposed to hostile action. An essential command function is to weigh the resource allocation cost and hostile fire risk against the value of timely attack.

Within those broad command functions, this section will examine some detailed challenges to the subsidiary functions that we call the *sensor-decider-shooter* framework. We will discuss some key challenges faced by each function as it strives to support the timely, accurate execution of the "Kill Chain." There are, we note, several more or less equivalent versions of the "Kill Chain." The one depicted in Figure 1 has seven steps.

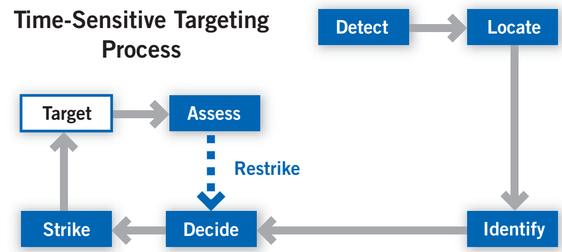

Figure 1. The Kill Chain.

Another draft Joint Kill Chain fits TST into a four-phase process of "Acquire, Decide, Strike, Assess." The much-quoted Air Force version uses "find, fix, track, target, engage, assess."[33] This paper, with apologies for adding to the nomenclature pile, uses a three function breakdown of *Sensor, Decider* and *Shooter*. These three functions encompass the activities of the kill chain and much more.

There are other metrics associated with the attack process, such as the efficient use of resources, reducing platform losses due to adversary actions, and overall number of targets killed per day of combat. Indeed, these other metrics so dominated the scene in the past that many believed that time-sensitive target capabilities were being slighted or altogether ignored.

The kill-chain notion was invented in large measure to draw attention to the need to take special efforts to improve timeliness of attack as a combat goal.

In the discussion to follow, we will use some concepts and nomenclature from systems engineering. In particular, we will use the concept of a "function." In systems engineering a function is a set of activities that accomplishes a specified result. Important functions typically are performed by the combined and harmonized efforts of several persons and organizations distributed

[33] See Appendix B

over several geographical locations and mobile platforms and using many types of equipment. The system engineering design process is the subdivision of an overall function into sub-functions and the allocation of the sub-functions to particular organizations, places and equipment.

For example, the *Sensor* function encompasses the collection, processing, fusion, storage and dissemination of data from many sensors of diverse types and locations. It also encompasses the management of the location and technical settings of these diverse sensors. This management sub-function is executed in response to the on-going combat situation, the commander's intent, and specific directions and requests from the *Decider* and *Shooter* functions.

The irritating collection of disparate sensors that show up is the unavoidable by-product of rapid advances in capability of the new over the old.

Similarly, the *Decider* function will have a major set of activities performed within the Coalition Air Operations Center, but within the CAOC these activities will be distributed over many individuals operating with many distinct computer programs.[34] Moreover, these individuals will be relying upon other individuals in other locations for supporting sub-functions (e.g., "reach back" to CONUS).

With that prelude, let us now map the *Sensor-Decider-Shooter* framework of "functions" onto the Kill Chain depicted in Figure 1. The *Sensor* function covers most of the "detect, locate and identify" links, as well as part of "track" process if the target is mobile. The *Decider* function is centered on the "decide and assess" processes. The *Shooter* function covers the "strike" sequence and utilizes processed information from the *Sensor* and *Decider* function to re-strike as required.

In the *Sensor-Decider-Shooter* framework, processed intelligence is considered as a resource to be called upon by each of the three functions as needed. For example, the "detect" link clearly needs intelligence as to where to look for targets, what targets to look for, and what impediments to expect from nature or actions of the adversary. Similarly, communications and navigation utilities are additional resources to be called upon as needed. To be sure, the reliability, timeliness, accuracy and availability of these background resources will affect to varying degrees the performance of each function in the *Sensor-Decider-Shooter* framework.

Challenges for the *Sensor* Function

Based on the preceding general discussion, we can now examine the part of the general *Sensor* function related to time-sensitive targets.

The collection of data from sensors supporting TST has some critical difficulties. Such sensors are inherently ambiguous.[35] Such sensors are traditionally in short supply. Such sensors are almost always provided to the combat commander in unmatched sets of diverse capability with various communication modes.

Some organizers would dream of imposing discipline to clean up this act. But the world of sensors is a fast moving, technology-based world. The irritating collection of disparate sensors that show up is the unavoidable by-product of rapid advances in capability of the new over the old. Only by refusing the benefit of the new could one be confident of maintaining discipline.

In the authors' view, the path ahead lies in promoting the skill of Sensor Management to orchestrate our growing array of sensor suites. It is a big job, complex, and contains both operational and technical aspects. Already we see combat staffs realigning the traditional J2 and J3

[34] In *Operation Desert Storm*, 2458 people were employed in the CAOC supporting about 2000 sorties per day. 2467 people populated the CAOC during Operation Allied Force in support of 800 sorties/day. 1730 people were estimated for a CAOC to direct a major theater air campaign in the CENTCOM AOR. The CAOC has been described as an enterprise "composed of many different systems that are manually intensive." There are 48 separate systems and 50 communications interfaces in a typical AOC. Department of Defense, PSAB CAOC Tiger Team Report, July 8, 2002.

[35] A sensor will always have some probability of detection less than unity and some probability of a false report greater than zero. Moreover, most current sensors cannot distinguish vehicle types with certainty.

functions to better address the Sensor Management challenges. Sensors, be they airborne, space-based or grounded, can be collecting useful data almost continuously. In a networked environment, every node can be a sensor in the generic sense. Recent combat activities have highlighted the valuable role of Special Operations Forces as providers of data not available otherwise.

The skill of Sensor Management is sufficiently complex as to warrant formal training, selection and assignment processes. Fortunately, it is amenable to modern methods of simulation to aid in the training. Such simulation allows students to become familiar with a wide array of sensor types and combat situations in a positive learning environment. Similar simulation methods can be incorporated in operational facilities to allow incoming personnel to quickly become familiar with the particular sensors and operational situations at hand. They can also serve to speed the incorporation of new sensors and to develop tactics and techniques to respond to new operational situations.

A common response to sensor ambiguity is to demand that some targets be "confirmed" by a second sensor type prior to issuing attack authorization. To be sure, this reduces ambiguity and error in general, but it by no means eliminates either. Often a look by the same sensor type, but from another direction would serve as well or better. However it is done, the management of sensor looks on a given target is a big job for the command and control arrangement. It can be more demanding than the management of weapon attacks themselves.

For C2 of TST, the request for a "second look"—even if it is just asking another analyst to review the original image—is inevitably a source of delay in the kill chain. The delay can be considerable if the call is made only after time has been used to process the data from the first look, or if a second sensor is not yet in a position to sense the target at issue. We will call this a "lateral delay" as it requires an action to the side of the standard depiction of the "kill chain" as a linear process, as shown in Figure 1.

It is widely understood that the *Sensor* function includes accurate geo-location of targets in addition to target recognition, identification, tracking and efficient, effective search. This challenge grows with the increasing precision of weapon guidance and the increasing precision of the supporting global navigation aids. In recent years many technical advances have been made, particularly in geo-registration[36] of images from tactical sensors. However, full integration of these techniques into the overall C2 structure remains a challenge.

Geo-registration provides a solid basis for fusing the information content of diverse sensors looking at the same target area. But all sensors provide much more information than geo-location alone. The challenge is to fuse these broader data sets, to do it in a timely manner and to add value to the product for the *Decider* function.

For example, certain types of airborne radars can measure, within some accuracy, the height, length and width of a vehicle, the speed of the vehicle on the flat and on hills and curves, and its acceleration and deceleration. They can also measure the radar return as a function of angle off the nose of the target vehicle. By comparing these to known characteristics of known vehicles, one can infer vehicle type, albeit with some ambiguity.

A particular critical aspect of information fusion is encompassed during the "track" link in the kill chain. Monitoring a moving vehicle of interest can be thought of as the fusion of successive geo-location reports into one coherent record, commonly called a "track." But note that "where a track has been," and "where it appears to be going toward" add valuable content to the track, may disclose the vehicle's mission, and may establish its value as a target.

Moreover, if another sensor has a look at the vehicle somewhere along the track, and thereby establishes vehicle type, then it is useful to associate those data with the track into the future. Clearly there is value in being able to keep the separate identities of tracks that cross. In this regard sensors that provide continuity of signature are more valuable than those that merely report "blobs."

[36] "Geo-registration" determines the location of all parts of an image with respect to a predetermined grid coordinate system, such as latitude and longitude, and may include determination of altitude above a reference 3-dimensional shape, such as the standard geoid, at least for selected points of interest.

But all of this detailed analysis and fusion of detailed sensor output will take time, particularly if personnel are not well trained and processes are not well-supported.

Another sensor challenge occurs after the attack—find out what happened. In the past, it was commonplace to rely upon post-strike photography for battle damage assessment. But that method was always slow and disrupted by weather. Many modern munitions do not provide much of a post-attack signature for such imagery. On the other hand, these modern weapons have, or technically could have, the ability to radio back very valuable and accurate data, such as the likely point of impact. And there is growing interest in ground-emplaced sensors to monitor targets both pre- and post-strike. Collection and processing of these data for assessment is another challenge.

Finally, it is well to remember that the sensors that serve TST also serve other activities. Indeed, for many of these sensors, the originator of the sensor requirement takes an unduly parochial "ownership" view of the fielded sensor. The commander, of course, deserves the product of whatever sensor can advance his mission. Thus, a key task of Sensor Management is to make proper arrangements to serve all customers and to adjudicate the inevitable conflicts as they arise.

Challenges for the *Shooter* Function

From a command and control perspective, the coordination of multiple shooter platforms operating in the same battle space is a long-standing and essential challenge. In the TST context, multiple sensor platforms must also be coordinated. Appendix A to this paper describes several stylized coordination techniques and combat situations. Two conclusions should be drawn from a review of Appendix A. First, coordination among multiple shooter platforms and multiple sensor platforms can become very complex as the number of platforms increases. Even a handful of platforms is a big number in this context. Second, even modest levels of coordination are in tension with timely delivery of weapons.

From the *Shooter* function perspective the underlying challenge for time-sensitive targeting is that the function is often performed in a cramped, maneuvering platform, while at risk to hostile fire. At its core there is only one task for the shooter—place the cursor over the target. But there are at least four other full-time tasks going on concurrently: a) operate the platform properly and safely, b) survive hostile fire through management of countermeasures and maneuver, c) manage on-board sensors and d) manage the preparation and launch of weapons toward their targets.

Thus workload management is a major challenge. Modern aircraft incorporate increased automation, particularly for "old" activities where the experience is long enough and deep enough to support reliable automation. But for the "new" activities, generally associated with the new sensors and new weapons, automation may be rudimentary, unreliable, or require intensive monitoring and operator intervention.

Today, a major challenge for *Shooter* personnel is real time geo-registration of images from on-board sensors with stored, processed images incorporating fused target information. To be sure, applicable techniques are getting better, but more progress is possible and needed.

Another challenge is that the preferred tactics and procedures for defense suppression and avoidance are often not those most suitable for timely and accurate delivery of weapons. Even if alternative tactics and procedures, that is, for different defense environments,[37] have been learned, there is always ambiguity as to which defense environment exists for any particular target set, location and time.

Some authorizations come to the shooter as "conditional." That is, release authority is granted, provided certain conditions are met, conditions that the crew is thought to be in a position to verify. A common condition is for the weapon delivery crew to establish contact with friendly forces in the target vicinity. But one must be mindful that meeting such conditions comes at a price of delay. It is another instance of "lateral

[37] The term "defense environment" is commonly used to denote the array (numbers and types) of opposing air defense equipment present and active in a geographical region of interest.

delay." To be sure, there may be no other practical method for resolving some residual ambiguity, and in many cases the value of resolution is worth the delay.

Challenges for the *Decider* Function

At its core, the *Decider* function deploys sensors to collect data on targets, chooses targets and directs shooters to attack them. But TST activities take place within an ongoing, generally much larger, combat operation. Accordingly, the demanding task of the *Decider* function, the one that takes the most people and the most time, is to coordinate the TST activities with the rest of the campaign.

That is, the *Decider* function needs to accomplish all of the coordination needed to ensure that the TST activities, both sensor and shooter related, a) advance the commander's intent to a significant extent, b) do not unduly interfere with the efforts of other combat elements to do the same, c) do not deviate from sanctioned, high level, politico-military rules of engagement and d) do not unduly risk striking a wrong, sensitive target or inflicting unwanted collateral damage.

But there is an unavoidable and inherent tension between adequate coordination and achievable timeliness. A well-organized and executed *Decider* function strives to find ways to achieve "adequate" coordination while striving for the desired timeliness for the kill chain. One powerful technique is truncation. That is, one can judiciously decide which sections of the whole coordination structure can safely be eliminated for particular attacks under particular circumstances. For example, detailed, weapon-by-weapon, target-by-target collateral damage estimates might be waived for a TST against missile launchers in an open desert area.

A good *Decider* function should also work in an orderly fashion even if the target set attracts the involvement of higher command echelons into the decision-making. Attacks on opposing command structures frequently have this challenge.

Command entities typically develop sets of rules to guide personnel in implementing the *Decider* function. These have different nomenclature and structure depending upon the military and political situation. For this paper we will use the term "Rules of Engagement" to denote a general set of rules applicable to many targets over many days. We will use the term "Attack Order" to denote a refinement of the more general "Rules of Engagement" that pertains to the attack of a particular set of targets by a particular set of attacking platforms.

The "Attack Order" for the actual release of weapons on legitimate targets is the end goal of the *Decider* function. The overall purpose of the "Attack Order" is to connect the specific act of releasing this particular weapon on this particular target to everything else that is going on in the combat arena and in the wider political context. It seeks to coordinate these weapon releases with other concurrent operations, furthering the commander's intent and avoiding fratricide and unwarranted collateral damage.

It focuses the coordination activities in the *Decider* function and focuses the weapon delivery activities in the *Shooter* platform crew. This division of activities will not always be complete. Sometimes the Attack Order will be a very broad "mission-type order," allowing substantial discretion to the crew. Sometimes, as the combat situation may direct, it will be very narrow, with little discretion allowed the crew apart from weapon delivery, per se.

See Box 1 for typical contents of an "Attack Order."

Box 1 — *Typical Contents of an Adequate Attack Order*

- **Geographical extent of the authority**
- **Time duration for the authority**
- **Types of targets authorized**
- **The standard for target identification**
- **Types of weapons that can be used**
- **Further conditions that must be met,**
  - **such as coordination between the Shooter and friendly forces in the target vicinity**
- **The level of risk to the delivery platform that these targets warrant**

Clarity, completeness, and consistency with current Rules of Engagement, proven concepts of operation and prior training are essential characteristics of an Attack Order. As was discussed in the *Shooter* challenges section, there is great value in having the Attack Order in such a form as to minimize the workload on the crew of the shooter weapon delivery platform. For example, the "level of risk" could be expressed in terms of the delivery tactic to be used. But to be complete, there needs to be direction, such as aborting the attack, if unexpected defenses are encountered in the target area. These kinds of direct instructions are preferred over more general instructions that amount to little more than "be careful."

There is a corresponding "Collection Order" for sensor platforms. This order typically directs the efficient use of scarce collection resources, protection of sensor platforms from hostile action and conformance with political over-flight protocols. The proper construction of a Collection Order is part of the Sensor Management skill set described above. As such, its implementation could well occur within the *Sensor* function.

There are combat situations where destruction of a legitimate, time-sensitive target is not the preferred course of action, at least for the moment.

Returning the discussion to higher levels in the *Decider* function, we note that there are combat situations where destruction of a legitimate, time-sensitive target is not the preferred course of action, at least for the moment. See Box 2 for some examples.

Clearly, such deferrals, though they bear on the attack of individual time-sensitive targets, involve consideration of data not directly associated with an individual target. Such deliberate deferrals are more common than most observers expect. They are often not explained to personnel and observers outside of the *Decider* function. As such they lead outsiders to misjudge the ability of the C2 to accomplish timely attacks. Unfortunately, such misjudgments have led to improper post-action recriminations.

Box 2 — ***Some Reasons to Defer Attacks on Particular Targets***

1. **There may be interference with other operations, for example with the complex operations now routinely being undertaken in collaboration with Special Forces.**
2. **There may be expectations of higher target value, visibility or vulnerability later.**
3. **There may be a need for a second sensor look, for reasons as described above or to provide a "cover" if the first look is from a covert sensor we do not wish to compromise.**
4. **There may be expectations that we can extract further intelligence by leaving the target intact, for example, by following a mobile target to its hiding place.**
5. **There may be reason to include this target into a later, multi-target, effects-based attack.**

Given that a particular physical entity has become a "target of interest," there is a need to choose an appropriate type of weapon with which to attack that target. The optimization process that would truly provide the "best choice" is daunting, not only due to the enormous range of considerations, but also because much of the relevant data is ambiguous, unknown or even unknowable. Nonetheless, the command and control arrangement has to make a choice and do it in a timely manner.

A growing part of the *Decider* function is to provide reliable collateral damage estimates (CDE) that would ensue from candidate weapon-target pairings. In one sense this is just one more complication of choosing the best weapon for the target. In summary, it is a challenge a) because the CDE requirement is somewhat new, b) because it often involves entities with high political interest and c) because the underlying technical data is more uncertain than the data for direct damage. We will not discuss these CDE challenges further.

Management of sortie scheduling is another challenge. Sortie preparation takes place hours before takeoff and weapons delivery can take place hours after takeoff. For many target systems, much less individual targets, hours are an eternity. So the driving modality cannot always be "launch sorties to meet (known) target demand." Sometimes, if the friendly ground forces have a planned operation to which they are committed, or if there is incontrovertible intelligence of an imminent adversary operation, then pre-planned sortie generation can be confidently tied to known data.

But usually there has to be some level of uncertainty as to the relative value of a sortie launch at one time versus another.. The penalties for being right and being wrong must be weighed against the values for being right and being wrong. This calculation and judgment process is one important part of the command and control of the sortie generation process. At a more mundane level there is the sheer management of sortie generation as an industrial process of matching demand and supply of parts, servicing, crew rest, weapons and all the rest. The complexity and difficulty of this task varies with the scale of the combat operation.

The loitering modes commonly used in TST operations present a special difficulty. Loitering ties up scarce resources. It potentially exposes the aircraft to hostile action. The *Decider* challenge is to collect, process and display the data needed to adjudicate the value of continued loiter and the relative value of loitering in particular locations.

Another task for the *Decider* function is to monitor the ongoing operation in order to discern needed adjustments and to prepare for future operations. Such monitoring includes, of course, looking for adversary activities that are aimed at degrading our sensors, our shooters and our networks. The customers for this *Decider* task are outside of the kill chain and are typically at higher command echelons. The challenge is to identify adverse events promptly and accurately. Fortunately, modern communications and data processing permit higher standards of performance in this arena.[38]

Finally, the *Decider* function needs to adapt rapidly to changes in the operational situation as changes are made by the adversary and as we make our own changes in activity patterns. This flexibility puts additional demands on training of personnel. Active collaboration among personnel in widely separated command entities is a key enabler of such flexibility.

[38] Air Force General Hal Hornburg, AFA/AEF Air Warfare Symposium Transcripts, Feb 13, 2004. http://www.afa.org/media/scripts/Hornburg 04aws.html

IV. C2 Arrangements for TST Attack: Decider-Led, Sensor-Led, Shooter-Led

In this section we will explore how the three functions—*Decider, Sensor* and *Shooter*—could be implemented in a Network Centric C2 System in order to accomplish attacks on time-sensitive targets.[39] That is, we seek to reduce the time delays associated with the C2 system to well below those of the weapon delivery. Moreover, we will focus on situations where both sensor and shooter platforms are deployed in loitering modes. This is desired so that the sensors can observe the battlespace more or less continuously and the shooters can be at or quickly move to a suitable location from which to launch weapons.

Network-Centric Command and Control

The following diagram labeled "Network Centric" is a schematic intended to illustrate the relationships among the three functions—*Decider, Sensor* and *Shooter*—and another function which we will call *Other Information Sources*. That is, we will henceforth in this paper restrict the *Sensor* function to systems that collect more or less real-time information about the battlefield. *Other Information Sources* will include items such as normal intelligence production, weather, technical support for sensors and shooters and communications with higher headquarters.

The main point of the "Network Centric" diagram is that each of the three functions—*Decider, Sensor* and *Shooter*—is "well-connected" to each other and to *Other Information Sources*. We denote the term "well-connected" by two-ended arrows to emphasize the ability of each function to both push and pull information. By "ability" we mean that the functions have been empowered to do so and that the network infrastructure can in fact provide the technical means.

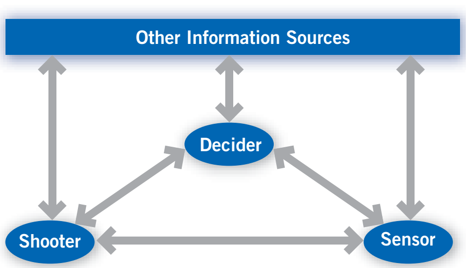

Figure 2. Network Centric

One characteristic of a *Network-Centric* Command and Control system is its ability to operate, for particular episodes and tasks, in C2 modes tailored to the operational situation at hand. For the task of C2 for TST, timeliness is usually enhanced by restricting the actions, and communications, to a few necessary persons. Indeed, time-sensitive targets are often defined as targets whose urgency is such that certain normal coordination activities can be curtailed or waived.

The remainder of this section will explore several broad C2 "operating modes" that should be available within a well-constructed Network Centric C2 System. They are called "operating modes" because they are temporary in nature. They are set up to deal with ever changing operational situations. For example, as the moment of attack approaches, broad situation awareness has to give way to focused situation awareness until the attack is successfully prosecuted. But then, in the flick of a moment, circumstances can change so that broader situation awareness becomes essential for set up of the next attack and, often, for survival.

This ability to adjust to different operating modes is constrained by two realities: a) the technical capabilities of the network infrastructure, the shooter systems and the sensor systems as they exist and b) the operational situation including adversary capabilities, nature of the battle and the objectives of both sides. Understanding these

[39] Former Air Force Chief of Staff General John Jumper referred to "time of flight" TST, meaning he wanted targets hit in the amount of time it takes for weapons delivery. Depending on the weapon, that could be less than one minute.

realities is a *Decider* task that generally requires a lot of collaboration among personnel having detailed, but not comprehensive knowledge. The C2 system needs to provide support for such collaboration. Each combat situation and C2 infrastructure will have its own particular constraints.

Each combat situation and C2 infrastructure will have its own particular constraints.

Appendix A to this paper lays out some simple, stylized examples of C2 operating modes. They provide some concrete examples for the reader. The main text will explore three generic operating modes that deliberately suppress some of the connectivity of a fully collaborative, network-centric C2 system in an effort to improve timeliness.

Decider-Led Mode

We will start our exploration with a C2 operating mode in which the *Decider* function takes undisputed lead. As depicted in the diagram below, the *Shooter* and *Sensor* functions no longer communicate directly with each other, nor do they communicate directly with *Other Information Sources*. They still have the ability to communicate indirectly through the *Decider* function. So, in this mode, the *Decider* function controls not only decisions and direction, but also information flow.

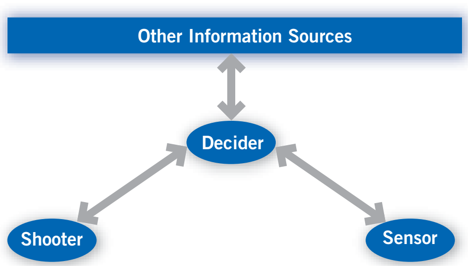

Figure 3. Decider-Led Mode

A *Decider-Led* operating mode is commonly used and generally effective in carrying out large campaigns against fixed targets. The *Decider* function, mostly housed in a large CAOC facility, starts from a statement of the overall strategic objective of the campaign, the desired role of air operations in carrying out that objective, the assets available, and other comparable level considerations. From this foundation the *Decider* function develops an overall plan for air operations of all types, to include subordinate objectives, schedules for major phases, allocation of resources, measures of success and estimates of outcomes.

Within that framework, an attack plan for ground targets is developed, to include arrangements for coordination with ground, naval and space forces. Also within that framework the *Decider* function places requirements for targeting information on the sensor assets and their operating organizations. In the nomenclature of this paper, these would be called *Collection Orders*.

With some initial understanding of the target structure, a ground attack plan is developed. Then attack sorties are allocated and scheduled to fulfill the ground attack plan. We know that product most commonly as the Air Tasking Order (ATO). In the nomenclature of this paper, that product would be a set of *Attack Orders* plus the necessary instructions to support elements such as refueling tankers, electronic countermeasures (ECM) support and so forth.

To be sure, there are plenty of feedback loops in the process as capabilities are matched against desired actions and adjustments are made to accommodate unanticipated opportunities and shortfalls. But the overall flow of activities is a measured one, led by the *Decider* function, with the *Sensor* and *Shooter* functions responding to the *Decider* function.

In many campaigns of the past, the bulk of the attack activity planned in the ATO has been against fixed ground targets. In such cases it is common, effective and efficient to adopt a *Decider-Led* C2 mode to carry out the main attack on these fixed ground targets. One main reason is that the three major activities of attack (e.g., target development, attack planning and attack execution) tend to take place sequentially, typically over a few days, and somewhat independently. Therefore, allowing the *Decider* function to control the process, including the information flow, does not cause any difficulty. Indeed, it is common for just a very few individuals to have a comprehensive grasp of the entire operation.

In most campaigns, there are time-sensitive targeting requirements that need to be fulfilled concurrently within the context of this larger activity devoted to fixed targets and using the same assets. These TST requirements may be very much at odds with the fundamentals of the fixed-target attack plan. Typically in TST attacks, the major attack activities take place concurrently, typically within an hour. They are not spread over days as for the corresponding fixed target activities. Moreover, there is typically a need for *Sensor* and *Shooter* entities to have direct, intense collaboration on both operational and technical matters. A *Decider–Led* operating mode does not provide for such direct, real-time communication and collaboration.

The current generation of air leaders, to its everlasting credit, has decided to make a headlong run at the time-sensitive targeting problem.

From the *Decider* function point of view, the large ground attack plan is the *main plan*. It is what most of the personnel in the CAOC work long and hard to develop. It is what demands most of the assets. It is the plan that brings a multitude of considerations and co-ordinations into a coherent, effective, efficient and harmonious whole. Indeed, once the main, pre-planned attack plan is in place, there is a huge aversion to any change. Change introduces friction, often in unexpected ways and to a surprisingly large degree. If the plan was developed using a "federated" work plan, with individual targeting cells working on their own allocations of targets and sorties, then the disruption of anything cutting across these cells is all the larger.

The effort to attack time-sensitive targets, if pursued with vigor using a lot of loiter, threatens to disrupt the main plan. It takes aircraft assets away and puts them in "endless" loiter, just waiting for time-sensitive targets to appear. It wants to have authorizations to attack fleeting targets whenever and wherever they appear without regard for what else is going on. It wants to fly both scarce sensor platforms and otherwise useful shooter platforms into harm's way, thus risking the force needed for the main plan. And it wants to do this on the off chance that time-sensitive targets will appear in adequate numbers and value to matter to the overall campaign. This "loiter" school of battle management and resource allocation has traditionally run counter to the "sortie generation" approach, which is natural for campaigns against non-time-sensitive targets.

The tension is palpable. It is no wonder that efforts to improve time-sensitive targeting have languished for many years. But the current generation of air leaders has decided, to its everlasting credit, to make a headlong run at the time-sensitive targeting problem. They have found that there are many individual impediments, but also very many opportunities for improvement. Progress has been made by working each issue carefully and thoroughly. Quite clearly, the advent of precision munitions in affordable quantities has helped to adjust this mindset, vastly improving the number of targets destroyed per attack sortie.

A *Decider-Led* C2 Mode will always be present at the upper, strategic level of the campaign. This is true even if the TST activities at the lower level utilize another operating mode in the interest of timeliness.

But before discussing these other operating modes, we should point to two special TST situations where a *Decider-Led* mode is a natural fit.

First, if new intelligence should arrive that indicates that the extant *Attack Orders* and *Collection Orders* are no longer appropriate, then the *Decider* function would intervene by countermanding the extant orders and issuing new ones.

Second, if the relevant information about the TST operation is arriving primarily at the *Decider* function, say from national level sources, then the *Decider* function would naturally need to play a continuing, important role. There are two somewhat extreme cases: a) If the indicated TST attack is small and very politically sensitive, then the *Decider-Led* mode could properly remain in place throughout the attack execution. Indeed, the mode could continue to involve higher headquarters quite intimately. b) If the new information merely enriches the TST operation, e.g., by providing confirmative information not available from real-time sensors, then the *Decider* function should simply package it in a useful form and send it as an amendment to the extant *Attack Orders* and *Collection Orders*. Clearly, there could be intermediate cases where the proper actions would be more complex.

Turning to other operating modes, we will now explore *Sensor-Led* and *Shooter-Led* C2 operating modes. Both of these modes seek to provide more opportunity for collaboration and timeliness. In these modes the *Decider* function would not micromanage the execution of time-sensitive attacks, but rather construct authorizations that allow the sensor and shooter crews substantial autonomy to accomplish specific tasks. That is, a set of proper *Attack Orders* and *Collection Orders* would set up *Sensor-Led* and *Shooter-Led* C2 operating modes for specific assets. These assets would be empowered at specific times and places to actually carry out the search for time-sensitive targets and the attacks upon them.

The choice between *Sensor-Led* and *Shooter-Led* operating modes will depend upon both technical and operational factors, as will be discussed.

Sensor-Led Mode

As depicted in the diagram below, in a *Sensor-Led* mode the *Sensor* function takes the lead based on general instructions from the *Decider* function. These instructions would empower the *Sensor* function to issue subsidiary instructions and require the *Shooter* and *Other Information Sources* functions

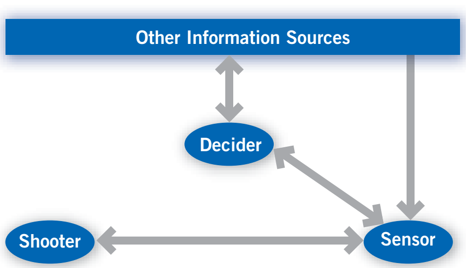

Figure 4. Sensor-Led Mode

to respond—all within defined limits as to assets, time and place. The defined limits are necessary to maintain clear lines of command and control.

The two-headed arrows indicate intense collaboration between the *Sensor* function and the *Shooter* and *Decider* function. In the version depicted, the *Other Information Sources* function is being instructed by the *Decider* function to send relevant, pre-packaged information directly to the *Sensor* function, so that the *Sensor* function does not have to manage the preparation of that packaged information.

So we see that the *Sensor-Led* mode is tailored to the specific operational situation. The *Decider* function first evaluates the situation and decides what kind of *Sensor-Led* mode is desired. The *Decider* function then develops an appropriate set of *Attack Orders* and *Collection Orders*. Then the *Sensor* function leads execution of the TST operation with specific objectives and assets, and within authorized times and places.

Sensor-Led operating modes are natural when the bulk of the relevant information about the targets of interest is derived from real-time observation of the target area by sensors operated by the *Sensor* function. Such sensors may range from wide-area surveillance radars to Special Forces Teams on the ground.

Now the reader may well wonder why this is called "*Sensor-Led*." We consider this a *Sensor-Led* operation because essential C2 functions take place on the *Sensor* platform. One could just as well say the arrangement merely places some of the *Decider* function on the sensor platform. But our purpose is to emphasize the value, even the technical necessity, of placing critical elements of the *Decider* function on the sensor platform under appropriate circumstances.

For example, the full information rate received by wide-area radar sensors is enormous. One could, in principle, relay all of this information throughout the combat arena to all interested parties. However, that undertaking is currently infeasible. It is likely to remain infeasible in the future under many circumstances. Moreover, many interested parties, shooter platforms in particular, do not need all of the information available in those data streams and would be hard-pressed to extract what was useful to them from the unneeded information.

Sensor-Led C2 operating modes are not new. They evolved out of the Ground Control Intercept (GCI) technique made possible in WWII by the technology of ground-based radar. The application of GCI in the Battle of Britain is legendary. In Vietnam, *Sensor-Led* modes were prominent as Forward Air Controller (FAC) led operations.

More recently, the *AWACS, Joint STARS*, and E-2 sensor platforms were designed to carry a crew on board to enable a *Sensor-Led* mode. These "back-end" crew members are trained and empowered to view the high bandwidth sensor output, interpret that output in operational terms and disseminate their interpretation over a low-bandwidth, dedicated link to selected users. In addition, these crews are capable and empowered to act as airborne command and control centers *(ABCCC)* directing shooter platforms toward interesting targets. The E-10 series now under development is being designed to provide near-real time command and control, albeit with much better sensor, computation and communication equipment. One suite of equipment will be optimized for surface moving target indication (SMTI) and cruise missile defense.

For the *Sensor-Led* operating mode to work, of course, the *Shooter* platform needs to have authorization to respond to direction from the *Sensor* function, as described above.

The *Shooter* platform also needs the technical means to accurately deliver weapons on the targets selected by the *Sensor* function. It is common for the *Shooter* to host an on-board sensor capable of reacquiring the target and aiding in accurate weapon delivery. In addition, this on-board sensor can, in many instances, be able to determine or confirm the identity of the suspected target, thus adding valuable information.

More recently, weapons have been fielded that can receive, at least in principle, target information directly from the *Sensor* function that is adequate for delivering a weapon to a target. Weapons that are guided by GPS coordinates are one such example. Weapons with target-sensing seekers are another. The arming and launch-enabling actions are normally carried out by the shooter platform crew in the interest of safety of the shooter platform. With such weapons the *Shooter* platform tends to become simply a bus, with the most of the attack control resident on the Sensor platform.

The *Sensor-Led* C2 operating mode prospers when the available sensors have a field of regard that can detect and identify most of the valuable targets in the battlespace of interest. It needs to be emphasized that the standard for identification varies widely with the combat and political situation and that the ability of any given sensor to meet the instant standard depends upon the type of target, the type of background, the weather and efforts by the adversary to conceal identity. For example, airborne radars that are adequate to distinguish ship types in the open ocean may not be able to distinguish among types of land vehicles, especially if they have about the same dimensions.

For many cases of irregular ground combat we would look for sensors that make their observations from close range in order to meet the higher standards of identification inherent in those situations. The use of Special Forces combat teams in Afghanistan to direct precision strikes from B-52 aircraft is a good example.

This operating mode works well if sufficient shooters can be positioned close enough to prosecute attacks before the targets disappear from view. In addition, the shooter platforms need to have weapons that can defeat the selected targets with one or two shots. And, of course, the shooter platforms need to be able to survive both their loitering episodes and their weapon delivery episodes.

New technical advances have given more utility to *Sensor-Led* C2 modes. First, data links to the shooter platforms are a big improvement over the traditional voice links with respect to timeliness, accuracy and precision. Second, precise geo-location accuracy through systems such as *"RainDrop"* and *"RainStorm"*[40] improve the ability of the

[40] "RainDrop" was the name of a computerized system designed to rapidly provide precise geolocation/positioning information for targeting purposes. That system, originally located in the CAOC and requiring considerable time for target mensuration has been upgraded and replaced by "RainStorm" which provides the underlying web-based architecture to support the evolving TST needs of multiple users.

shooter platform to reacquire the target. Third, somewhat in the future, the secondary sensor platforms can be unmanned vehicles that have flexible flight paths and different survivability modes. Fourth, high power processing of the full-bandwidth main sensor data improves the crew's ability to distinguish the type of target, thus aiding in the relative valuation of the target under consideration. This, in turn, reduces the probability that the shooter platform would be directed to a low-value target—or a forbidden target.

A *Sensor-Led* operating mode is challenged if too many targets appear and then disappear before they can all be attacked. Conversely if targets appear too seldom, then the arrangement is challenged because too many resources, both shooters and sensors, must be devoted to keeping watch over the battlespace.

There are also technical challenges. For example, wide-area SMTI sensor systems such as *Joint STARS* necessarily cover most of their viewing area at low grazing angles. This interferes with clear line of sight for the sensors leading to local shadowing from terrain, vegetation, buildings and deliberate concealment counter-measures. One approach to solving these limitations of individual sensors is through integration of data from several sensor platforms.

For example, consider the concurrent deployment of secondary, complementary sensors on shooters or other small platforms. These secondary sensors would look at suspect areas from other azimuths or steeper grazing angles and with other types of sensors. The objective is to provide higher confidence of a thorough search and higher quality of target identification. Sometimes individual secondary sensors would be, at least temporarily, joined closely to individual shooter platforms, as discussed in Appendix A. Other cases would call for wider collaborative arrangements, so that any sensor would be able to provide information to any shooter, at least for specified assets, times and places.

The airspace management of the loitering shooters and sensors is a big job. Their locations and headings need to be managed in relationship to the target locations and relative target value. As the number of shooters and sensors increase, this task gets big in a hurry. Eventually, it could overwhelm the airborne crew in the main sensor platforms.

Accordingly, for most *Sensor-Led* and *Shooter-Led* operating modes we would expect the *Decider* function to retain the main burden of airspace management for all aircraft, leaving the main sensor platform crew to focus on timely target prosecution. And the *Decider* function will almost surely retain the burden of sortie scheduling, to include adjustments for actual progress in sortie generation.

So, although we may say that a particular operation is being prosecuted under a *Sensor-Led* or *Shooter-Led* operating mode, we see that the *Decider* function is very active and much of its action is still with the CAOC. Accordingly, a true network, allowing facile switching among many different connectivity arrangements, is necessary even if most of the timely action is delegated to the sensor-shooter inner loop.

This delegation has the effect of isolating and freeing the sensor and shooter crews to focus on meeting time-sensitive target requirements. The manifold lateral and topside coordination remains with the *Decider* function, much of it done by personnel resident in the CAOC. The extent of delegation is controlled by the set of *Attack Orders* and *Collection Orders* that are issued by, and periodically adjusted by the *Decider* function.

Shooter-Led Mode

As depicted in the diagram below, in a *Shooter-Led* mode the *Shooter* function takes the lead based on general instructions from the *Decider* function. These instructions would empower the

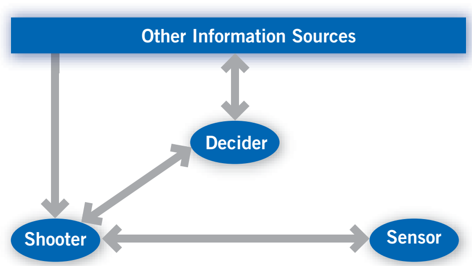

Figure 5. Shooter-Led Mode

Shooter function to issue subsidiary instructions and require the *Sensor* and *Other Information Sources* functions to respond—all within defined limits as to assets, time and place.

The two-headed arrows indicate intense collaboration between the *Shooter* function and the *Sensor* and *Decider* function. In the version depicted, the *Other Information Sources* function is being instructed by the *Decider* function to send relevant, pre-packaged information directly to the *Shooter* function, so that the *Shooter* function does not have to manage the preparation of that packaged information.

So we see that a *Shooter-Led* mode is tailored to the specific operational situation. The tailoring and set up is done by the *Decider* function and then the *Shooter* function leads execution of the TST operation with specific, authorized objectives, assets, times and places.

Shooter-Led operating modes are effective whenever sufficient information about the targets of interest can be derived from real-time observation of the target by sensors onboard the shooter platform. In the past, when communications to and from shooter platforms were slow, unreliable or nonexistent, *Shooter-Led* operations were the best that could be done. Appendix A describes some stylized, simple examples of *Shooter-Led* operations.

Typically the mode has worked as follows. The *Shooter* platforms would be given, usually before take-off, an *Attack Order* denoting what targets were authorized for attack and where to look for them. If the sensors on the shooter platform were adequate to find the authorized targets, and if the weapons on board were adequate to defeat the targets found, then all went reasonably well. Those same considerations apply equally well today—except that now the sensors and weapons are better, and the *Shooter* platform can receive abundant, useful updates on likely target locations, behavior and relative priority.

Overall, a *Shooter-Led* operating mode prospers when a) the non-target specific data can be adequately captured and conveyed to the shooter in an *Attack Order*, b) on-board sensors are adequate for identifying targets and supporting weapon delivery and c) real-time data from off-board sensors is available to the shooter crew or not required during the attack episode. In those circumstances the *Shooter-Led* mode offers very quick response from target detection to weapon delivery.

For example, the AC-130 Gunship typically operates well in a *Shooter-Led* operating mode. When in a firing position, it has a kill chain under 30 seconds against a variety of pop-up ground targets, to include vehicles and dismounted troops. Its suite of integrated, on-board sensors supports operation under conditions of darkness and poor visibility. The suite's great acuity and contrast support careful target identification and discrimination. The tactics, techniques and procedures that have been developed for the AC-130 support operations in defense environments of interest in the current war on terrorism.

Another typical *Shooter-Led* mode would be associated with a stealthy shooter platform that did not transmit very much or very often in order to preserve stealth. But it would receive a great deal of sensor information, fully processed for immediate use. The shooter would use this off-board information, combined with information from on-board sensors, to prosecute the attack.

The *Shooter-Led* operating mode does not work well a) when critical real-time targeting data are being generated away from the shooter platform and b) when it is difficult to provide those data to the shooter platform in a clear, accurate and timely fashion. It also does not work well when the on-board sensor has difficulty in detecting and identifying the desired targets in time for the shooter platform to execute an effective attack maneuver.

To alleviate this latter difficulty, one can have another shooter platform or secondary sensor platform act in concert. That is, the shooter is made part of a hunter-killer team, as discussed in Appendix A. Making such arrangements work smoothly requires considerable work on tactics, techniques and procedures to integrate considerations of sensor limitations, attack maneuver requirements and air defense mitigation actions.[41]

In the fullness of the *Shooter-Led* operating mode, the shooter crew would be empowered to call for all manner of processed information from off-board sensors, to direct the placement of secondary sensor platforms, and to manage all of the information resources, both on-board and off-board, needed to prosecute the attack.

Such high level management activities have hitherto been difficult for fighter crew members because of workload stemming from aircraft operations. But recent technical advances in automation, particularly for the F/A-22 and F-35 aircraft, will relieve that burden. An autonomous Joint Unmanned Combat Air System (J-UCAS), combining sensor and shooter capabilities, will further refine the solution.[42]

All of those difficulties notwithstanding, a *Shooter-Led* operating mode has an inherently short kill chain. If the operational and technical conditions can be met, then a *Shooter-Led* operating mode is very attractive for time-sensitive targeting.

[41] Notable here is the "affordable moving surface target engagement system" (AMSTE) which can turn a Joint Direct Attack Munition (JDAM) designed to strike fixed targets into a mobile-target killer. A recent live exercise termed "Resultant Fury" effectively targeted moving naval vessels by providing the B-52-dropped JDAM with continuous updates on the target's location from a Joint STARS' moving target indicator radar. See Nicole Gaudiano, "Moving Targets Beware," *C4ISR Journal*, November 29, 2004 and at http//www.isrjournal.com/story; and "Resultant Fury successful thanks to 'test' airmen," http//www.af.mil/news/story.asp/storyID=123009411.

[42] The current DoD J-UCAS program is an operational assessment/advanced concept demonstration program to give the Navy and the Air Force an option to acquire a stealthy, refuelable unmanned aircraft at low risk over the relatively near term. Baseline missions for the J-UCAS include persistent ISR, targeting, strike, SEAD/EW and CAS/SOF support.

V. Network-Centric C2 Infrastructure Issues for TST Attack

The preceding text explored various C2 arrangements to pursue TST attack. This section will explore some issues of the network infrastructure that affect its capability to support TST activities. These issues include some hardware items, but there is a strong focus on supporting doctrine, systems engineering, procurement methods, training, management of sensors, monitoring of performance and adversary counter-measures, management of information flows and interoperability. The issues were chosen to further illuminate the challenges and difficulties that are being encountered in the ongoing work to improve TST timelines, as discussed in the main text above.

Doctrine

The listing of doctrine may come as a surprise to the reader, but we note the following four doctrinal decisions that are quite determining in the design and construction of C2 network infrastructures: a) U.S. military operations are to be conducted on a joint basis among all military services and other appropriate agencies of the government, b) these services and agencies have been granted substantial autonomy for procurement, particularly in determining technical characteristics, c) many U.S. military operations are conducted as part of a multi-national coalition, each member having its own C2 infrastructure and d) the United States has chosen to incorporate new technology into its C2 systems as expeditiously as possible.

These four decisions result in continually changing C2 systems, even during on-going campaigns. Indeed, some observers would say, "particularly during on-going combat operations." The current facility of digital electronics and the rapid advance of electronic technology have led to a culture that expects and accepts continuous incorporation of improved hardware and software.

In many private sector situations, where system engineering is strong, vendors can be chosen and interfaces controlled, this continuous incorporation is managed reasonably well. However, in the case of military C2 systems at the joint and coalition level, many of the pieces come "full-born" without much prior coordination of technical characteristics. Regrettably, there should be only limited expectation that this situation will improve substantially or quickly. This is because the four decisions outlined above are very deeply entwined in fundamental tenets as to how governments should operate. They are not likely to be changed. Thus, U.S. command and control systems will simply have to learn how to quickly and effectively incorporate repeated, unexpected deliveries of new hardware and software that were not built to preferred standards.

Another major problem in making progress is the substantial investment in legacy systems. The legacy systems exist, they function, they have trained personnel and they are familiar. So there is substantial reluctance to abandon them. But, they are, to a large extent, stove-piped, sequential, saturated and ad hoc. They do not possess the desired characteristics for C2 of TST. Those networks should be shared, distributed, integrated horizontally, and interoperable. Above all, they need to be quickly reconfigurable to meet fast moving combat situations.

There are, of course, a number of detailed technical characteristics of networks that need to be satisfied. Among those are connectivity, quality of service, throughput, latency, authentication, ease of use and so forth. The prosecution of time-sensitive targets has its own distinct needs for these characteristics.

Systems Engineering

So what would help? We note that normal systems engineering techniques are geared to the design and implementation of a fixed, finished system that will operate in a well-defined environment to perform a set of relatively well-defined tasks. But top-level military C2 systems are going to be under continuous change, to operate in changing, somewhat unpredictable environments to perform, at least in part, unexpected tasks.

The point being that military C2 systems have real, distinct challenges that are not addressed by the normal systems engineering techniques. And C2 for time-sensitive targeting has even more distinct challenges. Clearly, the systems engineering procedures that guide C2 system development must address these real, distinct challenges. In the authors' view, such procedures need additional development to adequately meet this critical need. And we will need a steady supply of systems engineers well trained in the specialized procedures supporting C2 networks. To remind, many performance failures, schedule slippages and cost over-runs of technical programs have been traced to weak systems engineering support.

From the discussions in the main text we would identify the following top-level needs for the requisite system engineering procedures: a) Timely configuration management[43], to include comparisons with prior configurations and expectations of future configurations as essential aids to users who may be coming and going in response to the demands of combat operations; b) Rapid evaluation of the pros and cons of proposed changes and additions to the C2 system in both technical and operational terms, recognizing that there is intense pressure during combat to institute improvements, but approvals need to be well-informed; c) Techniques for implementing changes, and tailoring changes to reduce disruption and implementation errors; and, d) Techniques for on-going evaluation of operations with a view toward identifying root causes of poor performance and opportunities for improvement. This list is not intended to be comprehensive, but to illustrate items that flow from TST requirements.

Procurement and Budget

The same conditions of continual change in environment, tasks and technology will put a strain on the procurement and budget processes for the C2 system as a whole. So will the inevitable appearance of additions of hardware and software from multiple, independent sources. For example, just the integration of these additions will incur costs that could be considerable. But such costs may not have been covered in an explicit form in any budget. So, if the incorporation of new capabilities is to be timely, then the C2 systems will need a budget structure that provides liquidity for a certain level of unexpected expenditures. The normal bureaucratic paradigm of "budget—then spend" will not suffice. Fortunately, the governing procurement regulations provide for such flexibility, even though lower bureaucratic layers too often fail to recognize that fact.

To be sure, this example is simplistic, perhaps overly so. But it illustrates a key principle. The continuous modification of the C2 system, which is based on deep doctrinal decisions as set forth above, challenges normal governmental financial and procurement procedures. Now these procedures have been developed over the years to ensure accountability and to control fraud, waste and abuse. They cannot simply be tossed overboard.

But they can be amended, tailored and adapted to meet the needs of continuous modification. Indeed, if integrated into the specialized systems engineering procedures called for above, they can serve to strengthen both sets of objectives—namely, the systems engineering discipline and the financial discipline. For example, if the performance of the system is viewed as worth improving in some area, then the system engineer should know to provide a provisional budget for the improvement, even if the technical solution is not well known. Typically, there will be many such impending improvements at any one time. The provisional budget for any one improvement may well be uncertain, but the aggregate is likely to be a reasonably good estimate.

Training

In the preceding text we pointed out a number of specialized activities that are needed to support TST operations. We believe that many of these are sufficiently special, unusual and demanding

[43] Configuration management refers to the disciplined process of authorizing and recording changes in the component pieces of a system, their interconnections, operating modes and performance, together with benchmark performance metrics of the system as a whole. A recognized single manager is essential.

that formal training in TST procedures is appropriate. Such training would cover actions within all three functions—*Decider, Sensor* and *Shooter*. The needed training protocols need not be elaborate. They probably can be implemented effectively with "distance learning" techniques since their operational use will entail "distance collaboration." Indeed, training in teamwork skills for "distance collaboration" is an essential aspect of the needed training protocols.

We see value in making these training activities available to promising leaders, as well as those individuals slated for duty in C2 posts. That is, many of the operational principles apply more broadly than to TST activities and many of the technical principles apply to future sensors, weapons and communication devices. It is always valuable to have leaders who know their basic crafts.

A particular, somewhat urgent need is to develop Sensor Management as a specific combat skill. There is a growing array of sensor types and sensor platforms being introduced into the combat forces. At any given time even a modestly sized campaign will have dozens of sensors observing some aspect of the battlespace. Sensor Management would control the location of the sensor platforms, the pointing of the sensors and their technical settings—all in response to appropriate *Collection Orders*. Sensor Management would, to some degree, include monitoring the output of the sensors for quality, evidence of adversary countermeasures, and to develop suggestions for improved equipment and procedures.

In *Operation Iraqi Freedom*, for example, the USAF and CENTCOM planners used a system called "ISR Manager"[44] to correlate multiple intelligence sources and provide a more comprehensive view of the battlespace. During the OIF conflict, it tracked and displayed information from U-2s, *Predators, Global Hawk,* and *Joint STARS*, while facilitating weapons pairing and BDA. This enhanced the ability to direct the ISR assets, driving down engagement times and allowing more rapid engagement of unplanned and fleeting targets.

To support TST operations, we need a very collaborative procedure for sensor management that has feedback among the *Decider, Sensor* and *Shooter* functions. This is distinct from the traditional sensor management called "Task, Process, Exploit and Disseminate" (TPED). That arrangement evolved during WWII to handle aerial photography. It was further developed during the Cold War to manage a few very precious sensors for a few very high-level customers. For that purpose it worked well. Still later it was able to incorporate digital imagery and electronic dissemination of product. But TPED is not well suited for support of time-sensitive targets using multiple diverse sensors and multiple diverse customers. As currently practiced it is human intensive and cumbersome in re-tasking of sensors.[45]

Finally, we see two arguments for all command and control equipment to have built-in training modes. First, the continuous evolution of the equipment means that even experienced operators will be faced routinely with new equipment. Second, assignments do not always follow formal training, however hard the system tries.

Information Flow and Interoperability

As generally agreed, there is great value in managing the flow of information to the appropriate individuals and entities based on their information needs. The *Decider* function has this responsibility. For completeness we could say that the *Decider* function would issue *Information Flow Orders* to control this distribution process. As in many other aspects of TST operations, the construction of information flow orders entails the adjudication of conflicting desires and demands. For example, it entails the balancing of the urge for empowerment for more data against the technical capacity of the network to deliver and the recipients to assimilate.

[44] "ISR Manager" is the Air Force application of the Tactical Exploitation System (TES), now being adopted by all services to attain interoperability of sensor fusion through the spirally-developed Distributed Common Ground System (DCGS). TES pioneered modern ground station technology providing field commanders with accurate, reliable tactical imagery from multiple sensor sources using a common imagery processor.

[45] See, for example, Report of the Defense Science Board Task Force on "Future of Strategic Strike Forces," February 2004, pp. 3-4 & 3-5. Office of the Under Secretary of Defense for Acquisition, Technology and Logistics, Washington, DC 20301-3140.

In the past, when communications were "owned" by agencies external to the combat forces, bandwidth arguments were all too often used for unsupported bureaucratic reasons. Hopefully, we are all mostly beyond those dark days. Extra bandwidth is always useful, of course. Extra bandwidth is essential for network flexibility to meet new situations, for encryption, jam resistance and redundancy. Technical advances that provide high bandwidth at a fair price are to be encouraged and supported.

But the urge to deliver more and more data, raw or processed, has to be constrained by considering what decisions and actions those data empower.

But the urge to deliver more and more data, raw or processed, has to be constrained by considering what decisions and actions those data empower. In that context, the viewpoint of the recipient is of monumental importance. That viewpoint focuses on data and information that are known to be of value, that have been requested, and that are being delivered in a timely, accurate manner.

There are a number of techniques that can advance the user's viewpoint. For example, one can post primary sensor data (lots of data bits) in a readily retrievable form and distribute small amounts of "meta-data" that succinctly describe what has been posted, who might find it valuable and how to retrieve it. Or, another example, packages of data, processed for immediate use, can be sent to specific users using electronic addresses similar to the familiar Internet Protocol address system. That system, of course, has some technical flaws that need to be corrected before it can be safely used in all military operations. But the principle is sound, send people what they need—nothing more, nothing less. And to make sure that happens, nothing improves service like listening to the customer's feedback. So we would add feedback mechanisms to the needs list.[46]

The heart of C2 in supporting TST is, of course, timeliness. There are two powerful techniques to improve timeliness—machine-to-machine transfer of data and co-location of multiple functions on the same platform. Both work together.

To get some idea of how matters were handled several years ago, consider the following sketch from *Operation Northern Watch*, the continuous reconnaissance/ strike missions flown over Iraq prior to OIF. The collocation of *Sensor* and *Decider* functions within the CAOC and AWACS worked well.

Box 3 — *Operation Northern Watch Reconnaissance/Strike Missions*

- **Target imaged by a sensor and the image sent to the CAOC.**
- **Target mensurated at the RainDrop station in the CAOC.**
- **Data hand carried within the CAOC to a secure radio.**
- **Voice transfer of data to AWACS and transcribed by AWACS crew.**
- **AWACS sensor operator locates a suitable F-15E for weapon delivery.**
- **Attack instructions relayed by voice to chosen F-15E.**
- **Transcribed on knee board in the cockpit by F-15E crew.**
- **Target location plugged into F-15E weapons computer.**
- **F-15E transits to launch point and weapon delivered.**

But there remained plenty of opportunity for machine-to-machine data transfer to improve both timeliness and error control.

That arrangement also had throughput limits, both in the CAOC and in the AWACS. In the CAOC the *RainDrop* system was used for both routine targets and time-sensitive targets and it was difficult to insert TST requests into the head of the queue. The more advanced *RainStorm* system has improved throughput and the ability to insert multiple TST requests in priority order. To achieve this flexibility and improved performance it uses a form of the two techniques noted above, namely meta-data and electronic addressing. A priority scheme built into the system allows TST requests to take precedence over lower priority geo-location requests already in the queue. As workstations complete mensuration requests, they are sent back to the Web server to pass the results back to the requestor—a quickened, partially automated process of linking sensor, decider, and shooter.

[46] See Appendix B for reference to the Global Information Grid (GIG) and the net-centric system providing web-based enterprise services to the GIG (NCES).

For another example, consider the following sketch from Afghanistan which used a *Sensor-Led* mode of TST C2. In this case Special Forces teams directly observed the ground action. They were equipped with combined GPS location devices, viewing optics and laser range finders. The teams thereby provided GPS coordinates to loitering B-52 platforms carrying GPS guided, gravity powered weapons. The co-location of both *Sensor* and *Decider* functions within the Special Forces teams allowed the mode to work well. The teams could discern the identity, relevance, location and timeliness of targets to support our Afghani, coalition-partner ground forces. The B-52s could fly for extended periods safely above the rudimentary air defenses. Problem areas included voice communication and manual recording of target coordinates. These were slow and subject to error. Machine-to-machine handling of the target coordinates would address this issue.

Returning to the theme of continuous evolution of C2 systems with additions from diverse sources, let us explore the implications of that theme for interoperability. Most of the literature and regulatory action regarding interoperability focuses on the design of interoperability standards and the discipline of their enforcement.

There is no doubt that standards are very helpful. Within platforms standards are virtually essential. But there is real difficulty with enforcement of standards at the cross-platform, cross-service, cross-national environment found at the theater level of operations. The individual participants in fact have independent design and financial authority. The products that each provides will have a diversity of standards. Such diversity has to be accommodated. Several approaches to this accommodation have arisen in the real world.[47] More recently, the *Battlefield Airborne Communications Node (BACN)* is being developed to serve this objective and to provide electronically addressed data flows.

All of these real world approaches share the principle of accepting and accommodating the inevitable diversity of transmission standards followed by information sources by placing the burden of interoperability on the information user community. That is, the information user community needs to be responsible for designing, funding and controlling an information infrastructure that collects and collates information from diverse sources, packages it into a data stream and publishes it in one or more readily useful formats.

To be sure, the less diversity in original data source standards, the better this works, so efforts to enforce standards should be pursued as well. But governments are not likely to accept "non-compliance with technical communication standards" as a legitimate excuse for defeat in combat.

There is one major application of interoperability that is worthy of notice—the widely desired "common operational picture" of air, ground, sea and space units. It would be in a form to be shared, to combine diverse data streams, to use uniform symbology and to allow near-real time updates. However, with each theater, command, service and agency developing its own operations and planning databases, this is a big challenge. Not only is there a diversity of communication and data standards, there are diverse operational nomenclature and the need to protect aspects of security and sovereignty. Efforts to accomplish these mergers through the enforcement of uniform standards have led to the conclusion by many that a single, joint and combined "common operational picture" remains a long way off.[48]

We would suggest that placing a larger burden on the entity constructing the common operational picture will hasten its accomplishment. To be sure, this application has a much larger scope than the Tactical Exploitation System. But the success of "user accommodation" approaches in the real world to date suggests that these approaches have merit for this application as well.

[47] Two of these are exemplified by the "Tactical Exploitation System" or TES. First, TES is designed to accept data from a number of intelligence sources, each source using its own communication and data standard. These separate data streams are then translated by TES into a common data standard, correlated as to time, location and substance, and provided to a wide range of users as a combined product. In many cases this merged product can shield "sources and methods," thus reducing the classification of the merged produce. Second, the TES engineering team maintains close technical contact with the individual intelligence sources and is prepared to quickly adjust the TES hardware and software to accommodate changes by the sources. This allows the individual sources independence to meet their own technical needs for change without coordination delays or revelation of "sources and methods."

[48] The challenge for Joint BMC2 is to make interoperable, provide for information exchange, allow for distributed operations and fold in collaborative missions from three distinct service-specific command and control systems: FORCEnet (maritime BMC2), LANDWARnet (Ground BMC2) and the C2 Constellation (Air/Space BMC2). National sensors and systems need to be integrated as well.

VI. Summary and Conclusions: C2 Arrangements for TST

At the top level, we have identified three essential command functions.

First, attacking time-sensitive targets is inherently difficult and complex involving geographically distributed and technically advanced equipment and personnel. An essential command function is to develop the equipment and personnel into a harmonious organization and to lead them to execute the commander's intent.

Second, the need to coordinate actions throughout a theater of combat is in tension with the need to attack quickly. Coordination takes time and the more places and considerations that are included the more time it takes. An essential command function is to adjudicate the tension between timeliness and coordination.

Third, timely prosecution of time-sensitive targets demands the allocation of sensor platforms and shooter platforms to loitering modes in the vicinity of where such targets are expected to appear. This allocation of scarce resources is in direct tension with the efficient and effective prosecution of the main combat action. Moreover, these loitering platforms may well be exposed to hostile action. An essential command function is to weigh the resource allocation and hostile fire risk against the value of timely attack.

In support of these functions we have identified the following guidelines for action:

Doctrine related guidelines:

- Recognize that the attack of time-sensitive targets is a valued combat goal that has its own particular Tactics, Techniques, Training and Procedures.
- Recognize that particular sets of technical capabilities and combat situations lead to a preference for <u>temporary</u> command and control arrangements such as the *Shooter-Led, Sensor-Led* and *Decider-Led* C2 operating modes described herein.
- Recognize that a principal value of an overall Network-Centric Command and Control System is its ability to support two actions: 1) the top-level adjudications set forth above and 2) the devolution to support particular operating modes tailored to particular operational situations.
- Recognize that the overall combat goal is to fulfill the commander's intent and to translate that into wise and effective operational choices. Those choices, in turn, rest on judgments as to the relative priority of individual time-sensitive targets and the overall priority of groups of time-sensitive targets in relation to groups of pre-planned targets.
- Remember that over time the opponents will adapt.

Training related guidelines:

- Develop special training protocols for attack of time-sensitive targets for all parties involved—*Sensor*-related, *Shooter*-related and *Decider*-related—as well as teamwork related skills.
- Establish Sensor Management as a specific combat skill worthy of formal training, selection and assignment monitoring.
- Exploit modern methods of training and simulation in these protocols that 1) facilitate participation by those exceptional individuals who are likely to be in combat command positions some day, 2) explore a wide variety of combat circumstances and 3) familiarize participants with a wide variety of *sensor, shooter* and *decider* equipments and applications.
- Include training modes in all command and control equipments and procedures that can support fast-track training of newly assigned

personnel, in recognition that 1) modern command and control procedures, processes and equipment will always be in a state of continuous evolution, and 2) the assignment process often loses lock with the training process.

Technology related guidelines:

- Place the burden of information interoperability on translation services within the C2 infrastructure that are designed, funded and controlled by the information customer. Information sources already have legacy transmission systems that have been designed to meet demanding operational requirements. It is unreasonable to expect these diverse sources to adopt some new transmission, especially in Joint and Coalition operations. This guideline often leads to separate, valuable nodes, e.g., distributed common ground stations utilizing *ISR Manager/Tactical Exploitation System* and the *Battlefield Airborne Communications Node (BACN)*. These nodes collect and collate from diverse sources into a composite data stream and publish that stream in a format readily useful to many customers.

- Strive for machine-to-machine transmittal of data. The payoffs are reduced delay, fewer errors and the ability to more easily combine and process diverse data streams into higher order, more coherent combat information. Even one-way machine-to-machine transmittal is valuable and is often a lot easier to implement.

- Provide for robust, real-time collaboration among people who can turn data into information, without regard for their geographical and organizational location.

- Curtail the propensity to "push" large volumes of data (e.g., images) upon customers that are not needful of such data, at least at the current time. Such data transmissions use up communication and processing resources and add little value. There are more suitable processes such as posting primary data in a retrievable mode and distributing small amounts of "meta-data" that succinctly describe what has been posted, who might be interested in it and how to retrieve it.

- Exploit the value of preparing electronic "mission packages" that are 1) tailored to particular customers for specific missions, 2) sent via electronic address techniques (secure IP) to designated platforms, and 3) provide feedback mechanisms for questions, amplifications and corrections based on the customer's immediate experiences.

- Pursue the development and use of platforms that combine portions of two or three of the *Sensor, Shooter* and *Decider* functions. Whenever that is feasible, then the TST attack timeliness is greatly enhanced. Such combined function platform can range from a weapon (e.g., *Viper Strike*) with its own homing sensor, to an unmanned aircraft (e.g., *J-UCAS*) or ground vehicle with sensors and, perhaps, human control to a large aircraft (e.g., E-10, E-2D, P-8A) with sensors and command elements.

- Support the continued development of technical aids to command and control such as data and analytic techniques for 1) collateral damage estimation, 2) precise geo-location and mensuration, 3) damage assessment and combat implications thereof, 4) information warfare matters such as recognition of cyber attack and real-time measurement of network performance, and 5) near real-time monitoring of the performance level of sensors in the presence of adversary countermeasures and unexpected weather.

System Engineering and Procurement Guidelines:

- Develop specialized system engineering techniques and procedures for command and control facilities, particularly large ones such as CAOCs, that facilitate the following needs: 1) timely configuration management, 2) rapid evaluation of the technical and combat relevant value of proposed changes and upgrades, 3) adjusting the implementation of changes to reduce disruption and opportunity for error and 4) diagnosing on-going operations to evaluate the performance of functions and to identify opportunities for performance enhancement.

- Tailor procurement arrangements for augmentation projects for command and control facilities to meet the following needs: 1) achieve timely approvals without sacrificing accountability, 2) explicitly record judgments and estimates made with respect to cost, schedule and performance in a manner to support the development of the system engineering procedures in the previous bullet, 3) allow for the inclusion of equipments and software derived from a variety of funding sources and physical sources, e.g. coalition partners.

- Approach true invention with humility. We cannot simply “order up” something that needs to be invented. True, history shows that we can usually find willing organizations that will agree to deliver such a something. But that agreement, in itself, will assuredly lead to effort and expense, but not necessarily to an invention.

These guidelines are not intended to cover a comprehensive set of actions for the improvement of C2 for time-sensitive targeting. Indeed, many useful and important actions not mentioned here are being taken throughout the C2 community that will bring improvements.

The selected guidelines set forth above were chosen to highlight perspectives and approaches that we felt were particularly promising, or under appreciated, or highly dependent upon the personal efforts of individuals who are probably scheduled to leave their posts over the next few years. We do believe that following these guidelines for action will bring added improvement.

We are ever so mindful that time-sensitive targeting has only recently been recognized as a valuable and distinct combat goal. The progress to date has been significant. But there is much left to do. Only continued, thoughtful efforts, well financed, will finish the job.

Appendix A — Command and Control for Time-Sensitive Targets: Five Stylized Examples

The main text has laid out many of the challenges of the time-sensitive attack problem. This Appendix will describe five stylized examples of solutions. For each example it will describe some of the strengths and weaknesses of the solution set as well as some circumstances for which each is likely to be well suited.

Example 1—Dedicated Sensor Coupled to Dedicated Shooter

This example couples a single "good enough" sensor to a single "good enough" shooter and provides the team of two with "adequate" authority to attack. If implemented by a team that has had reasonable training, this solution can come close to executing a kill chain within the technical limits of the equipment provided to the team.

The keys to success of this example are as follows:

A) The "adequate" nature of the authority is key. Clarity, completeness and consistency with agreed concepts of operation and prior training are essential characteristics. Box 1, repeated here from the main text, contains the typical contents of an adequate authorization.

B) The "good enough" character of the sensor and shooter means that the sensor can find and fix the authorized types of target objects, that the target can be tracked as necessary and the data transferred in a timely and accurate manner to the shooter, and that the shooter can destroy same with one or perhaps two shots. If the sensor type or the weapon type is not well matched to the target type, then this criterion will be difficult to meet. Clearly, the communication mode should be "machine-to-machine" for adequate accuracy and timeliness.

C) The overall number of targets is small enough so that the team can engage an adequate number of them in a time consistent with the overall mission. That is, not only is there a time-sensitive nature to the kill chain for individual targets, but also there is a time rate of killing of a set of targets that must be met. If too many of the target set appear all at once, then some will survive simply because the team could not prosecute them all before they disappear, lose value or reduce their vulnerability.

D) The overall value of the set of targets warrants the dedication of a sensor and a shooter long enough to prosecute the target set. If the targets individually appear only occasionally, then this criterion will not be met.

Box 4 — *Typical Contents of an Adequate Authorization*

- Geographical extent of the authority
- Time duration for the authority
- Types of targets authorized
- The standard for target identification
- Types of weapons that can be used
  - Further conditions that must be met, such as coordination with friendly forces
- The degree of risk to the delivery platform that these targets warrant

Example 2—Multiple Sensors and Multiple Shooters in the Same Kill Box

This is a natural extension of Example 1 that seeks to solve the target-rich case described in C above. It provides a higher rate of fire, but for that we get the penalty of managing multiple sources of target data and distributing that data among multiple shooters.

Several solutions to this management problem are known:

A) Form the sensors and shooters into small teams and allocate a portion of the overall kill box to each small team. For this to be efficient, the target set would have to appear more or less uniformly in each portion of the kill box. But the solution is simple.

B) Collect all the sensor data centrally and distribute kill missions to shooters based on their current ability (i.e., location, remaining weapon load) to prosecute attacks on particular targets. This extends the time line by introducing three new steps (collecting, processing and distributing target data) and one new failure mode (allocation errors).

C) Provide all the sensor data to all the shooters and let the shooters choose which target to attack based on their current capability. This eliminates two of the three additional steps and the new failure mode of solution B above. Without some fix, however, it often leads to a feeding frenzy wherein apparently lucrative targets attract too many shooters and too many targets escape attack. One simple fix is called "shoot and shout." It obliges shooters to announce, via broadcast mode, their choice of targets based solely on their own sensors and a decent decision rule. It obliges other shooters not to shoot at any target previously "spoken for." If most shooters observe reasonable discipline, this fix is typically 95% as effective as a set of "perfect" assignments. The fix requires minimal communications and little additional computation over that needed for a single shooter.

Example 3—Wide Area Sensors, with On-Board Command, that Direct Shooters

This is a natural solution to the target-poor case, where a large area needs to be held under continuing observation with modest use of sensor assets. In practical application there is usually background intelligence that would indicate areas within the wider field of regard, where targets of interest are more likely to be. Shooters, whose weapons are typically of shorter range than the shooter platforms or the wide area sensors, would be directed to loiter in promising locations.

Some characteristics of this solution follow:

A) The wide field of regard and the desire for modest use of assets imply a long range from the sensor platform to the target. This, in turn implies a relatively low grazing angle, with concomitant terrain shadowing, modest sensor resolution and modest target identification capability. As a result there will often be a need for follow-up target observation from the shooter platform or from some other sensor platform that operates at shorter ranges and higher grazing angles.

B) The wide field of regard is very valuable for overall situation awareness at the operational level of combat. Indeed, this is often a sufficient justification for the use of these assets, quite apart from their value as targeting sensors and managers of shooters.

C) For present communication techniques, on-board interpretation of the full sensor feed is indicated as the bandwidth for full speed sensor data transfer is quite large. This, in turn, leads to the desire for on-board command and control of the shooter assets. And this, in turn leads to the need for connectivity of the sensor platform to the broader network of non-target data that bears on target value, coordination with other operations and so forth, as discussed in the main text.

D) For the target-rich case, this solution also works reasonably well. Currently available sensor equipment can handle expected high-end traffic rates. Indeed, manned, on-board interpretation could well become overloaded at somewhat lower rates. This leads to the well-known need to communicate semi-processed sensor data to ground stations. At ground stations, presumably, more trained operators could be brought to bear on the interpretation and shooter guidance tasks. However, if the high traffic rates come as a surprise against a low traffic rate background, then the additional operators might well not be at their workstations and delays would ensue.

Example 4—Shooter Platforms that Serve as Trucks for Smart Weapons

A) In this example the shooter platform would have only one responsibility—to loiter where told and to pass target data to its weapons when authorized and directed. In the extreme, one can imagine the data going directly to the weapons, but antenna aperture and jamming countermeasure considerations argue against that extreme design choice.

B) This arrangement is appealing when the non-target associated data, as discussed above, are a very large part of the decision process as to which targets should be attacked and at what time.

C) This arrangement works equally well for shooter platforms that are on the earth's surface. It is the solution used for many decades for our strategic nuclear attack command and control—which does execute a time-sensitive attack plan.

D) This arrangement also worked well in Afghanistan, where Tactical Control Parties on the ground had adequate battlefield knowledge to allocate weapons to important targets when needed and adequate target coordinates to direct weapon delivery.

Example 5—Self-Sufficient Platforms with On-board Sensors and Weapons

A) In this example, self-sufficient platforms are dispatched and provided with an adequate authorization to prosecute attacks. The content of the authorization could be changed after dispatch, many times if need be. See Box 1, above, for the typical contents of an adequate authorization.

B) The relevant data not derived from the target would be considered by the dispatching entity and its implications for the attack mission conveyed to the self-sufficient platform crew through the attack authorization content.

C) The necessary target specific data would be collected and processed by the self-sufficient platform. It would then proceed to execute attacks in accordance with its authorization and its own target-specific data.

D) This solution is appealing when the target-specific data dominate the attack decision. It is often necessary when communication with the delivery platform is weak or absent. From the point of view of the overall command and control function it is very simple. And it does have reliable, fast, high-bandwidth connection (true "machine-to-machine") between sensor output spigot and the shooter's computer and display. This solution should have the shortest kill-chain duration, at least if duration is measured after the self-sufficient platform has arrived in the authorized kill box.

E) This solution does place a high training burden on the self-sufficient platform crew. It does require very good sensor pre-processing and thoughtful displays for the crew. It does require sensors suitable for shooter platform installation that have the capability to prosecute the kill chain for the desired target types. Fighter-attack aircraft, tanks and submarines have long used this mode of C2 for TST.

F) The armed *Predator* is being used in a variation of this mode. The Predator aircraft has no crew on-board. But it has a dedicated and well-trained crew in a remote ground station. This remote crew is connected to the aircraft through a high quality radio link. The radio link has sufficient bandwidth, range and reliability to permit a) management of the on-board sensors, b) interpretation of the sensor data, c) a decision to engage and d) management of the on-board weapons launch—all within the authorization parameters provided to the remote crew.

G) Autonomous unmanned vehicles are often envisioned as operating in this mode. The challenge here is to automate what is now a demanding human activity. One particular challenge is what is called exception handling in software design. That is, what is a practical and useful response for the autonomous vehicle system if something unexpected happens? The *Global Hawk*, designed as an autonomous ISR platform, added much value in Iraq when operators intervened and directed it to time-sensitive targets. The *Tactical Tomahawk*, which qualifies for this case, is assigned to a target prior to launch but includes on-board sensor function allowing small-scale adjustments of navigation and aim-point selection. Such limitations reduce the complexity and increase the reliability of the autonomous mission. Other examples include weapons that attack only certain types of targets with unambiguous target signatures in target-rich kill boxes. The *Brilliant Anti-Tank* munition (BAT), now configured as *Viper Strike*, was such a weapon.

Appendix B — An Air Force View of Network-Centric C2 for TST

This Appendix briefly examines a network-centric C2 arrangement optimized for precision engagement of TSTs. What might such a network-centric arrangement look like, and what steps should be taken to achieve that vision? In their 2004 "Future Capabilities" wargame, The U.S. Air Force compared and contrasted the warfighting capabilities of two 2020 air forces—one that had not yet realized a true net-centric environment (the baseline force) and an "alternative force" that operated in a world of true command and control connectivity. If we put this idealized force in the context of the kill chain, the following is how the Air Force visualized ideal future C2 connectivity.[49]

The Air Force version of the Kill Chain is expressed in terms of six actions: Find, Fix, Track, Target, Engage and Assess. The qualitative description of how those actions would be supported in a good, network-centric system was set forth as follows:

Find: Tasking and deployment of tactical/strategic assets is dynamic, and automated ISR sources are controlled as one joint coordinated resource pool. Smart, multi-intelligence correlation of ISR sensors, including those not under direct USAF control, is the norm.

Fix: All entities in the network have accurate knowledge of the positions of all other forces (red, blue, and gray) in the battlespace.

Track: Fast dynamic tasking of ISR sources and fused, multi-int information give the C2 system a robust TST capability.

Target: "Cursor on the target" provides integrated multiple source data and automated decision aids that enable and accelerate the targeting process.

Engage: The rich data streams available to deciders and shooters allows for an automated, informed decision to strike the target in a timely and efficient way with the most appropriate asset and weapon, coupled with accurate effects-based prediction.

Assess: BDA occurs rapidly and accurately based on fused data enabling the decider to quickly assess the need for re-strike of the TST. The kill-chain has become a "kill-dot."

Unfortunately, we are still a considerable distance from the idealized C2 arrangements of 2020. For example, after-action reports examining the organization, equipment and processes of the CAOC during combat operations have numerous implications for the command and control of TSTs. Specifically:

- Although the CAOC was designed to streamline C2, it remained a family of stove-piped systems that had never been integrated in a single facility before.
- Owing to the need to shield certain displays and information, the ISR cell was not co-located with the personnel involved in the TST process.
- Because of the stress involved in the "swivel-chair" or "swivel-head" process of trying to integrate separate and diverse streams of data delivered to separate display screens, personnel manning these positions fatigued very quickly.
- Improved information technologies enabled increased targeting functions to be distributed to CONUS, decreasing the CAOC workload in TST situations. However, relying on "reach-back" meant relying on organizations not commanded by the Joint Force Air Component Commander (JFACC) that were less responsive and not in tune with the battle. Reachback was seen as valuable only for non-time-sensitive support.
- The manually-intensive system on which the CAOC relies for TST demands upgrades to

[49] "The Networks in the Future Capabilities Game '04," describing the Baseline and Alternative networks used in the wargame played in Maxwell, AFB, Alabama, January 2004.

facilitate integration and interoperability to provide operators the ability to perform weapon target pairing to prosecute time sensitive targets.

- While automation helps reduce operator errors, the continuing requirement to ensure precise target coordinates (mensuration) and avoid collateral damage has increased the operators' workload. Automated systems and displays can help avoid errors, but they my not improve the speed of the task.
- Confused lines of authority and command have an adverse impact on targeting decision timelines.
- TST operations require adaptive processes to allow for situations—such as the targeting of senior leadership—in which decision-making is raised to the highest levels. Key to this process is a series of automated C2 and decision aids to standardize TST operations as well as education and training of our own decision makers.

To be sure, the Air Force has taken many actions in response to these and other findings.[50] These experiences and lessons identified from the prosecution of TST during combat operations have additionally led to a series of studies and initiatives to improve TST organizations, equipment and processes.[51] From those studies, the most important initiatives for C2 arrangements for TST appear to be:

Sensors:

- Establish an integrated and joint TPED system for the shared exploitation and fusion of target information.
- Test high-capacity bandwidth links, including augmented decision-making tools and the integration needed to produce a fused picture of sensor inputs.
- Pursue and field systems such as "ISR Manager" that fuse, integrate and display multi-int data from a multitude of sources.

Deciders:

- Develop a common joint grid and automatic geo-registration system to speed, simplify, and tailor precision targeting of TSTs to varied decision levels. *RainDrop/Rainstorm* combines with *"Gridlock,"* a computerized coordinate confirmation system, to rapidly provide mensurated target coordinates from different and distributed sensors. Through *Gridlock's* automated processes, targeteers can put a cursor on the target and get instant (less than one minute) mensurated coordinates to pass to the shooter. (This presumes the required digital terrain elevation data, DTED, are in the *Gridlock* data base).
- Initiate methods of rapid target development, nomination, and weapons pairing, coupled with timely decision, attack order, and assessment dissemination.
- Continue to pursue the efficient pairing of sensors and deciders in platforms such as the E-10A, E-2D and follow-on systems.

Shooters:

- Deploy the secure Link-16 communications data link on all tactical platforms.
- Pursue the Data Link Automated Reporting System, which connects Link 16-equipped aircraft with the CAOC through machine-to-machine interfaces.
- Explore the multiple and complementary roles and missions of advanced aircraft with sensing and shooting capability, particularly the Joint-Unmanned Combat Aircraft System (J-UCAS).
- Develop weapons data links/"bell-ringers" to provide BDA feedback loops.

Networks:

- Pursue Network-Centric Collaborative Targeting, which compiles sensor data from a

[50] "The average time required has dropped from 120 minutes in 2002 to 10 minutes today," General Hal M. Hornburg, ACC Commander, quoted in Air Force, November 2004, p. 72.

[51] For example, see The Under Secretary of Defense, Memorandum Subject Precision Engagement/Time Sensitive Targeting (FOUO), April 2, 2002, Adam J. Hebert, "Compressing the Kill Chain," Air Force, March 2003, p. 53, Enhancing Dynamic Command and Control of Air Operations Against Time Critical Targets. Santa Monica: RAND, 2002, and Air Force Experiments with Time-Sensitive Targeting at JEFX 2004," Inside the Air Force, August 6, 2004. http://www.insidedefense.com/secure/defense_docnum.asp

variety of ISR platforms into a common, shared database;

- Emphasize the timely integration of information, including access to multi-int data, correlation of data into information and services, and, displays of these data in support of military decision makers.

- Develop networks to assist in the targeting-related areas of Collateral Damage Estimation, Battle Damage Assessment, and Operational (effects-based) Assessment.

- Remove communication as a constraint through the development and deployment of the global information grid (GIG)[52], open to all sensors, deciders and shooters. Move from a "provider-centric" approach to data distribution—a "smart push" to a "smart pull" in which the TST consumer can pull just what he needs from any source. Tie together sensor-shooter-decider grids through common wireless networks (JTRS)[53] and wideband IP routers in space (TSAT).[54]

- Facilitate C2 for TST through DCGS (distributed common ground stations) facilitate TST (*Predator*-C-130 gunship links), combined with building an Internet for ISR. Move from a family of labor intensive, service-owned systems to net-centric, simple workstations.

- Explore DARPA's concept of Dynamic Networked Combat Capability—a "confederated" approach to networks connecting sensors, deciders and shooters. A confederated approach would speed response by allowing individual sensors, deciders and shooters to form arbitrary, spontaneous packages to attack targets immediately.

The preceding summation, taken from published reviews and studies, emphasizes how many and varied are the needs for improvement in the command and control of TST. The opportunities also are many. Indeed, within the major headquarters of the services and the combat commanders many programs and initiatives are under way. And many dedicated and hardworking personnel are engaged in keeping a host of important improvements on track.

There are, of course, a number of classified improvements under way that cannot be covered here in any detail. But we have reason to believe that they are consistent with and further the aims of the programs that have been described in open publications.

[52] An important addition to the GIG, GIG-BE will acquire bandwidth from commercial providers and extend fiber optic links to bases not in proximity to commercial networks. The GIG-BE will provide secure high-speed messaging worldwide using Internet Protocol (IP). Net-Centric Enterprise Services (NCES) is designed to support the GIG by allowing the user pull-down menus accessing any source on the network with minimum latency.

[53] The Joint Tactical Radio System will develop a family of interoperable, software-defined radios significantly increasing voice, data and video communications capabilities.

[54] The transformational satellite program will use a number of technologies, including laser cross-links, to provide high bandwidth connectivity to the warfighter.

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Acknowledgements

The authors appreciate the contributions of those in the Washington defense community who shared valuable insights when this paper was being developed. In particular we would like to acknowledge Dr. Myron Hura and his RAND colleagues for their path-breaking work in this area. Within the Analysis Center, Adam Cushing provided essential support. Thanks also to our external editor, Kimberly Capozzi, for her efforts. Finally, we are deeply indebted to the many operational and technical practitioners of the craft of military command and control who have, over the years, patiently shared their experiences and perspectives with us. Without that help, we would not have had much useful to say.

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Printed in the United States of America.

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