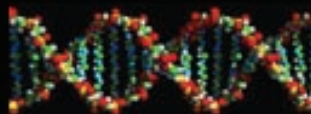


Blue Horizons 2007 "Horizon 21" Project Report



Air University Center for Strategy and Technology
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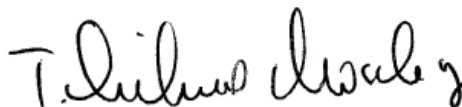
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Foreword

Today's Air Force is built on the visions of the future strategic environment developed from important studies of the distant future, such as Theodore von Karman's New Horizons, General Bernard Schriever's Project Forecast, and the New World Vistas and AF 2025 studies of the mid-1990s. After a pause of over a decade, HQ USAF, in conjunction with Air University, has begun to generate a new strategic estimate of the future under the banner of Blue Horizons.

I am proud to endorse and release the first year results of this exploration - Horizons 21. The study represents the efforts of 54 of our brightest ACSC and AWC researchers who spent a year becoming conversant in the technological trends in info/cyber technology, nano-technology, bio-technology, and directed energy. After assessing what impact the trends might have on the future operating environment and the USAF's ability to deliver military power within it, the students offered a number of ideas to exploit the opportunities and mitigate the threats they identified.

As we make decisions today to shape the Air Force of tomorrow, I invite each of you to examine and consider the implications of the study's findings and conclusions.



T. MICHAEL MOSELEY
General, USAF
Chief of Staff

Introduction

This study is about the future. On one level, it is about general trends and tendencies which will change our world and ourselves, and about which we can be fairly certain. On another level, it is an inquiry into the limits of the possible and an informed speculation about the probable—what could occur by 2025, not necessarily what will occur. While one can estimate with some degree of accuracy some aspects of the pace of progress, the fruits of that process are more difficult to discern. The future may not be predictable, but one can see the shape of things to come, if not their detail. This study has not been produced by scientists or futurists. Scientists tend to be poor prophets and prophets tend to be poor scientists. Rather, this study has been produced largely by serving Air Force officers, operators for the most part, who spent ten months becoming not expert in, but conversant with, the science and technology (S&T) progress in cyber-technology, nanotechnology, biotechnology and directed energy. They did so by reading, studying, and listening to outside speakers about the future. They also conducted TDY site visits with industry, academia, and government laboratories, and interviewed key experts in various scientific and technological fields. They wrote individual research papers on some aspect of the application of the technology they had studied, then came together for several weeks to examine the potential for synergistic effects among these technologies and their possible implications for the USAF.

In the process, they assessed a number of capabilities—several hundred— that could emerge in each of the four technological areas. They created a set of CONOPS and capabilities which could have operational impact in 2025. From these they created a list of priorities for investigation today that will help prepare the USAF for 2025.

Findings

Warfare is changing in fundamental ways. War—what it is, how it is waged, the participants, and its impact on the state, and the state system—is changing. While its essential nature and purpose may remain the same, its character and the manner in which it is waged are changing dramatically. In the first quarter of this century we will witness what amounts to a change in the physics of war. Matter, energy, space, time and information are all being transformed by emerging technologies. Being able to change things on a molecular/atomic scale, utilizing photons as well as electrons, navigating both outer space (our universe) and inner space (ourselves), and being able to fight and communicate at the speed of light changes the levers of power and threatens traditional superiority. That reality will alter combat waged in air, space and cyberspace. In order to compete successfully in this radically altered environment, the USAF must prepare now.

The insights the group gained and the recommendations they felt were important to emphasize are of several types and on several levels. Selected key technologies and synergies are identified in the briefing associated with this document. Many specific technology insights are contained in the selected individual research summaries in Appendix C. Other important insights are highlighted briefly below. They provide a description of salient aspects of the environment the USAF will face between now and 2025. Some are generally well understood, others less so, but all were deemed by the group to be sufficiently important to include based on their more focused findings.

Exponential change is the norm. The pace of accelerating technological change, the interaction of fundamental discoveries in science, and the “Internet-ed”

global pursuit of knowledge and its application are transforming the global order in fundamental ways. Over 70 percent of the research and development in the world occurs outside the U.S. and the bulk of it is in the private sector. Increasingly, neither the U.S. government nor DoD have much control over the direction, pace, quantity, quality, or proliferation of science and technology knowledge and its application.

Superiority may be fleeting. Because so much technology is civilian designed, commercially available, and globally distributed; and so many have access to it; periods of superiority in militarily critical technologies are likely to be more volatile and shorter in duration. Periods of superiority in all fields, including the military, may be increasingly short or even impossible. As transparency increases, secrets will be more difficult to preserve, while knowledge becomes ubiquitous and available to both state and non-state actors.

The test of survival is responsiveness to change. The former sources of dominance—being bigger, stronger, and faster than an opponent—may no longer suffice. Foresight and adaptability may be the future keys to survival and prosperity. Increasingly, being smarter—and just as importantly, more clever—may confer the greatest advantage. The U.S. held a substantial advantage in the industrial age because the criteria for dominance included massive production. In the coming age, it will not be enough to out-produce or out-spend an adversary...one must out think him.

Risk, reverses, and reinvention come with the territory. In attempting to cope with exponential change, risk increases dramatically. This is an inevitable effect of accelerating change, where change can outpace traditional planning and will necessarily create more surprise. Surprise in turn creates the necessity to scrap current concepts and

programs to meet the changing environment. Mistakes and wrong choices; as well as wasted time, money, and effort; will be inevitable if we are to successfully reinvent ourselves amid a constantly changing technological and strategic landscape.

Our technological superiority is at risk. This is not because we are less capable, but because there are more competitors with increasing skill levels in areas which were once monopolies or duopolies of superpowers. Overhead imagery, laser target designation, night vision goggles, direct broadcast satellite capability and instant global communications are now all available commercially to individuals. Seventeen years ago, only the U.S. and USSR possessed all of these.

Place bets now for 2025 capabilities. Given the increasing pace of scientific and technological progress, and the rate of advancement in certain fundamental areas, investments in 6.1 (basic research) funding are now a prerequisite for ensuring future capabilities exist or are within reach later. Robust science and technology spending is essential to meeting our obligation to try and shape future warfare as best we can. Realizing that we have no guarantee of control over outcomes, this spending amounts to an insurance premium that we must pay to guarantee our ability to rapidly adapt and successfully compete in unanticipated types of future warfare.

The major threat is operational surprise, not technological surprise. The synergistic interplay of cyber technology, biotechnology, nanotechnology and directed energy will produce capabilities that may not even be imagined now. The potential of these synergies may not be apparent until they are upon us, in somewhat the same way as many uses for GPS were unknown at its inception. We cannot predict the innovative ways that a disaffected, technologically savvy, ideologically dedicated individual

adversary (notionally referred to as “Bubba Einstein”) could catastrophically employ these technologies. While there may be some technology surprise, (particularly from the unexpected convergence of technologies), the bigger danger is operational surprise generated by first use of novel or existing technology in innovative ways. Coping with these threats requires an operator’s perspective on emerging technology to anticipate operational surprise, vigilant monitoring of adversary war preparation, and the ability to adapt or customize rapidly if surprise occurs.

An air campaign can be defeated without an air force. It is entirely possible to use nano particles to contaminate fuels, biological agents to degrade human performance, cyber attack to disrupt time over target, and directed energy to blind pilots—now. The use of these technologies to produce even greater havoc and destruction in the future is guaranteed, and will be possessed by many more actors, state and non-state alike. No potential adversary can compete with the USAF in the air, but they may not need to in the future.

Disruptive change will overshadow incremental change. The Air Force Scientific Advisory Board (AFSAB) concluded last summer that sustaining innovation—doing what we now do better and faster—will no longer suffice. Incremental change cannot keep pace with the overall accelerating pace of technological change. We must return to our roots of being a leader of disruptive change in the military and being the leading technological service in introducing new capabilities and concepts to provide for the common defense.

Weaponry is increasingly remote, robotic, cheap, small and swift. While the signs of this are with us now, the future will only amplify these tendencies. Nano-scale

particles, photons moving at the speed of light, molecular manipulation of the biosphere and life in it, the ability to create autonomous intelligent machines with sufficient processing power, and the replication of these in large numbers and at small cost, all suggest major changes in war. It may no longer be about conquest involving large numbers of people engaged in lethal, precision, kinetic kill, but increasingly a continuing contest among machines which is non-lethal, non-kinetic, and volumetric (i.e., wide-area oriented) – conducted at great distance over long time periods.

Everyone can play. The power of these emerging technologies is such that they can empower the weak and dispossessed to have inordinate impact. Some of the key forces driving technological change are societal demand, scientific discovery, corporate profits, ideological desires, and state and non-state envy and hatred of the U.S. These factors, not simply U.S. preferences, ensure progress for good and ill in war fighting technologies. These are available with increasing frequency and ease as reliance on commercial off-the-shelf (COTS) technology grows.

Recapitalization of people and expertise is paramount. Accelerating technological change necessarily demands significant procedural and organizational change. As the USAF reinvents itself in mastering space and cyberspace as well as air, the leadership of enlightened people will be an indispensable element in the process. One cannot overstate the importance of educating and organizing the force to create an agile, adaptive, learning organization capable of contending with the array of adversaries and the pace of technological change we face in the future.

Making operators knowledgeable about future science and technology is essential. If the USAF of the future is to be successful, it must recruit, retain, motivate,

challenge, educate, assign, and promote the right people with the right competencies at the right time. The pace and nature of accelerating technological change will demand a diverse, versatile and flexible personnel structure that has broader and deeper technological expertise as well as an understanding of the nature and implications of technological change. An officer corps with technological savvy, a broad perspective (strategic/operational/future oriented), and the dedication to duty that comes with wearing the uniform and taking the oath could be the difference between success and failure in the years to come.

General Recommendations

1. The USAF needs to plan for how it will cope with accelerating technological change. Our ability to shape the future and control the direction, quantity, quality, and proliferation of technology is limited, if possible at all. While we still have the dominant role in much global technology, that position is eroding. Over time, we may face a serious threat for which we are ill-prepared if we do not become more knowledgeable about, and responsive to, global progress in science and technology (S&T) and the implications it has for the USAF. Coping effectively with this situation might include such things as: 1) establishing an S&T Attaché Corps to monitor S&T progress in academe and industry, as well as the public sectors of a dozen key countries; 2) monitoring venture capital flows into those technology areas which others find most useful, threatening, or significant; and 3) changing the personnel system to create a “CRAF” like vehicle for the use of people, not aircraft, to insure needed expertise at the right time in service to the nation.

2. Initial investment compounds; one degree of course correction makes a dramatic difference at some over time and permits us to "lead turn" our adversaries for a future combat advantage. Investments now in certain areas deemed to be high payoff and potentially either war winning or war losing may make a significant difference in our ability to cope with a novel strategic and technological environment. Understanding which aspects of these technologies are not likely to be funded by private industry, but which may be very important, is critical. 1) The USAF should invest in critical technologies not funded by private industry. It should continue to fund those areas deemed to be revolutionary in impact on the mission areas of air, space or

cyberspace. 2) Funding for areas that are more disruptive than sustaining is necessary in such an environment.

3. Exploitation of opportunities is offensive as well as defensive and requires increased data-mining and virtual reality. If the USAF is serious about space and cyber superiority, it will require: 1) Establishing a credible, demonstrable offensive capability in space and cyberspace. Without these, it can neither establish a deterrent posture with future adversaries nor fight effectively in these domains. A whole series of advances in cyber technology will be required, as well as advances in space situational awareness technologies and those required for offensive and defensive counterspace. 2) The USAF needs to pay particular attention to capabilities that enhance data mining and meta-data tagging; the use of virtual reality testing of systems and CONOPS of all kinds; and the integration of air, space, and cyberspace. Delivering appropriate effects will be an increasingly complex operation calling for expanded and novel air, space and cyber campaigns. Exercising multiple visions of these in wargames and virtual reality simulation and modeling will be increasingly important.

4. The best investment we can make is in the education of USAF people to be agile, versatile and future oriented. Investment in human capital, as well as physical capital, is critical, for it in turn leads to development of the ideas and systems the USAF will utilize in the conflict arenas of the future. Among the steps that should be taken are, 1) the reinsertion of S&T as a Joint Learning Objective for Professional Military Education (it was removed in 2001); 2) increased emphasis on S&T in programs attended by AFROTC students, and in reimbursable programs for serving enlisted and officers; 3) a more tailored approach to developing specialties within the USAF that may be critical

to coping with emerging technologies; and 4) the investment in senior leadership S&T education so they will be conversant with accelerating technology and decisions related to it. These must be combined with, 5) a PME system that focuses more on the future than the past, that fosters adaptive, innovative thinking, and develops airmen who are willing and able to accept greater risk taking in a rapidly changing environment.

5. We need better space situational awareness, defensive counter space, and offense counter space technologies. Full advantage must be taken of the potential for smarter, smaller, cheaper, better, satellites that will provide increased computing power, increased electrical power and maneuver capabilities, and improved autonomous control – all with decreased size and weight. 1) The USAF should pursue space superiority as it did air superiority. Space will become a more important arena than it already is for sensors, and possibly weapons. While the U.S. may not wish to take the lead in weaponizing space, it must be ready to confront the possible necessity. 2) The USAF needs immediate investments to insure greater space based situational awareness as the first step toward space superiority, and possible weaponization. 3) Effective space situational awareness must be complemented by defensive and offensive counter space capabilities. Given the U.S. reliance on space for information gathering and communication, protection of space based assets and a reconstitution capability is essential.

6. The acquisition process must be changed if the USAF is to compete in the environment of 2025 and beyond. We have gone through multiple “improvements” to the acquisition system, but these have been incremental. Accelerating technological change is creating a need for fundamental change in the acquisition process. Long

delivery times, which previously created severe challenges, will in the future become a fatal weakness. A 24-year lag between concept and initial operational capability for an F-22 is no longer acceptable if we are to maintain a position of dominance where “no one comes close.” 1) Force production is as important as force protection—we must have a rapid, agile, adaptive acquisition system. While the system may be overly bureaucratic, and politically burdened by oversight and reporting, the people who run it need not be the same. 2) The USAF should pay more attention to selecting, educating, training and managing the acquisition force to make it more efficient. Changing from the bottom up—through the people within the system—rather than purely from the top down—offers a greater probability of success.

Conclusion

The Horizon 21 study was conducted with a different methodology, with different participants, with a different charter, and yet produced a set of conclusions remarkably similar to those presented to the USAF by the Air Force 2025 study completed 11 years earlier. Hence Horizon 21 validates the earlier study and the earlier study would seem to suggest greater confidence in the most recent one. Furthermore, rapidly accelerating technological change suggests that the conclusions of the prior study are even truer today than they were in the mid-1990s. The conclusions of Air Force 2025 are reproduced here and are without exception consistent with the findings of Horizon 21.

- **All boats rise on a rising technological tide. Maintaining superiority will become more difficult but is possible. We should make investments for the future in the technologies which enhance vigilance, decision-making capabilities, and communications architectures.**
- **The U.S. has an opportunity to achieve integrated dominance to *oppose* strength with strength to *impose* strength on weakness. The key to achieving and maintaining lasting superiority that cannot easily be duplicated by others lies in the integration of information, air, and space.**
- **Information is no longer a staff function but an operational one. It is deadly as well as useful.**
- **Superiority may derive as much from improved thinking about the employment of current capabilities and the rapid integration of existing technologies as from the development of technological breakthroughs.**
- **Courage and confidence in technology and our ability to deploy it quickly will enable many of the current missions performed today by manned aircraft to be performed in the future by uninhabited vehicles and space systems.**
- **The revolutionary information technologies of the future are so fast moving that they suggest the need for dramatic changes in planning, budgeting, and acquisition if we are to continue to compete successfully.**

- **Increasingly, the U.S. government will both voluntarily relinquish being the owner of militarily relevant technologies and become a user, licensee, and lessee of commercially developed systems with military applications.**
- **The USAF must pursue the exploitation of information and space with the same fervor with which it has mastered atmospheric flight.**
- **A revolution in military education (RME) will be required if we are to achieve a revolution in military affairs (RMA).**

If we wish to survive and prosper as a nation and as a service, we need to take these conclusions, validated in this most recent study, as a guide to action—now. The future is not about future decisions. It is about the future consequences of current decisions. We know what has to be done. The test is to take action on these insights to insure the nation’s security. Horizon 21 is neither new nor distant. It is here—and now.

APPENDIX A: THE CHARGE

The preceding discoveries and recommendations are products of a study, known internally and initially as “Horizon 21” – the first in an on-going series of long range strategy and technology studies initiated by the Chief of Staff of the Air Force and AF/A8 called “Blue Horizons.” Horizon 21 sought to capture the knowledge resources of Air University—its faculty subject matter and research expertise and the student operational perspective resident in the ten month masters programs at Air Command and Staff College (ACSC) and the Air War College (AWC)—to accomplish the latest in the series USAF long range studies. These studies began with Theodore von Karman’s *New Horizons*, and progressed through the years with such notable studies as General Bernard Schriever’s *Project Forecast*, the Air Force Scientific Advisory Board’s *New World Vistas* and the Air University *Air Force 2025*. But it has been 11 years since the last of these had been completed, and this gap is effectively widened by the increasing speed of technological change. Previous long range studies were large, expensive, and infrequent. This study was conceived as the first part of an ongoing series of smaller, shorter and more focused studies which would be annual assessments, largely from an operator’s perspective, of the emerging technologies and strategic challenges of the next 25 years.

The AF Chief of Staff identified specific responsibilities for both the execution and oversight of the study. The specific charge to AU students and faculty was “to extrapolate strategic trends, identify capabilities to advance or disrupt air and space power, and evaluate capabilities’ strategic impact.” Study oversight and guidance was to be provided by a newly formed Air Force Futures Group (AFFG) drawn from key USAF planning organizations. The AFFG consists of representatives from A5, A8, A9, the AF Chief Scientist, the Air Force Office of Scientific Research (AFOSR), the Air Force Research Laboratory (AFRL), the National Air and Space Intelligence Center (NASIC), the Cyber Task Force, and the Center for Strategy and Technology (CSAT). CSAT, as part of the research arm of Air University, served as the primary organization responsible for conducting the annual studies. In sum, the AFFG, under the leadership of AF/A8 and the Air University Commander, was charged with overseeing a series of annual studies to be known collectively as *Blue Horizons*, which will present reports to the CSAF after the close of each academic year.

APPENDIX B: RESEARCH APPROACH

The initial study was comprised of 24 Air War College students and 30 Air Command and Staff College students. These students devoted hundreds of hours of class time, individual research, TDYs and field studies to four major areas of technological change: cyber technology, directed energy, nanotechnology, and biotechnology. Since space is such a critical area for the Air Force in 2025, a group at ACSC was created to assess the implications of these technologies for space applications. Seven mid-year students conducted assessments of the previous *AF 2025* study to capture lessons and provide advice and guidance for the new study. This year's graduates focused on the new initiative – to conduct an environmental scan and produce a strategic estimate of emerging technologies between now and 2025.

There were no preconceived notions about the findings save that they be the product of serious academic inquiry. Students were purposefully NOT told what to research in order to let the students, as operators, pursue what interested them most. Having supervised student research many times in the past, the project directors believed this approach would produce two beneficial effects. First, students selected topics in which they were interested, and believed to be important. This served as a litmus test from the operator perspective of what technologies were important. Second, bringing together what students wanted to do with what they had to do brought the group as close to "research Utopia" as one is likely to get. Students work harder and longer, doing more and doing it better than they otherwise would. This approach has generally proven to be very fruitful, and student feedback suggested that this was the case during Horizon 21.

In conducting their research, students completed a 45-hour elective course on science and technology and a variety of future projections about the possibilities and probabilities of progress over the next 20 years. They then narrowed their focus to a particular technology area, created and defended a thesis question, and spent the next five months writing a research paper. During this period a number of speakers from government laboratories and organizations such as AFRL and DARPA, universities to include Stanford and University of Cincinnati, and representatives from Lockheed Martin and Boeing, all gave presentations.

A great bulk of their study and research occurred outside the class room – often away from Air University and even outside the country. In doing their research, students went on numerous site visits to locations such as MIT, Genentech, Boeing, the NRO, Rice University, Lockheed Martin, DARPA, a number of AFRL Directorates (Kirtland AFB, NM; Rome, NY; and Wright-Patterson AFB, OH), the Air Staff and the Joint Staff. They interviewed a wide array of scientists, technologists, program officers, and academics who were experts in a variety of areas. Additionally, where possible, students on the Air War College Regional and Cultural Studies trips made visits abroad. They visited places such as Infosys in India, Singapore's One North Research Center

(biotechnology and nanotechnology research), and other business and academic sites as well as Ministries of Defense to gain information about the importance and priorities of research areas around the world to get a sense of the proliferation of advanced technology. In addition, students electronically engaged in conferences and conducted interviews with knowledgeable individuals about technologies and research issues.

Students then utilized the contacts they made along with those provided by the Center for Strategy and Technology, the Air War College, and Air University, as well as referrals to persons on USAF and MAJCOM staffs, to test ideas and concepts that were emerging from their studies. The opportunity to gain understanding of technologies, develop and discuss CONOPS, and test ideas with a wide variety of experts from academia, industry and the military proved invaluable. Some students took advantage of this opportunity by conducting Delphi studies on expert panels to work toward expert consensus on technology futures issues.

After completing the process described above, there are two principal products of the study. One is the individual student products resulting from the 10-month long research effort. Of the 54 papers submitted, 46 were selected for quality, appropriateness and importance for the overall H-21 report. The research papers ranged in length from 20 to 120 pages and covered specific aspects of the four technology areas: cyber-technology, biotechnology, nanotechnology and directed energy. Several papers focus on the application of these technologies in space. In addition, there are others that use one of the technologies as a case to illuminate related issues such as personnel, education and training of the officer corps, and energy.

After completion of the research papers, students came together in a series of “technology area hot washes” and brainstorming sessions to review and share what they had learned through the research and writing process, and attempt to generate ideas on areas of possible technological/operational surprise. These sessions were followed by a series of workshops where the students consolidated their ideas and developed the group products – this project summary, and a complementary slide presentation entitled, “Operational Impact of Exponential Technological Change on the Air Force.”

The other major product is 54 military leaders from diverse specialties who are now armed with the broad awareness of emerging S&T capabilities required to lead the USAF and our nation through the challenges of the coming years. The investment in their education in emerging technologies, the development of their familiarity with leading scientists, and the nurturing of their ability to ask tough questions will enable them to contribute to the force development process now underway, and to the continuing recapitalization of the U.S. Air Force in all its guises—human, physical and financial.

APPENDIX C: SELECTED RESEARCH PAPER SUMMARIES

Cyber

Placing U.S. Air Force Information Technology Investment Under the “Nanoscope”: A Clear Vision of Nanotechnology’s Impact on Computing In 2030

Joseph H. Imwalle, Major, USAF

Nanotechnology promises to create a new generation of information technology (IT) devices that will enable computing and networking capabilities in unimaginable ways. The U.S. Air Force (USAF) heavily relies on IT systems to execute its technology-oriented mission and, as a result, must understand and seek to shape the potential impacts of nanotechnology. By targeting its precious time and money investments on high-value,

mission-oriented capabilities not driven by commercial needs or interests, the USAF can achieve the greatest benefit from nanotechnology in the realm of IT.

This study used the Delphi method, a technology forecasting approach that combines the opinions of a panel of subject-matter experts to determine the most probable future state of nanotechnology in the realm of IT. The panel of experts anticipates IT advances of the next 23 years will allow a revolution in aircraft as well as their associated systems. Smaller, autonomous vehicles and remote-pilot-assist systems enabled by embedded nanotechnologies will reduce the need for manned aircraft and transform the way the USAF fights. While the military will benefit from commercial, sensor development efforts, the USAF will need to invest in advanced, autonomous sensor systems. National defense requirements are more stringent, to include greater sensitivity per detector and superior redundancy to handle more false positives.

Recommendations: 1) The USAF should also target and cultivate security capabilities such as anti-tamper technologies that guarantee trusted IT systems as well as undermine malicious, adversary abilities. 2) In addition, the USAF must understand where to best spend its time to enable nanotechnology-in-IT success. 3) The panel overwhelmingly believed that the USAF must expand its commitment to long-term, fundamental research which is critical to achieving essential, high-payoff knowledge discoveries. 4) Finally, the USAF must also create the conditions to grow educated airmen and U.S. contractors with the knowledge to develop and use nanotechnology.

Pervasive Atomic Computers in 2025

Mark G. "Doc" Langenderfer, Lt Col, USAF

Personal computers in 2025 will be many times more powerful than supercomputers in 2006 and have more processing power than the average human brain.

Supercomputers will be able to “think” faster than the combined mental ability of a small town. More impressively, the world will see the widespread use of a new type of incredibly powerful “quantum computers” that function solely due to the unique characteristics of atomic particles.

Wearable, voice activated personal computers, or personal computer interfaces, will provide pervasive computing through ubiquitous devices connected by wireless digital links to provide information when desired. This continuous communications capability will allow users to instantly acquire information through pull and push technologies. The speed of computers in 2025 will allow near real time data mining with pattern and data recognition to detect trends, dangerous situations, opportunities, and more. In addition, automated synthesis and decision support processes will inform users about the meaning, impact and recommended solutions to issues discovered in stored and emerging data.

The intelligence community will be able to take advantage of massive processing power for pattern recognition and change analysis to crack codes, identify people through facial recognition, detect trends, predict future possibilities, and many other specialized capabilities. This is also an enabling technology for deploying fleets of unmanned, mutually aware collectives of ground, air, sea, and space vehicles to execute combat operations.

Decrypting intercepted classified message traffic is a specific challenge that is tough for classic computers, but easy for quantum computers. The first nation or consortium that builds a useful quantum computer will be able to decrypt its adversary’s communications, securely encrypt its own communications, and render all secure web

sites, encrypted e-mail, digital signatures, common access cards, electronic funds transfers, secure socket layer connections and other transactions that rely on current encryption methods, vulnerable to exploitation.

Supporting technologies needed to develop quantum computers such as quantum manufacturing, electro-optics, single-photon detectors, and quantum display interfaces will have significant impact on military operations. This research needs to continue to maintain the U.S. and its allies' asymmetric advantages in any conflict in 2025 and beyond.

Recommendations: 1) The USAF must give the same priority to cyberspace as it gave to achieving air superiority. Investments in information processing have the highest return. 2) Though technically challenging and some way off, development of quantum computing will pay huge dividends and may well be war preventing as well as war winning.

Future Air Force Operations in Cyberspace

John F. Schrader, LTC, U.S. Army

The United States Air Force is poised to make another of the technological and strategic leaps that have marked its short and storied history. The emergence of cyberspace as a recognized domain is the latest in a series of technology-based mission sets dating back to the beginning of air power. This paper proposes that by examining the three historical cases of strategic bombing, intercontinental nuclear forces, and space and precision strike in terms of ideas, technology, doctrine, and effect, it is possible to identify relevant lessons and warnings as the Air Force navigates its way into the cyberspace domain.

The ideas of 1920 that generated the strategic bombing of 1945 did not have the technology in place to make them a reality. The ability to see past the limitations of “what is now possible ” and see into what “ could be ” enabled the Air Force to push technology development and drive institutional thinking to create the platforms needed to turn the idea into reality. The synchronization of idea and technology established and refined the doctrine which enabled the Air Force to provide singular sovereign options to the national leadership.

The creation of strategic nuclear forces was likewise the natural extension of strategic bombing. By pushing technology to develop the missiles and bombers required for a global strategy the Air Force maintained a qualitative edge that enabled several iterations of doctrine from deterrence, to preemption, to mutually assured destruction.

Finally, the ability to operate in, through, and from space harnessed technology and enabled operations establishing space as a co-equal domain with air, land, and sea. The mastery of orbital operations further enabled the development of precision guided munitions. The ability to put a small bomb on target anywhere in the world is a uniquely American way of waging war and is one of the unique contributions of the Air Force.

Recommendations: 1) The Air Force should continue to aggressively press ahead with organizing for operations in cyberspace. As national policy evolves and the other services begin to stake out their roles and missions, the momentum generated by the Secretary and the Chief will pay off in the form of acknowledged leadership of the effort and come with executive agency and some degree of control over budgets and strategy. 2) While the Air Force is well positioned to take on the leadership of the cyberspace domain through a combination of historical experience and forward thinking leadership,

it must be prepared to cede control of training and equipping functions to a truly joint effort that enables all services to fuse their operations into one seamless network. Only with central cross service command and control can effective cyber operations be mounted and sustained. 3) DoD should establish a warfighting command to address the issues of organizing, training and equipping in order to develop the capability to deter, defend, and defeat enemies in this new realm.

Information Technology Allows for New Leadership and Command and Control Philosophies

Thomas A. Freese, Lt Col, USAF

Air Force doctrine dictates that centralized control and decentralized execution is the primary approach to running an air campaign. That same philosophy naturally filters into running day-to-day operations, but such an approach may not lend itself as well to the self-synchronizing organizations that will be possible in a net-centric environment. Nor does it take advantage of the vast amount of information that will be available for decision makers by 2025. The concept of “power to the edge” promulgated by advocates of net-centric operations increases distance between the leader and the command and control of forces, taking advantage of the vast situational awareness available at all levels of command. This method decreases coordination requirements and improves response to rapidly changing situations

There are numerous “food fights” occurring within the Air Force over control of organizations and assets. The bottom line is that the human factor is the leading inhibitor of taking full advantage of information technology. Centralized control and decentralized execution has served well, but in this new information-rich environment it is imperative

that this concept be continually tested and challenged to prevent the enemy from gaining the upper hand in decision making and execution.

Recommendations: 1) Require blocks of instruction on information operations and net-centric operations at PME institutions. 2) Engage in research and testing of net-centric C2 schemes at PME institutions and in other venues. 3) Develop and assess alternative C2 frameworks that technology makes possible with onboard processing for sensor/shooter platforms (decentralized control and decentralized execution).

Connecting the Edge: Mobile Ad-Hoc Networks (MANETs) for Network Centric Warfare

Brent A. Peacock, Major, USAF

The principles of Network Centric Warfare (NCW) are at the heart of DoD transformation plans and are the driving concept of several high profile acquisition programs. This paper investigates the question of what communications and networking technology breakthroughs are required to fully realize mobile ad hoc networking (MANET) and deliver on the promises of NCW at the tactical edge of our military forces in the 2025 timeframe.

Viewed from the vantage point of the year 2025, a review of challenges and trends in research on radios and networking identified several key enabling technologies that will be critical to achieving the characteristics of our objective MANET. Specifically on the radio side, the foundational technology of software defined radios (SDR) was judged as being strongly supported by both the commercial and defense markets. Achieving the necessary SDR capabilities envisioned for our 2025 timeframe is considered to be low risk and does not require any additional funding beyond the levels already planned to support near term Joint Tactical Radio System (JTRS) related

acquisitions. Building upon SDRs, the technologies of multiple input multiple output (MIMO) receiver/transmitters and cognitive radio (CR) also enjoy broad base support in the commercial sector.

Recommendations: 1) The USAF should undertake a low level, long range investment in integrating adequate routing solution with commercial networking solutions. 2) The Air Force should immediately fund basic research in MANET theory and scalability at government labs and universities. 3) Move CR forward in a timely manner by continuing DoD pressure on the Federal Communications Commission (which is already inclined to support CR) to create a streamlined CR certification process. 4) Increase targeted investments in CR algorithm development and testing efforts at government labs and universities.

Future Cyborgs: Human-Machine Interface for Virtual Reality Applications

Robert R. Powell, Major, USAF

This paper explores what the state of virtual reality interface technology may be in the future by analyzing the current state of the art, forecasting trends in areas relevant to virtual reality interface research and development, and highlighting the barriers to providing virtual reality environments that are immersive and interactively indistinguishable from reality (strong VR). This research shows that the evolutionary pathway of virtual reality technology development will not be able to overcome all of the barriers and limitations inherent in the current generation of interfaces. The current VR interfaces are limited primarily through their design to interface directly with the human senses (primarily sight, touch, and sound). The current interfaces are usually better suited

for to be either immersive OR interactive, not both at the same time. A reverse tree methodology was used to explore alternate pathways to achieve strong VR. Brain-machine interfaces (invasive and non-invasive) represent the most likely pathway that will lead to a strong VR interface.

This research is important because of the ubiquitous nature of virtual reality applications. VR will enhance our ability to operate and train while reducing the costs associated with these areas. In addition, this technology would allow the enemy the same capabilities for training, rehearsal, and operational support. The full impact of strong VR and its information uses is difficult to predict.

Recommendations: 1) The USAF should invest in basic research of the human brain and neural systems with a goal of mapping brain functions and neural pathways. We should fund applied research and development for brain-machine interfaces that enhance our ability to provide stronger VR interfaces. 2) The USAF should continue to develop common VR interface technology using widely available interfaces, but should increase its funding and support for technologies that will enable enhanced brain-machine interfaces to ensure dominance in training and simulation for the future. 3) The USAF should develop a standard desktop configuration VR interface that enables software development to enhance our current training programs with modular applications. 4) The USAF should continue to improve the data structures that will support immersive, interactive VR software environments.

Cyber Weapons School

Mark D. "Snapper" Mattison, Lt Col, USAF

If the current acceleration in technology continues, by the year 2025 defending U.S. cyberspace equity will require speed only achievable through automated cyber

systems and decision making processes. To fly, fight and win in cyberspace, the USAF should prepare for an OODA loop (observe, orient, decide, and act) measured in microseconds. Key questions presented by this situation are: 1) Who will harness the capabilities of the cyber domain and integrate them with existing air and space capabilities? 2) The infrastructure to protect our networks exists, but where is the cadre of cyber warriors to be educated?

This paper examines the need for the USAF to combine the specialized skills of cyber warriors with tactical genius and a warrior culture in a Cyber Weapons School (CWS). To achieve strategic military decision making superiority in the same way it has achieved air superiority, the USAF will need to educate bright and elastic military minds in cyber warfare and tactical military planning. While bureaucratic factors may inhibit its creation, the accelerating pace of change in cyber technology and its availability to all players from nation states to small terrorist cells and criminals demands creation of a CWS.

Recommendations: 1) Create a CWS and use curricula developed by Rome Lab to leverage existing cyber expertise. 2) To overcome cultural biases in the USAF, the CWS should be located at Nellis AFB. At Nellis AFB, the cyber education will provide benefits to cyber students and to the students from other weapons systems.

Air Force and the Cyberspace Mission: Defending the Air Force's Computer Network in the Future

Lt Col Shane P. Courville, USAF

This research examines the defense of the cyber domain in the 2030 timeframe, and begins by suggesting potential areas an adversary may infiltrate in cyberspace. It succinctly illustrates how a lack of an active denial program can generate significant

vulnerabilities to the cyber domain of the Air Force. A brief historical look at computer technology is provided, followed by an examination of today's systems, and concludes with a discussion of potential future vulnerabilities of computer systems used throughout the Air Force. One key area of concern is the Department of Defense (DoD) heavy reliance on commercial off-the-shelf hardware and software in its acquisition of computer components. While the process is cost effective, it introduces the potential for introducing numerous vulnerabilities inside the cyber domain. Another concern are that numerous reports point to lack of a congruent plan in DoD to actively defend its cyber domain—each service is left to fix the problems of the past in order to protect itself in the future.

A snapshot of current computer vulnerabilities within the Air Force, to include the operating systems, software and network/Internet connectivity is also discussed in this work, as are additional hurdles the United States faces in the form of shortages of science and technical experts to conduct future-oriented research. This paper concludes that there is a valid and urgent need to begin steps *today* to proactively protect Air Force computer systems, and to dominate the cyberspace domain of the *future*.

Recommendations: 1) The Air Force should actively monitor the future of quantum computing. 2) The Air Force's legacy systems, purchased over the past decades, must be upgraded and synchronized in order to tighten security loopholes which still persist today. 3) The Air Force must consider the effects of cyberspace in the future, and should consider that this domain may be the weapon system of choice over the next 25 years. 4) Uncertainty regarding the shape of cyberspace and its defense demand ongoing reassessments of alternative scenarios by futures study groups.

How the Air Force Should Stay Engaged In Computer Vision Technology Development

Mark B. Skouson, Major, USAF

This paper investigates the availability of computer vision technologies for future Air Force applications. It makes a major contribution in the form of the results of a Delphi-style survey that forecasts advances in computer vision through 2030. The survey shows that while that computer vision technology appears to be progressing in general agreement with Air Force needs for the 2030 timeframe, a few gaps exist that the Air Force must address. The survey combines the judgment of 13 experts from academia and industry, and the results are compared to the Air Force's expected computer vision needs, as documented in the Air Force 2025 Study.

The results show expected maturity information for specific computer vision technologies, estimate the relative difficulty in maturing the technologies, and provide a list of technical and non-technical hurdles. The information is invaluable for anyone making strategic technology-related decisions. The Air Force must continue to play an active role in shaping future computer vision technologies by investing in sensors networks, data fusion, technology transition, and artificial intelligence.

Recommendations: 1) The Air Force should apply additional resources to help mature technologies in the high-intelligence systems area and consider using grand challenges to promote advances in artificial intelligence, especially since traditional funding methods have had little success. 2) The Air Force should continue to invest in professionals that are able to facilitate technology transfer from academia and industry to the military. 3) The Air Force should apply resources to promote advances in sensor

networks. 4) The Air Force should also focus on ways to combine the data from the various sensors and focus on data fusion.

Advanced Information Display Technology: Holographic Enhancements to the Air, Space and Cyberspace Fight

John “Wahoo” Edwards, Major, USAF

This study argues that advanced information display technology in the form of *holographic* can enhance several Air Force mission areas. Holographic displays may provide advantages to fuse sensor data in the counter air fight while also providing a tool to visualize the cyberspace domain. Additionally, holographic provides true 3D displays to provide greater mission effectiveness. Current and near-term display technologies (2.5D, Virtual Reality and Volumetric Displays) suffer from several limitations. Holographic not only overcomes these obstacles but also provide true binocular and monocular cues. Holographic’s current limitations rest on enabling technology—processing power, bandwidth and costs. These current challenges will diminish with time as we approach 2020.

The astronomical rise in information requires systems that can display this data in a format that fully taps into humans’ visual processing capability. Holographic technology provides the USAF with an advantage for managing the battlefields of tomorrow in air, space and cyberspace at a tactical, operational and strategic level.

Recommendations: 1) The USAF should invest in developing holographic to create a truly 3D interactive image with all the depth cues and resolution sufficient to provide extreme realism. 2) The USAF must follow commercial developments in this field closely as the breakthrough in this technology may well occur in the private sector and must be transferable to military applications in air, space and cyberspace. 3) The Air

Force must invest in holovideo technology to attain an advantage in information technology in 2020 by partnering to share information with those people and organizations involved in holovideo technology and by providing funding for holovideo in its nascent stage.

Nanotechnology

Next Generation Assembly Fabrication Methods: A Nanotechnology Trend Forecast
Vincent T. Jovene Jr., Lt Col, USAF

Today, the continued success of many industries, especially the area of microelectronics, relies upon the ability to fabricate structures with nanometer precision. Silicon material and circuit technology has progressed for nearly five decades, but is approaching barriers to further chip development due to limitations of fabrication techniques. A consistent trend is the continuous shrinking of electronic transistors over the last 30-40 years and ways to overcome these barriers are found to continue the increase in performance of integrated circuits with decreasing the cost. The impact of nanotechnology will reach beyond next-generation integrated circuits and unfortunately, easily migrating into technologies that can threaten, harm, and/or kill. It has this potential to cross into other disciplines that is creating a need for an early warning system to monitor this field closely in order to prevent a future catastrophe.

There is no doubt that the countries, corporations, and even individuals that achieve breakthroughs in nanotechnology and bottom-up self-assembly will revolutionize many products, processes, and capabilities. Unlike major technological breakthroughs of

the past, such as the industrial revolution and nuclear power, this is an area in which *individuals* will be able to participate. We do not know where the science and technology will take us with any specificity, but it is safe to say achieving bottom-up self-assembly would be truly revolutionary. This is an area rife with the possibility for true surprise.

Recommendations: (1) The Air Force, through Air Force Research Lab (AFRL), Air Force Institute of Technology (AFIT), and Air Force Office of Scientific Research (AFOSR), should ensure that its scientific community stays engaged in basic research in nanotechnology broadly defined. (2) Groups such as the National Air and Space Intelligence Center (NASIC) should monitor closely the scientific programs in nanotechnology in other countries. (3) Air Force Material Command (AFMC) should be tasked to catalog and monitor commercial applications in nanotechnology, specifically focusing on civilian designed, commercially available nanoelectronics and nanostructures. (4) Information from the above efforts should be reviewed annually by AFRL in conference or symposium alongside civilian academics to gauge progress made in nanotechnology and its linkages to synthetic biology, biotechnology, and progress toward self-assembly.

Nanotechnology Risk Analysis for a 2025 Air Campaign

Lt Col Steve “Judy” Garland, USAF

This paper investigates the impact of nanotechnology on an Air Campaign in 2025 by extrapolating 6.1 and 6.2 research ideas into potential weapons in the future. There currently is not a dedicated tech transfer function focused on evaluating 6.1 and 6.2 research initiatives evaluating them for potential disruptive effects. If the USAF were to create a process where basic research ideas could be funneled into virtual reality, the power of Metcalf’s law could help identify the highest leverage ideas. Those ideas could

then be evaluated by front line operators in the Distributed Military Operations Center (DMOC) at Kirtland AFB, NM, in an attempt to find disruptive technologies as well as point out potential areas for integrating new technology into legacy systems.

For the USAF to be successful in 2025 we will need to be able to detect and react to nanotechnology threats in a timely manner. As a Blue capability, the process would allow the USAF to identify potentially disruptive technologies and develop concepts of operations before the capability is even partially developed. As a Red threat, an adversary could generate operational surprise by potentially creating a first use advantage.

This detection-reaction capability might be generated by developing a suitable virtual reality environment and recruiting large numbers (i.e., millions) of people who would be willing to spend free hours helping to develop and refine potentially disruptive technology ideas. We have a long history of operators partnering with researchers much later in the development cycle of a capability. Given the exponential change curves facing us, the process being proposed is an attempt to help shift the USAF toward looking for new employment ideas much earlier in the development process.

Recommendations: 1) The USAF needs to exploit options for generating disruptive technologies by developing a mechanism to feed 6.1 and 6.2 research projects into virtual applications for validation of advanced design concepts. 2) Monitoring of foreign patent office research submissions along with the normal exploitation information derived from intelligence channels could provide a range of potential adversary ideas that could be validated and run against U.S. systems in the virtual network created for U.S. nanotechnology research ideas. 3) Use the DMOC to test concepts in a controlled

environment like “Virtual Flag” in order to provide scientists with requirements to help focus future capability developments for USAF.

X-MAVs United: Swarms of Extremely Small Air Vehicles and the Future of the Air Force in 2025

Russell E. Taylor, Lt Col, USAF

Tiny UAVs smaller than a normal bumblebee may hold the potential to change the way the United States fights and wins wars by 2025. This paper lays out the argument for development and employment of such vehicles. Termed X-MAVs, these UAVs offer great potential to relieve the burden on low density, high demand (LDHD) assets, enhance the performance of traditional weapons systems, and enable entirely new missions that only they can accomplish. The paper identifies a clear need for X-MAVs and highlights the fact that many of the technologies necessary for their creation are under development in laboratories today. While many technologies will be important in this effort, nanotechnology will likely be the most critical in addressing the key issues surrounding X-MAV operations. The paper identifies a number of roles and missions that X-MAVs could support. Finally, it points out that a number of critical R&D, policy, and investment decisions must be made to ensure X-MAVs are available by the 2025 timeframe.

The paper concludes that X-MAVs hold great potential to change the future of warfighting. Their ability to provide ubiquitous sensing and direct action could provide dominant battlespace knowledge and yield increased speed and accuracy of force employment decisions. As X-MAVs become an operational and credible weapons system, they will impact operations at all levels of conflict (tactical, operational, strategic), across the spectrum of warfare (from peace operations to high intensity

warfare), and without regard to the normal dividing lines between America's separate military service departments. Initially, this will provide friendly forces a great advantage. However, it is only a matter of time before this capability becomes widely available. Though not discussed in the paper, such an asset in the hands of Red forces will force the U.S. to fight in a much more transparent environment that we would prefer.

Recommendations: 1) The USAF should lead a joint acquisition and development effort to keep the U.S. at the forefront of exploiting future X-MAV capabilities. 2) The USAF should concentrate its R&D on basic research, remain engaged with the commercial sector during development, and pursue military-specific applications as the technology reaches maturity. 3) Leaders must start thinking in broader, more innovative terms about the proper roles and missions for X-MAVs and other small UAVs. 4) Policy makers within DoD must determine who has the authority and responsibility to mandate standards, procedures, and practices concerning multi-level security from various sources and sensors. 5) DoD needs to establish a joint program office to develop automated decision systems to aid in the exploitation, fusion, and evaluation of multiple intelligence data provided by X-MAVs.

Nanotechnology Applications for ISR: The Solution to the Intelligence Gap?

Morgan D. Mackey, Major, USAF

To remain viable in the Intelligence, Surveillance, and Reconnaissance (ISR) arena by 2030, the United States (U.S.) must actively incorporate nanotechnology advances into ISR sensing capabilities. As several countries continue their efforts to close the technology gap, today it is more important than ever for the U.S. to be the world's nanotechnology leader. Current development trends reveal a continuing march

toward ever-smaller sensor and sensing capabilities. Meanwhile, nanotechnology appears to offer the capability for transformational improvements that will more rapidly carry these trends into the nanoscale realm. Such capabilities will enable a host of new persistent and inconspicuous ISR sensors over the next two decades.

Regardless of the U.S. public's acceptance of nano-enabled ISR sensors or the U.S. decision to become the global nanotechnology leader, the world of 2030 is one in which both Blue and Red forces will have access to and will employ such sensors. In such an environment, the U.S. will need an offensive nano-enabled ISR sensor capability, even if used only on a limited scale or external to U.S. soil. Although the country with the nanotechnology lead can best incorporate advances to improve ISR capabilities and will achieve an interval of information advantage, the cat-and-mouse game between blue and red ISR capabilities and counter-capabilities will likely be an ever-continuing struggle.

Recommendations: 1) The U.S. and the USAF need to invest in nano sensors to achieve the ability to detect and defeat adversary nano-enabled ISR sensors. 2) The USAF needs to maintain a strong science function that develops in-house nanotechnology-enabled capabilities and maintains awareness of nanotechnology developments around the world.

Requirement for Nanotechnology Improvement Programs on Fighter Aircraft in 2025

James E. Fairchild, Lt Col, USAF

This work explores the possibility of using nanotechnology to enhance U.S. Air Force fighter aircraft. In the USAF today, a primary concern is the aging of the fighter fleet. Unexpectedly high costs in the acquisition of the F-22 program have led to

increased congressional oversight and scrutiny of the F-35 Joint Strike Fighter. The costs of the F-22 have helped lead the Air Force to cut personnel by 40,000 people to allow for recapitalization. Fighter aircraft acquisitions will lag aircraft retirements and the Air Force will see its fighter forces dip below the minimum required 2,000 fighter aircraft resulting in a “fighter bathtub” which defines a period of reduced combat capability.

Early successes for nanotechnology will include advances in materials, coatings, computers and electronics. Fighter aviation can exploit all of these technological areas to lengthen the service of older aircraft. Because of the aging fleet, the costs associated with the acquisition of new aircraft, and the ever-shrinking periods of technological superiority, it is imperative that the Air Force take advantage of these emerging technologies in an expeditious manner. One way to address all three of these issues is to develop cost-effective, nano-enabled service life extension programs and improvement programs for both legacy fighter aircraft and the Air Force’s next generation fighters in the 2025 timeframe. Legacy fighters should be included to enhance commonality and interoperability with our potential coalition partners who may not be able to afford our next generation fighters. The next generation fighters, the F-22 and the F-35 should be included since they are being built today without the benefit of the advances that will occur through nanotechnology.

Recommendations: 1) As nanotechnology enables advances in areas important to aviation, the Air Force should be prepared to invest further in them and, after conducting economic feasibility assessments, incorporate them into improvement programs for the appropriate systems: legacy fighters, next generation fighters, or both. 2) The Air Force must monitor nanotechnological progress in the areas of coatings, structural materials,

and electronics and computing. This monitoring coupled with investments of research and development dollars in areas offering the greatest military utility will ensure that the Air Force fully exploits the potential of nanotechnology.

Nano Air Vehicles: A Technology Forecast

William A. Davis, Major, USAF

This paper documents a future technology forecast of when operationally useful nano air vehicles (NAVs) will be achieved. The study used the Delphi Method to refine and combine the views of a number of experts and develop the forecast. The study concluded that NAVs capable of operating in swarms will be available within 10 years to perform operational missions; however, these missions would be restricted to intelligence, surveillance and reconnaissance due to limited lethality in such a small airframe. Additional research in light, highly energetic materials is required to increase NAV lethality to execute other mission types. NAVs operating in large swarms will enable the Air Force to use lower cost UAVs to perform complex missions not possible today.

Recommendations: 1) The NAV presents a substantial systems engineering challenge and the first step must be to define the mission requirements in order to tackle the difficult design tradeoffs that will be required. 2) The Air Force should begin work now to fully develop operational concepts and requirements for NAVs that will guide future development work. 3) The USAF should enter the Joint Capabilities and Integration Development System to fully define capability requirements for swarming NAVs across the services to gain efficiencies in development and acquisition and to avoid duplicative requirements and programs.

Enabling Battlespace Persistent Surveillance: The Form, Function, and Future of Smart Dust

Scott “Grins” Dickson, Major, USAF

Information superiority in 2025 will fuse U.S. demand for intelligence data with an array of technological capabilities. It will likely require sensors that measure heat, magnetism, vibration, or video, in a wireless ad-hoc network, capable of uploading data to an orbiting UAV or satellite and obtainable by flying aircraft, counterinsurgency forces, or information-hungry combat operations centers. It will also very likely require shrinking those sensors to the size of dust. At that size, these nanoscaled devices, called motes, penetrate previously inaccessible urban buildings, jungle canopies, or weather-covered terrain. Deployable from orbiting aircraft or an aerosol can, this wireless sensor network, called Smart Dust, also acts as a localized backup to U.S. space-based ISR assets.

Based on the current state of technologies and the potential future for the United States, Smart Dust is achievable, employable, and effective in 2025. As a future persistent surveillance solution for battlespace awareness, homeland defense, and WMD identification, Smart Dust offers the intelligence advantages of ubiquity, flexibility, timeliness, and persistence to military leaders, planners, and operators. With the right U.S. support in terms of policy, funding, and education, Smart Dust represents a revolutionary leap in persistent surveillance and produces an informational asymmetric advantage for whoever possesses it – friend or foe.

Recommendations: 1) Support and fund research into nanotechnology and measurement and manufacturing. 2) Continue funding and research in the development of nanoscale sensors and power supplies. 3) Develop new antennae capable of larger

gains to offset reduction in size. 4) Continue research into the use of nanoscale devices in networks.

Biotechnology

DNA Possibilities and Military Implications

Phil L. Samples, Colonel, USAF

The results and benefits of the human genome project, and advances in DNA technology have significant potential benefits and military applications. Besides the future military implications of these DNA-based technological advances by the year 2025, developments in areas such as DNA sensors and DNA vaccines, with more immediate potential. This paper investigates numerous DNA technologies to include: our ability to forecast and treat diseases, and DNA manipulation to enhance human performance. Military implications for enhanced human performance through exploitation of DNA vaccine technology may produce the best near-term advance of all current DNA technologies. Once perfected, effective plasmid DNA vaccines used in all military personnel will increase survivability in known biological attacks, decrease disease, and enhance safety, virtually eliminating risk of adverse reactions because of the immunization.

Most, if not all, advances in this area of study will come as a result of private sector research. Although there are significant benefits to humanity in the advancement of these technologies, there is also great potential for misuse by an adversary. Blue

capabilities to understand, exploit, and plan for active defense against Red use are vital. Failure to do so could render U.S. forces incapable of defending the nation and providing for the common defense.

Recommendations: 1) To keep pace with the rapid rate of discovery in biotechnology the USAF should collaborate with other DoD agencies, especially the Army, to develop relationships with biotechnology companies and leading research universities. 2) To achieve success, the USAF must increase the current level of investment in medical education. Specifically, we should develop fellowships with universities and industry for specific medical career fields, physicians and biomedical scientists with significant life science experience (e.g. pharmacists with a doctorate, microbiologists, etc.), with follow-on assignments to DARPA, AFRL and United States Army Medical Research Institute for Infectious Disease (USAMRIID).

Biofuels: An Alternative to U.S. Air Force Petroleum Fuel Dependency

Mark S. Danigole, Lt Col, USAF

Dependable, affordable fuel is a pressing concern for the United States Air Force (USAF) and will be for the foreseeable future. Volatile oil prices force the USAF to divert money from training budgets and weapon system procurement accounts in order to cover increased costs due to unbudgeted fuel expenses. This paper examines the development of new, domestic sources of fuel—specifically biologically produced fuel alternatives, and evaluates their ability to meet USAF jet fuel requirements by the year 2025. Ethanol, terrestrial produced biodiesel, algae oil and biobutanol are considered in terms of their ability to fulfill three requirements:

- 1 The fuel must meet current JP-8 energy density standards

- 2 The petroleum fuel alternative must not require major engine modifications or prevent the use of petroleum-based JP-8
- 3 Fuel production must meet Air Force fuel demand in terms of quantity, transportability and stability

The comparison of ethanol, biobutanol, terrestrial produced biodiesel and algae produced oil, makes clear that ethanol and biobutanol will not meet USAF fuel requirements primarily due to low energy density characteristics. Terrestrial produced biodiesel meets jet fuel energy density requirements, but exhibits poor cold weather characteristics that are incompatible with high altitude flight. Additionally, terrestrial produced biodiesel production capacity is limited due to feedstock availability.

Algae produced oil clearly offers the most likely solution. Algae have the potential to out-produce all other biofuels. With yields of 5,000 to 15,000 gallons per acre of algae, algae could produce 100 times the volume of other biological fuels each year. Algae produced oil that is then refined into jet fuel currently costs \$4 per gallon, but is an environmentally sound jet fuel alternative that meets JP-8 fuel standards. With continued research, algae produced jet fuel has the potential to reach a \$2 per gallon threshold and meet USAF fuel demands by 2025. Once an economic pathway is established, algae produced jet fuel production could meet not only USAF, but also U.S. national biofuel demand.

Recommendations: 1) Continue current work on developing synthetic hydrocarbon fuels made from coal, oil shale and biomass as this offers the best near-term alternatives to traditional petroleum products. 2) Algae-produced jet fuel should be the long-term objective of the USAF alternative fuels program. 3) In order to succeed, the USAF must continue to partner with National Renewable Energy Laboratory (NREL)

and industry to develop algae-based jet fuel production requirements. By fostering this partnership, the USAF can reduce its dependency on foreign procured oil, and do so with a renewable, environmentally friendly jet fuel alternative. The potential for this technology to reduce overall U.S. dependence on foreign oil makes it an even more attractive opportunity.

The Air Force In Silico – Computational Biology In 2025

Chris Coates, Lt Col, Canadian Forces

This paper examines the development of computational biology as an emerging technology and its potential for the USAF of 2025. A critical assumption is that computational biology's game changing potential would result from the capability to simulate entire biological systems and processes at the molecular and atomic levels. At the high level of detail and precision needed to satisfy this assumption, computational biology is inherently ultra-complex and is not expected to fulfill its ultimate potential by 2025. Simulating biological systems in such extreme detail will require new methodologies to address the complex, stochastic and random nature of biological processes and effects. Although substantial improvements in computational ability are expected, they are not likely to provide the ability to create effective, "designer-engineered" biology by 2025.

Advanced computational biology will likely be the result of interdisciplinary teams that work across functional domains and across international borders. A risk assessment revealed that due to the highly complex and interdisciplinary nature of computational biology it is unlikely that it would be easily employed by non-state or non-institutional actors. States with the advanced capabilities in biology, computer science and the physical sciences that contribute to computational biology are not currently

hostile to the U.S., thus computational biology does not present an emerging technological threat to the USAF so long as these states' relationships with the U.S. remain unchanged. Computational biology does present enormous potential to allow man to purposefully control or alter biological processes.

Recommendations: 1) Given the technology's maturity and the challenges to be overcome, the USAF should encourage development of, and participation in, scientific networks that promote the development of computational biology and its exploitation to address certain Air Force problems. In the not too distant future it is likely that "in silico" simulations and models will form the foundation of a new approach to health care, warfighter management, and materiel engineering. 2) Monitoring civilian progress is all that is required at the moment but it should not be overlooked as the long-term advantages could be significant.

Force Health Protection and Biotechnology in 2025

Larry Kimm, Col, USAF

This research assesses the impact of developments in biotechnology on Force Health Protection (FHP) applications in 2025. Strategic planning documents, historical and current casualty and disease rates, non-battle injury rates and medical intelligence were reviewed to determine relevant trends. The analysis indicates that accidents due to fatigue, human performance optimization (HPO) challenges, infectious diseases, and battle casualty blood loss are the most significant operational health threats expected in future conflicts.

Some biotechnology advances show substantial advantages in treating war injuries, strengthening fighting power, countering fatigue, sensing and battlefield monitoring, and manufacturing of military materials. Unfortunately, modern biotechnology research also provides the means to identify factors that are extremely hazardous to humans, and reveals potential to inflict great harm on target populations in a selective, accurate and effective fashion. As biotechnology-related information becomes more widely available, the potential for enemy advances in biotechnology to create new and previously unknown threats to U.S. forces will increase. The ability to rapidly identify disease-causing organisms and to produce vaccines to protect against them may be critical for future military operations.

Recommendations: 1) The Air Force must play a leading role in Department of Defense human performance optimization efforts, and storage and transport aspects of the advanced blood products programs. We must also contribute our significant epidemiological, microbiological and immunology expertise to advanced vaccine programs. 2) Research in basic and applied sciences; conducted, managed or monitored by Air Force scientists and engineers with a long-term view; is critical to ensuring our technological lead is maintained and future operational requirements are met.

Bio-nanotechnology: The Future Fusion of Stem Cell Research and Nanotechnology to Improve Survivability of Injured Troops

Joseph W. Ellison III, Major, U.S. Army

This paper proposes a future merger of the fields of adult stem cell research and bio-nanotechnology. This merger will accomplish the goal of enabling the DoD to replace the limbs, tissues and organs of injured soldiers and airmen, making them whole again. The enabling technology is based on the future ability to control the

differentiation of stem cells into viable replacement tissues—a process that will be enabled, controlled and regulated by a variety of nanoscale robots. The findings of this research effort indicate that this technological advance is not only possible, but actually moving toward fruition on its own momentum.

This proposal has the potential to elevate the Air Force into a leading position in an area of technology and science with which it is not traditionally associated. The USAF could take a dominant role in this high-profile, life-changing technology which will literally transform military health care. The collateral benefits of public relations, cooperation with private sector institutions and profitable spin-off technologies should not be overlooked.

Recommendations: 1) Protect research funding and target it at projects that advance the overall goal. 2) Focus on use of adult stem cells to minimize moral/ethical objections to the research, and eliminate bureaucratic interference in the use of adult stem cell research. 3) Create a career team that spans political cycles to oversee public and private research. 4) Control of this essential program should be isolated from the unwieldy and inefficient acquisition system and government academic offices. Service members in all branches place themselves in harm's way every day, all around the world. It is the solemn duty of the nation to apply every resource to their care when they fall.

Directed Energy

Weaponizing the Future: Direct Energy Weapons Effectiveness Now and Tomorrow
Chadwick "Cheat" Fager, Major, USAF

When direct energy weapons arrive in numbers on the battlefield, the war planner will need to know what probability of damage these weapons can attain. Currently, the Joint Munitions Effectiveness Manual calculates a "single sortie probability of damage" for conventional blast and fragmentation weapons. Adapting the single sortie probability of damage formula for lasers, microwave and millimeter wave weapons will allow a determination of their effectiveness.

Adjusting probability equations for various inputs enables a forecast of the future capabilities of each weapon. The current trend trajectory is used to establish a baseline estimate of future probabilities of effect, and the Status of Futures Index (SoFI) method is used to compare complex entities across multiple dimensions. Finally, disruptive technologies are analyzed for their effect on the weapons capabilities.

The SoFI for each direct energy weapon indicates a potentially bright future if managed properly. The current trajectory of lasers makes a Pd/Pe of 1.0 barely possible at the 30 year mark for a lase time of 0.5 seconds from ranges similar to current blast/frag weapons. Microwave data is less conclusive. Trend data shows microwave power increases should place distance ranges at 70km in 30 yrs! But empirical data shows a reverse trend due to atmospheric ionization shortening the range. The millimeter wave trend line shows a very steep rise in range, power and dwell time. However, data for the millimeter wave weapons is less available and has a shorter history. Overall, the SoFI indications for the current trajectory of direct energy weapons is positive, but does not indicate a major shift to DE from blast/frag before the year 2035. If direct energy weapons are to meet their full potential, disruptive new technologies must be found.

Recommendations: 1) The direct energy weapon types of laser, microwave and millimeter wave weapons each require unique investments. Research in all three areas should be continuously supported. 2) The USAF should pursue research on fiber, air or liquid lasers, or some combination of these and/or current chemical and solid state lasers. 3) The main effort in regard to millimeter wave weapons should be in improving the supporting industries.

High Energy Laser on the Joint Strike Fighter: A Reality in 2025?

Jeffrey A. Hausmann, Lt Col, USAF

High energy lasers (HEL) promise speed-of-light engagement, precision effects, and low collateral damage. These characteristics along with a nearly unlimited magazine make HELs attractive for installation on a tactical platform. This paper proposes that a HEL equipped F-35 Joint Strike Fighter (JSF) could be fielded in 2025. This conclusion hinges on three requirements – technical maturity of HELs sufficient to permit installation on a fighter platform; sufficient technical maturity of key supporting systems, to include power generation and storage, thermal management, and beam conditioning and control; and development schedules and funding for the HEL, key supporting systems, and the JSF.

The evidence clearly indicates that all of the technologies needed to produce and support a LSF are achievable by 2025 with modest technical risk. The key issues that could prevent the Laser Strike Fighter (LSF) from becoming reality are not technical, but rather are questions of institutional resolve and availability of funding. There are presently programs in place or planned that support bringing the HEL and associated subsystems to sufficient technological maturity in time to field a LSF in 2025. Air Force Research Laboratory supports several key LSF technologies with its Focused Long-Term

Challenges programs. These include HEL technical maturity, power generation, power storage, thermal management, adaptive optics, and active flow control. Lockheed Martin has produced a proposed LSF development roadmap, which would support a 2025 LSF flight test program. Funding emerges as the key issue. The estimated price for a single squadron of 24 LSFs would be over \$1 billion in 2002 dollars, assuming a unit cost of \$44.5 million based on Government Accountability Office data. The \$44.5 million dollar unit cost is conservative for the LSF since it applies to the current CTOL version of the JSF.

Recommendations: 1) Air Force Research Laboratory continues research into key LSF technologies with its Focused Long-Term Challenges programs. 2) In-depth study of requirement for LSF capabilities in the 2025 time frame should be conducted. 3) If LSF capabilities are essential, a formal LSF roadmap should be developed.

Targeting at the Speed of Light
Richard Hughey, Lt Col, USAF

This paper argues that laser weapon systems are a disruptive technology of the future, and that the Air Force and U.S. military must capitalize on them to retain control of the air, space and maritime domains. It investigates the sub-systems, targeting (in the doctrinal sense) and operational utility of laser weapons in the future. It concludes that laser weapon systems will allow the Air Force to retain the requisite air/space/maritime domain control for forced entry land operations around the world.

The capability to control the commons will continue to be essential for the USAF in 2025. Laser weapon systems will offer the capability to maintain this control by creating temporal and spatial compression that accelerates the dynamic targeting process

and overwhelms the decision-making process of future competitors. These scalable, speed of light, ultra-precise, low collateral damage weapons present disruptive potential for the uncertain future security environment. They will be key enablers of U.S. military advantage in the future.

Recommendations: 1) Advanced Technology Capabilities Demonstrations (ATCD) should be accelerated to the fullest extent financially feasible. This means rapid progression for ABL and ATL. Furthermore, there should be increased funding for research & development for promising future laser weapon systems that spin off of these ACTDs. 2) Accelerate the testing by the AFRL laser test facility to determine the effects of specific lasers against specific materials. 3) Perform a thorough study of target susceptibility to laser effects. Presently, it is roughly estimated that 40 percent (minimum) of the surface targets in a given theater are laser susceptible targets. It is assumed that all air and space targets are laser susceptible. Validation of laser technology capabilities will allow for better counter-laser assessment and force protection of U.S. military assets.

4) Enable the geographic Combatant Commands to weaponize laser susceptible targets to build up target folders with laser solutions through current applications that will allow for proper target development. 5) Assign the Air Force Combat Climatology Center (AFCCC) and Air Force Research Laboratory, Directed Energy Directorate (AFRL/DE) to continue climatology analysis by depicting environmental limitations regarding laser weapon systems employment. 6) The ultimate advantage of the U.S. military, according to the 2006 QDR, is “superbly trained, equipped, and highly dedicated people.”

Therefore, continuing to invest in the recruitment, development and career progression of

the people serving in DoD should be an ongoing focus for the future. 7) Air Combat Command, Air Warfare Center, AF Space Command and Air Armament Center, should begin developing laser weapon Concepts of Operations (CONOPS). 8) Adjust the technology development-acquisition process to accommodate the expected rapid technological change rate.

Tactical Air-To-Air Laser Systems on Fighter Aircraft By 2025

Jeff “Lenny” Gustafson, Lt Col, USAF

Accelerating Solid State Fiber Laser (SSFL) research will fuel progress toward a mature 100+ kilowatt tactical air-to-air laser employable from fighter size platforms by 2025. This paper investigates how technological improvements today and those forecast for future development offer the opportunity to incorporate laser technology into legacy and future fighter platforms. The value of a tactical air-to-air laser system capable of employment from podded legacy and future Low Observable (LO) platforms is so compelling that extraordinary efforts justify a Joint requirement for research, funding, development and acquisition of such a system. The failure to pursue this tactical “speed of light” defensive and offensive air-to-air capability could be devastating to future U.S. air and space superiority. Although the U.S. dominates these mediums today, future battles with globally advancing technologies such as DE laser systems and improved kinetic devices could inflict dramatic losses upon the U.S. and its allies. For this reason, current USAF leadership is advocating the F-22A and F-35 stealth fighters along with rapidly advancing UAV and DE research programs. With such vehicles, the U.S. will continue its superiority of air and space well into the future.

Laser systems for legacy and future fighter aircraft are the next evolutionary step in air-to-air combat. Detailed simulation of tactical employment has demonstrated the

importance of lasers in sustaining an air and space superiority force in the future. It is critical that DoD maintain the technological lead in DE through prioritization of laser research and development, and equally essential that a joint SSFL system be developed and fielded for the projected legacy fighter force. In addition to the capability increase it will provide, this externally podded system will enable the development of the Tactics, Techniques and Procedures (TTPs) necessary to inform employment of future internally mounted SSFL systems. These new speed of light weapon systems will compliment current and future kinetic systems to continue the USAF's current air and space dominance, and in turn secure our homeland and those of our allies against threats to the free world of tomorrow.

Recommendations: 1) The USAF, USN, and USMC coordinate with USSOCOM a Joint requirement for an externally podded SSFL system for legacy air-to-air and air-to-ground fighter aircraft. This requirement must ensure integrated Joint simulation testing, training standards, and tactical employment standards. This will cement seamless future integration with the F-35 Laser Strike Fighter, UCAV type vehicles and follow-on strike platforms. 2) The USAF, USN, and USMC coordinate with USSOCOM to immediately develop a Joint requirement for the Laser Strike Fighter (F-35 variant). Current Lockheed Martin projections require an initial decision for funding by 2009-2010 in order to get engineering pre-design activities started by 2016 to produce an operational Laser Strike Fighter by 2020-2025. 3) Update and refine the USAF Directed Energy Roadmap annually with focus on current breakthroughs and testing successes/failures. Emphasis today must address our ability to counter current and emerging capabilities that are being exported globally and pose a significant strategic threat to the United States of

America and its allies abroad. 4) Triple the current High Energy Laser Joint Technology Office budget and closely track all fields of interest IAW the Directed Energy Roadmap. Give special emphasis to the areas focused on the SSFL for podded and internally integrated tactical laser systems per the Directed Energy Roadmap timeline. 5) Study simultaneous employment of kinetic and laser weapons in the air-to-air environment for synergy, survivability and reliability.

Tactical Airborne Ladar (Laser Radar) System in the Operational Environment of the Future

Kelly Noler, Lt Col, USAF

This paper considers whether ladar could provide significant capability in future operational environments, specifically as an integral part of an autonomous airborne weapon system. As the backdrop for this determination, a lengthy look at current applications, as well as research for future ladar capabilities is accomplished. In addition, comparisons are made between ladar and other systems with similar (postulated or existing) capabilities. The findings of the paper are that ladar will provide substantial capability within multiple (but not all) future operational environments. The most significant contribution ladar will make is relative to its ability to three-dimensionally (3-D) image objects with extreme precision and accuracy. Ladar provides the ability to detect, identify and target objects more expeditiously and at greater distances than current day capabilities. Within limited applications, ladar will perform at a high level of detail while 3-D imaging objects through dense foliage.

To date, a sizable amount of ladar research has already been accomplished at the international level, covering a large spectrum of operational applications. Within the U.S., priority has not been adequately placed on ladar's research and development to

ensure it remains ahead of potential adversaries' development efforts. An entity which possesses this capability will have a distinct advantage over an entity that does not. Ladar will provide target identification at greater range, with greater confidence in target specificity and enabling target attack at greater range with a lower potential for collateral damage. It's in America's best interest to maintain its leadership in the pursuit of such weapon systems. Investing in this capability today will ensure the U.S. remains ahead of competitors and potential adversaries of tomorrow.

Recommendations: 1) It is paramount to recognize LADAR's capabilities and potential as part of an integrated weapon system. The view of ladar as an independent system does not realize LADAR's full potential and will not encourage provision of increased resources (funding/research) for its maturation. By itself, ladar holds the potential of providing several useful capabilities. However, developing ladar in conjunction with other systems (such as automatic target recognition) exponentially increases the capabilities of all systems associated. 2) Fund research and procurement of ladar in order to reap substantial and diverse benefits in the operational environment. Investing in this capability today will help ensure the U.S. remains ahead of competitors and potential adversaries of tomorrow.

Space

Responsive Space Situation Awareness in 2020

Russ Teehan, Major, USAF

The U.S. strategy to assure freedom of access in space hinges on Space Situation Awareness (SSA): the ability to find and track space objects and determine their capability and intent. As a result, Air Force Space Command (AFSPC) is investing much

to overhaul aging sensors, network sensors to enable data sharing and dissemination timeliness, and improve the tactics, techniques, and procedures required to integrate space surveillance into command and control operations at the Joint Space Operations Center. Regardless, AFSPC is projecting a shortfall in our ability to characterize objects in deep space and in SSA at the end of the mid-term planning cycle in 2020. This research paper recommends a few strategy refinements and a key technology investment necessary to erase these shortfalls.

The strategy refinements include: seeking out more contributing sensors, establishing a layered network to free up dedicated sensors to monitor high interest objects and respond to events, using all means to erase the “lost” object list, switching some SSA missions from persistent to routine for the sake of reducing cost and complexity, and using the network as a teammate (rather than just a data provider) capable of sharing in the decision-making. This paper recommends investment in artificial cognition technology and improving the pertinence of such investment by creating a decision support team to “train” the computer at the Maui High Power Computing Center.

Investment in artificial intelligence is pertinent to many other mission areas including cruise missile defense, defensive counter space, responsive logistics, integrated battlefield ISR, and defensive counter air. The bottom line is that due to information overload and reduced battlefield timelines, each mission area must look for the right mix of artificial and human cognition to be prepared for the battlefield of 2025.

Recommendations: 1) To reduce the size of the catalog of lost space objects, establish a reward system for private sector actors who locate lost spacecraft. Also,

launch less-capable satellites routinely on rideshares to characterize deep space high-interest objects and drifting satellites nearing end of their life in geosynchronous orbit. 2) To enable responsiveness, acquire more sensors and dedicated assets to enable focusing attention on high-interest objects and ensuring robust coverage of high-interest areas, enabling our ability to respond to multiple events. 3) Increase the number of sensors, creating a layered SSA approach, which brings all contributing space systems and sensors onto a single network to enable data sharing and timely information dissemination. 4) Invest in artificial cognition to automate many SSA functions to respond to the increasing complexity and to operate at the speeds required by 2020.

Persistent Space Situational Awareness: Distributed Real-Time Awareness Global Network in Space (DRAGNETS)

Dustin “Zig” Ziegler, Major, USAF

U.S. dependence on space brings with it an inherent vulnerability and a compelling need for robust Space Situational Awareness (SSA). Over the next 20 years, nanotechnologies will enable a shift toward distributed networks of very small satellites to maintain continual cognizance of the space environment. The Distributed Real-time Awareness Global Network in Space (DRAGNETS) concept leverages this trend using constellations of thousands of sugar cube-sized “femtosats” instead of the current paradigm of large, specialized, one- or few-of-a-kind systems. The recent explosions in nanotechnology research and projections for even greater future growth have laid the foundation for the substantial miniaturization that will be required. Advances in sensors, propulsion, processing, power, and other key satellite subsystems will enable the Air Force to package SSA capabilities on the femtosats, allowing DRAGNETS to perform the mission globally on a continuous basis.

DRAGNETS will also offer substantial cost efficiencies through rapid, automated mass-production and testing processes as well as flexibility in launch options. A full constellation of several hundred thousand femtosats can be placed in orbit at once with the same launch weight as a medium class satellite, or deployed incrementally using space-available opportunities. In order to realize the DRAGNETS vision, the Air Force should plan phased investments that leverage ongoing worldwide nanotechnology basic research while leading the charge in nano-scale modeling and manufacturing technologies, building toward an operational assessment of a prototype DRAGNETS constellation at a technology readiness level of 7 by 2025.

Recommendations: *Near-Term (2008 – 2014)*—Develop an overarching nanotechnology roadmap within the Air Force technology enterprise. Such a roadmap would enable the various science and technology elements (AFRL, AFOSR, AFIT, Air Force Academy, etc.) to coordinate their basic research and application investment strategies while providing strong traceability back up through DoD to the National Nanotechnology Initiative (which provides DoD with \$350M per year). On the development side, the Air Force should leverage ongoing commercial and academic basic research at the component level, taking full advantage of Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) opportunities to capture the ingenuity of those at the leading edge while continuing similar efforts at the research laboratories. One area the Air Force and commercial sectors stand to benefit from more than the academic is in manufacturing. The Air Force must ensure robust and level funding of nanoscale production technology development within AFRL's Manufacturing Technologies (MANTECH) program in order to provide a stable, long-

term partnering incentive industry can plan for. Modeling and simulation will also be a critical need, particularly early on. Strong leadership and investment in a coordinated M&S effort will pay dividends down the road through better understanding of how to use these technologies in applications of interest to the AF.

Mid-Term (2014 – 2020)—Emphasize application-oriented efforts, leading the demonstration of femtosat subsystem performance in key areas such as image formation from ultra-small nano-enabled cameras at low light levels, fully testing flight software packages, and integrating nano-enabled attitude control and propulsion systems. Constellation management and cooperative multi-vehicle SSA operations should be demonstrated on orbit using larger, mature nanosatellite platforms such as the CubeSat satellite bus. By 2020 the USAF should have integrated all femtosat subsystems and flown test articles to demonstrate functionality while establishing opportunities for early operational assessments. In parallel, the USAF should leverage advances in nanotechnology-based supercomputing and artificial intelligence with an eye toward fielding highly efficient ground control architectures.

Far-Term (2020 – 2025)—Drive toward an AF-led on-orbit demonstration of a distributed femtosat constellation. Important milestones will include simulating autonomous investigation of an uncooperative space object and sharing the information with other portions of the constellation, cueing other space-based and ground-based SSA assets, sending out test alerts to satellites with self-defense capabilities, and relay of data in near real time. The culmination of this stage of development will be a series of incremental operational assessment activities leading to a technology readiness level (TRL) designation of 7 rather than the TRL 6 traditionally identified for transition to an

acquisition program. This may help reduce technology risks that seem to plague many of today's space programs.

Upon This Rock: A Foundational Space Situational Awareness Technology for 2030
Todd "Einstein" Wiest, Major, USAF

The use of space permeates all aspects of the American way of life. If the U.S. is to continue this reliance on space in the year 2030, it must increase its capabilities to diagnose and attribute events occurring in space. This diagnosis and attribution requires an increase in Space Situational Awareness (SSA) to include awareness of small objects. To enable awareness of small objects, this paper recommends the USAF investigate the potential use of infrared and visible fluoride fiber lasers (FFLs) as the active sensor on a fleet of small satellites to increase SSA by tracking and imaging objects as small as 0.1 centimeter.

After establishing the threat, technical, and strategic imperatives for locating small space objects, the paper conceptualizes a space-based system with FFL payload to identify the utility of this system. As a U.S. capability, this system allows diagnosis and attribution of space debris and small satellite counter space threats to protect U.S. access to space capabilities and manned space flights including space tourism. For the USAF to have this capability by 2030, we must channel funding to academic and commercial laboratories to increase pulsed laser output power, create fluoride fiber devices, and create small diode pump lasers. In addition, the USAF needs to investigate the sensors necessary to further identify key system parameters to drive technology development.

Recommendations: 1) Invest in a space based laser detection system to insure SSA. Laser technology does not have the limitation of radar; lasers can track and collect information about objects smaller than 0.75 cm. A laser placed in space eliminates the

shortcomings imposed by the atmosphere. With a fluoride fiber laser, laser design and alignment are simpler in a smaller, more lightweight package. The system enables the U.S. to diagnose, defend, and attribute a space event to another country's satellite and triggers either an offensive counter-space response or the application of other IOPs to remedy the situation. 2) Fund academia and commercial laboratories to focus fluoride fiber laser development. In particular, the USAF should fund both entities to increase pulsed laser output power from fluoride fiber lasers. 3) Fund commercial laboratories for development of all fluoride fiber devices. 4) Fund commercial laboratories to develop small, lightweight pump lasers operating at the appropriate wavelengths. To make this funding available, the USAF should re-align its science and technology priorities. 5) Lead studies of the sensors identified in the conceptual SSA system. These studies should establish parameters for imagery resolution. Following the sensor study, the USAF should lead a concept exploration study refining the necessary parameters for conceptual SSA system development

Autonomous Defensive Space Control via On-board Artificial Neural Networks
Mike Manor, Major, USAF

Future advances in neural network technology, coupled with increased computer processor capability, may create an opportunity to develop systems that enable satellites to autonomously differentiate, detect and defend against attacks. The Air Force should take advantage of this potential opportunity by investing the necessary resources for the development of space-based neural networks.

Artificial neural networks (ANNs) offer one of many space control technologies to address protecting U.S. space assets from these threats. ANNs are intelligence systems created to mimic the ways and methods in which our own brains respond to and learn

from inputted stimulus. Each of these networks consists of an array of neuron-like gates, programmed to take action once a designated threshold is crossed. Like our brains, these networks learn based on the continued processing of inputted stimuli, and develop a memory by storing the action it takes in response to them. This memory, gained through storing data, enables ANNs to become somewhat autonomous over time because they have the ability to recall an action taken based on a past input received.

By giving satellites the ability to identify attacks and take self-protection actions through ANNs, the effects of an attack by U.S. adversaries can be minimized. Essentially, an ANN will put the satellite in a protective mode to shield it from directed energy (e.g. jamming, lasers) only for the duration of attack. Such actions will also limit the time a satellite is out of operation to the amount of time that particular satellite is within range of attack. For a LEO satellite, this is only minutes as it rapidly passes over an adversary's weapon location. Such capability would be a huge leap forward from current satellite systems that are only able to turn the satellite off, with ground operators being required to intervene to fix them. This process is often lengthy and may involve many engineers. An on-board ANN that brings increased autonomous decision-making capability to a satellite would likely shorten this time.

On-board ANNs have the potential to give the U.S. and the Air Force a means of protecting some of their most valued assets in space. It is critical that the U.S. in general, and the Air Force in particular, continue to develop neural networks and integrate them into its satellites.

Recommendations: 1) The Air Force should continue its development of ground based neural networks, such as the Aerospace Corporation's Satellite as a Sensor (SAS).

2) Once the Air Force fields SAS, it should conduct live fire ground or on-orbit testing using simulated direct energy attacks on one or more of its satellites. These tests should facilitate identification of neural network performance shortfalls, as well as data shortfalls from the satellite's telemetry and sensor inputs. 3) Once these tests are completed, the work to develop a neural network capable of being housed aboard a satellite. 4) Once a feasible on-board neural network is developed, identify remaining technology hurdles affecting neural network operations. 5) In addition to system considerations, the Air Force must examine its current space decision-making culture. Currently, the decision-making process within the Air Force's space community is extremely hierarchal and stovepiped. Furthermore, strict security enclaves prevent information cross-flow. This culture must change in order to fully utilize the potential of a neural network or any system that has the capacity to make man-out-of-the-loop decisions (or increase machine to machine contacts) and actions.

Improving Satellite Protection with Nanotechnology

Joseph Huntington, Lt Col, USAF

This paper argues that nanotechnology may be useful for mitigating the threat posed to U.S. satellites by ground-based directed energy weapons. Nanotechnology exhibits properties that may enable it to protect against the effects of directed energy weapons, but this has not been sufficiently demonstrated and more research is needed. Nanotechnology will likely have significant impact on U.S. satellite design by 2025. Nano-enhanced power generation and storage, and advanced radiation hardened microprocessors will be available in the next five-to-seven years. Enhanced surface coatings that can more efficiently dissipate thermal and electrical energy will be available in the next seven to ten years.

By incorporating nanotechnology into satellite designs, U.S. satellites can be made smaller, and lighter in weight. By 2025, this will permit the launch of multiple satellites on the same launch vehicle used to launch a single satellite today. These satellites on-orbit will be able to act like a swarm and provide redundant on-orbit capability. Continued investment in nanotechnology research and development, as well as monitoring academic and industrial research efforts, will require a long and expensive commitment for the USAF, but one that is necessary for the USAF and nation to maintain space supremacy.

Recommendation: The USAF should continue investing in nanotechnology research and development to understand and harness its capabilities for protecting critical satellite systems. The benefits of nano-enhanced structures and functions (i.e., power generation and storage, radiation hardened microprocessors, and structural rigidity) will result in a lighter weight satellite that occupies less volume and costs less to launch, with the savings possibly outstripping the costs of the R&D.

Wild Ride: Launching Troops through Space for Rapid Precision Global Intervention
Shon “Gus” Williams, Major, USAF

The USMC has identified a valid need to transport troops through space for rapid response to crisis situations anywhere in the world. Although achieving a viable, responsive troop space transportation option comes with significant challenges, the USAF as the lead service for space should invest in capabilities that will satisfy the stated Marine Corps need as well as make possible other missions that would benefit from fast, low-cost, reliable space transportation. This paper examines technologies supporting worldwide point-to-point space transportation, and the implications for the USAF between now and 2025. While this futuristic method of achieving rapid global mobility

requires maturation of a several technologies, launch vehicle and propulsion technologies receive primary focus in this study. This work also expands upon the global strike concept and introduces the idea of “Rapid Precision Global Intervention,” or the ability to take the full range of the nation’s capabilities quickly and accurately anywhere in world to achieve desired effects.

Rapid Precision Global Intervention through space brings many benefits and capabilities to the warfront that do not currently exist. Enabling technologies are maturing rapidly with the potential to deliver a truly revolutionary, responsive suborbital or orbital space lift capability (manned and unmanned) sooner than 2025, but they have not been adequately demonstrated in a single system. The USAF needs to develop a rapid troop space transport for joint operations. With the proper investments, disciplined planning, and the right partnerships, the space domain will offer a speed and responsiveness not currently available by land, sea, or air.

Recommendations: 1) The Air Force should initiate a discussion of rapid troop space transport with the USMC. 2) The Air Force should increase investment in AFRL’s Fully-reusable Access-to-Space Technology (FAST) program. This program has the right management approach to proceed. Involve other stakeholders in evaluating and modifying the technical approach in order to fulfill joint troop mobility requirements. 3) Create a technology roadmap for responsive spacelift with clear milestones and execution responsibilities, targeting initial operational capability in 2025 to 2030. 4) Plan a series of incremental demonstrations and tests to prove specific advanced technologies and the overall concepts and CONOPS. Include a robust plan for experimental vehicles (X-vehicles) in the technology roadmap. 6) Integrate Rapid Precision Global Intervention

with related programs as part of one plan for the nation with a common end state. This should include continuing investments in ARES, Falcon family, and CAV; and supporting Navy and NASA on hypersonic propulsion technology. 7) Establish structured partnerships within military, civil, and commercial space specifically targeting rapid, responsive suborbital and orbital spacelift.

Getting to Space on a Thread: Space Elevator as Alternative Access to Space

Jason R. Kent, Major, USAF

Assured access to space is essential for the USAF. The space elevator, a concept where a tether is used to lift cargo and personnel into space, provides the means to meet this need. This one-meter wide tether will reach from the surface of the Earth to a point some 62,000 miles up. The base of the ribbon will be attached to a floating platform while the space end of the tether will extend past geosynchronous orbit to a counter weight. Twenty ton vehicles called lifters are powered by ground-based lasers and travel 125 miles per hour on this tether, cheaply carrying heavy loads. Of these 20 tons, about thirteen would be pure cargo, 65 percent of the total weight compared to about five percent for current launch vehicles.

The technology which makes the space elevator possible is the carbon nano-tube (CNT), a material that is theoretically more than one hundred times stronger and ten times lighter than steel. A space elevator is estimated to cost \$10-15 billion (compare this to the cost of a single shuttle mission costing \$500 million). Follow-on threads would be much cheaper, about \$3 billion, since the research and development and support infrastructure would already be established. For the initial \$10 billion investment, the cost per pound into space would drop from \$10,000 to \$100. The USAF,

as the DoD Executive Agent for Space, can lead the U.S. in developing and deploying this alternate means of accessing space in support of DoD missions.

Recommendations: 1) Monitor the maturation of nanotechnology which may enable the space elevator to become a reality. 2) Consider the space elevator as a viable space launch alternative in the 2030 time frame.

Splitting the Atom on the Way to the Moon and Beyond: Nuclear Reactors in Space
Chris Hamilton, Major, USAF

With the probable increase in both commercial and foreign utilization and potential militarization of space during the next two decades, the U.S. needs to monitor and encourage the pursuit of technologies that will enhance our capability for military operations in space. Space nuclear reactors (SNR) provide compact, long duration, continuous high power generation, without a dependence on line-of-sight to or distance from the sun. They can enable or greatly enhance many space force application, space force enhancement, counter space, and space support missions. However, this technology has significant political, legal, and safety constraints that must be dealt with during all stages of development and operations.

While there does not appear to be any near-term military requirement for the capabilities that space nuclear reactors (SNR) can provide, this technology becomes essential in any future scenario where state-to-state tensions are high and political constraints against weaponizing space are ineffectual. The USAF now needs the capability to at least monitor advances of nuclear reactor or associated critical technologies. Intelligence activities should include evaluation of foreign advances in this arena due to the capabilities it could provide to an adversary. DoD and the USAF should encourage any NASA or DoE effort to advance these technology areas or to boost the

nuclear infrastructure. By assisting these efforts now, the USAF needs very minimal investment now, but will be capable of ramping up effort to meet expanding mission needs.

Recommendations: 1) Until such time that the USAF can define a mission requiring SNR capabilities with great enough need to justify the expense, political effort, and potential international treaty modification or withdrawal, the USAF and DoD need to take steps to monitor and encourage technology development at a small level. 2) If offensive military actions in space by other nations increase to the point where their compliance with the Outer Space Treaty or peaceful use of space resolutions is questioned, then a decision to open up certain prohibited missions will need to be made. If these missions are going to be adopted, the USAF should shift into a full leadership role for the development of SNR systems. 3) Make a small investment now to allow the USAF to leverage other agencies SNR technology development when and if it is needed.

Commercial Eyes in Space: Implications for U.S. Military Operations in 2030
Scott Bell, Major, USAF

Commercial remote sensing from satellites provides massive amounts of information about objects on the Earth's surface for a variety of business, civil, and recreational needs. Using two case studies, this research paper investigates how commercial satellite remote sensing capabilities in 2030 could impact U.S. military operations and analyzes what investments should be made today to protect U.S. interests from adversaries using these capabilities. Interviews with multiple experts from the commercial remote sensing community combined with research of open-source documentation provide unique insights into possible futures. The preponderance of the evidence shows that by 2030, the commercial remote sensing industry will be able to

provide dynamic and vertically-integrated multi-source information in near-real-time. These advances will provide digital information in near-real-time to worldwide consumers. However, all military actions will be observable by commercial sensors, and this information could potentially be sold to U.S. adversaries.

The implications for the U.S. military include access to a wealth of information to supplement national intelligence collection, as well as a need to develop capabilities to deny its use by adversaries. To preserve information superiority in 2030, the U.S. must advocate international policies to prevent sales of commercial information products. Creation of international policies is only the first step to reducing the threat. The U.S. Air Force should invest today in technology development efforts such as counter-communications, synthetic aperture radar jamming and spoofing, computer network attack, and mobile laser technologies as part of a comprehensive counter-ISR fielding program. A comprehensive counter-ISR system will be essential for the U.S. to maintain the space and information superiority critical to fighting and winning future wars.

Recommendations: 1) Monitor foreign satellite remote sensing capabilities to analyze potential threats. 2) CONOPS for employing counter-ISR systems should be developed in conjunction with system capabilities. 3) Techniques should be jointly developed with industry to protect satellite packages from laser blinding and communications jamming.

Radiation Belt Remediation: Satellite Survival in Low Earth Orbit after a High Altitude Nuclear Detonation
Herb Keyser, Major, USAF

This paper examined the proposed radiation belt remediation (RBR) system currently under investigation by AFRL, NRL, and DARPA. With the proliferation of

nuclear weapons and ballistic missile technology, it becomes increasingly likely that another country (either independently or in connection with terrorists) could create a High Altitude Nuclear Detonation (HAND) to defeat the U.S.'s asymmetric advantage in space. The radiation remaining in space after the detonation would persist and destroy or disable all satellites in Low Earth Orbit within 60 days and prevent the launch of replacements for up to two years. This study uses a scenario approach to conclude that an RBR system is an essential component of U.S. space operations and urges continued emphasis on these programs.

Radiation belt remediation (RBR) represents a defensive counter space capability needed to protect America's satellites and access to space – both military and civilian. An RBR system will decrease the radiation in less than 30 days, preventing the loss of critical low earth orbiting systems while allowing reconstitution of the fleet. While not preventing all loss of satellites from the HAND, it will help maintain the U.S. advantage in space.

Recommendations: 1) The USAF needs to invest in the RBR program, first through development of full modeling of high altitude nuclear detonation effects and the resultant space environment. 2) The AFRL-designed space experiment needs to fly to validate the models and determine the appropriate system design characteristics. This will in turn determine whether the operational system needs to be space- or ground-based.

Other

Joel “Spicoli” Luker, Major, USAF

To evaluate properly the utility of a proposed technology, especially one developed for military purposes, one must also understand the context in which the developer will employ that technology; therefore, to provide a context for application of the proposed Blue Horizons technologies, this paper develops four scenarios that describe state actor threats in the year 2025. The *Wishful Thinking* scenario envisions a state whose military is materials-based and fights the U.S. military in a large-scale, force-on-force conflict. The *Information Immobilization* adversary will also attempt to fight the U.S. on the regular battlefield, but will do so using information-based systems to counter USAF capabilities. The *David and Goliath* scenario postulates a threat where a materials-based military attempts to fight the U.S. using irregular tactics. And, finally, *The Phantom Menace* state is one whose information-based forces will take on the U.S. in an irregular manner.

The analysis indicated *The Ghostly Menace* provides the highest potential for a state actor to inflict catastrophic damage to the U.S. However, experience has shown that, to be prepared properly for any future contingency, the USAF cannot focus its acquisition efforts solely on meeting the requirements of any one or two scenarios; the best return on investment will come from developing capabilities that provide an advantage across the entire threat spectrum.

Non-state Actor Threats in 2025: Blue Horizons Scenarios

James “Buster” Myers, Major, USAF

To determine technologies that provide the best return on Air Force investment, decision-makers require a common context regarding the future threat space. The author discusses the future non-state actor threat using four plausible scenarios. By combining

joint operational planning concepts, effects-based operational principles, capabilities-based planning processes, and scenario thinking, a list of most likely adversary capabilities for each scenario was developed. Since common context is the primary deliverable, the uniqueness of each scenario is discussed, as well as aspects that challenge the future choice and application of technology solutions.

The *American Insurgency* scenario depicts a future in which the adversary creates cascading effects to cause the overthrow of the American government. In the *Cyber 9/11* scenario, the enemy attacks with informational tools to cripple U.S. infrastructures temporarily. The *Blind Battlefield* adversary attempts to replace the fog of war that U.S. informational tools typically eliminate. The *Guerillas in the Mist* scenario demonstrates the adversary's use of precision attack to drive a wedge between occupiers and the local populace. The four scenarios illustrate challenges and concerns that affect the future procurement and employment of military technology solutions, as adversaries are equal partners in deciding strategic and operational effectiveness.

Acquisition Leaders for Rapid Technology Insertion Programs

Christopher M. Coombs, Lt Col, USAF

In order for the United States to maintain its position as a hegemon, to maintain its technological superiority, and to meet the requirement to fight “any enemy, anywhere, anytime,” the Department of Defense (DoD) must revamp policies and procedures to ensure rapid technology transition. We must have able people and sufficient funding to generate military capability from private sector technological advances as they become available. DoD probability of success in future conflict will be increased by leveraging the experience, training, investments and advances of independent research by civilian companies and universities. This paper reviews the impact of technological advances in

four areas: biotechnology, nanotechnology, cyber technology and directed energy. It also looks at the findings of several Horizons students, and addresses challenges to reforming the acquisition model that stem from people, process, technology and the organizational structure.

Recommendations: 1) Review and modify the selection, promotion and assignment of acquisition officers. 2) Inculcate a risk taking rather than a risk averse mentality toward leadership in the realm of ideas.

Developing Technical Leaders

David W. Hiltz, Lt Col USAF

The thesis of this paper is that the Air Force needs to recruit and educate officers who better understand science and engineering, and provide its technical officers a leadership development program that is experience-based.

People should be our first investment priority. To be successful in 2025, the acquisition community will need officers who possess great leadership skills and can adapt to rapidly changing technology. Air Force Material Command's best senior captains and majors in the program management, scientific development and engineering fields need more opportunities to lead people (not simply projects) earlier in their careers. For example, senior captains should formally compete for the best leadership jobs at their product center or depot, as well as operational leadership positions throughout the entire command. Broadening these officers' leadership experience will enhance the effectiveness and credibility of these officers. General Bernard Schriever illustrated the

importance of a combination of engineering talent, operational experience and extraordinary leadership ability as he led the fielding of ICBM's during the 1950's.

Today, radical inventions may change the nature of how wars are fought. Consider the ability of a femtosecond laser to vaporize a small target area using 120 volts of power from a wall socket. Potential uses for femtosecond lasers span the optical, electrical, computer, materiel and even biological sciences. A broader understanding of science and technology will be required to effectively anticipate, develop, and employ radical inventions. Unless the USAF develops top leaders who understand these radical new technologies, it will lose at least some of its edge in air, space, and cyberspace.

Recommendations: 1) Develop Air Force technical leaders who can adapt to the new environment of accelerating change. If our leaders are faced with technology they don't understand, and that doesn't relate to their education or experience, they can make bad decisions. 2) The developmental teams for the acquisition officers should review and identify our best mid-level captains and majors. These officers should be tracked and given first consideration for a wide variety of leadership opportunities.

Continuously Available Battlefield Surveillance

James "Hooter" Lake, Major, USAF

Current and future battlefield surveillance needs continue to outgrow deployed technological capacity. The AF needs a ubiquitous continuous surveillance system that would enable troops operating anywhere on the battlefield to remotely operate airborne cameras and other sensors to pinpoint selected targets and disseminate this information instantly to those who require the information. Such a system will need to operate at high altitude (greater than 65,000 ft) with an endurance measured in days, if not longer. The design will include multiple sensors, low observable features, and internally stored

weapons for time-sensitive targets. For operating areas still heavily defended by potentially hostile forces, a stealthy Global Hawk derivative is required. For extended operations in coalition held environments, a lighter than air ship can provide surveillance for months at a time. Using either system, the extreme altitude provides coverage of an area approximately equal to the nation of Iraq with a single aircraft. All the technology required to create these systems either exists or is in development, providing an initial operational capability by 2020.

Recommendations: 1) The USAF must work to eliminate the key obstacle in producing any of these systems: the slow approval process of the FAA for approval of UAV flights in national airspace 2) The USAF should continue to explore the possibility for using near space to afford continuous battlefield surveillance.

Solar Powered Aircraft in 2025: Beyond Atmospheric Satellites

Dean Anderson, Lt Col, USAF

By the year 2025, solar powered aircraft will become a reality. Advances in nanotechnology and biotechnology will take solar energy collection and battery technology to new heights. Photovoltaic cells by 2025 will achieve enormous efficiencies. They will provide ample power for a solar powered aircraft.

Nanotechnology will advance battery technology, achieving an astounding three kilowatts per kilogram. This will provide enough energy for both solar powered aircraft propulsion and onboard systems.

An aircraft powered by advanced photovoltaic cells and nanotechnology batteries will have extreme endurance, enhanced mobility and broad autonomy. It will have the same capability as all conventional unmanned aerial systems (UASs) as well as fulfilling roles currently given to satellites. The *DoD UAS Roadmap 2005-2030* divides UAS roles

and missions into three broad categories: Dull, Dirty, and Dangerous. Solar powered aircraft are ideally suited for all of these missions. Ultimately, solar powered aircraft utility will be limited only by the imagination of those operating them. The Air Force should pursue this capability by partnering with NASA and the European Space Agency to develop solar powered aircraft.

Recommendations: 1) DoD should name the USAF the executive agent for development of solar powered aircraft. 2) The USAF should team with NASA and the European Space Agency to leverage their tremendous work toward building a future high endurance solar powered aircraft. 3) The USAF should sponsor research through the Air Force Research Laboratory (AFRL), Defense Advanced Research Projects Agency (DARPA) and the Air Force Office of Scientific Research (AFOSR) to achieve improvements in solar collection capability and energy storage capability.

Accelerating the Kill Chain via Future Unmanned Aircraft

Julian “Ghost” Cheater, Major, USAF

In 2025, the United States could have a great impact on accelerating the kill chain by investing early in research that 1) advances autonomous and intelligent control of Unmanned Aircraft and 2) enables a mobile ad-hoc network using unmanned aircraft as communications nodes. This mobile ad-hoc network should interface with the Internet to provide maximum warfighter access; it will relay information via a combination of radio frequency, laser communication, and satellite communication links. Warfighters tend to focus on kinetic effects such as improving munitions instead of less glamorous but critical tasks such as gathering, analyzing, and distributing vital information to the right person for action. Autonomous unmanned aircraft operations will reduce manpower and bandwidth requirements while an improved airborne communications network will

increase situational awareness for warfighters and decrease reliance on satellites. Based on China's demonstration of downing a low-earth orbit satellite, along with the potential for an array of other ASAT weapons, the US military cannot afford to rely completely on satellites for beyond-line-of-sight communications.

The military often seeks to "revolutionize" warfighting via cutting-edge technologies, but in this case, it can gain more by selectively improving existing technologies to promote autonomy and interoperability with less risk. This survey of 46 unmanned aircraft experts suggests that the kill chain can be accelerated by investing in autonomous/intelligent control and mobile ad-hoc networks, but the limiting factors will be 1) the quality of information that the commander receives, and 2) how much that commander trusts an automated system (cultural mindset). By overcoming both technical and cultural barriers, the United States can accelerate the kill chain and *anticipate* enemy actions instead of *reacting* to attacks.

Recommendations: 1) Use a combination of military research laboratory studies, university research grants, corporate development contracts, design competitions, and international consortia (where appropriate) to generate sophisticated algorithms used for UA autonomous operations and apply intelligent control as it advances. The military must provide incentives so that pure research translates into practical military applications. 2) Use DARPA and other agencies to sponsor conferences and information sharing on unmanned aircraft development that spans a variety of disciplines. This cross-flow of information between disciplines has the potential to promote military advancements in many areas. 3) Ensure joint requirements shape the research and development phase to preclude interoperability issues and unwanted duplication. 4)

Continue to invest in laser communications for both atmospheric and space applications. Laser communications will enable the transfer of large amounts of data at high speeds with little chance of interception. 5) Develop mobile ad-hoc networks as a theater backup to communications satellites and use a variety of airborne platforms including unmanned aircraft as nodes. Mobile ad-hoc networks will accelerate the kill chain by *distributing* actionable intelligence to in-theater warfighters.

6) Develop a communications architecture using a combination of lasercom, radio frequency, and satellite communications links to enable mobile ad-hoc networks. These links should securely pass classified and unclassified information via Internet Protocols to maximize interagency interoperability. 7) Develop robust security measures for mobile ad-hoc networks during the research and development phase with a clear understanding of the impact of a compromised network. 8) Comply with current Internet Protocols (IPv6 in 2008) and provide military advisors to shape future standards decided by organizations such as the Internet Engineering Task Force. This partnership with civilian working groups benefits the Air Force because it enhances security of civilian infrastructure that augments military communications. 9) Allow commercial influences to drive advances in computer processors. Faster processing speeds will accelerate the analysis and information flow to decision-makers.

Battlefield RFID: Super Tag Capability for the 21st Century

Gregory C. Bainum, Major, USAF

Radio Frequency Identification (RFID) technology in the 21st century is changing the spectrum of situational awareness by enabling systems-of-systems to track, monitor and locate everyone, everything, everywhere, at any time. This paper proposes that the United States military gain revolutionary benefit in battlefield management by pursuing a

merged RFID, GPS (Global Positioning System) and wireless network technology, dubbed here as a “super tag” capability. By 2025, if not sooner, situational awareness will need to be accurate, timely and decision level appropriate. Friendly and enemy forces will need to be accurately identified and located for any engagement time window while channeling the most necessary data to the decision maker (i.e. shooter, planner, headquarter commander). RFID combined with smart network and wireless technologies could conceivably provide Soldier-IFF (Identification Friend or Foe), as well as soldier-level blue and red force tracking.

The objective of this research is to provide a technology review and investment strategy as a starting point for the U.S. military to consider RFID technology for battlefield situational awareness. Technology gaps and potential alternative solutions are presented. Future antenna technology is explored to increase transmission distances and bandwidth. Battery design and materials to miniaturize and increase power capacity are examined. Integrated circuit technology is investigated for circuitry miniaturization. Wireless network technology is reviewed to find ways to create connectivity where infrastructure is limited or non-existent. The culmination of this paper is to recommend a two tier investment strategy to develop the super tag capability for battlefield situational awareness.

Recommendations: 1) DoD should undertake a two tier investment strategy to develop Super Tag capability and integrate it throughout the U.S. military. RFID is a mature technology worth investing in now for military use on the battlefield in the next 10 to 15 years, if not sooner. 2) Tier one research and development investment should include: a.) multi-frequency, multi channel antennas; b.) wireless mesh networking that

can manage itself and communication across the multiple platforms (i.e. radio, cellular, SATCOM, etc.); c.) a silicon chip radio with the ability to communicate across the RF spectrum; d.) a miniaturized mobile power source to give the individual soldier the most powerful, long lasting energy source on the battlefield; and finally, e.) miniaturized and integrated associated super tag circuitry (i.e. RFID, GPS and silicon radio, etc. 3) Tier two research and development investments should include: a.) wearable computer systems, antennas and power systems; b.) integration of super tag protocol across all military weapon systems and communications platforms; and, c.) development of an radio frequency tag dart device and delivery system for soldiers to fire with their weapons.

Improving Situational Awareness during CBRN and Hazardous Material Response via Unmanned Aerial Systems

Philip E. Goff, Major, USAF

There is a significant shortfall in our ability to provide continuous surveillance of chemical, biological, radiological, and nuclear (CBRN) materials in a “hot zone.”

Current CBRN response doctrine has a fully-protected, manned team enter a potentially-contaminated area with several pieces of equipment to test the air and let command and control know the results. If the team is wearing an air pack, their endurance is thirty to forty-five minutes; if they are wearing a traditional gas mask, their limit can be two to three hours. Once the team leaves the hot zone, all situational awareness is lost.

Likewise, current technology in sampling equipment prohibits ubiquitous, accurate measurements needed to make scientifically-based decisions. Current equipment is too slow, too bulky, unreliable, and inaccurate. Advances in technology, if channeled properly via an autonomous unmanned aerial system-of-systems, will fill this

gap and enable ubiquitous, fast-response sampling unencumbered by today's physical and technical limits, therefore increasing commander situational awareness and decision-making ability. A unmanned aircraft system coupled with chemical, biological, radiological, nuclear and/or hazardous materials sensors could provide continuous, extended-duration air testing. Sensor advances provide great promise in terms of accuracy and speed. Advances in power technology will enable the smallest unmanned aircraft system to remain airborne for days or weeks. Micro- and nanotechnology will enable systems that would today fit in the back of a truck to tomorrow fitting in a briefcase. The military must be prepared to mitigate CBRN attacks, and a UAS will fill an obvious need and a mandate from national and military leadership.

Recommendations: 1) Fund research related to more sensitive and faster chemical, biological, radiological, nuclear, and hazardous material sensors. Identify the revolutionary capabilities advanced sensors can provide and how best to exploit them for U.S. military purposes and how to protect against technological surprise from an adversary. 2) Copy Taiwan's UAV Industry Association to foster research and development of needed UAS. 3) Fund research of micro and nano-technology in sensors, motors, pumps, actuators, power, and communication, and control systems related to hazardous materials detection and unmanned aircraft systems applications. 4) Continue funding research to find any adverse health and/or environmental effects and determine the proper human health and environmental protection needs. 5) Submit mission needs statements and build this program into the Air Force budget.

For more information concerning the Horizon 21 study or the Blue Horizons program:

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