United States Air Force
Scientific Advisory Board

Report on

Air Force Operations in Urban Environments

Volume 1:
Executive Summary and Annotated Brief

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Foreword

As cities increase in number and importance, the population of the world is rapidly gravitating toward these centers of commerce, culture and society. In addition, our adversaries have learned that urban environments diminish the effectiveness of our legacy systems, tactics, techniques, and procedures, resulting in extremely difficult challenges for US and coalition military forces that have traditionally focused on direct engagement of forces in open terrain. It is therefore logical to expect increasing numbers of military engagements in urban areas. To be ready for the future, the Air Force must fully understand the evolving urban operational environments and organize, train and equip its forces for these challenges.

This study addresses the need to develop more effective *Air Force Operations in Urban Environments.* The study has been conducted in response to a request by the Secretary of the Air Force and the Air Force Chief of Staff.

In response to the Terms of Reference, the Urban Operations Study Team conducted an extensive set of visits to Air Force, Army, Marine and Joint operating commands, centers and laboratories. The Team also reviewed numerous briefings from Air Force, Army, Marine and Joint organizations concerning current and future operations, systems and procedures. The assistance of these organizations was essential to the effort, since their insights, experience and vision led the Study Team to the findings, concepts, conclusions and recommendations incorporated in this study. The Study Team greatly appreciates the cooperation of these organizations and acknowledges the valuable contributions their efforts made to this study.

The Study Team utilized previous studies conducted by the USAF SAB, Army Science Board and Defense Science Board as a point of departure for this study. The Team benefited immeasurably from those efforts and extends its appreciation to those who participated in the earlier studies.

Finally, the undersigned wish to acknowledge the outstanding effort put forth by the Air Force Scientific Advisory Board Secretariat, the members of the Urban Operations Study Team and the Study Team Executive Officers/Technical Writers in the conduct of this study and preparation of the reports—whatever value is found in this work is attributable to them.

Mr. Wallace J. Hoff
Urban Operations Study Chairman

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Urban Operations Study Vice Chairman

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Executive Summary

Introduction

The relationship between air and ground operations changes dramatically as forces encounter an urban environment. In an urban scenario, many of the advantages of airpower are significantly diminished. The ability to use stand off precision weapons is compromised because of severe physical and operational constraints, including buildings that constrain weapon flight trajectories and frequently block target designation. Decisions to fire are nearly always encumbered by serious concerns of collateral damage and fratricide, so the ability to respond rapidly is compromised. Targets are typically small and fleeting so desired timelines for support are shortened. Communication is often compromised by blockage, multipath or interference in a dense signal environment. Intelligence, Surveillance, and Reconnaissance (ISR) is often limited because of noise, target obscuration and interruption of tracks—all a result of the compressed population and layout of roads and buildings in the urban environment. Many of these limitations reflect the fundamental situation that warfare in open terrain is essentially two-dimensional while warfare in urban terrain is emphatically three-dimensional.

Approach

This team built its analysis on past Department of Defense (DOD) studies and collected data on recent experiences and current perspectives based on interviewing personnel in Air Force, Army, Marine and Joint commands, centers and laboratories. The team also obtained inputs from Federally Funded Research and Development Centers (FFRDCs) and from industry and they reviewed ongoing programs across DOD.

The team was organized into four functioning panels as follows:

a) System Concepts and Integration (SC&I),
b) Modeling, Simulation and Training (MS&T),
c) Command, Control, Communications and Intelligence, Surveillance and Reconnaissance (C3ISR), and
d) Attack.

The team assessed Urban Operations in all stages; namely, Understand, Shape, Engage, Consolidate and Transition (USECT). Findings from the panels were consolidated and vetted through vignettes generated by the SC&I panel. Generally, these findings could be viewed as capability shortfalls, or gaps, in the current Air Force. The team next created visions of Air Force capabilities with all of those gaps resolved and then looked at what steps in capability would get to those capabilities. Those steps became the study recommendations.

General Conclusions

There were some very clear and fundamental conclusions that became evident as the study progressed. Those conclusions were as follows:

a) Urban Operations (Urban Ops) is a three dimensional scenario,
b) The USAF brings a critically important vertical dimension to Urban Ops,
c) The USAF is essential in all five USECT phases of Urban Ops,

d) The USAF has some "star performers" (AC-130 Gunship and Predator/Hellfire) that are highly regarded and frequently requested by Ground Commanders,
e) Unit size for typical ground maneuvers is typically small, either a platoon (40 personnel) or a squad (8-13 personnel),
f) Air support in Urban Ops is not a lesser included case of Conventional Close Air Support (CAS),
g) The desired response time to a call for support from a ground maneuver unit should be in single digit minutes (ideally, one to two minutes),
h) Communications and some forms of ISR are considerably less effective in urban environments because of obscuration, multipath and interference in dense signal environments,
i) While rapid response time in support of ground maneuver units is critical, the number of aircraft (A/C) capable of delivering the desired effects in the airspace over an urban area is severely constrained by airspace management procedures, and
j) When the USAF is able to upgrade capabilities for Urban Ops, many of those capabilities will also enhance other missions (Urban Ops is the "most stressing case" for several capabilities).

Recommendations

As the study progressed through the stages of analyzing shortfalls and generating visions, the team was then able to identify some specific recommendations that are near term, quantitative steps toward an ultimate capability. Those recommendations are summarized below:

a) Support Joint CONOPS, TTPs and training—At this time, there are no USAF or Joint Concept of Operations (CONOPS) or Tactic, Techniques, and Procedures (TTPs) for Urban Ops. There are "practices" that have evolved as Urban Ops continue, but it is extremely important to generate CONOPS and TTPs and make them a part of the overall structure of the Air Force. When those are in place, Urban Ops should be incorporated into the training curriculum and we will then be able to send both Air Force and Joint command personnel to the field fully trained in Urban Ops.
b) Lead Development of a Joint Automated Control Capability (JACC)—To resolve the procedural limitation of the number of A/C over an urban area and to dramatically reduce timelines for delivering effects when called for by ground maneuver units, the team recommends that the USAF lead an effort aimed, in the long term, at an automated, man-on-the-loop system that performs airspace management, ISR platform positioning/sensor management, management of an integrated "information system", weapon-target pairing and modeling and simulation based planning/rehearsal. In the near term, the team recommends that the Air Force work jointly with the Army to integrate real time USAF weapon platform data into the Advanced Field Artillery Tactical Data System (AFATDS) to enhance joint fires capability. Another near term recommendation is to define the JACC architecture as a first step toward implementation of JACC.
c) Augment Mobile ad hoc Urban Ops network—To resolve many of the communications problems for ground maneuver units, the team recommends that the USAF build on existing USAF Roll-On Beyond-line-of-sight Enhancement (ROBE) communications node capability by expanding the functionality to include key waveforms used by the ground forces. Then as ground forces transition to more advanced waveforms, the ROBE system can be upgraded

correspondingly. In the near term, the team recommends that the Air Force select a platform for this communications node capability and begin upgrading ROBE for this application.

d) Deliver Urban-Tailored ISR—To enable progress toward a multi-sensor Joint Battlespace Information Enterprise Service (JBIES) system the team recommends that the Distributed Common Ground System (DCGS) be viewed as a point of departure. By utilizing data from DCGS, we can evolve toward an accessible all-source information database and we will have enhanced near term capability that will provide valuable experience in serving various echelons of users in a responsive manner. The team further recommends that all USAF sensors be upgraded to have autonomous geo-registration capability so the information they provide can be properly registered in an all-source database. Further, the team recommends that the on-going Defense Advanced Research Projects Agency (DARPA) sensor management system address cordoning as an important function of a sensor platform. Additional recommendations are to proceed with three dimensional (3-D) mapping capability for urban areas using active laser technology and to proceed with the next phase of "staring ISR" as being developed at Air Force Research Laboratory (AFRL).

e) Improve Operations via Modeling, Simulation and Training (MS&T)—The team observed that current efforts in the area of MS&T, particularly as it relates to Urban Ops, are quite dispersed among and between the services and generally not well coordinated. Therefore, the team recommends that the Air Force take a proactive role in ensuring that urban MS&T is pursued as a Joint R&D Development Activity, and that special emphasis be placed on incorporating realistic urban infrastructure models and cultural/social/behavioral models. It is reasonable to expect that capabilities will evolve as spirals and they should be incorporated in operational systems as they become available. Models should be designed to be adaptive and responsive to feedback so they can be used operationally in a "learning" mode. MS&T will also be extremely useful for training/rehearsals, for prediction of outcomes and for evaluations of various courses of action (COAs).

f) Develop weapons tailored for Urban Ops—Legacy USAF weapons are typically highly lethal but, in many cases, are inappropriate for use in urban environments where limiting collateral damage is vitally important and where friendly forces and non-combatants may be nearby. The urban environment is ideal for non-lethal weapons and the team recommends them whenever they can be effectively employed; but, there is still a clear need for kinetic weapons with yields considerably lower than currently available. The team recommends development of a low yield, precision weapons that can be used effectively against targets within 150 meters of friendly forces or non-combatants. The team also recommends that AFRL look at techniques for achieving a cockpit-selectable yield weapon and for a maneuverable air dropped munition capable of vertical decent at low speed into urban canyons. Continued work on non-kinetic weapons such as Directed Energy, Laser and Information Operations (IO) are also important and should be institutionalized so they are considered by a warfighter or planer on an equal footing with more conventional weapons.

g) Develop Joint Urban Ops S&T Plan—For each of the capability visions addressed in the study, there are key technologies required to enable their implementation. As a part of the study, the team worked with AFRL and determined that 30 development areas apply to Urban Ops and that three of AFRL's eleven future long-term challenges also apply to Urban Ops. The team recommends that AFRL coordinate with the other services and development agencies to develop a Joint Urban Ops Science and Technology (S&T) strategy.

In summary, the urban environment is increasingly important in military operations and Air Force support of those operations is critical. The study team believes that the USAF is already highly capable of supporting ground commanders in many ways but the potential exists for being considerably more effective in the future. It is axiomatic that the US will be engaged in Urban Ops until we are as effective in cities as we are in open terrain warfare. The study team believes that implementation of the recommendations described above will put the Air Force on a path to achieve the visions and allow the joint force to achieve mission success in urban operations.

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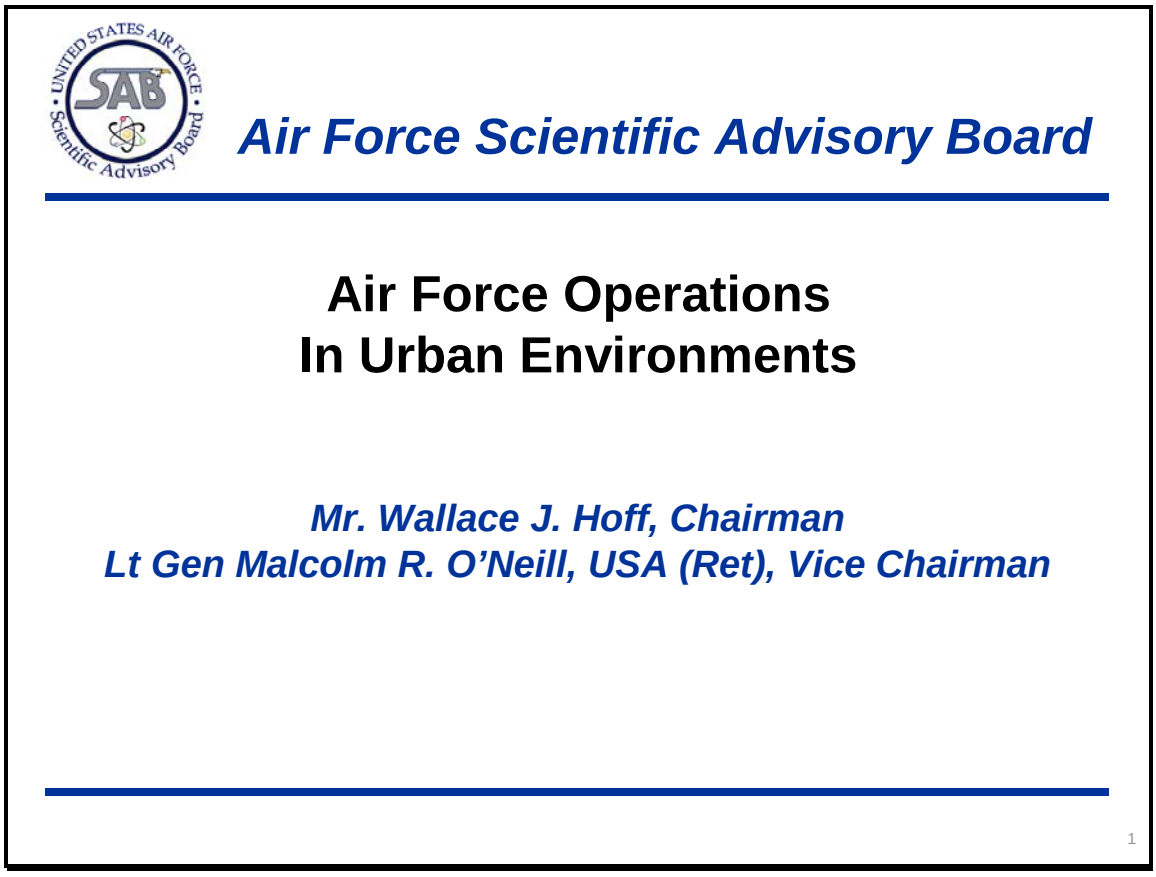
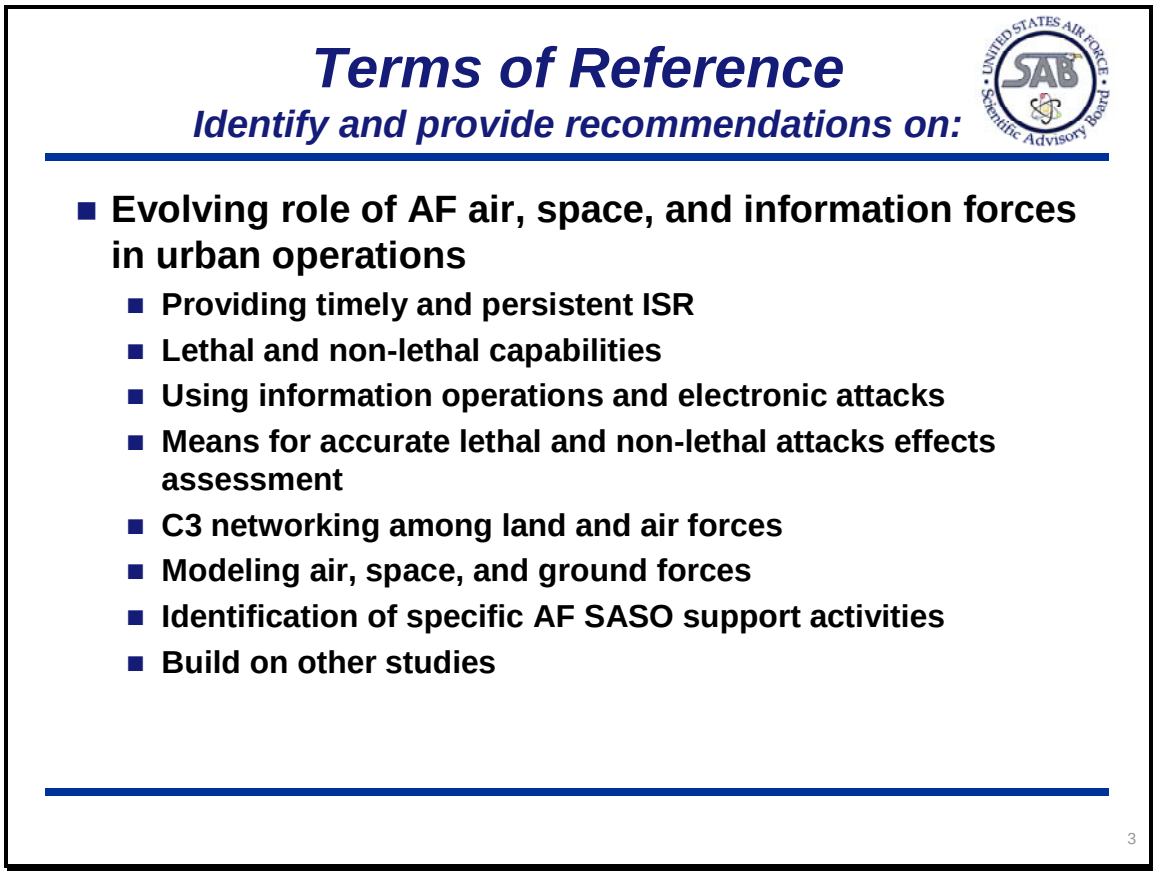
Section 1: Introduction



This briefing summarizes the Air Force Scientific Advisory Board Study on Air Force Operations in Urban Environments. It is the culmination of an eight-month assessment of the topic. Recent conflicts have highlighted the urban environment to be a very difficult operating environment but one in which U.S. forces must be prepared to operate.



This is a summary of the terms of reference generated in the fall of 2004 (see Appendix A). They identify the key questions that focused our study. The terms indicate a focus on timely and persistent ISR, lethal and non-lethal attack, information operations, networking, and modeling to help predict what the enemy actions may be. A key theme is crystallizing what the Air Force role in Urban Operations should be. All of these are important themes in the Terms of Reference, so we have tried to address each of them in our work for this study.

Initial Conditions…Urban Ops

- USAF brings a very important vertical dimension to the urban combat environment
- Many USAF operations in urban environments will be in support of a ground force commander
  - Often in a coalition operation
  - Nearly all AF involvement will be Joint
  - Unique Mission…not just a subset of Close Air Support
- Rules of Engagement
  - Minimize collateral damage
  - Minimize coalition and noncombatant casualties
- Maintain focus on all phases of urban operations
  - Understand-Shape-Engage-Consolidate-Transition (USECT)

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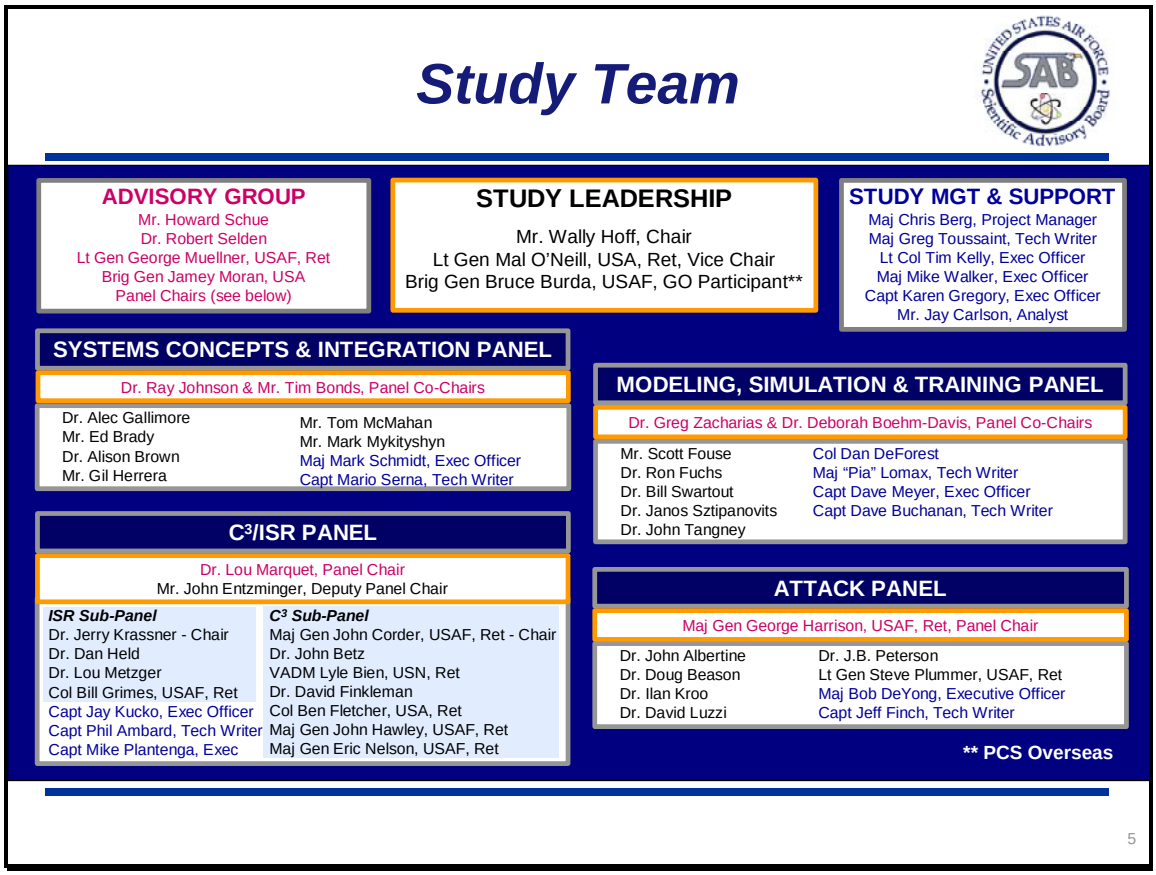
We established a set of initial conditions, which need little debate and which underscore our assessments of the Urban Ops challenge. First, the Air Force brings to the urban scenario a very important vertical dimension, what we might call a "top-down" perspective, which we will talk more about as we go. This Air Force operational perspective provides enhanced urban ISR, communications relay, and delivery of both weapons and logistic support.

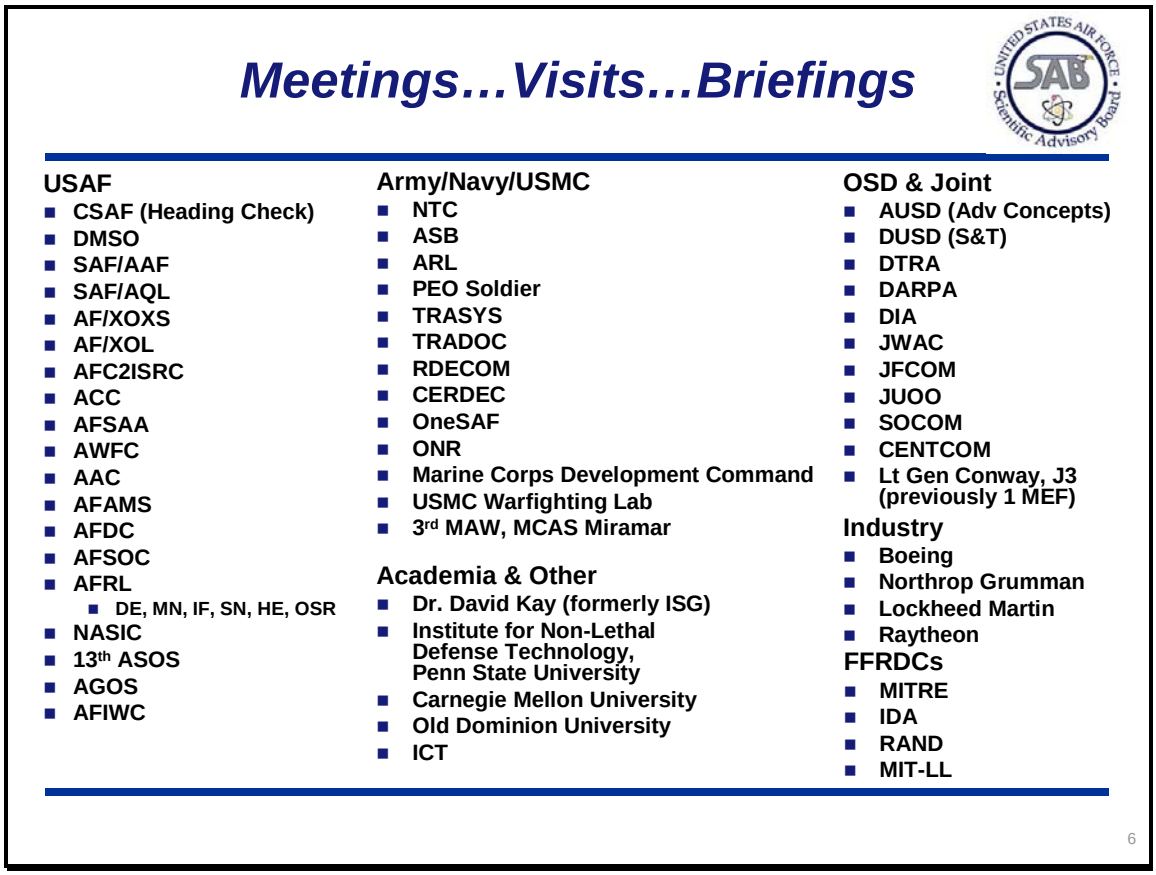
Also, we understand that many Air Force operations will be in concert with, and in support of, a ground force, very likely in a coalition environment. Furthermore, because of the unique character of the urban environment and its impact on the allocation and employment of ground and air forces, the mission cannot be considered a simple subset of conventional air support. Urban rules of engagement are very stressing, especially in close support of ground forces – missions must be accomplished with minimum collateral damage. Also, the concern for friendly forces and non-combatants acts as a major consideration whenever the application of airpower in urban terrain is planned. Joint Pub 3-06 describes the urban venue and partitions the elements of urban operations into five phases: understanding the environment, shaping and positively influencing the situation, engaging the enemy force, consolidating the results, and transitioning to a non-conflict situation. Our study considered each of these phases as we investigated the role of the Air Force in urban operations.



This chart identifies the participants in the study, which was organized around four panels. The first was System Concepts and Integration, which helped pull everything together. The other three panels focused on C3ISR, MS&T, and Attack. Work was done at the panel level and then integrated as we went through the study. We also had an advisory group as shown on the chart that helped us create actionable recommendations. The group was very helpful throughout this study.

Given the Terms of Reference, we reviewed the Service and Joint documents, as well as previous studies. We made a number of visits, and received briefings by a number of organizations, which are outlined on the next chart. The 1999 Air Force Scientific Advisory Board (SAB) study *Operations Other than Conventional War* served as the baseline for our investigation. A number of studies from the Defense Science Board (DSB) and the Army Science Board (ASB) also directly or indirectly address areas related to urban operations.

With that data, views, and opinions, we assessed the issues by looking at the Air Force roles in each of the five phases of urban operations: understand, shape, engage, consolidate, and transition. As we thought through, analyzed, and consolidated what we heard, we came up with a set of findings, many of which identified shortfalls in Air Force capabilities related to urban operations. We vetted these findings in several vignettes. These vignettes allowed us to assess the importance of the findings, develop a vision of future capabilities for the Air Force, and determine the leverage and thus the priority of our recommendations.



The organizations we visited are shown here. Visits were made to a large number of Air Force activities and installations. We also went to Army, Navy, and Marine installations and talked to people from various commands and activities. From the military, we received inputs reflecting recent urban combat experience, as well as well-constructed analysis, current doctrine, and the latest DOD policy. The clear message from most of our meetings was, "This is a vital mission for which the Air Force can play an important role." We went to the Office of the Secretary of Defense (OSD) and to a number of Joint organizations, including Joint Forces Command (JFCOM), Special Operations Command (SOCOM), and Central Command (CENTCOM). We included meetings with academia, industry, and Federally Funded Research and Development Centers (FFRDCs). All visits were worthwhile, especially those which exposed us to briefings describing the status and results of research and studies related to urban operations. The broad base of inputs has provided us with an in-depth perspective and an excellent collection of supporting facts.

We will now take a moment to look at the urban environment and the unique challenges it presents.

Urban Operations Environment

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Urban operations do not occur in a homogenous type of terrain or place. The setting varies greatly across a given city, and obviously cities in themselves vary. The terrain and structures that we often envision and speak of are the urban canyons of the city core, which typically comprise only three percent of the urban area. Urban operations can involve other locations within an urban area, where some of the salient features found in the city core, such as obscuration from tall buildings, may not be the driving issues. There are other important factors to consider, such the population and industrial sites. It is important to emphasize that the urban environment is a complex collection of terrains for military operations.

This chart identifies the key challenges of Urban Operations.

First of all, military operations in urban terrain result in a very complex and dense environment. Urban canyons significantly reduce visibility from both ground and air. Subterranean, surface, and elevated features complicate military maneuver and observation. An admixture exists of friendly, enemy, and other persons, including tribal/religious groups and various political entities. The airwaves are filled with traffic, including cell phones, TV, and commercial radio, and the urban structures themselves interfere with transmissions from tactical radios. The congestion of vehicular traffic both on the ground and in the air adds a further degree of complexity to the conduct of any military operation.

The implications of uncertain knowledge are more challenging in the urban environment. Targets are often smaller, fleeting, difficult to discriminate from the background, geo-locate, and hard to engage without collateral damage. The ground maneuver units are widely dispersed and operating at platoon and squad level. The ground combat actions are often conducted at point-blank ranges. The reaction times to achieve Air Force support can lead to almost no time for decision making. Knowledge of weapons effects in the confined urban environment may be so uncertain as to dissuade the use of air support, as the risk of significant collateral damage may be unacceptable.

Thus, urban operations provide a uniquely stressing environment for military forces, both ground and air.

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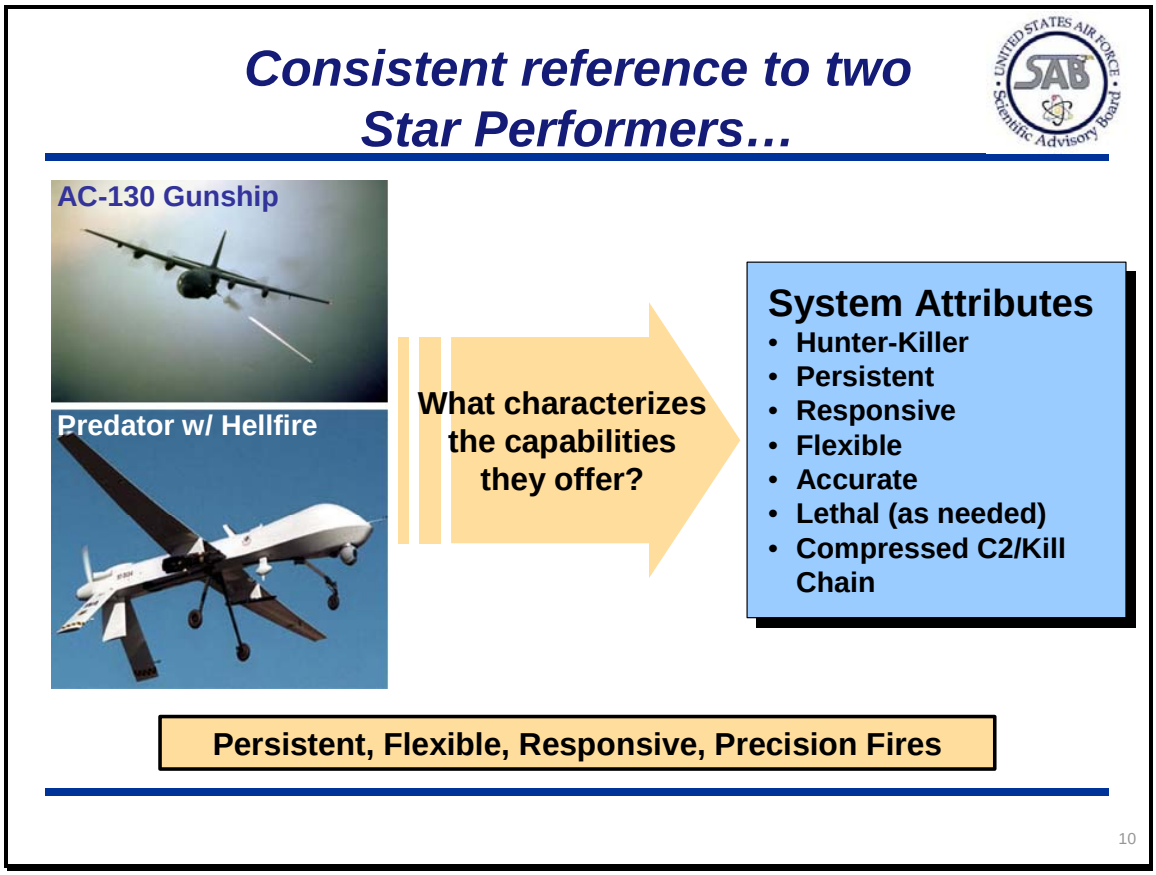
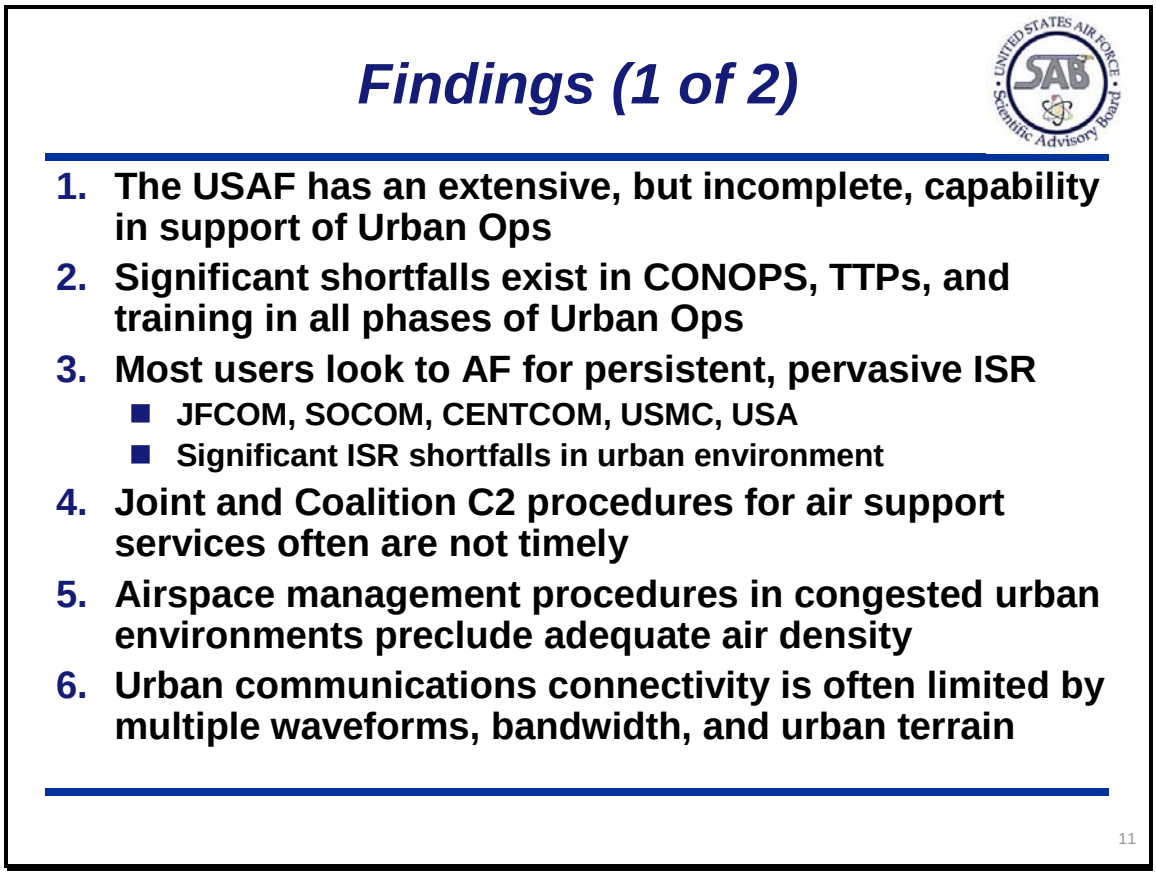
Section 2: Findings



One of the consistent messages we heard from users was how valuable two existing Air Force systems were in urban combat. The first of those being the AC-130 Gunship and the second being the Predator Unmanned Aerial Vehicle (UAV) equipped with a Hellfire missile. Positive comments from the ground forces regarding these systems were almost universal, and many mentioned how they successfully employed the two systems in recent urban combat. Our Army General Officer participant identified these systems as "Star Performers".

We examined the common characteristics of the systems and found that positive attributes included the ability to act as a hunter-killer while maintaining excellent persistence and rapid responsiveness. The systems were very flexible, provided highly accurate fires, were highly lethal against urban-type targets, and offered a simplified chain for sensor-to-shooter and target kill.

The characteristics of these systems have made them highly useful in the urban environment. We conclude that persistence, flexibility, responsiveness, and precision fires are traits of systems that can be successful in the urban environment.



This is a list of principal findings that we collected and consolidated as we went through the study.

1. Clearly the Air Force has demonstrated the abilities to support urban operations, including execution of surgical strikes and significant surveillance support, but is lacking some key capabilities for this environment.

2. We believe that there are significant shortfalls in CONOPS, TTPs, and training across all USECT phases of urban operations. We observed units that trained and operated as Joint teams, developing a degree of trust that was essential in a dynamic urban environment where friendlies, enemies, and non-combatants were separated by meters – not miles.

3. We talked to the major combatant commanders who told us that what they needed or expected from the Air Force included persistent ISR. Persistent ISR is extremely difficult in these urban scenarios. The best approach for persistent ISR is to have multiple sensors to enable blending of the data. Where there is blockage for some sensors, there may not be blockage for others and a persistent ISR picture can be created. Even with blending existing sensors, we have shortfalls in sensor coverage and in obtaining increased penetration of urban structures.

4. As it presently exists, the Joint Command and Control (C2) system does not generally enable timely fire support for those troops on the ground in the urban environment. In this case, we are talking about support within single digit minutes—maybe one or two minutes. The

opportunities are short and fleeting and we need what the Army described as “Now Time” firepower or fire support within the weapon’s time-of-flight. The hunter/killer systems mentioned on the previous chart are examples of systems providing timely effects.

5. We also observed that airspace management procedures severely limit the number of air vehicles that can be simultaneously operating in the airspace over an urban area. Procedural de-confliction keeps everybody safe, but limits the amount of timely air support that can be provided.

6. Urban communications connectivity is often inadequate in these urban environments. Limitations including multi-path, multiple waveforms, and bandwidth inhibit ground-to-ground, ground-to-air, and air-to-ground communications. These problems limit the ability to provide timely support.

Findings (2 of 2)

7. **Geospatial positioning is often difficult due to inadequate maps, multiple coordinate systems, and GPS blockage**
8. **AF kinetic weapons do not support close-in ops and are not maneuverable in urban canyons**
9. **MS&T for Urban Ops is not well coordinated; AF does not have an effective Urban Ops MS&T effort**
10. **Models needed to predict the effects on adversaries, population, and infrastructure in support of EBO**
11. **IO, non-lethal, DE capabilities not yet fully integrated**
12. **AFRL has 30+ UO-related programs—focused on sensors, platforms, C2, MS&T, exploitation, materials**

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7. Geospatial positioning is more difficult in urban areas than it is in flat terrain, due to Global Positioning System (GPS) shadowing and multipath. In addition, different types of maps are being used by various services and even in units within a service. These include maps based on Universal Transverse Mercator (UTM) and Universal Polar Stereograph (UPS) projections, maps based on different geodetic datum (WGS-84 or other), maps with Military Grid Reference or Latitude/Longitude coordinates, and special maps made with grid lines on reconnaissance photos. The maps are often out of date or inaccurate. Joint urban operations are required by JCS Instruction to standardize on WGS-84 datum reference as used in GPS today and that eliminates a portion of the problem. However, there is little question that there is significant opportunity for error, so we feel this potential for error is a problem we need to monitor and to continue to address in the future.

8. We found that most kinetic weapons have such a large danger-close distance (several hundred meters for a 500-pound-class bomb) that they have limited utility in a close-combat environment. Further, the vertical dimension of the urban environment demands that weapons be able to maneuver in the environment to cope with urban canyons.

9. Modeling and simulation for urban operations is immature and poorly integrated across various Air Force communities such as training, test, acquisition, and operations.

10. Limited efforts to incorporate effects-based operations (EBO) into MS&T are underway, but generally missing is the inclusion of effects on people and infrastructure in an urban setting.

11. We found ample anecdotal evidence that experience and training in information operations is lacking, resulting in sub-optimum use of these important capabilities. We also believe that limited operator knowledge of the potential for directed energy weapons is responsible for the lack of a strong operator demand for these capabilities.

12. Across the Air Force technology base, AFRL has a large number of active programs focused on urban operations-related topics. Three of AFRL's 11 long-term challenges apply to urban operations. These AFRL programs need to be harmonized with other DOD S&T activities.

Section 3: Future Capabilities (Vision)

What follows is a vision of what Air Force operations in urban environments could be with improvements in how we plan, prepare for, and execute in this challenging environment.

Our Vision as Evolved through Findings and Vignettes (1 of 2)

1. **Persistent, pervasive coverage**
   - Across USECT phases
   - Coordinated, Cross-cued, multi-INT systems
   - Airspace management for enhanced effectiveness
   - Comm links to and between small units… individual soldiers
2. **Distributed Integrated Data Base**
   - On-demand situational awareness and intel - warfighter pull
   - Information and actionable intel
   - Integrated, multi-source, geo-registered, time tagged ISR
   - Publish / subscribe (smart push)
     - Relevant data and intel sorted, partitioned… pushed down
   - Targeting data and BDA in near real time

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After vetting our findings, we identified the specific shortfalls and envisioned capabilities to overcome the shortfalls and improve the Air Force's ability to provide needed support.

1. The Air Force can provide the eyes, ears, and enable communication over the urban operating scene. We envision the Air Force exploiting its air and space platforms to provide persistent, pervasive coverage of ISR, cross-cued sensors, multi-INT systems, and the communication links between small units, platoons, and squads. Another key mission for the Air Force is providing dynamic airspace management over the urban battlefield. We must be able to safely increase the density of support aircraft while also deconflicting fire support.

2. We see the Air Force being in an excellent position to accumulate data and knowledge and then to disseminate it as needed—in many cases, on demand. We would like to have a system where ISR and other pertinent data are collected and, upon request or need from an operator on the ground, delivered to that person. The information delivered would include all that is pertinent for that area of the city. Now, there is also the issue of what that person does not know that he needs to know. That is an information push and we need a system that collects and pushes this information to that individual alerting them, for example, that there is something just around the corner. So, the concept incorporates publish and subscribe and information on demand. These are areas where the Air Force, operating from the "High Ground" can play a large role in future urban operations.

Our Vision as Evolved through Findings and Vignettes (2 of 2)

3. **"Now Time" Effects**
   - Characteristic of *star performers*
   - Survivable, persistent, pervasive coverage
   - Critical effects in <1-2 minutes depending on USECT phase
   - Targets within 150m of ground forces (BG J. Moran, USA)
   - Lethal and non-lethal… EW, DE, IO
4. **Models, Simulations, and Training**
   - Essential for effective Urban Operations
   - MS&T significantly enhances Joint Urban Operations
   - Provides model-based sensor queuing and weapon selection
   - Simulation-based planning, execution, and BDP… BDA

Enhanced by a Joint Automated Control Capability

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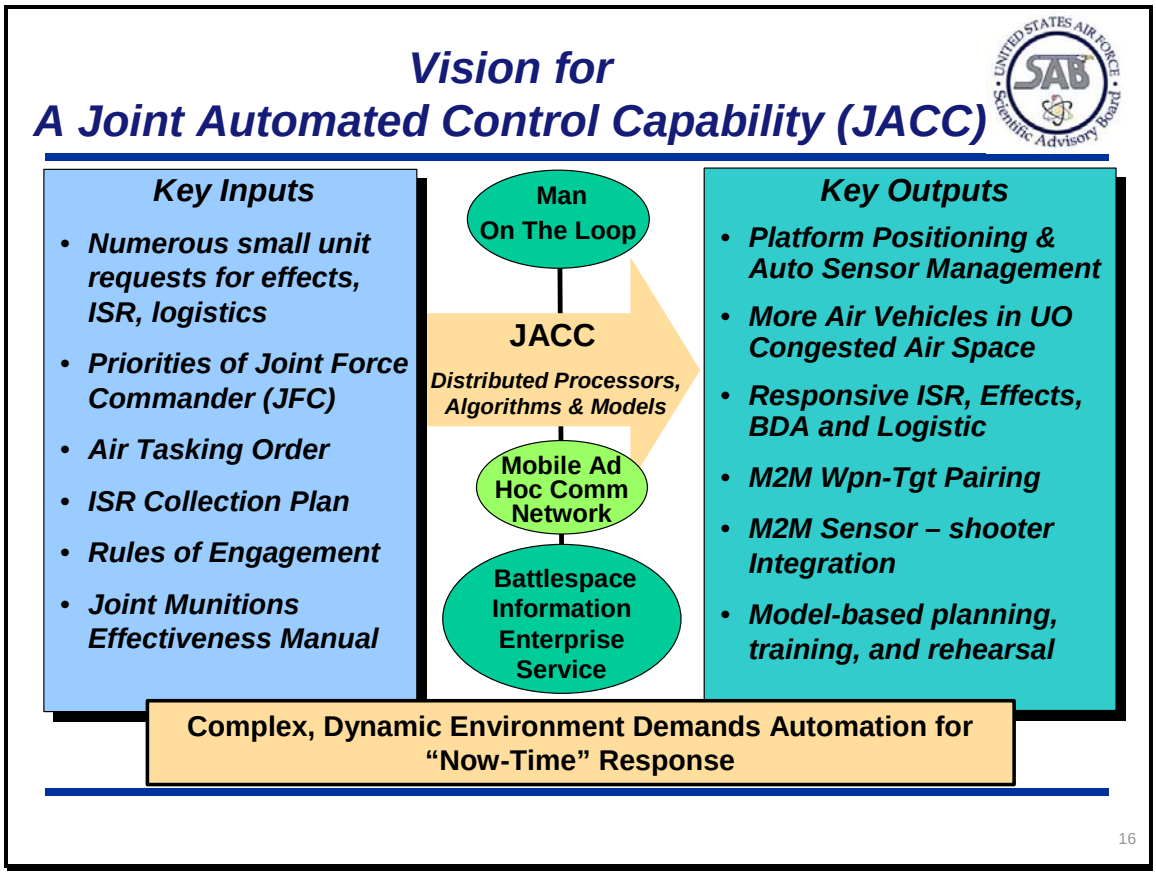
3. Delivering firepower is clearly a role for the Air Force. "Now-time" is a term we picked up from an Army General that we were fortunate to have supporting us on our program. "Now-time" essentially means time-of-flight, which can be one or two minutes—a very short time. We can achieve that response time by having platforms in the area and being able to deliver those effects as close as 150 meters from our own ground forces. The effects of interest include kinetic, non-kinetic, IO, lethal, non-lethal, and even logistic support.

4. The urban environment is very complex and operations would certainly benefit from models and simulations that would support evaluation of COAs, battle damage prediction, (which is especially important for non-lethal weapons) and also support training of the joint forces.

A key characteristic of the urban environment is the demand for a very rapid response. Reduced engagement distances and a multitude of distributed force elements mandate increased automation if we are to provide timely support. A key element of our future state is a capability that will allow us to automate, via machine-to-machine (M2M) connections, many of the processes that enable Air Force Operations in Urban Environments.



Using only a procedural means for tracking and controlling air vehicles in this environment greatly inhibits the number of air vehicles that can be effectively employed in the fight. In addition, joint air power is often not very responsive to the information, firepower or "effects," and/or logistics needs of the ground forces that have to operate under very difficult urban conditions. Our vision to cope with these problems involves the development of a Joint Automated Control Capability (JACC). The JACC is a set of distributed computer processors running algorithms that, when fully developed, will provide automated assistance to C2 warriors commanding and controlling the employment of air power in support of urban operations. It exploits an integrated database, which we call the Joint Battlespace Information Enterprise Service (JBIES), and relies on a Mobile Ad Hoc Communication Network to perform its role. The JACC provides a high degree of automation and decision aiding, enabling the C2 warrior to be "on the loop" rather than "in the loop". In other words, humans will closely monitor what the processors and algorithms are doing and will ultimately be controlling operations by exception or by providing consent or denial of computer recommended actions as required. This allows the C2 warrior to be a decision maker while M2M activities handle the routine tasks.

The highly congested urban environment requires a well integrated automated system both within and across service boundaries. Urban operations not only take place within this environment, but also they often require air and ground force collaboration within very short timelines between sensing and response. Both air and ground forces have current automated systems for command and control, ISR, and communications. In addition, many stand-alone

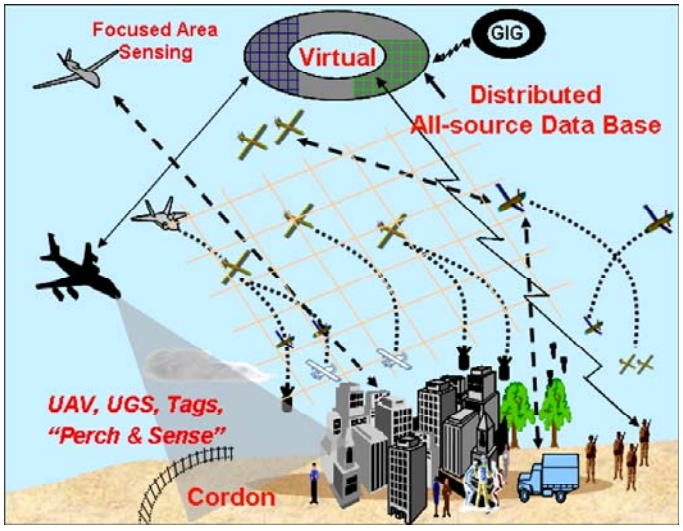
systems exist for requesting ISR and fires effects, managing assets, and providing technical control. Thus, there are many automated inputs available as indicated on the left side of the chart.

Providing automated control of the congested Urban Operations fight will have several benefits. First, air platforms (manned with autopilots or unmanned with computerized control systems) will be automatically positioned so that the right platform with the right sensor and/or weapon is optimally positioned so that it can be employed immediately upon request. Also, automated man-on-the-loop platform control enables dynamic airspace control vice procedural airspace control, which in turn, allows more air vehicles to operate simultaneously in a very confined and congested airspace. In addition, there should be a set of algorithms as part of the JACC that automatically manages sensors to collect enough information on various battlespace objects to help identify those objects and then directly integrate sensor outputs with shooter platforms and/or the weapons themselves. The JACC will provide improved Battle Damage Assessment (BDA) collection and responsiveness, and a capability for "just-in-time" logistics delivery. Once the JACC is fully developed, we envision the JACC will be able to do M2M Weapon-Target pairing, taking into account the Joint Force Commander's (JFC's) priorities, the rules of engagement, Joint Munitions Effectiveness (JMEM) Data, prohibited drop areas, and other factors in order to achieve the desired effects with minimal collateral damage. Direct M2M sensor-to-shooter integration will greatly improve airpower responsiveness in urban operations. Modeling and simulation capabilities will also be imbedded within the JACC to support model-based planning, training, and mission rehearsal.

The bottom line is that the highly dense, uncertain urban environment demands automation to provide the required responsiveness (1-2 minutes or "now time" response) to ground forces engaged in urban combat. We strongly recommend the Air Force lead a DOD effort to develop a JACC.

Vision for ISR Future Capabilities

- **Persistent ISR tailored to urban challenges**
  - **Focused area sensors**
  - **Deployable, close-in ID/characterization**
- **Networked Joint Battlespace Information Enterprise Service**
  - **All-source, geo-registered, data**
  - **Coordinated sensor management**



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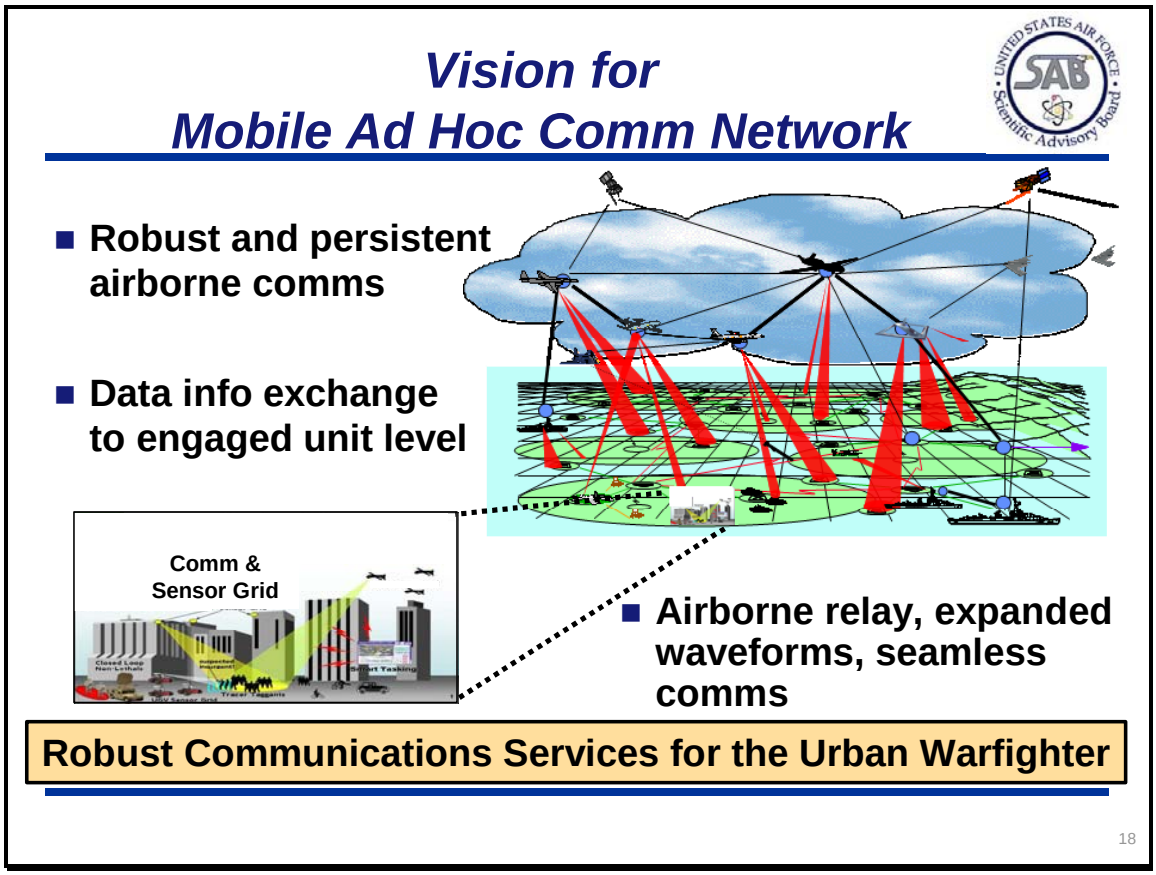
Our vision for the Air Force's ISR capabilities for the urban fight focuses on persistent collection using sensors tailored to the difficulties of the urban environment—its 3-D verticality, movement, and the density of "confuser" objects with similarities to targets of interest.

These challenges require additional sensor types. One of these is envisioned to be an imaging radar with sophisticated signal processing, carried on a high altitude UAV (e.g., Global Hawk), circling above the urban area of interest, so that high look-angles are obtained to minimize obscuration from building shadowing. Such a system would provide a staring ISR capability for persistent surveillance focused on a 10-20 km diameter circular urban area.

Our current and even advanced standoff sensors (such as described above) have to be augmented with close-in sensors for target characterization and identification. We envision an inventory of such sensors carried on and deployed from Air Force platforms, with the Air Force also providing airborne communications for exfiltration of their data. These deployable sensors could include mini- and micro-UAVs, unattended ground sensors (UGS), and sensors that fly into and adhere to buildings ("perch and sense"). Tagging technology can also contribute clues to the close-in picture. Airborne or air-deployed assets certainly could provide connectivity to the Joint Battlefield Information Enterprise Service (JBIES).

To provide maximum utility, all sensor information, accurately geo-registered and time stamped, will be networked into a distributed, all-source, database containing unexploited sensor output as well as value-added analyst products. Information from this database will be published

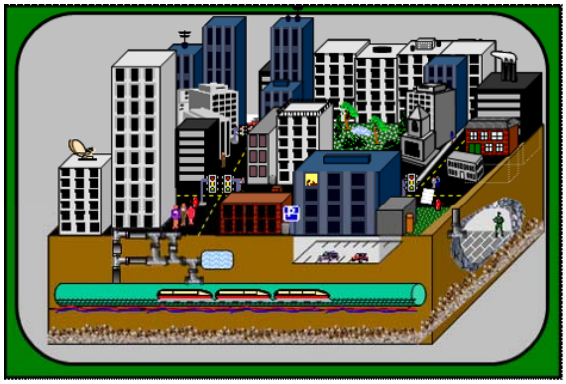
to be available for user subscription, “smart pushed” to users under some circumstances, and coupled to search and discovery services. Together with the capability to receive and respond to user requests, these features will comprise the JBIES. Sensor information requests that cannot be fulfilled with already available and stored data will become an input to the JACC for coordinated sensor management and tasking.



This vision is for a mobile ad hoc networking capability. The Air Force provides airborne nodes in the network, which enable the robust connectivity required by the ground forces. The network is independent of any fixed physical or network infrastructure. It is wireless, although it can seamlessly interact with wired, fixed networks. It is characterized by multi-hop routes within a continuously changing network topology. Every node has comparable technical capability, particularly the ability to "discover" the dynamic configuration of the network. It is software-enabled with adaptive protocols at the Open Systems Interconnection (OSI) link, network, and transport layers, so latency, power consumption, and computational demands are optimized. Significant advances in civil and commercial applications can be enablers for this capability.

Vision for Weapons Future Capabilities

- **Air Force achieves capability to employ and deliver effects from:**
  - **Lethal, non-lethal, kinetic, non-kinetic**
  - **Directed energy, information operations**
  - **On demand with high accuracy in cluttered environment**
  - **"Now Time"**
  - **Accurately predicted results**



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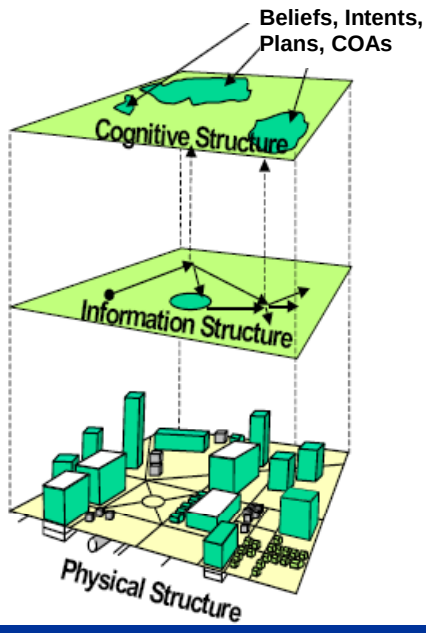
To implement our vision of enhanced effectiveness in urban combat, the Air Force must expand its set of weapons capabilities well beyond existing kinetic effects. A range of smaller, more agile weapons is required for the urban environment. Additionally, non-lethal and directed energy weapons, along with information operations, must be tailored for the cluttered urban environment. The Air Force must ensure that users, or customers, have adequate knowledge of the range of effects available. These effects must be responsive and available across the breadth of the urban environment. Weapons effects must also be well characterized and modeled, so that users know what to expect and can assess success or failure (BDP and BDA). This model-based approach for assessment is essential when dealing with non-lethal weapons and information operations.

Vision for MS&T Future Capabilities

- **Joint, integrated shared MS&T architecture, including**
  - **Strategy, acquisition, CONOPS/ doctrine/TTP development, intel, operations, logistics, training**
- **Common data sources**
- **Common or consistent models**
  - **Adversary's intent**
  - **Embedded cultures / behaviors**
  - **Predictive COAs and effects, including non-kinetic, IO, BDA**
  - **Learning**
- **Joint training in USECT context**
  - **Augment live with virtual**



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Our vision of the future of MS&T in urban operations lies in a joint, integrated environment with a common understanding of CONOPS, TTPs, and effects. An Air Force focus on operations in the air and an Army and Marine focus on ground interactions has driven each to different data requirements and levels of fidelity for MS&T. Cultural, economic, and political side effects of operations need to be modeled in Air Force systems and training to enable the predictive analysis of COAs. The compression of time and space in urban operations demands maximum Jointness and understanding. MS&T is the enabler for this Jointness and understanding.

In order to realize these benefits, the services need a Joint, integrated, and shared MS&T architecture that spans all phases of military activities. Critical for the Air Force is the need to integrate considerations of intent, behaviors, and non-kinetic effects into its training, planning, acquisition, operations, and follow-up actions. An architecture provides a common framework that guides new development efforts and federation of existing models. In order to be useful, we will need a broadly accepted MS&T architecture including provision for rapid feedback and learning.

Section 4: Recommendations

Clearly, the visions we have just described will significantly enhance Air Force Operations in Urban Environments and in other mission areas. We will now describe a number of specific recommendations that will get us moving toward that vision.

Urban Ops Recommendations

1. Support Joint CONOPS, TTPs, training
2. Lead development of a Joint Automated Control Capability (JACC)
3. Augment Mobile ad hoc Urban Ops network
4. Deliver Urban-Tailored ISR
5. Improve operations via modeling, simulation, and training
6. Develop weapons tailored for Urban Ops
7. Develop Joint Urban Ops S&T plan

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This chart identifies the seven recommendations of the study, which will be described in more detail in the subsequent charts. We realized that the achievement of the visions for these functional areas, including ISR, C2, weapons, and MS&T should not be expected overnight. Progress must be paced by those interim improvements which can make a major difference, especially when they could be realized by exploiting or tailoring existing programs and capabilities, like the "Star Performer" systems identified earlier.

R1: Support Joint CONOPS; Develop AF CONOPS, TTPs, Training

- **CONOPS**
  - **Shape the battlespace during all USECT stages**
  - **Support small unit calls for effects**
  - **Provide ISR and other data to small units on demand**
  - **Maintain persistent comms relays and data dissemination**
  - **Evolve from procedural controls for deconfliction to dynamic airspace management**
- **TTPs / Training**
  - **Make consistent with CONOPS**
  - **Conduct TTP training/rehearsal in USECT context**
  - **Conduct virtual Joint training**

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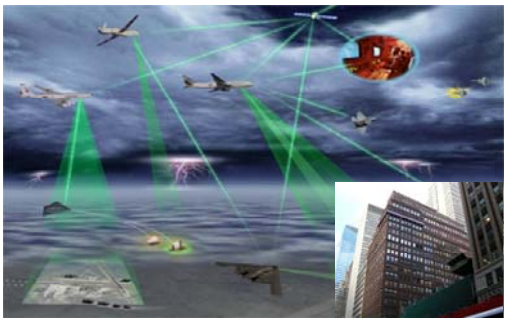
The strength of the US Armed Forces comes from a combination of superior systems and the people using them. By far, well-trained people using these systems in creative ways make the greatest contribution to effectiveness. The uniqueness of the urban environment and the limited number of new systems that will be developed dictate an emphasis on developing Joint CONOPS, TTPs, and training optimized for urban operations.

The Air Force should develop urban operations-specific CONOPS and TTPs to leverage its vast capabilities in support of urban operations. MS&T enables more extensive opportunities for developing CONOPS, TTPs, and training, but must be accomplished Jointly and specifically for Urban Operations. TTPs that permit a rapid (less than 2 minutes) response for fire support from units as small as an infantry platoon need to be developed. This will require rethinking how fire support requests are relayed from the person in the fight to the person in the cockpit. Obstacles (technical and procedural) that inhibit the flow of ISR information from Air Force platforms to ground forces must be eliminated. Ground forces should be able to pull necessary ISR information on-demand at a level and pace relevant to their operational responsibility. The Air Force has the capability to provide and maintain communication relays and other Command, Control, Communication, Computer, Intelligence, Surveillance, and Reconnaissance (C4ISR) infrastructures, and should deploy such systems and capabilities with Joint operations in mind. To accomplish this, the Air Force must evolve from procedural to dynamic airspace management to facilitate a more optimal use of limited airspace in an urban environment.

Today's training focuses almost exclusively on the execution phase and many improvements can and should be made in that training. Training should also be extended to other phases, especially to the understanding and shaping phases of urban conflict, but in this recommendation we will focus primarily on execution. As a first step, the Air Force and Army, using lessons from the Marine Corps, should Jointly develop urban operations training objectives and a training approach that assures that every operator deploying to an environment, where urban operations are expected, has trained for that environment. Currently Ft. Polk and Ft. Irwin have extensive urban environments for troop training. One or both of these environments should be expanded to include the routine employment of air power in Joint training. In preparation for these live training environments, Air Force operators should be trained on a series of virtual part task trainers for urban ops, which should be developed in conjunction with the existing Army training program.

R2: AF Lead Development of a Joint Automated Control Capability (JACC)

- **Leverage existing programs:**
  - **Army Advanced Field Artillery Tactical Data System (AFATDS) for Joint fires**
  - **DARPA work on sensor mgmt**
  - **J-UCAS for platform control**
- **Define a JACC architecture**
  - **Transition to networked airspace, logistics, sensor and effects delivery control**



- **Provide Air Component Coordination Elements (ACCEs) & Joint Terminal Attack Controllers (JTACs) trained to operate in the Urban Environment**

24

The concept for a Joint Automated Control Capability (JACC) was described earlier. Existing service and agency programs can be leveraged to develop this capability over time. Getting multi-service "buy in" on a vision and concept of operations is, of course, an important first step. The Air Force should immediately work cooperatively with the Army to modify AFATDS to include all available air-deliverable weapons. While this will not be a total solution to "Joint Fires Automation," it will be an initial step toward realizing the capability.

The Air Force must exploit the DARPA programs developing advanced technologies for automated sensor control. Joint Unmanned Combat Air Systems (JUCAS) can be leveraged to field a robust set of platform control algorithms. More advanced capabilities, such as effects-based weapons-target pairing in accordance with the JFC's Priorities, can be added to the above software capabilities as technology matures. Many of these applications are developed and being fielded as part of the Army's Future Combat System (FCS) Program.

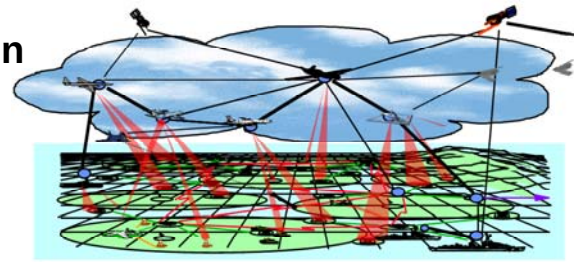
The Air Force must work in the Joint environment to define a JACC architecture leveraging existing applications and Operating Systems (e.g., C2C). This will allow a means to transition from procedural control of air power to networked (allowing increased automation) control of air power to reduce response times. When fully developed, a JACC will allow for highly responsive and dynamic airspace, ISR, fires/effects and logistics delivery control.

The implementation of JACC will enable model-based training to ensure that all individuals who are assigned either to Air Component Coordination Elements (ACCEs) and/or

Joint Terminal Attack Controller (JTAC) duty are well trained in Urban Operations. These individual C2 warriors will be highly critical to the success of future Joint urban air operations.

R3: AF Augment Mobile Ad Hoc Networking for Urban Operations

- Expand Roll-On Beyond LOS Enhancement (ROBE) specifically for urban terrain
- Field airborne nodes to extend Army's tactical networks to urban terrain



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Current communications "connectivity" to support the ground force is inadequate for urban operations. A first step is to provide an airborne node specifically to support communications for urban operations. This node can be based upon the technologies imbedded in the Roll-On Beyond LOS Enhancement (ROBE) fielded on KC-135 tankers. By adding key Ground Force waveforms and data links, additional connectivity for ground forces can be provided. A number of Air Force, Army, and DARPA programs and experiments are in place which, when mature, will allow this airborne node to extend its capability.

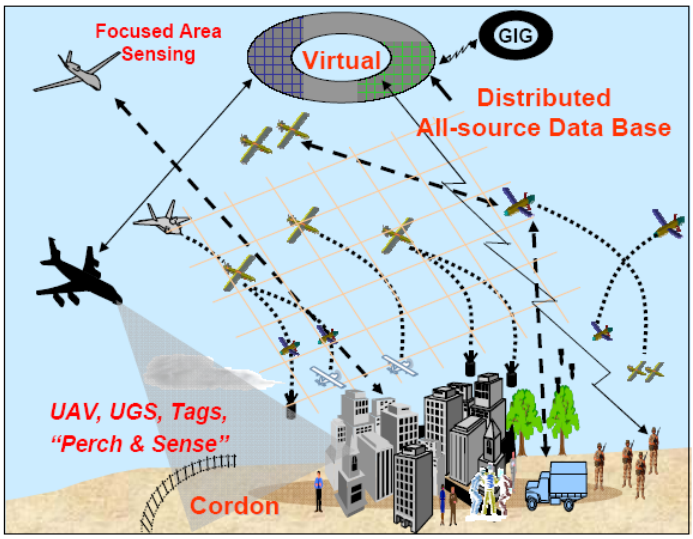
Air Force participation is absolutely essential to achieve the communications that urban operations demand. The insightful AFRL and AFRL/DARPA mobile ad hoc networking, Global Information Grid (GIG) and Joint Tactical Radio System (JTRS) compatible thrusts (TTNT, QNT, etc.) focus on networking in open battlespaces. The Air Force should extend these to urban terrain and several capabilities applicable to that environment.

DOD is rapidly maturing infrastructure free, wireless, mobile ad-hoc networking for combat in open terrain. These advances should be expanded to include urban terrain. The Army's Multifunctional On the Move Secure Adaptive Communications (MOSAIC) Advanced Technology Demonstration (ATD), DARPA's Tactical Targeting Network Technology (TTNT), and the Quint Networking Technology (QNT) program are making meaningful progress to network personnel, units, airborne resources, and satellites robustly and completely in open battlespaces. The Air Force and its airborne and space borne capabilities are absolutely essential

for these capabilities in urban operations. Airborne nodes have greater coverage, can penetrate urban canyons, and have the span to help the entire network know its instantaneous configuration and to route information among all participants. In the near term, the Enhanced Position Location Reporting System (EPLRS) requires a central registration and controlling node. Moving that node above the city would enhance EPLRS capabilities significantly. The Warfighter Information Network—Tactical (WIN-T) also demands airborne capabilities. Commercial, urban networking often uses nodes on the exterior of buildings or lasers (even through windows) to network separated elements of organizations. The Air Force should consider adapting these capabilities for communications with ground forces in urban environments. The Air Force should provide those capabilities and lead the application of these advances in the urban environment. In the longer term, advanced routers such as the TTNT and MOSAIC Router, and the real world warfighter networking of QNT should be deployed on every airborne platform possible.

R4: Deliver Urban-Tailored ISR

- Evolve toward an accessible all-source information database
- Add autonomous geo-registration to AF sensors
- Use airborne sensors for cordoning
- Develop sensing for rapid IPB — 3-D mapping first
- Pursue next phase of staring ISR (AFRL's "Gotcha")
- Develop air deployable ID/discrimination sensors



Joint Battlespace Information Enterprise Service

2

The USAF should adopt several actions to move toward implementation of a Joint Battlefield Information Enterprise Service (JBIES) capability, which will be tailored toward the unique challenges of an urban environment. Specifically, we recommend the following actions be implemented to evolve and enable the JBIES.

Evolve an all-source repository of ISR data and information, which will provide various echelons of users accessible, timely, responsive information as needed. DCGS, as a current multi-service program hosting data from a variety of sensor systems, provides a good starting point for this evolution.

Enable an automated geolocation capability on all Air Force ISR sensors to reduce registration errors, improve sensor data timeliness, and reduce reliance on disparate map coordinate systems.

Use Air Force sensor platforms to provide cordoning surveillance of national borders, cities, and neighborhoods. This will reduce infiltration of insurgents, limit their access to restricted areas (e.g. ammunition storage sites), and protect ground units from being flanked. For cordoning at national borders and city limits, the Air Force can use existing sensors (such as Joint Surveillance Target Attack Radar System (JSTARS) and Global Hawk), but competing mission priorities necessitate command decisions as to their use. For neighborhood cordoning, new staring ISR sensors, tailored to the urban environment, will be very effective.

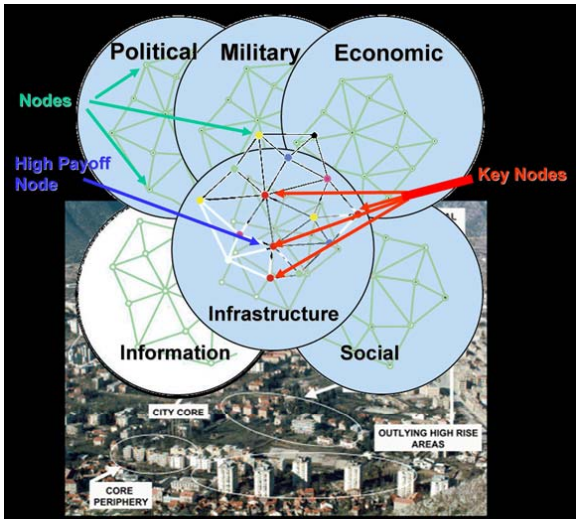
The Air Force should provide an accurate, up to date 3-D characterization of the urban terrain, via laser detection and ranging (LADAR), stereo imaging, or a similar technique. Likewise, characterization of the urban environment (such as the nominal traffic patterns, electronic environment, and Measurement and Signatures Intelligence (MASINT) background levels for Weapons of Mass Destruction (WMD) detectors) is an important part of the Intelligence Preparation of the Battlefield (IPB) function. Sensors for these functions need to be developed.

AFRL's GOTCHA sensor concept offers a major advantage for urban ISR. Its ability to provide persistent, staring ISR over a large area will reduce shadowing by urban canyons and enable day/night/all weather "eye in the sky" surveillance. Such a sensor is needed for effectively supporting urban operations, engagements, and, as noted above, neighborhood cordoning.

The JBIES must provide a target identification and characterization capability, in addition to detection. This requires a family of air deployable, low cost sensors, including perch and sense, unattended ground sensors, mini-UAVs, and taggants.

R5: Improve Operations via MS&T

- **Advocate and support a Joint UO MS&T strategy, architecture, and action plan**
  - **Evolve and integrate cultural/social/behavioral/ infrastructure models**
  - **Ensure adaptive and responsive feedback from ops (learning)**
  - **Deploy and train down to the small unit level**



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Urban operations are inherently Joint and the MS&T to support these operations also needs to be developed in a Joint context. The complexity of urban MS&T is such that a significant effort is required, in partnership with the Army and the Marine Corps, to lay out a strategy, architecture, and action plan that can provide the necessary framework. On-going disparate efforts across the services should be aligned according to this strategy and plan. The architecture should provide a federating mechanism for models and databases. It should also provide appropriate integration across domains that include strategy development, CONOPS/TTP development, operations, acquisition, and training. While disconnected and inconsistent models and databases are not just an urban problem, the complexity of urban operations increases the need for better model and database integration.

The architecture also needs to provide for learning adaptive models and databases so that, as operations are executed and data gathered on the effects, continual adjustments can be made to bring the simulated environment closer to the real environment.

The plan needs to include populating the architecture with models and data that include:

- Prediction of effects
- Cultural, social and behavioral modeling
- Urban infrastructure models and data
- Full spectrum of effects (lethal and non-lethal)

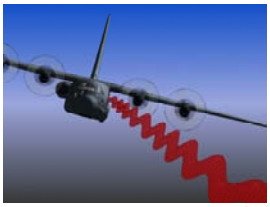
- Learning

Commonality, or at least consistency, across domains, and feedback of results from one domain to another is essential to establishing a process of increasing validity. A focused, aggressive data collection effort is needed in order to develop the wide spectrum of models that will be required to support Urban Operations.

Deployment of models and simulations should focus at the small unit level, and realistic joint training should be conducted to validate the models and prepare the joint forces for urban operations. Continuous feedback from use of the models in the training environment should be incorporated in the evolution of TTPs.

R6: Develop weapons tailored for Urban Ops

- Develop and rapidly field a kinetic weapon which allows improved danger close operations
- Develop cockpit-selectable yield munitions and low-cost, maneuverable air-delivered weapons
- Develop and deploy a DE capability to do close-in urban attack
- Include Urban Ops in future weapon requirements
- Institutionalize and make available Info Ops capabilities and potential effects to the Urban Ops warfighter/planner



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We must develop weapons specifically designed for the urban scenario, rather than continue to rely on residual capabilities from existing combat systems. As a first step, we should rapidly field a kinetic weapon that allows a 150-meter danger close operation so that we can support a friendly squad as close as 150 meters to the target location. In the longer-term, we need to develop a kinetic weapon with cockpit-selectable yield/fuzing and maneuverability. These weapons must be low-cost, so we should consider balancing variables such as single-shot probability of kill (SSPk).

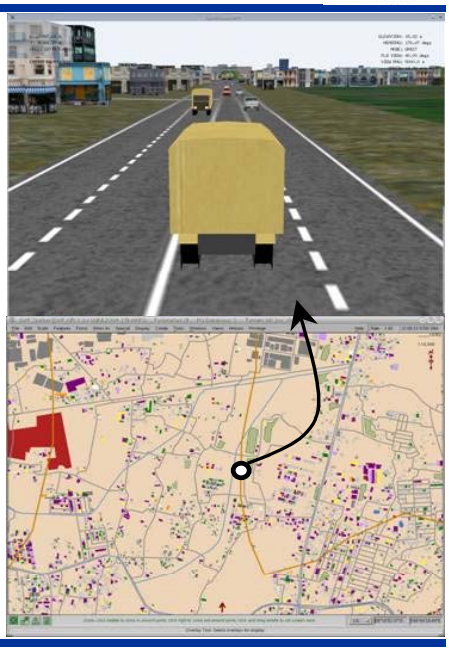
We need to develop and deploy a DE capability. While challenges in this area remain, DE offers great potential for electronic attack or non-lethal crowd control with essentially no collateral damage.

We also want to ensure that requirements for future weapons include urban operations scenarios.

Information operations must become more institutionalized in the operational Air Force. Since IO capabilities with great potential are not used in some cases, we need to correct this deficiency with training and formal instantiation of IO. This instantiation should include the ability to predict effects, determine results, and complement IO with other weapon systems.

R7: Develop Joint UO S&T Plan

- Three of AFRL's eleven Future Long Term Challenges apply to UO
  - Anticipatory Operations and Collaborative Sensing
  - Predictive Battlespace Awareness
  - Effects for Difficult Targets
- AFRL's Future Long Term Challenges should be coordinated with the other services to develop a Joint UO S&T approach



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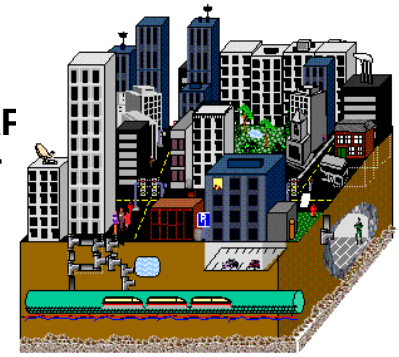
AFRL has a number of key technology programs addressing urban operations. In particular, three of the eleven Future Long-Term Challenges apply directly to Urban Operations. These efforts should address many of the challenges we have identified. However, future urban operations would benefit from a more efficiently coordinated S&T approach to eliminate redundancy and allow common applications to be more fully exploited.

Section 5: The Bottom Line

Bottom Line

- Extremely stressing and important environment
- Joint and AF CONOPS, TTPs, and training urgently needed
- Mission success requires focused AF support to ground force commander
  - Persistent surveillance, reconnaissance and focused intelligence
  - Robust communication; info services
  - Responsive, precise effects on demand
  - Priority for key Urban Ops technologies
- Training and operations demand MS&T-based approach



USAF must play a major role in Urban Ops

30

In conclusion, we have shown that the urban environment is very stressing. There can also be little doubt that it will continue to be a vitally important venue for future military actions.

We must accelerate the development of Air Force CONOPS and actively support the effort to complete a Joint CONOPS. Air Force and Joint TTPs must be developed and training needs must also be satisfied.

The Air Force actions must focus on providing ground forces with useful intelligence, more reliable communications and data links, and responsive precise effects in "Now time". The technology base in the Air Force should prioritize the key research and development (R&D) activities related to urban operations, and the Air Force should coordinate, with DOD, the establishment of a Joint Urban Operations S&T Program.

Any urban operations training initiatives or operational planning/rehearsal activities must depend on a model-based approach to credibly mirror the real urban scenarios.

Finally, our study team feels strongly that the Air Force can, and must, play a major role in urban operations, because it is likely to be the enemy's venue of choice and the ground force is heavily dependent on our support.

Appendix A: Terms of Reference

USAF Scientific Advisory Board

Summer Study
FY 2005
Air Force Operations in Urban Environments

Terms of Reference

Background

Recent conflicts illustrate that the role of the U.S. Air Force in all phases of urban operations is evolving. This evolving role necessitates increased coordination of air, space and ground operations. Future operations will also face increased challenges of real time information operations, highly flexible electronic warfare as well as the need to detect, locate and negate an evolving set of enemy weapons. Combat simulations of Combined Force strategies/tactics to predict potential outcomes, which include all aspects of air, space and ground operations, will be essential to understanding and predicting adversary actions and achieving desired effects. While current conflicts focus on finding hidden bombs, future conflicts in urban environments may involve entrenched urban forces with WMD or equally sophisticated weapons. Of special significance are Air Force actions in support of Stability And Security Operations (SASO), which have become a major challenge to coalition forces in Afghanistan and Iraq.

The Air Force must operate in this difficult joint environment in conjunction with ground forces to provide 24/7 persistent surveillance and reconnaissance, rapid timely detection, accurate identification, robust command, control, communication, and the capability to impair, incapacitate, or destroy fixed and mobile targets (while minimizing collateral damage) and provide accurate BDA.

Study Products

Briefing to SAF/OS & AF/CC in October 2005. Publish report in December 2005.

Charter

The study should identify and provide recommendations on the following issues:

- The evolving role of the Air Force air, space, and information forces in all phases of urban operations including non-lethal operations and considering a broad range of adversary weapons.
- Methods to provide timely and persistent ISR in difficult urban conditions.
- Lethal and non-lethal capabilities to impair, incapacitate, or destroy fixed or mobile targets while minimizing collateral damage.
- The use of information operations and electronic attacks in urban operations.

- Means for accurate lethal and non-lethal attacks effects assessment, including Battle Damage Prediction (BDP) and Assessment (BDA), in urban operations.
- Command, control, and communications networking among land and air forces in support of future urban operations.
- Modeling air, space, and ground forces to predict potential outcomes that can provide enhanced understanding of mission effectiveness by predicting the desired effects on adversaries and their COAs.
- Identification of specific SASO support activities that could be accomplished by the Air Force, including predictive ISR, rapid target identification and swift engagement of insurgent forces in an urban environment.
- This study will build on recent DSB studies, a 2004 ASB Study on Future Combat System - Urban Operations, and 1999 AF SAB Operations Other Than Conventional War Study.

Appendix B: Study Members

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Capt Jeff Finch, USAF – Tech Writer

Command, Control, and Communications / Intelligence, Surveillance, and Reconnaissance Panel
Dr. Lou Marquet – Panel Chair
Mr. John Entzminger – Deputy Panel Chair

C3 Sub-Panel
Maj Gen John Corder, USAF, Ret - Chair
Dr. John Betz
VADM Lyle Bien, USN, Ret
Dr. David Finkleman
Col Ben Fletcher, USA, Ret
Maj Gen John Hawley, USAF, Ret
Maj Gen Eric Nelson, USAF, Ret

ISR Sub-Panel
Dr. Jerry Krassner - Chair
Dr. Dan Held
Dr. Lou Metzger
Col Bill Grimes, USAF, Ret

Capt Jay Kucko, USAF – Executive Officer
Capt Phil Ambard, USAF – Technical Writer
Capt Mike Plantenga, USAF – Executive Officer

Modeling, Simulation, and Training Panel
Dr. Greg Zacharias – Panel Co-Chair
Dr. Deborah Boehm-Davis – Panel Co-Chair
Mr. Scott Fouse
Dr. Ron Fuchs
Dr. Bill Swartout
Dr. Janos Sztipanovits
Dr. John Tangney
Col Dan DeForest
Maj "Pia" Lomax, USAF – Technical Writer
Capt Dave Meyer, USAF – Executive Officer
Capt Dave Buchanan, USAF – Technical Writer

Systems Concepts and Integration Panel
Dr. Ray Johnson – Panel Co-Chair
Mr. Tim Bonds– Panel Co-Chair
Dr. Alec Gallimore
Mr. Ed Brady
Dr. Alison Brown
Mr. Gil Herrera
Mr. Tom McMahan
Mr. Mark Mykityshyn
Maj Mark Schmidt, USAF – Executive Officer
Capt Mario Serna, USAF – Technical Writer

Appendix C: Visits and Briefings

USAF
CSAF (Heading Check)
DMSO
SAF/AAF
SAF/AQL
AF/XOXS
AF/XOL
AFC2ISRC
ACC
AFSAA
AWFC
AAC
AFAMS
AFDC
AFSOC
AFRL/DE, MN, IF, SN, HE, OSR
NASIC
13th ASOS
AGOS
AFIWC

Army/Navy/USMC
NTC
ASB
ARL
PEO Soldier
TRASYS
TRADOC
RDECOM
CERDEC
OneSAF
ONR
Marine Corps Development Command
USMC Warfighting Lab
3rd MAW, MCAS Miramar

Academia & Other
Dr. David Kay (formerly ISG)
Institute for Non-Lethal Defense Technology, Penn State University
Carnegie Mellon University
Old Dominion University
ICT

OSD & Joint
AUSD (Adv Concepts)
DUSD (S&T)
DTRA
DARPA
DIA

JWAC
JFCOM
JUOO
SOCOM
CENTCOM
Lt Gen Conway, J3 (previously 1 MEF)

Industry
Boeing
Northrop Grumman
Lockheed Martin
Raytheon

FFRDCs
MITRE
IDA
RAND
MIT-LL

Appendix D: Glossary

Architecture – A framework or structure that portrays relationships among all the elements of the subject force, system, or activity. An orderly arrangement of parts; structure.

Battlespace – The environment, factors, and conditions that must be understood to successfully apply combat power, protect the force, or complete the mission. This includes the air, land, sea, space and the included enemy and friendly forces; facilities; weather; terrain; the electromagnetic spectrum; and the information environment within the operational areas and areas of interest.

Close Air Support (CAS) – Air action by fixed- and rotary-wing aircraft against hostile targets that are in close proximity to friendly forces and that require detailed integration of each air mission with the fire and movement of those forces. Also called CAS.

Coalition – An ad hoc arrangement between two or more nations for common action.

Collateral Damage – Unintentional or incidental injury or damage to persons or objects that would not be lawful military targets in the circumstances ruling at the time. Such damage is not unlawful so long as it is not excessive in light of the overall military advantage anticipated from the attack.

Command and Control (C2) – The exercise of authority and direction by a properly designated commander over assigned and attached forces in the accomplishment of the mission. Command and control functions are performed through an arrangement of personnel, equipment, communications, facilities, and procedures employed by a commander in planning, directing, coordinating, and controlling forces and operations in the accomplishment of the mission.

Command, Control, Communications, and Computer Systems (C4) – Integrated systems of doctrine, procedures, organizational structures, personnel, equipment, facilities, and communications designed to support a commander's exercise of command and control across the range of military operations. Also called C4 systems.

Communications – To use any means or method to convey information of any kind from one person or place to another.

Communications Network – An organization of stations capable of intercommunications, but not necessarily on the same channel.

Complexity – Something complex; the interesting aspect is usually how complexity scales with the size of the input (the scalability).

Concept of Operations (CONOPS) – A verbal or graphic statement, in broad outline, of a commander's assumptions or intent in regard to an operation or series of operations. The concept of operations frequently is embodied in campaign plans and operation plans; in the latter case, particularly when the plans cover a series of connected operations to be carried out simultaneously or in succession. The concept is designed to give an overall picture of the operation. It is included primarily for additional clarity of purpose.

Connectivity – The ability to exchange information by electronic means.

Danger Close – In close air support, artillery, mortar, and naval gunfire support fires, it is the term included in the method of engagement segment of a call for fire which indicates that friendly forces are within close proximity of the target. The close proximity distance is determined by the weapon and munition fired.

Data link – The means of connecting one location to another for the purpose of transmitting and receiving data.

Density – Complexity of structure or content.

Directed Energy (DE) – An umbrella term covering technologies that relate to the production of a beam of concentrated electromagnetic energy or atomic or subatomic particles. Also called DE.

Directed Energy Weapon – A system using directed energy primarily as a direct means to damage or destroy enemy equipment, facilities, and personnel.

Effects-Based Operations (EBO) – Consists of a set of processes, supported by tools and accomplished by people in organizational settings, that focuses on planning, executing, and assessing military activities for the effects produced rather than merely attacking targets or simply dealing with objectives. EBO complements, rather than replaces, target-based or objectives-based approaches (such as strategy-to-tasks).

Electronic Attack (EA) – That division of electronic warfare involving the use of electromagnetic energy, directed energy, or antiradiation weapons to attack personnel, facilities, or equipment with the intent of degrading, neutralizing, or destroying enemy combat capability and is considered a form of fires. Also called EA. EA includes: 1) actions taken to prevent or reduce an enemy's effective use of the electromagnetic spectrum, such as jamming and electromagnetic deception, and 2) employment of weapons that use either electromagnetic or directed energy as their primary destructive mechanism (lasers, radio frequency weapons, particle beams).

Electronic Warfare (EW) – Any military action involving the use of electromagnetic and directed energy to control the electromagnetic spectrum or to attack the enemy. Also called EW. The three major subdivisions within electronic warfare are: electronic attack, electronic protection, and electronic warfare support.

Electronic Warfare Support – That division of electronic warfare involving actions tasked by, or under direct control of, an operational commander to search for, intercept, identify, and locate or localize sources of intentional and unintentional radiated electromagnetic energy for the purpose of immediate threat recognition, targeting, planning and conduct of future operations. Thus, electronic warfare support provides information required for decisions involving electronic warfare operations and other tactical actions such as threat avoidance, targeting, and homing. Electronic warfare support data can be used to produce signals intelligence, provide targeting for electronic or destructive attack, and produce measurement and signature intelligence.

Fidelity – Exact correspondence with fact or with a given quality, condition, or event; accuracy.

Granularity – The quality of being composed of relatively large particles.

Information Operations (IO) – Also called IO; use of offensive and defensive information means to degrade, destroy, and exploit an adversary's information-based process while protecting one's own. Actions taken to affect adversary information and information systems while defending one's own information and information systems.

Infrastructure – An underlying base or foundation especially for an organization or system; the basic facilities, services, and installations needed for the functioning of a community or society, such as transportation and communications systems, water and power lines, and public institutions including schools, post offices, and prisons.

Intelligence Preparation of the Battlespace (IPB) – An analytical methodology employed to reduce uncertainties concerning the enemy, environment, and terrain for all types of operations. Intelligence preparation of the battlespace builds an extensive database for each potential area in which a unit may be required to operate. The database is then analyzed in detail to determine the impact of the enemy, environment, and terrain on operations and presents it in graphic form. Intelligence preparation of the battlespace is a continuing process.

Intelligence, Surveillance, and Reconnaissance (ISR) – An activity that synchronizes and integrates the planning and operation of sensors, assets, and processing, exploitation, and dissemination systems in direct support of current and future operations. This is an integrated intelligence and operations function.

Intratheater – Within a theater.

Joint Automated Control Capability (JACC) – A set of distributed computer processors running algorithms that, when fully developed, will provide automated assistance to C2 warriors commanding and controlling the employment of air power in support of urban operations.

Joint Battlespace Information Enterprise Service – A distributed, all-source, 4D (3 spatial dimensions plus time) database housing unexploited sensor output as well as analyst-processed products incorporating the functionality to publish information for subscription and "smart push" without user request. Additionally, it is coupled to search and discovery services via JACC to provide timely, responsive, and comprehensive sensor information.

Joint Force – A general term applied to a force composed of significant elements, assigned or attached, of two or more Military Departments operating under a single joint force commander.

Joint Force Commander (JFC) – A general term applied to a combatant commander, subunified commander, or joint task force commander authorized to exercise combatant command (command authority) or operational control over a joint force.

Joint Terminal Attack Controller (JTAC) – A qualified (certified) service member who, from a forward position, directs the action of combat aircraft engaged in close air support and other offensive air operations. A qualified and current joint terminal attack controller will be recognized across the Department of Defense as capable and authorized to perform terminal attack control. Also called JTAC.

Joint Urban Operations – Also called JUOs; all joint operations planned and conducted across the range of military operations on, or against objectives on a topographical complex and its adjacent natural terrain where manmade construction or the density of noncombatants are the dominant features.

Kill Probability (Pk) – A measure of the probability of destroying a target.

Laser Detection and Ranging (LADAR) – A technology that determines distance to an object or surface using laser pulses. Like the similar radar techology, which uses radio waves instead of light, the range to an object is determined by measuring the time delay between transmission of a pulse and detection of the reflected signal.

Line of Communication – A route, either land, water, and/or air, that connects an operating military force with a base of operations and along which supplies and military forces move.

Links – In communications, a general term used to indicate the existence of communications facilities between two points.

Machine-to-Machine (M2M) – Sensor to shooter integration capability.

Man-on-the-loop – Humans control, consent, and/or monitoring the processors, algorithms and models of an automated system.

Measurement and Signature Intelligence (MASINT) – Technically derived intelligence that detects, locates, tracks, identifies, and describes the unique characteristics of fixed and dynamic target sources. Measurement and signature intelligence capabilities include radar, laser, optical, infrared, acoustic, nuclear radiation, radio frequency, spectroradiometric, and seismic sensing systems as well as gas, liquid, and solid materials sampling and analysis.

Military Grid Reference System – A system which uses a standard-scaled grid square, based on a point of origin on a map projection of the surface of the Earth in an accurate and consistent manner to permit either position referencing or the computation of direction and distance between grid positions.

Model-Based Approach – A unique approach to modeling and simulation in which the knowledge is encapsulated in the form of models that are employed at various control layers to support the predefined system objectives.

Modeling – A schematic description of a system, theory, or phenomenon that accounts for its known or inferred properties and may be used for further study of its characteristics.

Node – The physical and functional grouping of communications and computer systems that provide terminating, switching, and gateway access services to support information exchange. See also common operating environment; global grid.

Nonlethal Weapons – Weapons that are explicitly designed and primarily employed so as to incapacitate personnel or material, while minimizing fatalities, permanent injury to personnel, and undesired damage to property and the environment. Unlike conventional lethal weapons that destroy their targets through blast, penetration, and fragmentation, nonlethal weapons employ means other than gross physical destruction to prevent the target from functioning. Nonlethal weapons are intended to have one, or both, of the

following characteristics: (1) They have relatively reversible effects on personnel or materiel or (2) they affect objects differently within their area of influence.

Persistent ISR – A collection strategy that emphasizes the ability of some collection systems to linger on demand in an area to detect, locate, characterize, identify, track, target, and possibly provide battle damage assessment and re-targeting in near real-time. Persistent surveillance facilitates the formulation and execution of preemptive activities to deter or forestall anticipated adversary courses of action.

Predictive Battlespace Awareness (PBA) – A multidimensional understanding of the operational environment achieved and maintained by a commander, allowing him or her to predict and pre-empt enemy activity. PBA results from the integration of Target Development, Intelligence Preparation of the Battlespace (IPB), Intelligence, Surveillance, and Reconnaissance (ISR), Strategy and Planning, ISR Employment, and Assessment.

Procedures – Standard, detailed steps that prescribe how to perform specific tasks.

Rules of Engagement – Directives issued by competent military authority that delineate the circumstances and limitations under which United States forces will initiate and/or continue combat engagement with other forces encountered.

Shape the Battlespace – The environment, factors, and conditions that must be understood to successfully apply combat power, protect the force, or complete the mission. This includes the air, land, sea, space, and the included enemy and friendly forces; facilities; weather; terrain; the electromagnetic spectrum; and the information environment within the operational areas and areas of interest.

Signals Intelligence (SIGINT) – A category of intelligence comprising either individually or in combination all communications intelligence, electronic intelligence, and foreign instrumentation signals intelligence, however transmitted. Intelligence derived from communications, electronic, and foreign instrumentation signals.

Simulation – A representation of the operation or features of one process or system through the use of another.

Special Operations Forces (SOF) – Those Active and Reserve Component forces of the Military Services designated by the Secretary of Defense and specifically organized, trained, and equipped to conduct and support special operations. Also called SOF.

Tactics – The employment and ordered arrangement of forces in relation to each other.

Techniques – Non-prescriptive ways or methods used to perform missions, functions, or tasks.

Time-of-Flight – In artillery, mortar, and naval gunfire support, the time in seconds from the instant a weapon is fired, launched, or released from the delivery vehicle or weapons system to the instant it strikes or detonates.

Unmanned Aerial Vehicle (UAV) – A powered, aerial vehicle that does not carry a human operator, uses aerodynamic forces to provide vehicle lift, can fly autonomously or be piloted remotely, can be expendable or recoverable, and can carry a lethal or nonlethal payload. Ballistic or semiballistic vehicles, cruise missiles, and artillery projectiles are not considered unmanned aerial vehicles. Also called UAV.

Weapons of Mass Destruction (WMD) – Weapons that are capable of a high order of destruction and/or of being used in such a manner as to destroy large numbers of people. Weapons of mass destruction can be high explosives or nuclear, biological, chemical, and radiological weapons, but exclude the means of transporting or propelling the weapon where such means is a separable and divisible part of the weapon.

Appendix E: Acronyms and Abbreviations

3-D	Three Dimensional
AADS	Airborne Active Denial System
ACCE	Air Component Coordination Elements
AF	Air Force
AFATDS	Advanced Field Artillery Tactical Data System
AFRL	Air Force Research Laboratory
ASB	Army Science Board
ATD	Advanced Technology Demonstration
ATL	Advanced Tactical Laser
BDA	Battle Damage Assessment
BDP	Battle Damage Prediction
C2	Command and Control
C3	Command, Control, and Communications
C3ISR	Command, Control, Communications, Intelligence, Surveillance and Reconnaissance
C4ISR	Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance
CAS	Close Air Support
CENTCOM	Central Command
COA	Course of Action
CONOPS	Concept of Operations
DARPA	Defense Advanced Research Projects Agency
DCGS	Distributed Common Ground System
DE	Directed Energy
DOD	Department of Defense
DSB	Defense Science Board
EBO	Effects-Based Operations
EPLRS	Enhanced Position Location and Reporting System
EW	Electronic Warfare
FCS	Future Combat System
FFRDCs	Federally Funded Research and Development Centers
GIG	Global Information Grid
GPS	Global Positioning System
ID	Identification
IO	Information Operations

IPB	Intelligence Preparation of the Battlefield
ISR	Intelligence, Surveillance, and Reconnaissance
JACC	Joint Automated Control Capability
JBIES	Joint Battlespace Information Enterprise Service
JFC	Joint Force Commander
JFCOM	Joint Forces Command
JMEM	Joint Munitions Effectiveness Manual
JSTARS	Joint Surveillance Target Attack Radar System
JTAC	Joint Terminal Attack Controller
JTRS	Joint Tactical Radio System
JUCAS	Joint Unmanned Combat Aerial System
LADAR	Laser Detection and Ranging
M2M	Machine-to-Machine
MASINT	Measurement and Signatures Intelligence
MS&T	Modeling, Simulation, and Training
OIF	Operation Iraqi Freedom
OSD	Office of the Secretary of Defense
OSI	Open Systems Interconnection
QNT	Quint Networking Technology
R&D	Research and Development
ROBE	Roll-on Beyond Line of Sight Enhancement
S&T	Science and Technology
SAB	Air Force Scientific Advisory Board
SASO	Stability and Support Operations
SASO	Stability and Security Operations
SIGINT	Signals Intelligence
SOCOM	Special Operations Command
TTNT	Tactical Targeting Network Technology
TTP	Tactics, Techniques, and Procedures
UAV	Unmanned Aerial Vehicle
UGS	Unattended Ground Sensors
UPS	Universal Polar Stereograph
USA	United States Army
USAF	United States Air Force
USECT	Understand, Shape, Execute, Consolidate, Transition
USMC	United States Marine Corps
UTM	Universal Transverse Mercator

WIN-T	Warfighter Information Network—Tactical
WMD	Weapons of Mass Destruction

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Appendix F: Initial Distribution

Air Force Leadership
Secretary of the Air Force
Chief of Staff of the Air Force
Under Secretary of the Air Force
Vice Chief of Staff of the Air Force

Air Force Secretariat
Deputy Under Secretary of the Air Force (International Affairs)
Assistant Secretary of the Air Force (Acquisition)

Air Staff
Assistant Vice Chief of Staff of the Air Force
Director of the Air National Guard
Chief of Air Force Reserve
Scientific Advisory Board Military Director
Chief Scientist of the Air Force
Air Force Warfighting Integration and Chief Information Officer
Air Force C2ISR Center
Deputy Chief of Staff of the Air Force Air and Space Operations
ISR Directorate
Operations and Training Directorate
Requirements Directorate
Deputy Chief of Staff of the Air Force Plans and Programs

Air Force Major Commands
Air Combat Command
Air Education & Training Command
Air Force Materiel Command
Air Force Space Command
Air Force Special Ops Command
Air Mobility Command
Pacific Air Forces
U.S. Air Forces in Europe
Air Force Reserve Command

Other Air Force Elements
USAF Warfare Center
Air Force Research Laboratories
Air Force Electronic Systems Command

Executive Office of the President
National Security Council

Office of the Secretary of Defense
Under Secretary of Defense (Intelligence)
Under Secretary of Defense (Policy)
International Security Programs – Office of National Disclosure Policy
Assistant Secretary of Defense (Network Interoperability and Integration)
Office of Force Transformation

Joint Chiefs of Staff
Chair, Joint Chiefs of Staff
Vice Chair, Joint Chiefs of Staff
Joint Chiefs of Staff, Director of Intelligence
Joint Chiefs of Staff, Director of Operations
Joint Chiefs of Staff, Director of Strategic Plans and Policy
Joint Chiefs of Staff, Director of C4 Systems
Joint Chiefs of Staff, Director of Operational Plans and Interoperability

Defense Agencies
Defense Information Systems Agency
Defense Advanced Research Projects Agency

Combatant and Regional Commands
U.S. Central Command
U.S. European Command
U.S. Joint Forces Command
U.S. Northern Command
U.S. Pacific Command
U.S. Southern Command
U.S. Special Operations Command
U.S. Strategic Command
U.S. Transportation Command

North American Air Defense
Joint Inter-Agency Task Force- South
Joint Inter-Agency Task Force- West
U.S. Forces Korea

Department of State
Bureau of Political Military Affairs – Office of Regional Security and Arms Transfers

Intelligence Community
Army Intelligence and Security Command,
Air Force Intelligence Agency
Central Intelligence Agency

Coast Guard Intelligence
Defense Intelligence Agency
Department of Energy – Office of Intelligence
Department of Homeland Security – Information Analysis and Infrastructure Protection Directorate
Department of State – Bureau of Intelligence and Research
Department of Treasury – Office of Intelligence Support
Federal Bureau of Investigation – National Security Division
Marine Corps Intelligence Activity
National Geospatial-Intelligence Agency
National Reconnaissance Office
National Security Agency
Office of Naval Intelligence

Advisory Boards
Army Science Board
Defense Policy Board
Defense Science Board
Naval Research and Advisory Committee
Naval Studies Board

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ABSTRACT (Maximum 200 Words)

Air Force Operations in Urban Environments:

As cities increase in number and importance, the population of the world gravitates toward these centers of commerce, culture, and society. Correspondingly, the cities will also attract an increasing proportion of military operations. Our adversaries know the complex urban environments present extremely difficult challenges for armed forces that have traditionally focused on the direct engagement of forces in open-terrain. To be ready for the future, the Air Force must fully understand the future urban environments it will operate in and then prepare, train, and equip its forces for these challenges.

This study addresses the challenge of developing more effective *Air Force Operations in Urban Environments*. The study was conducted in response to a request by the Secretary of the Air Force and the Air Force Chief of Staff.

In response to their direction, the Urban Operations study team conducted an extensive set of visits to Air Force operating commands and key operations centers, and reviewed numerous briefings from Air Force, Joint, and coalition organizations concerning current operations, systems, and procedures, as well as proposed future system and process improvements. The assistance of these organizations was essential to the completion of our effort. It was their involvement that guided the study team toward the findings, concepts, conclusions, and recommendations that comprise this study. The study team greatly appreciates the cooperation of these organizations, and acknowledges the valuable contributions their efforts made to this study.

14. SUBJECT TERMS

Urban Operations, Urban Ops, Urban Warfare, Joint Urban Operations, JUO, US Air Force, AF, USAF, UAV, Urban Attack, C3ISR, C2ISR, ISR, Command and Control, Modeling and Simulation, Systems Concepts and Integration, Non-Lethal Weapons, Mobile Networking, Urban Weapons, Mobile Communications, Science and Technology, Urban CONOPS, Urban Training, Urban TTP, Urban Strike

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