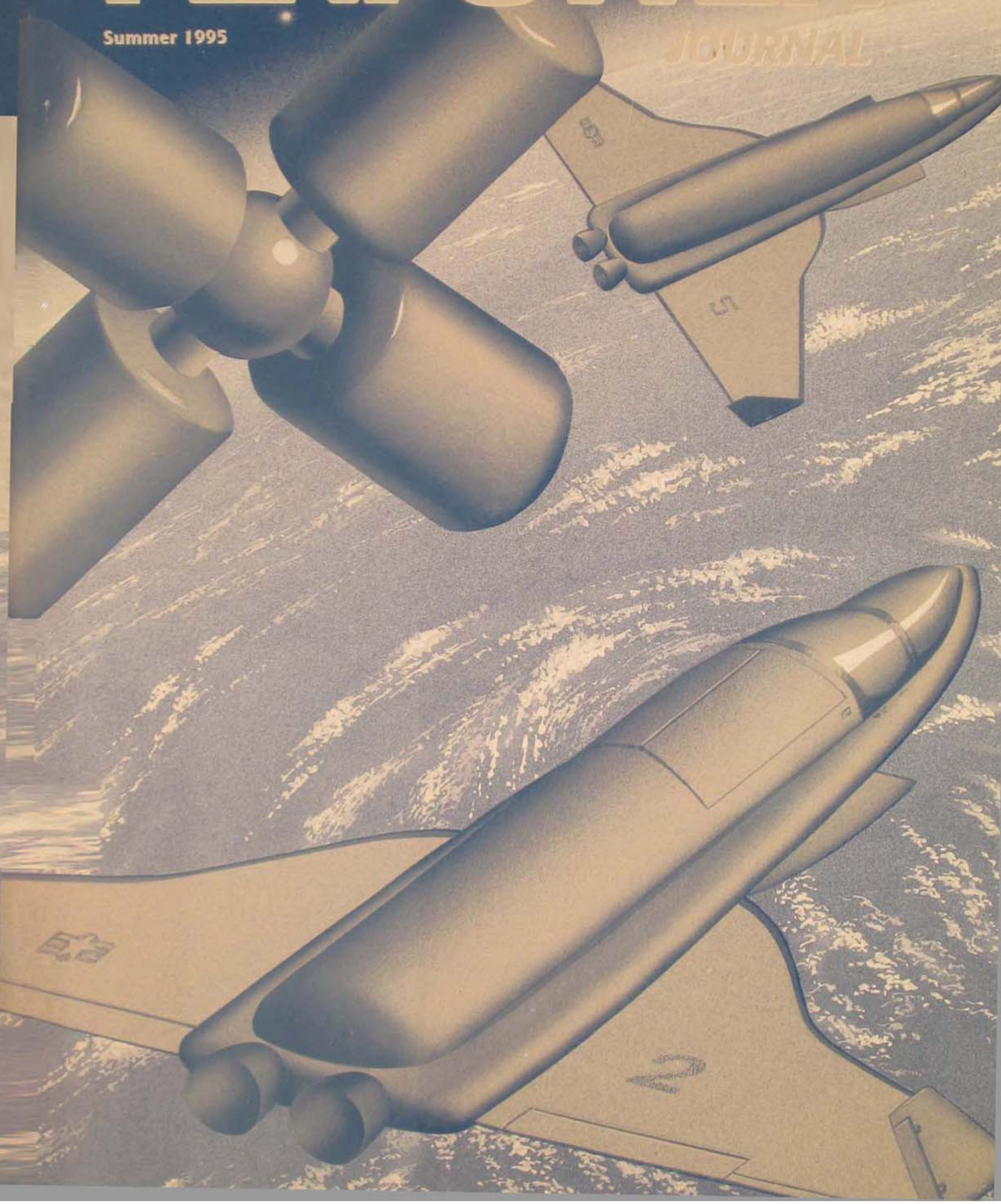
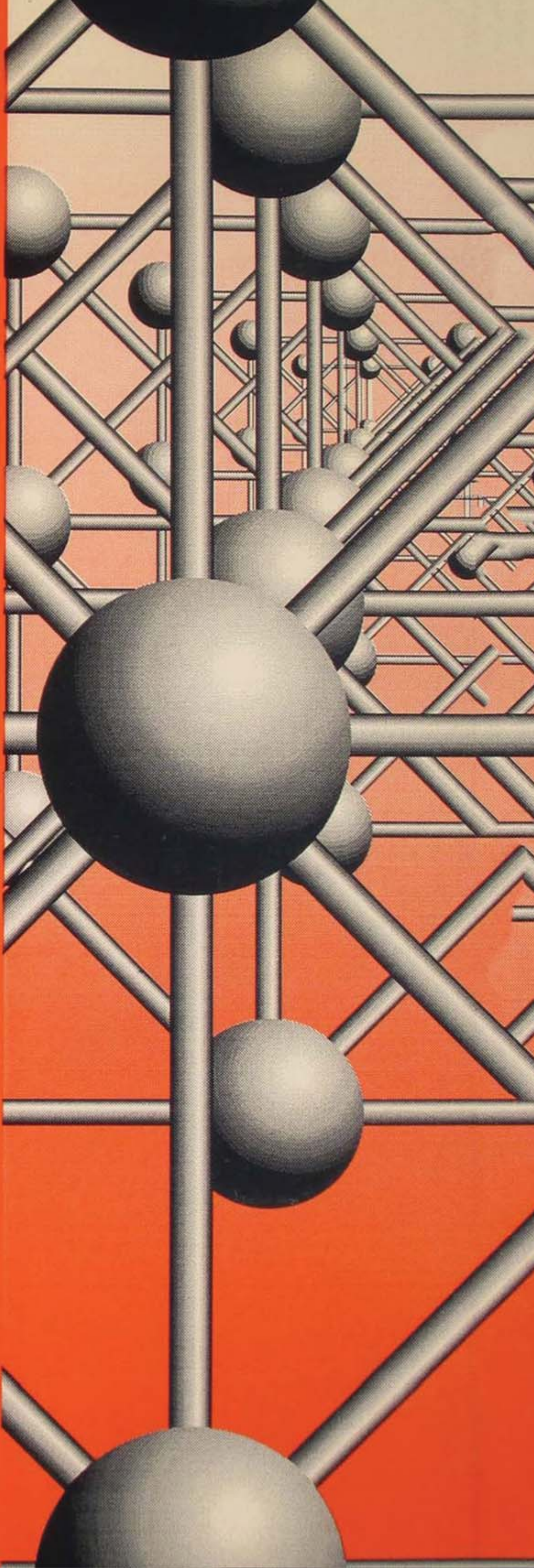
AIRPOWER JOURNAL

Summer 1995



Summer Readings

• SPACECAST 2020



AU PRESS

Editor
Lt Col James W. Spencer

Associate Editor
Maj John M. Poti

Professional Staff
Hugh Richardson, *Contributing Editor*
Marvin W. Bassett, *Contributing Editor*
Steven C. Garst, *Director of Art and Production*
Daniel M. Armstrong, *Illustrator*
L. Susan Fair, *Illustrator*
Thomas L. Howell, *Prepress Production Manager*

The *Airpower Journal*, published quarterly, is the professional journal of the United States Air Force. It is designed to serve as an open forum for the presentation and stimulation of innovative thinking on military doctrine, strategy, tactics, force structure, readiness, and other matters of national defense. The views and opinions expressed or implied in the *Journal* are those of the authors and should not be construed as carrying the official sanction of the Department of Defense, the Air Force, Air Education and Training Command, Air University, or other agencies or departments of the US government.

AIRPOWER JOURNAL

Summer 1995 Vol. IX, No. 2 AFRP 10-1

FEATURES

A MESSAGE FROM THE CHIEF

STRATEGY AND POLICY

SPACECAST 2020

OPERATIONAL ART

DEPARTMENTS

THE NEW *AIRPOWER JOURNAL*

A Message from the Chief of Staff

Gen Ronald R. Fogleman

I PROUDLY support recent changes in *Airpower Journal*'s editorial focus to include strategy and policy issues. In 48 years of publication, our professional journal has worked hard to stimulate reading, writing, and reflection by Air Force professionals. *Airpower Journal* is proving to each of us that the search for excellence is a continuous process and that the way we do business must adapt to meet the evolving needs of the Air Force community.

Gen Larry D. Welch, former chief of staff, told us why *Airpower Journal* was born:

> Our commitment to excellence and the unique sense of dedication reflected by military service in defense of the nation requires continued total dedication to professional values. Along with continued emphasis on our professional values, there is a need for increased appreciation within the Air Force of our basic organizational objectives and concepts of aerial warfare.

Since 1987, *Airpower Journal* has focused on the war-fighting spirit and application of airpower in combat. *APJ*'s format and editorials have aimed at the level of war known as operational art. This format has served us well and fulfilled its mission of stimulating the professional development of the officer corps. Yet, let me give you a few more thoughts to consider.

There is a continuing need to nurture fresh and innovative ideas in our professional military journals. Introspection, research, and new ideas—subjected to the crucible of criticism—help us expand our horizons, broaden our perspectives, and answer more of our questions. We're not changing our desire to promote the war-fighting spirit. We need a robust, lively dialogue on the profession of arms, leadership, and operational war fighting. But matters of strategy and policy should not be excluded from *Airpower Journal*. As a result, *APJ* is expanding its focus.

Give us your thoughts on strategy, policy, operational art, or history as they relate to the potential of air and space to meet our nation's security needs. They will merit the remarks of your peers, who will judge the balance of your argument, the preponderance of your evidence, and the power of your conclusions. If you're ready for the challenge, *Airpower Journal* is ready for you.

If we do not think prudently about the future, we will not be prepared when it arrives. That is why we are currently reviewing how the Air Force conducts long-range strategic planning. While I do not anticipate changing our overall focus, we need to institutionalize a process to ensure that we fully leverage emerging technologies and capabilities to meet the challenges of the twenty-first century. *Airpower Journal* can contribute to this process. It is an ideal forum to explore bold—even maverick—ideas on how the Air Force of today and tomorrow can best meet our security challenges.

I invite each of you to articulate your thoughts with the same care for our mission and professional values. Become part of our professional dialogue. I look forward to engaging each of you as you nurture ideas in this marketplace of ideas—our new *Airpower Journal*.

Headquarters United States Air Force

Ricochets and Replies

We encourage your comments via letters to the editor or comment cards. All correspondence should be addressed to the Editor, Airpower Journal, *401 Chennault Circle, Maxwell AFB AL 36112-6428. You can also send your comments by E-mail to Spencer=James%ARJ%CADRE@Chicago.AFWC.AF.MIL. We reserve the right to edit the material for overall length.*

OUT OF JOINT

"Air Operations Must Be *Joint,*" Maj Scott A. Fedorchak's article in the Spring 1995 issue of *Airpower Journal,* is strewn with dinosaur-like ideas and concepts. First, the phrase *joint air operations,* when used by officers of our sister services, is a code phrase for relegating airpower into a support role for land and/or maritime component commanders (LCC and MCC). Major Fedorchak has no problems with suggesting that the joint force air component commander (JFACC) should have staff representation from the other component commands. However, nowhere do I see any suggestion by him that the JFACC or proponents of the air campaign be represented in the other component commands. I don't think it dawned on him that the JFACC could be anything but a supporting commander. It is lost on him that one of the lessons of Operation Desert Storm is that the ground scheme of maneuver can support the air campaign. In that case, it is only natural that the interests of the supported commander (the JFACC) be represented in the councils of the supporting commands (LCC and MCC).

To rationalize the decisive nature of ground and sea campaigns, Major Fedorchak regurgitates the first mantra of ground officers: physical control of territory is the ultimate display of victory. Although control of territory can be accomplished from the air, for sake of argument, I will acknowledge his point. I would also say it's a rather uninteresting point. More important than the question of some poor 18-year-olds standing atop a hill as a demonstration of victory is the question of how they got there and how many died so that they could. The ground officer would have them slug their way to the top, exposing themselves to fire and death. The air campaigner would allow them to stay in their secured position to the maximum extent possible while the defenses were removed from above. It may take longer, but I'm sure those young people would prefer walking instead of fighting their way to the top—as would the American people who support them.

The second mantra of ground officers is that decisive battle settles conflicts. Major Fedorchak even identifies the enemy's army and navy (notice he leaves out the opposing air force) as "*the* strategic center of gravity" (emphasis added). A more sophisticated analysis of the relationships between centers of power and the instruments of power would lead to a different conclusion. Armed forces are but the expression of the enemy's will. The source of the enemy's will lies elsewhere. I believe Col John A. Warden's article "The Enemy as a System" in the same issue of *Airpower Journal* provides powerful arguments why battle with the opposing force is not strategic in nature and should probably be avoided.

Finally, Major Fedorchak makes the point a couple of times that instances existed that demonstrated the JFACC's subversion of the will of the joint force commander (JFC) in Desert Storm. On balance, the campaign General Schwarzkopf waged reflected his intent. Thankfully for the nation—and all those brave American soldiers—we had a JFC who had the vision to break through the boundaries of his training and education. He recognized the decisive effect airpower can have in a campaign and used it masterfully. I contend that the occasions which seem to suggest that his air campaigners were not following the letter of his allocation decisions were few and far between—and more the result of differing interpretations of events.

Lt Col Scott W. Gough, USAF
Tucson, Arizona

continued on page 90

A COMMENTARY*

GEN MICHAEL P. C. CARNS, USAF, Retired

THIS IS AN UNUSUAL yet welcome opportunity for me to discuss SPACECAST 2020 and its possible implications for the Air Force and the nation in the near and longer term. The Air Force has conducted a substantial inquiry. Its purpose has clear focus: how best to carry out the Air Force's mission to defend the United States through the control and exploitation of space. In operational terms, that should be rephrased as how best to harness and apply space technologies to

---

*Commissioned by the Air Force chief of staff in May 1993, Air University's SPACECAST 2020 project compiled a year's research into white papers that represent a huge paradigm shift in the Air Force approach to forming long-range concepts. In these comments to the National Security Industrial Association (NSIA) symposium, 10 November 1994, Gen Michael P. C. Carns, USAF, Retired, former Air Force vice-chief of staff, captures the thrust of SPACECAST 2020 and advocates for the Air Force's future in space.

support the operational war fighter. Let's pause on that thought for a moment—supporting the operational war fighter.

Begin with the baseline. The Defense Department's functional expertise is national security. Its constitutional responsibility is providing for the common defense. Its customer is its citizenry. The Defense Department has delivered on its contract with the American people.

We—all services—have decisively won this nation's wars, hot and cold. And the American public has unstintingly supported its warriors and provided the necessary resources to do the job—from World War I right on through Desert Storm. We are now in the most significant watershed of this century. We are moving from the conventional confrontations of the bipolar world of two superpowers to the confused and unfocused world of no identifiable national security threat with the irritation and unpredictability of ambiguous regional threats. In such circumstances, one could easily lose focus and momentum, and in so doing, lose the wellspring of our support, the American people.

SPACECAST 2020 has set out to attack this very problem: to link existing and emerging space technologies in a coherent way to the national security mission of the nation. The Air Force undertook SPACECAST 2020, but it should not be seen as Air Force–peculiar. This is a defense undertaking, with defense-wide implications. With that in mind, what are the useful observations for the nation and for this audience?

First, the military needs to appreciate that space is more and more a dual domain of military and civilian activity; we are far from alone in space. It is worth noting that of the 1,000 or so US space launches since 1959, the ratio of civilian to military launches has held at a rough 5:4 relationship. Interestingly, the forecast is for divergence of this ratio, favoring the commercial sector. Projects such as iridium and teledesic systems will total hundreds of launches should existing lifters be used.

My second observation would be that this increasing commercialization of space is bringing needed rigor to the economics of space launch and orbit. For decades, the US cost to reach space, in constant '93 dollars, has hovered around $8,000 to $12,000 per pound to orbit, both in low earth orbit (LEO) and geosynchronous earth orbit (GEO). US systems own the upper end of the scale; the French alternative tends to the lower band of the range. Suffice it to say that the pressure is clearly on to find cheaper and better ways to achieve orbit. It takes little vision to see that the market is clearly there.

A third observation is that despite the duality of space and its increasing commercialization, and despite the increased rigor and economic attractiveness of the space alternative, the military is seriously lagging in its operational understanding and appreciation for exploiting the opportunities of space to military advantage. This is a regrettable statement that requires further comment. At least two conditions have brought about this situation. First, although space has been the new frontier, it has been developed and shaped for some three-plus decades by functional specialties, not operators. For far too long, military space has been the dominant domain of national-level intelligence, reconnaissance, surveillance, and warning. These are functional areas well known for secrecy and compartmentation, limited oversight, generous funding, restricted access, and narrow application. That must change and is changing. Second, the conditions that allowed this narrow development of space utilization also created a protection system—a hard shell—that has prevailed beyond its time, even beyond the end of the cold war. It took a war-fighting event—Desert Storm—to crack the shell and force open the door. War fighters, suddenly in charge, were often amazed at what they discovered behind the door and at what was available for improved battlefield situational awareness, for innovative operational maneuver inside the enemy's decision loop, and for vastly improved targeting and damage assessment tools. In the words of an old saying: once they've been to the big city, it's tough to get them back on the farm. The operator is *not* going back!

That brings us to SPACECAST 2020, the conscious effort to improve the linkage between space technology and opportunity, and operational military-mission execution. What we have heard here for the past day and a half is the first cut at a very important redirection for the US Air Force and the military departments in general.

It is eminently clear that military exploitation of space desperately needs war-fighter sponsorship and operational focus. The functional specialist's needs in space will continue to be met, but the driver and shaper of space must shift to the operator. So, this is the first task that the USAF must undertake: operational sponsorship of space, a formal commitment, not just a dial-in such as this study but mainstreaming space with all of its aspects into the line Air Force. In space thought and doctrine development, the Air University is the right place. For space requirements, the Air Staff should drive them, but with far greater emphasis. As for space operations, a much more robust effort is due. More about that later.

The good news is that the operationalization of space doesn't require extensive additional research and development. As we heard here, technologies are largely in hand to undertake leading-edge operational applications. The Black Horse concept illuminated by Maj Chris Daehnick and commented upon by Capt Mitch Clapp is a clear case in point.

Yet, despite this clear operational focus, one should harbor concerns about how SPACECAST 2020 will be handled. The study is a very competent technical review as well as an operational document. The study's recommendations in integrated-demand information architecture, high-performance computing, multifunctional space-based laser systems, and materials technology must not become the major focus. That has too often been the mode of the past "techie" takeovers. We must stalwartly lock onto and drive the operational message and vision. And so, putting this all together—the important legacies and influences of space past, the transitional circumstances of space present, and the unique operational opportunities for space future—we should take away three thoughts from this session.

First, SPACECAST 2020 is an important beginning. We are thinking again, thinking operationally about space. This study provides focus, vision, and a beginning road map for sustained action. We have a start on the problem. We've defined the terrain and identified a number of fruitful paths to pursue. This beginning must now be converted from a batch task to a streamlined effort. Work it every day, week, month, and year. The Air University has an unprecedented opportunity to recover its leadership and heritage, recapturing the legacy and leadership of the Air Corps Tactical School of the 1930s that developed the concepts of war, which shaped the air war doctrine of World War II and the Air Force of today. The challenge is to shape the USAF space force of tomorrow.

The second foot-stomping message of this symposium is to get on with operationalization of space—NOW! This former exclusive domain of the specialist must now give way to operational leadership. The core mission must assume daily responsibility for space operations and activity. Unless and until this genuinely happens—that is, space moves to main street—we will continue to mark time and to lose ground. Many are of the mistaken belief that we "operationalized" space when the intercontinental ballistic missile (ICBM) force was reassigned from Air Combat Command (ACC) to Air Force Space Command (AFSPACECOM). Wrong. The ICBM force is not a space force. It does not operate in space; it only transits space—a happenstance of ballistics as we fire long-range weaponry over long distances.

Today, space operations are in the hands of the research, development, test, and evaluation (RDT&E) communities—military and civilian (National Aeronautics and Space

Administration—NASA). In the Air Force, Air Force Materiel Command (AFMC) and contractors do all our space launches—and have been doing so for decades. Never in the history of US military operations have we left such activity in the hands of developers and testers for so long. The inevitable result is a testing mind-set in space undertakings—every launch unique, long pad-prep times, heavy contractor reliance, extremely long recycle times, and extremely costly charges. As for NASA, despite an honored heritage of leading-edge work in aerospace technology development, it has opted for routine space operations for two decades. That should be *our* domain; NASA should be concentrating on rolling back aerospace frontiers. Bottom lines: Transfer space launch and control promptly over to operations with AFSPACECOM in charge—NOW. Routinize and standardize the function—blue-suit it. Reappraise shuttle operations. The goal should be to transfer launch, space operations, and recovery responsibility to the USAF. NASA would retain responsibility for the shuttle back end when R&D is the purpose and would also get on with other R&D such as the space station.

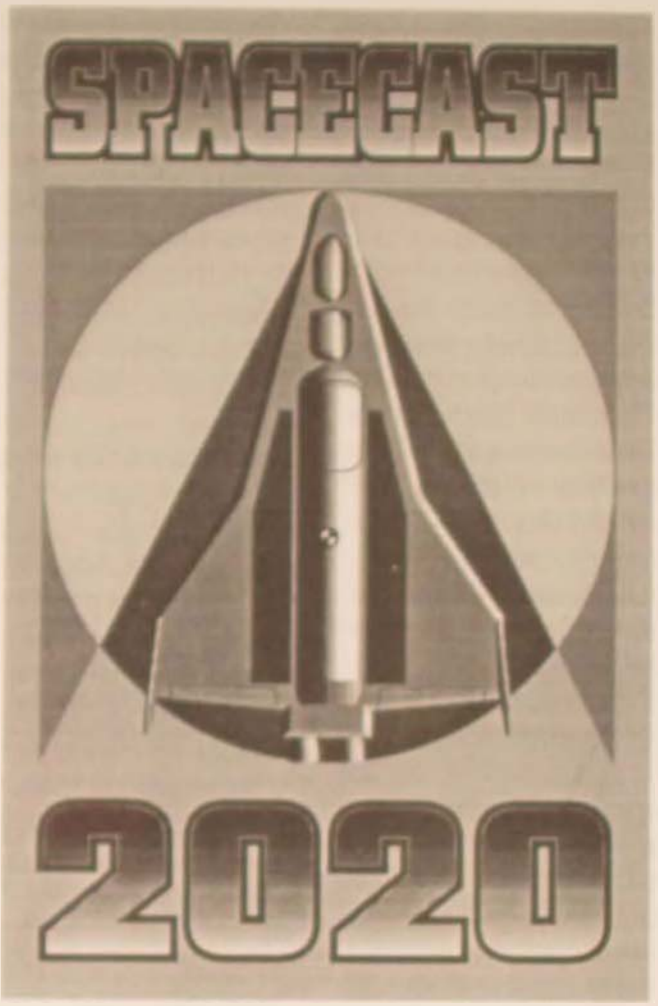
Third, it is time to rethink how we do specialized functions in space. There is huge leverage here with great benefits to all participants, commercial and military. The emerging commercialization of space for *specialized* tasks is shifting the dominance of development and innovation to that sector. The military needs to consider having the commercial sector to perform every task that doesn't require unique military control and handling. This thought, not likely to be popular, particularly in military communications sectors, is an *absolute* necessity. We need to force interoperability, standardization, and functional transparency into military communications and data transfer. Nothing will move this process faster than a requirement to conform to civilian standards when no compelling military requirement can be proven. Today, the Defense Switching Network (DSN) is the Defense Information System Agency's (DISA) responsibility but is operated by AT&T under contract. Why should space communications be any different conceptually?

Obviously, we need to get the word out to inform, to build dialogue, and to stimulate debate. Space needs to be an ongoing issue in all of its aspects—its vision, its utilization, its road map, its military value, its operational uses, its commercial tie-ins, and its resource share. We all have a role to play here. Get the SPACECAST message out to your people. Task Air University to help you. Gen Jay Kelley tells me he's prepared to send teams out, upon request, to brief military organizations as well as civilian corporations. Take advantage of this special opportunity.

In sum, we should be grateful to the Air University and its 2020 team as well as to NSIA for this important symposium. This is only a beginning. The effort must gather much more momentum and become the persuasive instrument of change that mainlines space with operations in charge. Everyone has a part to play, from Air University to Headquarters USAF to industry.

The test of success will be whether we come together in a year or so to assess progress, revise goals, reset the vision, and set up a new action plan—momentum and movement. What is at stake here is nothing short of sound national policy planning for the next century. Space is no longer just a place; it is now the medium for performing core war-fighting tasks. We must convert this powerful vision into mainstream reality with clarity of focus, determination of purpose, and commitment of substantial resources.

We are in charge of our destiny. We need only get on with the task. □



LEVERAGING THE INFOSPHERE

Surveillance and Reconnaissance in 2020

THE DATE IS 3 December 2020. It had been five minutes since the tingling sensation in her arm had summoned her from her office. Now she was standing alone in the darkened battle-assessment room wondering how she would do in her first actual conflict as commander in chief (CINC). "Computer on, terrestrial view," she snapped. Silently, a huge, three-dimensional globe floated in front of her. "Target: Western Pacific. Display friendly and enemy orders of battle, unit status, and activity level," was the next command. The globe turned into a flat battle map showing corps, division, and battalion dispositions. Lifelike images appeared before her, marking the aircraft bases with smaller figures showing airborne formations. Beside each symbol were the unit's designator, its manning level, and the plain-text interpretation of its current activity. The friendly forces were shown in blue, and the enemy in red. All the friendlies were in the midst of a recall. The map showed two squadrons of air-domination drones, a wing of troop-support drones, and an airborne command module (ACM) heading toward the formations of enemy forces. Shaded *kill zones encircled each formation. Enemy forces floated before her, also displaying textual information. The image displayed enemy units on the move from their garrisons. Speed, strength, and combat radii were marked for each unit. Some enemy units showed—still in garrison—but with engines running, discovered by sensitive seismic, tactile, and fume-smelling sensors. "Manchuria," came the next command. The map changed. The CINC was now in the middle of a holographic display. Ground superiority vehicles (GSV), identified by the reliable structural sensory signature system (S^4), moved below her, and drones flew around her. She could see her forces responding to the enemy sneak attack and monitored their progress. The engagement clock showed 10 minutes to go before the first blue and red squadrons joined in battle.*

Aboard the ACM, the aerospace operations director observed the same battle map the CINC had just switched off. By touching the flat screen in front of him, he sent target formations to his dozen controllers. Each controller wore a helmet and face screen that "virtually" put him or her just above the drone flight being maneuvered. The sight, feel, and touch of the terrain profile—including trees, buildings, clouds, and rain—were all there as each controller pressed to attack the approaching foe.

On the ground, a platoon sergeant nervously watched his face-shield visual display. From his position, he could see in three-dimensional color the hill in front of him and the enemy infantry approaching from the opposite side. If the agency had had enough time before the conflict, it could have loaded DNA data on the opposing commander into the data fusion control bank (DFCB) so he could positively identify him, but such was the fog of war. The driving rain kept him from seeing 10 feet in front of him, but his monitor clearly showed the enemy force splitting and coming around both sides of the hill. The enemy's doctrinal patterns indicated that his most likely attack corridor would be on the eastern side of the hill. Now the enemy was splitting his force in hopes of surprising our forces. The platoon sergeant's troop commander saw the same screen as her troops did, with the added feature of having her opponent's "predicted" movements overlaid with his actual movements. From her virtual command post, she arrayed her forces to flank the foe. She had to be careful not to be fooled by the holographic deception images put in place by the enemy—an all too frequent and disastrous occurrence in the last conflict. If she was lucky, surprise would be on her side today.

A scant five minutes had passed since the global surveillance, reconnaissance, and targeting (GSRT) system alerted the CINC of unusual activity on the other side of the border. Multiple sensors, some of which had been dormant for years and some that had recently been put in place by special precision guided munitions (PGM) delivery vehicles, had picked up increased signal activity and detected an unusual amount of motion, scent, heat, noise, and motor exhaust in and around enemy bases. Now GSRT activated two additional CINC satellite (CINCSAT) low earth orbit (LEO) multisensor platforms, launched four air-breathing sensor drones, and fired two "lightsat," intersystem, omnisensorial communications satellites into orbit to bolster the surveillance grid that watched the globe and space beyond, 24 hours a day. As the CINC, airborne controller, and ground-troop commander activated their situation assessment system (SAS), GSRT identified them, confirmed their locations, and passed information required to get them on-line. As each warrior requested target data, GSRT fused sensor data, tapped databases, activated resources, and passed templated, neurally collated information to each person in exactly the format he or she needed to get a clear picture of the enemy and the unfolding situation. This was the same GSRT that was also aiding San Francisco in responding to yesterday's massive earthquake. From the president to the city mayor to the fireman trying to find the best route through the cluttered and congested streets, each got the requested real-time information in seconds, just as our troops in the Western Pacific did.

The CINC paused for several moments, wondering how battles were ever fought without the *information systems she now used with practiced ease, and she was glad they were fighting an enemy still mired in the visual/electromagnetic intelligence (ELINT)-oriented maneuver force of the last war.*

Tomorrow's Challenge Today

As the United States moves into the twenty-first century in a world of diverse dangers and threats marked by the proliferation of weapons of mass destruction, unconventional warfare, and sophisticated enemy countermeasures, surveillance and reconnaissance are not only critical but essential for achieving the "high ground" in information dominance, conflict management, and war fighting. As defined by the Joint Chiefs of Staff (JCS), surveillance is the "systematic observation of aerospace, surface or subsurface areas, places, persons, or things, by visual, aural, electronic, photographic, or other means."[1] Similarly, reconnaissance refers to "a mission undertaken to obtain, by visual observation or other detection methods, information about the activities and resources of an enemy or potential enemy."[2] Both surveillance and reconnaissance are critical to US security objectives of maintaining national and regional stability and preventing unwanted aggression around the world.

Key to achieving information dominance will be the gradual evolution of technology (i.e., sensor development, computation power, and miniaturization) to provide a continuous, real-time picture of the battle space to war fighters and commanders at all levels. Advances in surveillance and reconnaissance—particularly real-time "sensor-to-shooter" capability to support "one shot, one kill" technology—will be a necessity if future conflicts are to be supported by a society conditioned to "quick wars" with high operational tempos, minimal casualties, and low collateral damage.

The rigorous information demands of the war fighter, commander, and national command authorities (NCA) in the year 2020 will require a system and architecture to provide a high-resolution "picture" of objects in space, in the air, on the surface, and below the surface—be they concealed, mobile or stationary, animate or inanimate. The true challenge is not only to collect information on objects with much greater fidelity than is possible today, but also to process the information orders of magnitude faster and disseminate it instantly in the desired format.

The Key to the Concept: Structural Sensory Signatures

The critical concept of this article is to develop an *omnisensorial* capability that includes all forms of inputs from the sensory continuum (fig. 1). This new term seeks to expand our present exploration of the electromagnetic spectrum to encompass the "exotic" sensing technologies proposed in this article. This system will collect and fuse data from all sensory inputs—optical, olfactory, gustatory, infrared (IR), multispectral, tactile, acoustical, laser radar, millimeter wave radar, X ray, DNA patterns, human intelligence (HUMINT)—to identify objects (buildings, airborne aircraft, people, and so forth) by comparing their structural sensory signatures (SSS) against a preloaded database in order to identify matches or changes in structure. The identification aspect has obvious military advantages in the processes of indications and warning, target identification and classification, and combat assessment.

An example of how this technique might actually develop involves establishing a sensory baseline for certain specific objects and structures. The system would optically scan a known source—such as an aircraft or building full of nuclear or command, control, communications, computers, and intelli-

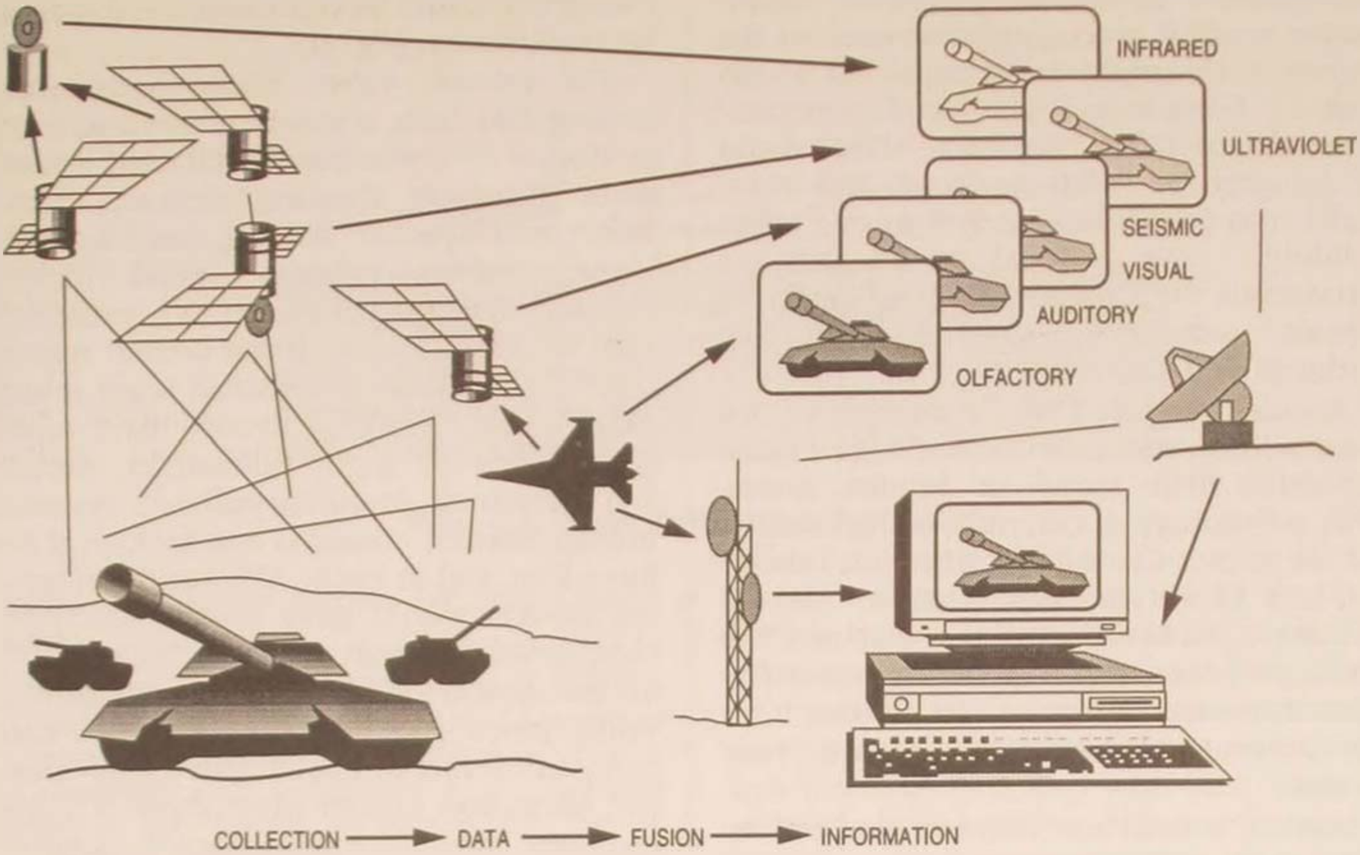


Figure 1. The Concept

gence (C⁴I) equipment—from all angles and then smell; listen to; feel; measure density, IR emissions, light emissions, heat emissions, sound emissions, propulsion emissions, air-displacement patterns in the atmosphere, and so forth; and synthesize that information into a sensory signature of that structure. This map would then be compared to sensory signature patterns of target subjects such as Scud launchers or even people. A simple but effective example of a sensory signature was discovered by the Soviets during the height of the cold war. They discovered that the neutrons given off by nuclear warheads in our weapons-storage areas interacted with the sodium arc lights surrounding the area, creating a detectable effect. This simple discovery allowed them to determine whether a storage area contained a nuclear warhead.[3]

Sensory identification could then use the information to create virtual images (similar to the way architects and aircraft designers use three-dimensional computer-aided design [CAD] software), including the most likely internal workings of the target building, aircraft, or person so one could actually "look" inside and see the inner workings. A good example is Boeing's use of computer-aided three-dimensional interactive application (CATIA) for design of its new 777 aircraft. The "virtual airplane" was the first aircraft built completely in cyberspace (i.e., the first built entirely on computer so that engineers could "look at" it thoroughly before actually building it).[4]

This "imaging" could be carried one step further by techniques such as noninvasive magnetic source imaging and magnetic resonance imaging (MRI), which are now used in neurosurgical applications for creating an image of the actual internal construction of the subject.[5] In fact, the numerous nonintrusive medical procedures now used on the human body might be extrapolated to extend to "long-range" sensing. The nuclear materials for these "structural MRIs" could be delivered by PGMs or drones and introduced into the ventilation system of a target building. The material would circulate throughout the structure and eventually be "sensed" remotely to display the internal workings of the structure.

Another extension of the concept of distance sensing would be the tracking of mitochondrial DNA found in human bones. DNA technology is currently being used by the US Army's Central Identification Laboratory for identifying war remains.[6] If this technique could be used at a distance, the tracking of human beings becomes conceivable. By extrapolating such techniques from medicine, one could generate endless possibilities.

Further, a mass spectrometer that ionizes samples at ambient pressure using an efficient corona discharge could detect vapors and effluent liquids associated with many manufacturing processes.[7] This technique is currently found in state-of-the-art environmental monitoring systems. There are also spectrometers that can analyze chemical samples through glass vials. Applying this technology from a distance and collating all the data will be the follow-on third- and fourth-order applications of this concept.

Another technology that would aid the identification of airborne subjects would be the National Aeronautics and Space Administration's (NASA) new airborne in-situ windshear detection algorithm.[8] Although designed to detect turbulence, wind shear, and microburst conditions, this technology could be extrapolated to detect aircraft flights through a given area (perhaps by using some sort of detection net for national or point defense). This technique, coupled with observing disturbances in the earth's magnetic field, vortex-detection tracking of CO_2 vapor trails, and identifying vibration and noise signatures, would create a sensory signature that could be compared to a database for classification (fig. 2).

The overall system would accumulate sensing data from a variety of sources, such as drone- or cruise-missile-delivered sensor darts, structural listening devices, space-based multispectral sensing, weather balloons, probes, airborne sound buoys, unmanned aerial vehicles (UAV), platforms such as airborne warning and control system (AWACS) and joint surveillance target attack radar system (JSTARS) aircraft, land radar, ground sensors, ships, submarines, surface and subsurface sound-surveillance systems, human sources, chemical and biological information, and so forth. The variety of sensing sources would serve several functions. First, spurious inputs could be "kicked out" of the system or given a lesser reliability value, much like the comparison of data from an aircraft equipped with a triple inertial navigation system when there is a discrepancy among separate inputs. Another important factor in handling a variety of inputs is that the system is harder to defeat when it does not rely on just a few key inputs. Finally, inputs from other nations and the commercial sector may be used as additional elements of data. Just as the current Civil Reserve Air Fleet (CRAF) system requires certain modifications for commercial aircraft to be used for military purposes in times of national emergency, so might commercial satellites contain subsystems designed to support the system envisioned above. In such a redundant system, failure to receive some data would not have a significant debilitating impact on the system as a whole.

To fuse and compare data, processors could take advantage of common neural-training regimens and pattern-recognition tools to sort data received from sensor platforms. Some of the data-fusion techniques we envision would require continued advancement in the world of data processing—a capability that is growing rapidly, as noted by Dr Gregory H. Canavan, chief of future

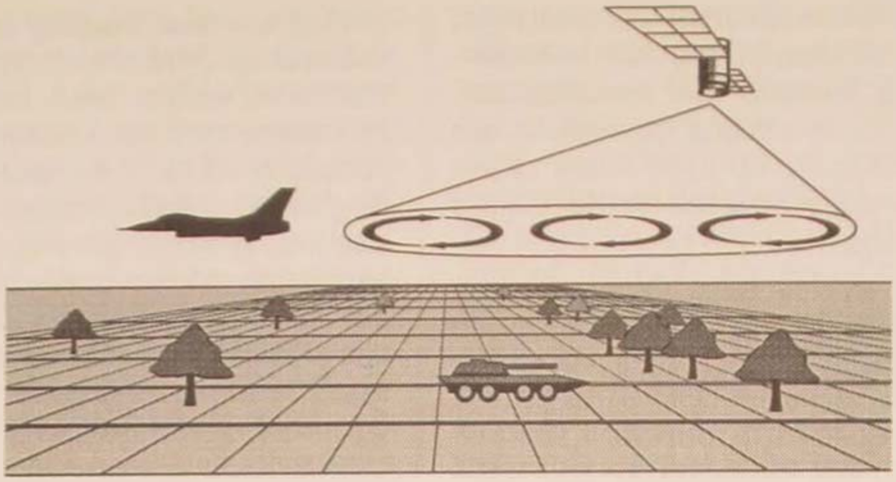


Figure 2. Wake Turbulence Detection

technology at Los Alamos National Laboratory:

> Frequent overflights by numerous satellites add the possibility of integrating the results of many observations to aid detection. That is computationally prohibitive today, requiring about 100 billion operations per second, which is a factor 10,000 greater than the compute rate of the Brilliant Pebble and about a factor of 1,000 greater than that of current computers. However, for the last three decades, computer speeds have doubled about every two years. At that rate, a factor of 1,000 increase in rate would only take about 20 years, so that a capability to detect and track trucks, tanks, and planes from space could become available as early as 2015.[9]

Dr Canavan also suggested that development time could be reduced even further by using techniques such as parallel computing and external inputs to reduce required computation rates.[10] The point is that with conservatively forecast advancements in computer technology, the ability to gather and synthesize vast amounts of data will permit significant enhancements in remote sensing and data fusion.

Using Space

As envisioned, this concept would be supported by systems in all operational media—sea, ground (both surface and subsurface), air, and space. However, space will play the critical role in this conceptual architecture. Although the system would rely on data from many sources other than space, using this medium as a primary source of data for sensing and fusing has definite advantages. Space allows prompt, wide-area coverage without the constraints imposed by terrain, weather, or political boundaries. It can provide worldwide or localized support to military operations by providing timely information for such functions as target development, mission planning, combat assessment, search and rescue (SAR), and special-forces operations.

Sensing and Data Fusion

The overall concept can be divided into three parts: the sensing phase, which uses ground-, sea-, air-, and space-based sensors; the data fusion phase, which produces information from raw data; and the dissemination phase, which delivers information to the user. This article examines the first two parts.

Sensing

The five human senses are used here as a metaphor for the concept of sensing described above. Although this representation is not precise, at least it provides a convenient beginning point for our investigation. For instance, human sensing capabilities are often inferior to those of other forms of life (e.g., the dog's sense of smell or the eagle's formidable eyesight).

Tremendous strides have been made in the sensing arena. However, some areas are more fully developed than others. For example, more advances have occurred in optical or visual sensing than in olfactory sensing. This article not only examines the more traditional areas of reconnaissance such as multispectral technology, but also discusses interesting developments in some unique areas. An exciting aspect is the discovery of research being conducted in the commercial realm, whose specific tasks require specific technologies and whose techniques have not yet been fully investigated for military uses.

The sensing areas examined here are (1) visual (including all forms of imaging, such as IR, radar, hyperspectral, etc.), (2) acoustic, (3) olfactory, (4) gustatory, and (5) tactile. There are two keys to this metaphoric approach to sensing. First, it unbinds the traditional electromagnetic orientation to sensing. Second, it provides a way of showing how all these sensors will be fused to allow fast, accurate decision making, such as that provided by the human brain.

Visual Sensing and Beyond. As mentioned above, remote image sensing has received a tremendous amount of attention, both in military and civilian communities. The intention here is not to reproduce the vast amount of information on this subject but to describe briefly the current state of the art and to highlight some of the more innovative concepts from which we can step forward into the future. We will not discuss the imaging capabilities of the United States, other than to emphasize that they will need to be replaced or upgraded to meet the needs of the nation in 2020. The technologies and applications discussed below pave the way for these improvements.

Multispectral imaging (MSI) provides spatial and spectral information. It is currently the most widely used method of imaging spectrometry. The US-developed LANDSAT, French SPOT, and Russian Almaz are all examples of civil/commercial multispectral satellite systems that operate in multiple bands, provide ground resolution on the order of 10 meters, and support multiple applications. Military applications of multispectral imaging abound. The US Army is busily incorporating MSI into its geographic information systems for intelligence preparation of the battlefield or "terrain categorization" (TERCATS). The Navy and Marines use MSI for near-shore bathymetry, detection of water depths of uncharted waterways, support of amphibious landings, and ship navigation. MSI data can be used to help determine "go-no-go" and "slow-go" areas for enemy and friendly ground movements. By eliminating untrafficable areas, this information can be especially useful in tracking relocatable targets, such as mobile short-range and intermediate-range ballistic missile launchers. By using MSI data in the radar, IR, and optical bands, one can more quickly discern environmental damage caused by combat (or natural disasters). For example, LANDSAT imagery helped determine the extent of damage caused by oil fires set by the Iraqis in Kuwait during the Gulf War.[11]

Although MSI has a variety of applications and many advantages, use of this sensing technique results in a decrease of both bandwidth and resolution from conventional spectrometry. Additionally, multispectral systems cannot produce contiguous spectral and spatial information. We must overcome these disadvantages if we are to meet the surveillance and reconnaissance needs of the war fighter and commander of 2020.

One promising technology for overcoming these shortfalls is hyperspectral sensing, which can produce thousands of contiguous spatial elements of information simultaneously. This would allow a greater number of vector elements to be used for such things as achieving a higher certainty of space-object identification. Although hyperspectral models do exist, none have been optimized for missions from space or have been integrated with the current electro-optical, IR, and radar-imaging technologies.

This same technology can be equally effective for ground-target identification. Hyperspectral sensing can use all portions of the spectrum to scan a ground target or object, collect bits of information from each band, and fuse the information to develop a signature of the target or object. Since only a small amount of information may be available in various bands of the spectrum (some bands may not produce any information), the process of fusing the information and comparing it to data obtained from other intelligence and information sources becomes crucial.

Several war-fighting needs exist for a sensor that would provide higher fidelity and increased resolution to support, for example, US Space Command (USSPACECOM) and its components' missions of space control, space support, and force enhancement. In addition to the aforementioned examples of object identification in deep space (either from the ground or a space platform), identification of trace atmospheric elements, and certain target-identification applications, requirements also exist in the following areas: debris fingerprints, damage assessment, identification of space-object anomalies (ascertaining the condition of deep-space satellites), spacecraft interaction with ambient environment, terrestrial topography and condition, and verification of environmental treaties.

Currently under development are several technologies that can be integrated into hyperspectral sensing to further exploit ground- and space-object identification. Two promising technologies include remote ultralow light-level imaging (RULLI) and fractal image processing. RULLI is an initiative by the Department of Energy to develop an advanced technology for remote imaging using illumination as faint as starlight.[12] This type of imaging encompasses leading-edge technology that combines high-spatial resolution with high-fidelity resolution. Long exposures from moving platforms become possible because high-speed image-processing techniques can be used to de-blur the image in software. RULLI systems can be fielded on surface-based, airborne, or space platforms, and—when combined with hyperspectral sensing—can form contiguous, continuous processing of spatial images using only the light from stars. This technology can be applied to tactical and strategic reconnaissance, imaging of biological specimens, detection of low-level radiation sources via atmospheric fluorescence, astronomical photography in the X-ray, ultraviolet (UV), and optical bands, and detection of space debris. RULLI depends on a new detector—the crossed-delayed line photon counter—to provide time and spatial information for each detected photon. However, by the end of fiscal year 1996, all technologies should be sufficiently developed to facilitate the design of an operational system.

The task of finding mobile surface vehicles requires rapid image processing. Automated preprocessing of images to identify potential target areas can drastically reduce the scope of human processing and provide the war fighter with more timely target information. Hyperspectral sensing can aid in quickly processing a large number of these images on board the sensing satellite, in identifying those few regions with a high probability of containing targets, and in downlinking data subsets to analysts for visual processing. Although fractal-like backgrounds can be defeated by cloud/smoke cover or camouflage, fractal image processing—if fused with information from other sensory sources—can help the analyst or the processing software identify ground-based signatures.[13]

Hyperspectral sensing offers a plethora of opportunities for deep-space and ground-object identification and characterization to support the war fighter's space-control-and-surveillance mission, remote sensing of atmospheric constituents and trace chemicals, and enhanced target identification. Collecting and fusing pieces of information from each band within the spectrum can provide high-fidelity images of ground or space-based signatures. Moreover, when combined with fused data from other sensory and nonsensory sources, hyperspectral sensing can provide target identification that no single surveillance system could ever provide. Thus, the war fighter has a much improved picture of the battle space—anywhere, anytime.

Acoustic Sensing. When matter within the atmosphere moves, it displaces molecules and sends out vibrations or waves of air pressure that are often too weak for our skin to feel. Waves of air pressure detected by the ears are called sound waves. The brain can tell what kind of sound has been heard from the way the hairs in the inner ear vibrate. Ears convert pressure waves passing through the air into electrochemical signals which the brain registers as a sound. This process is called acoustic sensing.

Electronically based acoustic sensing is not very old. Beginning with the development of radar prior to World War II, applications for acoustic sensing have continued to grow and now include underwater acoustic sensing (i.e., sonar), ground and subterranean-based seismic sensing, and the detection of communications and electronic signals from aerospace. Electromagnetic sensing operates in the lower end of the electromagnetic spectrum and covers a range from 30 hertz (Hz) to 300 gigahertz. Acoustic sensors have been fielded in various mediums, including surface, subsurface, air, and space. Since the advent of radar, most applications of acoustic sensing have been pioneered in the defense sector. Developments in space-based acoustic sensing in the Russian defense sector have recently become public. According to *The Soviet Year in Space, 1990,*

> Whereas photographic reconnaissance satellites collect strategic and tactical data in the visible portion of the electromagnetic spectrum, ELINT satellites concentrate on the longer wavelengths in the radio and radar regions. . . . Most Soviet ELINT satellites orbit the earth at altitudes of 400 to 850 kilometers, patiently listening to the tell-tale electromagnetic emanations of ground-based radars and communications traffic.[14]

It is believed that the Russians use this space-based capability to monitor changes in the tactical order of battle, strategic defense posture, and treaty compliance.

On the ground, the United States used different kinds of acoustic sensors during the Vietnam War. The first one was derived from the sonobuoy developed by the US Navy to detect submarines. The USAF version used a battery-operated microphone instead of a hydrophone to detect trucks or even eavesdrop on conversations between enemy troops. The air-delivered seismic detection (ADSID) device was the most widely used sensor. It detected ground vibrations by trucks, bulldozers, and the occasional tank, although it could not differentiate with much accuracy between vibrations made by a bulldozer and a tank.[15]

Numerous examples of applications of acoustic sensing are found in the civil sector. In the United States, acoustic sensors that operate in the 800–900 Hz range are now being developed to help detect insects. Conceivably, these low-volume acoustic sensors could be further refined, either to work hand in hand with other spectral sensors or by themselves to classify insects and other animals, based on noise characteristics.[16]

Sandia National Laboratory in New Mexico has made progress in using acoustic sensors to detect the presence of chemicals in liquids and solids. In the nonlaboratory world, these acoustic sensing devices could be used as real-time environmental monitors to detect contamination, either in ground water or soil, and have both civil (e.g., natural-disaster assessment) and military (e.g., combat-assessment) applications.[17]

An additional development in the area of acoustic sensing involves seismic tomography to "image" surface and subsurface features. Seismic energy travels as an elastic wave that both reflects from and penetrates through the sea floor and structure beneath—as if we could see the skin covering our faces and the skeletal structure beneath at the same time. Energy transmitted through the earth's crust can also be used to construct an image.[18]

In summary, acoustic sensing offers great potential for helping the war fighter, commander, and war planner of the twenty-first century solve the problems of target identification and classification, combat assessment, target development, and mapping. For acoustic sensing from aerospace, a primary challenge appears to be in boosting noise signals through various mediums. Today, this is accomplished by using bistatic and multistatic pulse systems. In the year 2020, assuming continued advances in interferometry, the attenuation of electromagnetic "sound" through space should be a challenge already overcome, thus permitting very robust integration of acoustic sensing with other remote-sensing capabilities from aerospace.

A more serious challenge in defense-related acoustic sensing may come from enemy countermeasures. As operations and communications security improve, space-based acoustic sensing will become increasingly more difficult. Containing emissions within a shielded cable or—better yet—a fiber-optic cable makes passive listening virtually impossible. The challenge for countries involved with space-based acoustic programs is to develop improved countermeasures to overcome these technological advancements. In the year 2020, remote acoustic sensing from space and elsewhere will be a critical element for developing accurate structural signatures as well as for assessing activity levels within a target. New methodologies for passive and active sensing need to be developed and should be coupled with other types of remote sensing.

Olfactory Sensing. Although this sense is somewhat "exotic" today, since the mid-1980s there has been a resurgence of research into the sense of smell. Both military as well as civilian scientists have aimed their efforts at first identifying how the brain determines smell and determining how science can replicate the process synthetically. The results of these efforts are impressive. An electronic "sniffer" for analyzing odors needs two things: (1) the equivalent of a nose to do the smelling and (2) the equivalent of a brain to interpret what the nose smelled. A British team employed arrays of gas sensors made of conductive polymers working at room temperature. An electrical current passes through each sensor. When odor emissions collide with the sensors, the current changes and responds uniquely to different gases. The next step entailed synthesizing the various currents into a meaningful pattern. A neural net (a group of interlined interconnected microprocessors that simulate some basic functions of the brain) identified the patterns. The neural net was able to learn from experience and did not need to know the exact chemistry of what it was smelling. It could recognize changing patterns, giving it a unique ability to detect new or removed substances.[19]

Swedish scientists took this a major step further. Their development of a light-scanned, seam-conductor sensor shows great promise in the area of long-range sensing. This sensor is coated with three different metals: platinum, palladium, and iridium, which are heated at one end to create a temperature gradient. This process allows the sensor to respond differently to gases at every point along its surface. The sensor is read with a beam of light that generates an electrical current across the surface. When fed into a computer, the current produces a unique image of each smell, which is then compared to a database to determine the origin of the smell.[20]

Despite these impressive findings, present technology requires the gases to come in contact with the sensor. The next step is to fuse the sensory capabilities into a sort of particle beam that—when it comes into contact with the odors—would react in a measurable way. Similar to the way radar works, beam segments would return to the processing source, and the object from which the odors emanated would be identified. This process could be initiated from space, air, or land and would be fused with other remote-sensing capabilities to build a more complete picture. Studies on laser reflection demonstrate the ability to correct for errors induced by moving from the atmosphere to space. There is every reason to believe that the next couple of decades will produce similar capabilities for particle beams. The ability to fuse odors sensors within these beams and receive the reactions for processing may also be feasible in the prescribed time frame.

Gustatory Sensing. Another area that has not received a tremendous degree of attention is the sense of taste. In many ways, ideas concerning the sense of taste may sound more like those concerning the sense of smell. The distinction is that the sample tasted is part of (or attached to) a surface of some sort. The sense of smell relies on airborne particles to find their way to receptors in the nose. The study of taste makes frequent reference to smell—probably due to similar mechanisms whereby the molecules in question come in contact with the receptor (be they smell or taste receptors).

Taste, in and of itself, will probably not be a prime means of identification. It can, however, be one of the discriminating bits of information that can aid in identifying ambiguous targets identified by other systems. It also provides another characteristic that must be masked or spoofed to truly camouflage a target. Taste could be used to detect silver paint that appears to be aluminum aircraft skin on a decoy. It could be used to "lick" the surface of the ocean to track small, polluting craft. It could even be used to taste vehicles for radioactive fallout or chemical/biological surface agents. We could detect contamination before sending ground troops into an area. By putting a particular flavor on our vehicles, we may be able to develop a taste version of identification friend or foe (IFF).

The sense of taste provides the human brain with information on characteristics of sweetness, bitterness, saltiness, and sourness. The exact physiological mechanism for determining these characteristics is not yet completely understood. Theory has it that sweet and bitter are determined when molecules of the substance present on the tongue become attached to "matching" receptors. The manner in which the molecules match the receptors is believed to be a physical interlocking of similar shapes—much the same way that pieces of a jigsaw puzzle fit together. Once the interlocking takes place, an electrical impulse is sent to the taste center in the brain. It is not known whether there are thousands of unique taste receptors (each sending a unique signal) or if there are only a few types of receptors (resulting in many unique combinations of signals). Experts think that saltiness and sourness are determined in a different manner. Rather than attaching themselves to the receptors, these tastes "flow" by the tips of the taste buds, exciting them directly through the open ion channels in the tips.[21]

To make a true bitter/sweet taste sensor in space would require technology permitting the transmission of an actual particle of the object in question. This ability appears to be outside the realm of possibility in the year 2020. An alternative would be to scan the object in question with sufficient "granularity" to determine the shape of the individual molecules and then compare this scanned shape with a catalog of known shapes and their associated sweet or bitter taste. Such technology is currently available in the form of various types of scanning/tunneling electron microscopes. The shortcoming of these systems is that they require highly controlled atmospheres and enclosed environments to permit accurate beam steering and data collection. The jump to a "remote electron microscope" also may not be possible by 2020.

An alternate means of determining surface structure remotely involves increasing the distance from which computerized axial tomography (CAT) scans or nuclear magnetic resonance (NMR)[22] are conducted. Although current technology requires rather close examination (on the order of several inches), at least a portion of the "beam" transmission takes place in the normal atmosphere. Extrapolation of this capability seems to offer the possibility of scanning from increased distances.

To perform a taste scan from space to determine the sweetness/bitterness of an object will require continued research and a truly great increase in technology. Taste research must continue, and the mechanics of taste must be fully understood. The product of this research would be a database that catalogs the appropriate characteristics of molecules related to taste. Without understanding how taste works, we could not produce a properly designed scanner.

Remote scanning is a great challenge that involves getting the beam to the targeted object and capturing the reflected beam pattern to determine the surface shape at the molecular level. Getting the beam to the target entails the generation, aiming, and power of the beam.

The scanning beam (of whatever type provides the desired granularity) must be generated with sufficient power to reach the target with enough energy to reflect a detectable and measurable pattern for collection and subsequent analysis. Both beam generators and collectors would be located (not necessarily co-located) in space (most likely in low earth orbit—the generators, at least). Maximum distance from generator to target is probably on the order of 1,000 to 1,500 miles or the slant range from a 300-to-400-mile LEO to the line-of-sight horizon. Target-to-collector distances would be, at a minimum, the same as those from generator to target (if collection is accomplished in LEO), to a maximum of 25,000 miles (if collection occurs in geosynchronous orbit).

To ensure the gathering of proper data, we must aim and focus the beam exactly at the desired target. Aiming will require compensation for atmospheric inconsistencies. Specifically, we would fire a laser into the atmosphere to detect anomalies along the general path of the actual beam and compensate accordingly. Refined focusing on the targeted areas should be on the order of no more than one or two square feet.

We must also consider what might happen when the beam (of whatever type) hits the target area. Will its power be so great that the target would be burned or damaged? Further, will adversaries be able to detect scanning in the target area? These are some of the challenges we must overcome in order to bring the taste sensor to reality.

Capturing the reflected beam also poses a significant challenge. The general technique for analyzing objects with scanning methods calls for a beam from a known location and of known power to "illuminate" the targeted object. Since the surface of the object is irregular, the beam reflects in various directions. Thus, the object must be surrounded by collectors to ensure the collection of all reflected energy. By noting the collector and the portion of the beam collected, we can reconstruct the surface that reflects the beam.

Since it is impossible to surround the earth completely with a single collecting surface, a large number of platforms must serve as collectors. All platforms would focus their collectors on the targeted area and compensate in a manner similar to aiming compensation for the beam generator (see above). Any platform with line of sight directly to the target would be suitable for collection. Platforms "below" the horizon but able to capture reflected energy in a manner similar to the over-the-horizon backscatter (OTHB) radar system would also be acceptable. With appropriate algorithms and beam selection, the entire sensor constellation could conceivably be available for collection all the time.

Fusing of the reflected data from a single "taste" would take place on a central platform, probably in geosynchronous orbit. Information about the taste measurement would include scanning-beam composition, pulse-coding data, firing time, location of beam generator, aiming compensation data, focusing data, location of targeted area, collector position, collector compensation data, and actual collected data including time. Because we are collecting only a fraction of the "reflected energy" from scanning beams, we need all this information in order to know which part of the "taste signature" we have put together.

Tactile Sensing. Potential exists for the development of an earth-surveillance system using a tactile sensor for mapping and object determination. Rather than viewing and tracking items of interest optically, objects could be identified, classified, and tracked via tactile stimulation-and-response analysis. This method of surveillance has advantages over optical viewing in that it is unaffected by foul weather, camouflage, or other obscuration techniques.

Tactile sense provides humans awareness of contact with an object. Through this sense, we learn the shape and hardness of objects, and—by using our cutaneous sensors—we receive indications of pressure, warmth, cold, and pain. A man-made tactile sensor emulates this human sense by using densely arrayed elementary force sensors (or taxels), which are capable of image sensing through the simultaneous determination of an object's force distribution and position measurements.[23]

Recent advances in tactile sensor applications have appeared in the areas of robotics, cybernetics, and virtual reality. These simple applications attempted to replicate the tactile characteristics of the human hand. One project, the Rutgers Dexterous Hand Master, combines a mechanical glove with a virtual-reality scenario to allow an operator to "feel" virtual-reality images. This research has advanced the studies of remote-controlled robots that could be used in such ventures as construction of a space station or cleaning up a waste site.[24]

The challenge lies in developing tactile sensors that are capable of remotely "touching" an object to determine its characteristics. This challenge elicits visions of a large, gloved hand reaching out from space to squeeze an object to determine if it is alive. We can develop this analogy by expanding the practical concept of radar.

Radar is a radio system used to transmit, receive, and analyze energy waves to detect objects of interest or "targets." In addition, it can determine target range, speed, heading, and relative size. One possible way to identify tactile characteristics of an interrogated target is to analyze the radar returns and compare them to known values. When a radio wave strikes an object, a certain amount of its energy reflects back toward the transmitter. The intensity of the returned energy depends upon the distance to the target, the transmission medium, and the composition of the target. For example, energy reflected off a tree exhibits characteristics different from those of energy reflected off a building (because a tree absorbs more energy). By analyzing the energy returns, we could conceivably determine target characteristics of shape, temperature, and hardness by comparing the returns to known values. By using virtual reality, we could then transform the tactile characteristics of various objects interrogated in an area of surveillance into a three-dimensional graphical representation.

The significant value of tactile sensor technology lies not in the development of a replacement for current surveillance sensors but in the prospect for gaining unique information. A typical surveillance radar provides the "when, where, and how" for a particular target, but a tactile sensor adds the "what" and, potentially, the "who."

Countermeasures to Sensing. Once an adversary perceives a threat to his structure and system, he usually develops and employs countermeasures. The concepts for sensing presented here, albeit rooted in leading-edge technology, are not exempt from enemy countermeasures. Potential enemy countermeasures in the year 2020 include killer antisatellites (ASAT), jamming, and ground-station attacks. Target-protection countermeasures include concealment, camouflage, and deception (CC&D) and operations security (OPSEC). Technical experts must address these threats and provide countermeasures early in the design phase of this sensing system.

Active and passive systems can overcome jamming, ground-station attack, and enemy OPSEC. Frequency hopping and "hardening" of space links are both effective in countering jamming. If hopping rates—which currently exceed 3,000 hops per second—continue to increase exponentially, many forms of jamming will become minor irritants. We can overcome ground-station attack by improving physical security and replicating critical nodes. Such redundancy can be expensive, but if we incorporate it early in the design phase, it can be efficient and cost-effective. But the best way to counter enemy OPSEC is through passive measures such as security training, HUMINT, and reduction of the number of people who "need to know" and through active measures such as HUMINT and exploitation of the omnisensorial capability of this system.

Killer ASAT and CC&D capabilities are much more difficult and costly to counter. Decoy satellites and redundant space-based systems can be effective. However, we must pursue some cost-effective means of hardening in order to ensure the survivability of our space systems.

Data Fusion

Fusion of all the information collected from the various sensors mentioned above is the key to making this data useful to the war fighter (fig. 3). Without the appropriate fusion process, the war fighter will be the victim of information overload, a condition that is not much better—and is sometimes worse—than no information at all. The goal of this initiative is to fuse vast amounts of data from multiple sources in real time and make it available to the war fighter on demand.

Today, we are able to collect data from a variety of sensor platforms (e.g., satellites, as well as air-breathing and HUMINT sources, etc.). What we are not able to do, however, is fuse large amounts of data from multiple sources in near real time. We have what amounts to "stovepipe" data—that is, data streams that are processed independently. As we discovered in Operation Desert Storm, deficiencies exist in sharing and relating intelligence from different sources. Consequently, the war fighter is not able to see the whole picture—just bits and pieces.

Today, sensor data is capable of drowning us. The sheer volume of this data can cripple an intelligence system:

> Over 500,000 photographs were processed during Operation Desert Storm. Over its 14-year lifetime, the Pioneer Venus orbiter sent back 10 terabits (10 trillion bits) of data. Had it performed as designed, the Hubble Space Telescope was expected to produce a continuous data flow of 86 billion bits a day or more than 30 terabits a year. By the year 2000, satellites will be sending 8 terabits of raw data to earth *each day*. (Emphasis in original)[25]

As staggering as these figures are, the computing power on the horizon may be able to digest this much data. The Advanced Research Projects Agency (ARPA) is sponsoring the development of a massive, parallel computer capable of operating at a rate of 1 trillion floating-point operations per second (1 tera FLOPS). Parallel processing employs multiple processors used to execute several instruction streams concurrently and signifi-

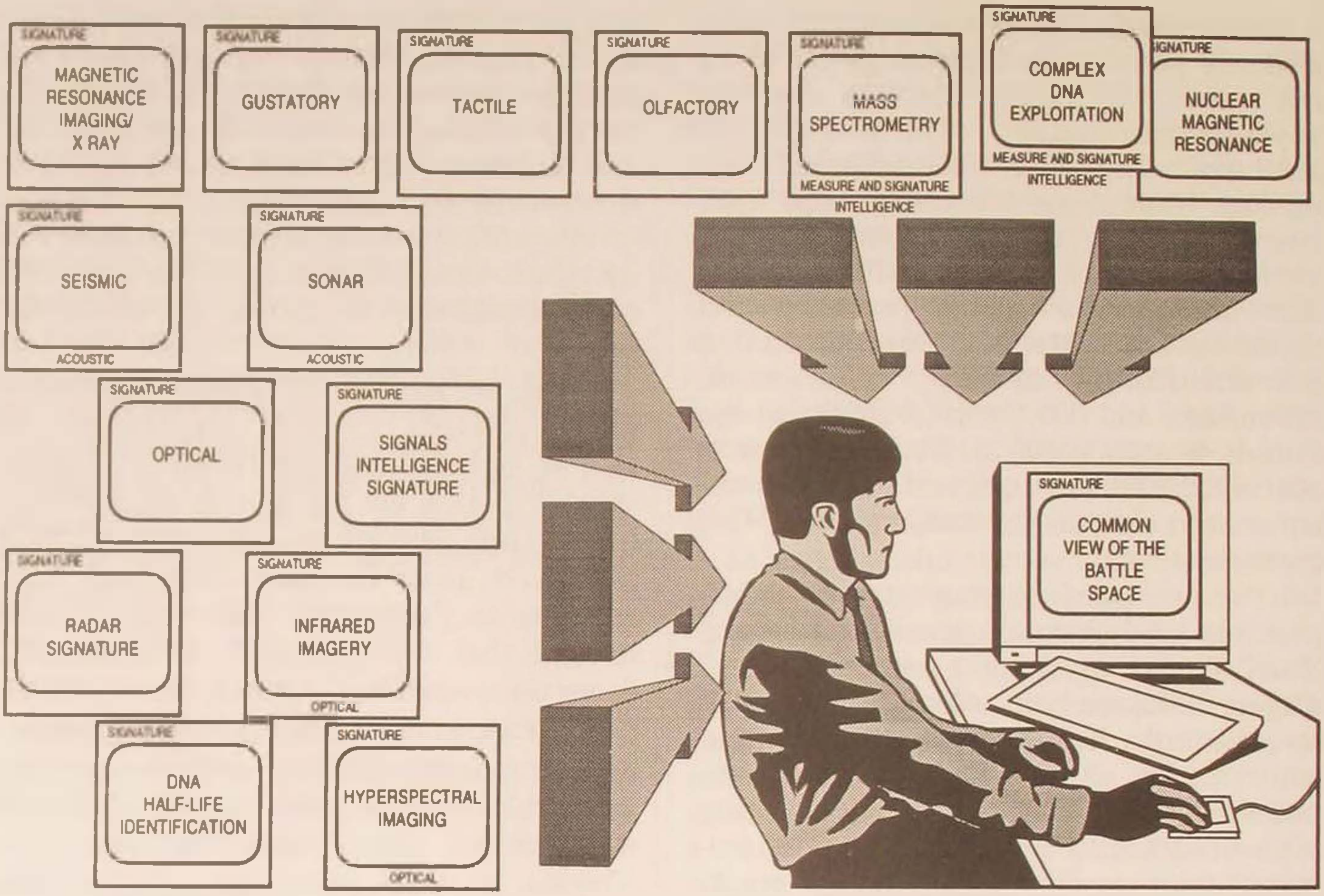


Figure 3. Omnisensorial Fusion

cantly reduces the amount of time required to process information.

Once the data is processed into usable information or intelligence, the next requirement becomes a means of storing and retrieving a huge database or library. "Advances in storage technology in such media as holography and optical storage will doubtlessly expand these capacities."[26] An optical tape recorder capable of recording and storing more than a terabyte of data on a single reel is under development.

Vertical block line (VBL) technology offers the possibility of storing data in nonvolatile, high-density, solid-state chips. This magnetic technology offers inherent radiation hardness, data erasability and security, and cost-effectiveness. Compared to magnetic bubble devices, VBL offers higher storage density and higher data rates at reduced power. VBL chips could achieve (volumetric) storage densities ranging from one gigabit to one terabit per cubic centimeter. Chip data rates, a function of chip architecture, can range from one megabit per second to 100 megabits per second. Produced in volume, chips are expected to cost less than one dollar per megabyte.

If we are to provide the user real-time, multisource data in a usable format, leaps in data-fusion technologies must occur. A new technology—the photonic processor—could increase computational speeds exponentially. The processing capabilities and power requirements of current fielded and planned electronic processors are determined almost solely by the low-speed and energy-inefficient electrical interconnections in electronic boards, modules, or processing systems. Processing speeds of electronic chips and modules can exceed hundreds of megahertz, whereas electrical interconnections run at tens of megahertz due to limitations in standard transmission lines. More significantly, the majority of power consumed by the processor system is used by the interconnection itself. Optical interconnections, whether in the form of free-space, board-to-board busses or computer-to-computer fiber-optic networks, consume significantly less electric power, are inherently robust with regard to electromagnetic impulses (EMI) and electromagnetic pulses (EMP), and can provide large numbers of interconnection channels in a small, low-weight, rugged subsystem. These characteristics are critically important in space-based applications.[27]

This technology of integrating electronics and optics reduces power requirements, builds in EMI/EMP immunity, and increases processing speeds. Though immature, the technology has great potential. If it were possible to incorporate photonic-processing technologies into a parallel computing environment, increases of several orders of magnitude in processing speeds might occur.

The fusing of omnisensorial data will require processing speeds equal to or greater than those mentioned above. Onboard computer (OBC) architectures will use at least three computers that perform parallel processing; they will also feature a voting process to ensure that at least two of the three OBCs agree. The integration of neural networks in OBC systems will provide higher reliability and will enhance process-control techniques.

Change detection and pattern recognition as well as chaos modeling techniques will increase processing speeds and reduce the amount of data to be fused. Multiple sensors, processing their own data, can increase processing speeds and share data between platforms through cross-queuing techniques. Optical data-transmission techniques should permit high data throughputs to the fusion centers in space, on the ground, and/or in the air.

The National Information Display Laboratory is investigating technologies that would aid in the registration and deconfliction of omnisensorial data, data fusion, and image mosaicking (the ability to consolidate many different images into one). "Information-rich" environments made accessible by the projected sensing capabilities of the year 2020 will drive the increasing need for georeferenced autoregistration of multisource data prior to automated fusion, target recognition/identification, and situation assessment. Image mosaicking will enhance the usability of wide-area, imagery-based products. Signals, multiresolution imagery, acoustical data, analyzed sample data (from tactile/gustatory sensing), atmospheric/exoatmospheric weather data, voice, video, text, and graphics can be fused in an "infobase" that provides content- and context-based access, selective visualization of information, local image extraction, and playback of historical activity.[28]

Near-term Technologies and Operational Exploitation Opportunities

Pursuit of nonmilitary omnisensorial applications in the early stages of development could provide a host of interested partners, significantly reduce costs, and increase the likelihood of congressional acceptance. These applications include government uses, consumer uses, and general commercial uses.

Government uses of this capability could include law enforcement, environmental monitoring, precise mapping of remote areas, drug interdiction, and assistance to friendly nations. The capability to see inside a structure could prevent incidents such as the one that occurred at the Branch Davidian compound in Waco, Texas, in 1993. Drug smuggling could be detected by clandestinely subjecting suspects to remote sensing. Friendly governments could receive real-time, detailed intelligence of all insurgency/terrorist operations in their countries. Finally, just as we presently track the migratory patterns of birds by using LANDSAT multispectral imagery, so might we track the spread of disease to allow early identification of infected areas.

Consumer uses could range from providing home security to monitoring food and air quality. Home detection systems would be cheaper and more capable. Not only would they be able to sense smoke and break-ins, but also gas leaks and seismic tremors. They could also provide advance warning of flash floods and other imminent natural disasters. Further, sensors could identify spoiled food and test the air for harmful particles.

Commercial uses could include enhanced airport security, major advances in medicine, and a follow-on to the air traffic control system. Everyone from farmers to miners would benefit from remote sensors by no longer having to rely on trial and error. For example, aircraft scans prior to takeoff would provide new levels of safety. Further, scans of patients would effectively eliminate exploratory surgery because doctors would be able to view internal problems on computer screens. Eventually, doctors may be able to treat patients largely on the basis of information obtained from computer imaging.

A good example of a commercial application is the development of an aerospace traffic location and sensing (ATLAS) system analogous to the current air traffic control system. Space is a hazardous environment because of the accumulation of satellites, debris, and so forth, and will be even more hazardous by 2020. Flying in space without an "approved" flight plan, particularly in LEO, is especially risky. The space shuttle, for instance, occasionally makes unplanned course corrections in order to avoid damage from debris. Similarly, as the boundaries between space and atmospheric travel become less distinct (witness the existence of transatmospheric vehicles), this system could conceivably integrate all airborne and space-transiting assets into a seamless, global, integrated system.

This system envisions that some of the same satellites used as part of the integrated structural sensory signature system would also be used for ATLAS. It would require only a small constellation of space-surveillance satellites (fewer than 20) orbiting the globe. ATLAS satellites would carry the same omnisensorial packages capable of tracking any object in space larger than two centimeters. All satellites deployed in the future would be required to participate in the ATLAS infrastructure and would carry internal navigation and housekeeping packages, perform routine station-keeping maneuvers on their own, and constantly report their position to ATLAS satellites. Only anomalous conditions (e.g., health and status problems, collision threats, etc.) would be reported to small, satellite-specific ground crews. ATLAS ground stations (primary and backup) would be responsible for handling anomalous situations, coordinating collision-avoidance maneuvers with satellite owners, authorizing corrective maneuvers, and coordinating space-object identification (particularly threat identification). The satellite constellation would be integrated via cross-links, allowing all ATLAS-capable satellites to share information. The aerospace traffic control system of the future would eliminate or downsize most of the current satellite-control ground stations as well as the current ground-based space-surveillance system.

Elements of the ATLAS system will include improved sensors for tracking space objects (including debris and maneuvering targets), software to automatically generate and deconflict tracks and update catalogs, and an analysis-and-reporting "back end" that will provide surveillance and intelligence functions as needed. Air and space operators would have a system that would allow them to enter a flight plan and automatically receive preliminary, deconflicted clearance. In addition, ongoing, in-flight deconfliction and object avoidance would also be available without operator manipulation. The system could integrate information from even more sophisticated sensors of the future, such as electromagnetic, chemical, visible, and omnispectral devices. "Handoffs" from one sector to another would occur, but only in the onboard ATLAS brain, which would be transparent to the operator. ATLAS provides a vision of a future-generation smart system that integrates volumes of sensory information and fuses it into a format that gives operators just what they need to know, when they need to know it.

The ATLAS system is just one small commercial application of the comprehensive structural sensory signature concept that fuses data from a variety of sophisticated sensors of all types to provide the war fighter of tomorrow with the right tools to get the job done.

Conclusion

The precision that technology offers will change the face of warfare in the year 2020 and beyond. Future wars will rely not so much on sea, land, or airpower as on information. The victor in the war for information dominance will most likely be successful in the battle space. The key to achieving information dominance will be the technology employed in the area of surveillance and reconnaissance, particularly a "sensor-to-shooter" system that will enable "one shot, one kill" combat operations. A network of ground- and space-based sensors that mimic the human senses, together with hyperspectral and fractal imagery, provides a diverse array of surveillance information that—when processed by intelligent, robust neural networks—not only can identify objects with a high degree of reliability, but also give the war fighter the sensation of being in or near the target area. The challenge for decision makers will be to develop a strategy that can turn this vision into reality.

□

Notes

1. Joint Pub 1-02, *Department of Defense Dictionary of Military and Associated Terms*, 1 December 1989, 355–56.
2. Ibid., 304.
3. Col Peter J. Engstrom, AF/XOXI, "Countering Weapons of Mass Destruction," speech, Air Command and Staff College, Maxwell AFB, Ala., 14 January 1994.
4. Fred Reed, "You Can Look but You Can't Touch," *Air & Space*, April-May 1994, 54–59.
5. "Technology's Brightest Stars," *R&D Magazine: The International Magazine of Research and Development*, October 1993, 17.
6. Joseph L. Galloway, "Identifying the Missing," *U.S. News & World Report*, 17 January 1994, 50–51.
7. "Analytical Chemistry," *R&D Magazine: The International Magazine of Research and Development*, October 1993, 29.
8. "Computers & Software," *R&D Magazine: The International Magazine of Research and Development*, October 1993, 37.
9. Dr Gregory H. Canavan, "Military Space in the Next Century," lecture, Air War College, Maxwell AFB, Ala., 24 January 1994.
10. Ibid.
11. Maj Jack Gardner, DIA/DB, conversations with Maj Bob Butler, commander, 23d Intelligence Squadron, 1992.
12. W. Prriedhorsky, SPACECAST Abstract no. A0045, 1 March 1994.
13. "Fractal Dimension Estimation for Optical Image Segmentation," *SPIE Proceedings*, July 1993, 361–70.
14. Nicholas L. Johnson, *The Soviet Year in Space, 1990* (Colorado Springs, Colo.: Teledyne Brown Engineering, 1991), 85.
15. Earl H. Tilford, Jr., *Setup: What the Air Force Did in Vietnam and Why* (Maxwell AFB, Ala.: Air University Press, June 1991), 211.
16. Deborah Erickson, "An Acoustic Sensor Spies on Insects," *Scientific American*, February 1991, 131.
17. Clarence A. Robinson, Jr., "Revolutionary Microsensors Stimulate Vast Applications," *Signal*, August 1993, 27.
18. John C. Mutter, "Seismic Imaging of Sea-Floor Spreading," *Science*, 27 November 1992, 1442.
19. Jeffrey Brune, "Porky's Defeat," *Discover*, January 1991, 51.
20. "A Nose by Any Other Name," *The Economist*, 28 September 1991, 97.
21. David H. Freedman, "In the Realm of the Chemical," *Discover*, June 1993, 69–76.
22. Stu Borman, "Laser NMR Technique Shifts Resonances," *Chemical & Engineering News*, 6 April 1992, 31–32.
23. P. P. L. Regtien, "Sensor Systems for Robot Control," *Sensors and Actuators*, June 1989, 91–101.
24. "The Feel of Reality," *Discover*, December 1992, 29.
25. Don Herskovitz, "On the Road from Data to Intelligence," *Journal of Electronic Defense*, October 1993, 95–96.
26. Ibid.
27. J. Cusack, SPACECAST Abstract no. A062, Rome Laboratory.
28. Briefing, Norm Winarsky, subject: Softcopy Tools and Technology, Maxwell AFB, Ala., 24 March 1994.

Air Chronicles

WHEN GUTENBERG invented the printing press, less than 5 percent of the world's population could read. By creating movable-type technology, he profoundly increased man's access to knowledge. World Wide Web (WWW) technology, a common staple on the Internet, promises to do the same. We are able to link computers full of information to each other and to exchange data worldwide quickly and efficiently.

AIR CHRONICLES, created by the staff at *APJ*, is now available on the Internet. It is designed to provide an avenue for airmen to become knowledgeable about issues of professional development in the next century and beyond and to engage in interactive research, education, and discussion concerning these issues.

YOU'LL FIND PAST and present *APJ* articles on-line in addition to previously unpublished articles, essays, and op-ed pieces. Countless book reviews, aviation images, and links to other Web sites are yours to explore. Got something on your mind? Join our discussion groups, and let your opinions be heard.

AFTER YOU'VE READ *APJ*, come visit us at *Air Chronicles*. See what others are saying about US Air Force concerns. And be sure to contribute what you can. We'll all be richer for the experience.

You can reach *Air Chronicles* at

http://www.cdsar.af.mil/air-chronicles.html

PROFESSIONAL MILITARY EDUCATION IN 2020

The effective employment of air and space power has to do not so much with airplanes and missiles and engineering as with thinking and attitude and imagination.

—Gen Merrill A. McPeak

The new military needs soldiers who use their brains, can deal with a diversity of people and cultures, who can tolerate ambiguity, take initiative, and ask questions, even to the point of questioning authority. . . . The willingness to ask and think may be more prevalent in the US armed forces than in many businesses. . . . As in the civilian economy, fewer people with intelligent technology can accomplish more than a lot of people with the brute-force tools of the past.

—Alvin Toffler

PROFESSIONAL Military Education (PME) 2020 will become a residency program unlike any that exists today. It will be a new concept of professional military education derived from today's distance learning, multimedia, virtual reality, and telepresence concepts. This article describes why the present PME system must change and what the new system should look like. After we've discussed the new PME system, we'll examine some of the objections that have been raised in response to these proposed changes. However, before we examine the PME system and suggest changes, we need to highlight potential technologies that can be exploited for use in PME 2020.

Emerging Technologies

Overall, technology is one of two factors necessary to meet the capability requirements of PME 2020. In general, current trends in technology indicate that the technological fields of the future will be tremendously fertile and highly affordable. For instance, comparing the 64K random access memory (RAM) computers of the early 1980s with the top-of-the-line desktop computers of today, we've seen a 1,000-fold increase in computer memory. The military can roughly predict that its desktop computers in 2020 will have about 16,000 times the power of today's computers,[1] a conservative estimate by many industry experts. Some experts predict the computers of the next century may have billions of times more power because of coming revolutionary replacements for the transistor. These new devices will squeeze even more power onto whatever replaces the computer chip. In other words, industry experts agree that the military will have plenty of power for whatever it may dream up. Project 2851, a new standard for digital terrain, is already facilitating automatic transformation of satellite information into 3-D virtual landscapes.[2] Extensive telecommunications, virtual reality, and computer simulation for PME 2020 are assured.

But what of the costs associated with this development? Again, analysis of today's technology cost trends predicts future cost. Currently the price of computing capability is reported as declining between 30 and 68 percent per year. ABC Evening News cited a 50 percent reduction in cost every 18 months. Using this conservative rate, if the military wants to determine what capability it will be able to buy for each office or classroom for $5,000 ('94 dollars) in 2020, it should look at the capability that $655,360,000[3] could buy today. Imagine the technology we could purchase in this price range for each classroom or each individual. Being able to use current technology in this price range would mean a significant difference in the office, home, and school. It will give each student's computer greater simulation capability than the latest simulators now used by the airlines or military, including surround picture and close-to-reality simulation. The technologies needed for PME 2020 will definitely be affordable.

Today's existing technologies also provide some specific examples and insight of what is possible in 2020. These potential technologies will solve the information, people, fiscal, and environmental problems of PME 2020. For example, potential technology exists today to solve the information overload problems of tomorrow. Human-computer interaction devices will also aid the war fighter in this area of information management. In addition, both virtual reality and worldwide instant access are assured.

Many current military personnel already belong to wide-area networks such as Internet and bulletin board services such as CompuServe. These connectivity providers are currently developing the next generation of network technologies. This includes automated aids used to find information and people over the networks. These automated aids are the beginnings of personally tailored automatic assistants. Edify Corporation has announced its "Information Agent," which gives users the ability to train computer networks to automatically gather and analyze data based on user demands.[4] Professor Nicholas P. Negroponte, founder of MIT's

Media Laboratory, stated, "We will soon have personalized 'newspapers' coming over the computer networks, with not only the news, but also the ads, aimed at the individual."[5] Automated assistants with even greater capabilities will ensure that each individual in 2020 receives the most current and relevant information—tailored to his or her needs and background.

Many systems are now on-line to assure instant access with other people and systems around the globe. New Jersey Bell plans on having all of New Jersey completely fiber-cabled by 2010.[6] Other companies in the US and in most industrialized nations are planning on doing the same, or in some way providing the same level of connectivity.[7] For those areas, however remote, that will not be interlinked with cable, space will provide the same functional connection through satellite links. Commercial enterprises will send into orbit a constellation of satellites that will enable instant contact anywhere on the globe, "a cellular system with very tall towers called satellites."[8]

All this information will be difficult to assimilate. Virtual reality itself is being used now as one solution to the information overload. One method of employing virtual reality as a "database navigating and mining tool" is used on Wall Street for managing stock portfolios. It uses a virtual world in which stocks and groups of stocks are represented by symbols of different color, shape, position, motion, and other characteristics. This enables a stock portfolio manager to use the computer to generate patterns and color changes that summarize at a glance the health and trends of many more stocks than could be managed as well by flipping through files or complex computer screens with tables of numbers.[9] It is easy to see how this type of application could be used to summarize much of the data that threatens to overwhelm the military person.

Another emerging technology comes in the area of enhanced human-computer interactions. In 1993 these interactions already included full-body suits for gesture and other motion detection,[10] computers embedded in clothing,[11] and experiments in controlling computers by thought. Regarding the latter, the Alternative Control Technology Laboratory at Wright-Patterson AFB, Ohio, is making significant advances in mental (hands-off) control of flight simulators. Grant McMillan, director of the lab, stated:

> All control is brain-actuated control, as far as we know. All we're doing is measuring the output at a different point. . . . Twenty or thirty years from now, we might be saying, "Gee, I'd never want a pilot to control the stick with his hands when he can do it so much better by manipulating his brain activity."[12]

Manuel De Landa discusses many of the military's developments in hardware, software, and even "wetware" [the implant of technology directly into the body] in his book *War in the Age of the Intelligent Machine.*[13] The military services are actively developing artificial intelligence and expert systems to help humans to digest information and act on it. For example, expert systems have been developed for analyzing radar signatures, labeling automatically generated maps, analyzing battlefield situations and air-to-air encounters (from command level down to helping an outnumbered pilot survive an engagement), planning for contingencies, diagnosing maintenance problems on aircraft, playing the role of intelligent opponent in war games, developing attack strategies for complex targets, helping to detect and counter C^3 countermeasures, providing advice on allocation decisions, assisting launch and recovery on carriers, and even predicting likely locations and times of outbreaks of violence.[14]

By far, however, the most exciting concept on our horizon is virtual reality. By 2020, virtual reality, or whatever its follow-on is called, will be ubiquitous. Military personnel will be used to the technology and to the capability it provides, a capability that will be a natural part of their lives. Nintendo is already reaching into the home with first-person virtual reality games. Already available are virtual reality eyeglasses with built-in stereo sound systems, similar in appearance to regular sunglasses.[15] Also available is software for less than $1,500 to build individualized virtual reality worlds, or one may get a head start by buying prebuilt worlds for $90 to $400 each. Although these inexpensive hardware and software systems don't currently match the movie studio multimillion-dollar systems, "they're sparking creative breakthroughs . . . and they're helping to drive the development of an industry, a communication tool, and the ultimate multimedium."[16]

Joseph Henderson of Dartmouth Medical School, looks at virtual reality in more practical ways as he describes virtual workplaces with virtual colleagues whose "physical counterpart may exist in any of the far-flung problem-solving teams deployed anywhere in the world." These virtual coworkers will meet and work in virtual hallways, virtual conference rooms, and virtual laboratories.

> One can as easily imagine a virtual high school, technical school, or university, which provides access to information and expertise that is anywhere in the world. Even difficult concepts, skills, and attitudes might be taught using vivid, three-dimensional and tactile representations of real world objects and issues. This kind of learning environment could be embedded in the work environment (even a non-virtual one) much as today's new performance support systems provide on-line training and reference on the assembly line. The worker need not leave his or her workplace to be trained; organizations need not establish and support fixed training facilities and travel costs can be reduced. Learning done in direct context with work is likely to be more efficient and effective.[17]

The military has already laid the foundation for the virtual reality world of the future. For example, Navy, Marine, and Army hospitals worldwide already use an interactive video, text, sound, and graphics system for training medical personnel in preventive medicine and the treatment of combat trauma in combat zones.[18]

> Virtual realities are a multimedia environment that gives users the sense of participating in realities different from their ordinary ones. . . . Such simulations, when done well, should provide to a user a sense of having a life-experience: learning occurs at an essential level, a fundamental change in attitudes and behavior results.[19]

Virtual reality, or "synthetic environments," was listed in 1992 as one of the Department of Defense's (DOD) seven main technology thrusts.[20] Victor Reis, DOD director of defense research and engineering, stated, "The demands of fighting on those battlefields [of the future], will be radically different from today's." He also stated that "synthetic environments represent a technology to let us learn how to use technology better. It's that feedback loop that does it." Reis had recently testified, "Network simulation is a technology that elevates and strengthens the collective problem-solving abilities of . . . design teams, manufacturing teams, education teams, training teams, acquisition teams, or war fighting teams." Finally, he pointed out that "another benefit" of the synthetic environments is "cost reduction."[21] Thus, by 2020, for cost and efficiency reasons, military personnel will have virtual reality experience and expectations—expectations that will depreciate or reduce effectiveness of any military education that fails to use the learning interface to which the students are used to.

We cannot overemphasize the importance of and the many advantages of using virtual reality and other interactive technology in education. First and foremost, interactive technology takes advantage of the strengths of experiential learning. It also provides flexibility. Well-constructed, interactive technology lessons allow for tailoring lessons to the individual, the individual's learning style, schedule, and the job at hand. Its also timely. Updated information can easily be dropped into the lesson and, if using a direct mode of delivery, is instantly available without waiting to deplete last year's printing. And finally, it's very student-centered. It can be self-paced and take advantage of the student's existing knowledge—teaching in the gaps. It can also provide personalized immediate feedback for everything the student does or asks.

Why Must the Present PME System Change?

Now that we understand the technological advances which are on the horizon, it's easier to see why the present PME system must change. PME must respond to changes surrounding three current and future issues: the exploding technological and informational environment we've discussed, evolving military personnel characteristics, and continued fiscal constraints.

Challenges of Technological Environment

Obviously, the technological environment surrounding military members will be very different than the one today.[22] Even assuming no revolutionary breakthroughs, unlikely though that is, and only the maturation of existing technologies, the technology environment of 2020 will be a rich one. It will include commonplace use of artificial intelligence, intense miniaturization, expert systems, virtual and artificial realities, and automated "computer assistants." PME 2020 must harness this technology to better educate the entire military force.

Since the rate of change in technology and the rate of growth in available information increase every day, all the technological advances mean that by 2020 information needs will grow exponentially and the amount of new information will be astronomical. Without careful planning and information-handling skills, the decision makers of the future will be susceptible to "analysis paralysis."[23] There are estimates that new information will double every few weeks (or days) due to quantum leaps in technology and the number of people using it. Instant access to the information superhighway, the Library of Congress, and numerous other sources worldwide will create an information overload almost unimaginable today. As the American military increasingly depends on technology and information to both deter and win war, the military member must understand technology and information and use them as the force multipliers upon which the nation has come to depend.

Space, another critical element in any future vision of the US military, provides many examples of this current and coming information explosion. One system of satellites alone, set to launch in the 1998–2013 time frame, will generate more than 10 quadrillion bytes of information about the Earth, "equal to about 10 billion books (Library of Congress holds a mere 27 million)."[24] The "Clementine" mission, now under way, is sending back 10,000 times the imagery of its predecessor.[25] "But sending data-collecting satellites spaceward is only half the task. Storing, analyzing, and rapidly disseminating the information once it is sent back will prove equally difficult."[26] "The helical scan storage technology NASA currently utilizes stores 45 terabytes [equal to 500 million pages of information] on top of a desk."[27] Improvements in sensors make more information potentially useful but also make searching for it a much greater task. How will future military analysts quickly determine and locate the critical information which can mean life or death and success or failure in the combat environments of 2020? The military education system must help analysts and operational units by determining which methods and technologies will be needed. PME 2020 needs to prepare the future war fighter for these informational and technological explosions because information itself could be the next battlefield.

Personnel Attributes

Just as the informational and technological environment will differ by the year 2020, the characteristics of military members also will be significantly different than they are today. First, there will be fewer military personnel of all ranks in 2020. Accordingly, the impact on the unit of attending PME in residence will be greater because there will be fewer people to fill in for anyone going TDY or PCS to school. Second, personnel will be located at geographically scattered stations in the US and abroad, locations which may be very different from those today. Third, there will be fewer personnel of senior rank, officer and enlisted, at any one location. This means both a higher cost incurred for those who must leave the unit for education or training and also less chance of finding enough people of a given rank to constitute a face-to-face, on-location seminar. PME 2020 must be able to accommodate this smaller, geographically separated military force that may not be able to afford the opportunity to attend lengthy and costly resident PME. "In addition . . . in 2020, students will be more familiar and comfortable with technology. For example, they will have grown up with virtual reality in the home and school. Personnel will also be familiar with the blurring between work, education, and home life and with the multiple careers and diverse demands on workers of 2020."[28]

Fiscal Constraints Increase

Another reason the PME system must change is to respond to future fiscal constraints. Military budgets, as a percentage of real gross national product (GNP), will continue to get smaller in the future. In particular, fiscal constraints will continue to impact the number of military members who will attend or enroll in PME.[29] Since there will be less money to spend on travel, we can infer that there will be fewer TDYs and PCSs to attend PME and other specialized training and less money for many kinds of equipment and infrastructure. As the military appropriation tracks downward, costs for technological capability (desktop, especially) are falling between 30 and 68 percent per year (and appear to be able to do so indefinitely). Therefore, fiscal constraints will mean increased use of technology to cover for personnel who are traveling or whose jobs have been automated or eliminated. PME 2020 has to be able to better educate more people with fewer dollars.

What Should PME 2020 Look Like?

> *If we should have to fight, we should be prepared to do so from the neck up instead of from the neck down.*
>
> —Jimmy Doolittle

As a result of responding to these three issues—the technological explosion, changing personnel requirements, and the increased fiscal restraints—PME 2020 will need to have an entirely new look, feel, and responsibility. Let's look at areas of emphasis for the new PME system, for while the present PME system may be adequate today, it will not be adequate in the future without these significant changes.

First, PME 2020 must respond to the information and technology explosion. One of the first of these responses is that PME 2020 must teach the war fighter how to navigate the information highways. Information navigation (searching) skills will be critical for all who expect to navigate the rapidly increasing sea of information. PME 2020 problem-solving techniques will emphasize the skills required to narrow the search for critical information in the aircraft, ship, or tank. The PME system will have to be much more adaptive, enabling it to respond to this ever-increasing and changing world of information. PME 2020's theme is capsulized in the statement "Knowing the knowledge terrain will be as important for third-wave armies as knowing the geography and topology of the battlefield was in the past."

In addition, the new PME system must maximize the technological environment by keeping every military member "connected." "Virtual residency" is the linking of telecommunications and computers in PME 2020. All 2020 military personnel will be "connected" to databases through wide area networks such as Internet. By the middle of 1993, Internet alone was already interconnected with over 15,000 other networks and over 20 million primary users.[30] Internet's membership is currently growing more than 20 percent per month.[31] Regardless of unit location, military personnel will have access to worldwide information networks capable of two-way data, image, and simulation transmission. "What telecommunications does is to remarkably expand the quantity and quality of information resources that can be in a classroom," says Linda Roberts, a senior associate in the science, education, and transportation program at the US Congress's Office of Technology Assessment. This manifests itself in "the ability to work with other classrooms, to expand the community of learners, and to have real access to people who know something."[32]

The telecommunications aspect of PME 2020 will also have a positive impact on the faculty. Edward Mabry, a communication researcher at the University of Wisconsin, noted that the strength of an academic department today "depends on the extent to which each faculty member is interconnected with other professionals—worldwide—pursuing similar interests."[33] Future technology will make for more of this than is allowed by current technology and fiscally constrained faculty travel opportunities.

Finally, PME 2020 needs to incorporate the new technology in order to broaden its horizons by becoming an open system that educates everyone and provides a curriculum that is continuously updated and distributed using enhanced distance learning methods known as virtual residency in PME 2020. Thus PME 2020 should be an open education and training program, a two-way gathering and sharing between students and faculty who simultaneously build an infrastructure on the expectations and experiences from personnel at all levels. To efficiently use military resources, information should be shared with other military services and with civilian institutions, especially in research and curriculum development. For example, history lessons might be developed by PME academies or civilian institutions and then shared among institutions. Current commercial CD-ROMs already include disks on almost every major war in US history as well as information on the space system and military aircraft. Military schools and other military organizations may find that their methodologies, information, and courseware have commercial value.[34]

These telecommunications and open system aspects of PME 2020 could then contribute to increased understanding and support for the military, giving PME 2020 the capability to reach larger audiences such as the media, Congress, and the public at large. A public better informed on military capabilities, competence, and needs will be beneficial for America, improving the chances of continued public support for the military. As Alvin Toffler observed, "Smart generals understand all too well that wars can be won on the world's television screens as well as on the battlefield. . . . Media policy, therefore, along with policies for communication and education, will together comprise the main distribution components of any overall knowledge strategy."[35] But responding to all of these technological issues is just the first step for PME 2020.

Second, in responding to personnel challenges, PME will have to make several more changes. PME 2020 must tailor its education to individual needs. It will have to become a self-modifying educational system that responds to the learning modes (such as "visual" or "aural") of each student and is able to adjust its instruction as the data changes from day-to-day. Faculty are then free to concentrate on instructing at higher levels of learning and developing courses for entirely new areas of instruction instead of chasing down items such as name changes of countries, organizations, or weapon systems. This tailoring of education to individual needs can be accomplished by using the same technology in PME 2020 that can be used for on-the-job training and education (OJTE), technology that transfers specialized or general OJTE directly to the war fighter by "beaming" it into aircraft, tanks, or ships.

Additionally, to meet the future personnel challenges, PME must also take advantage of the increased technological aptitudes of its people. The pre-adult environment of 2020 military recruits will have habituated them to technology and to more readily accept technological changes; however, in 2020, war fighters raised in this technologically rich environment may or may not have all the necessary skills to use all this information. The current college generation is characterized as "victims of declining educational standards. . . . Three quarters of college professors say students are 'seriously unprepared' in basic skills."[36] PME 2020 must be able to respond to the education and training needs of these individuals. A system that provides access to all resources at all levels to all students is the best method to counter any problems with basic skills.

PME 2020 will be a truly up-to-date curriculum. First, since courses will be available on demand, military members will be able to learn skills and find information when needed. Second, by establishing expiration dates on courses with time-sensitive material, PME 2020 will ensure that currency is maintained and that graduates of those courses are cued to their need for refresher courses or repetition of the original courses.

Another way the system responds to personnel challenges is to contribute to the recruiting and retention of the best-qualified personnel. A policy letter from the secretary of the Air Force cited concern with shrinking forces and budgets and noted that "the increasing frequency and duration of deployments will eventually make retention of high quality personnel more difficult."[37] The virtual reality, computer simulations, and telecommunications technology associated with PME 2020 could attract those interested in state-of-the-art technology.[38] Research results indicate the environment and opportunities of PME 2020 should be conducive to retaining technologically oriented individuals.[39] In addition, the level of technology represented in PME 2020 and the ability for personnel to be in contact with virtual seminars and research groups and to continue instruction even while on deployment to remote regions could aid retention.

PME 2020 should also take advantage of a changing work environment. Increasing numbers of challenges such as new warfare forms, combined with the technical environment, will mean that our people will have to be "more comprehensively trained, less specialized" and will have to cycle back through school often during their careers. They will need a "broader range of skills" in order to be "more flexible."[40] Virtual residency will provide the means for military members to accomplish those ends. But part of the building of the PME 2020 system should include implementing a change in the workday/workweek paradigm to include scheduling sacrosanct times (similar to the "Minuteman Education Program") for individuals to attend PME 2020 courses. Commanders must make the commitment to education and training to ensure time is set aside. PME 2020 must be as easy to schedule and attend as a staff meeting, including coordinating times for "virtual" seminars with members at geographically separated locations.

PME 2020 must also strive to continually educate and involve every military member. As Tom Peters states in his book *Thriving on Chaos*, we must (1) invest in human capital as much as in hardware; (2) train entry-level people and then retrain them as necessary; (3) train everyone in problem-solving techniques to contribute to quality improvement; (4) train extensively following promotion to the first managerial job, then train managers every time they advance; and (5) use training as a vehicle for instilling a strategic thrust.[41] This need to have a better educated and trained force requires that all military personnel receive their education and training through a quality PME system. The PME 2020 system will continue the "seminar" experience through "on-line" seminars and virtual residency. This telecommunication aspect of PME 2020 will provide PME continuing connectivity to every military member, allowing individuals to broaden their expertise and become educated in areas outside of their primary career fields. Additionally, there is a potential for unique combinations of backgrounds and interests working within the system on the same project.

This concept of "continual" education will use the above connectivity to achieve two other key aspects of PME 2020: lifelong learning and two-way involvement. Individuals will no longer have long periods of day-to-day jobs punctuated every five to ten years with a formal school. Instead, PME 2020 will offer the richness of continually updated courses of varying length on almost any subject, including those vital to improving day-to-day operations. Additionally, the opportunities for research (from simple questions to complex issues) and contacts with others will both increase the expertise of and enrich the lives of military members. Individuals with special skills or interest would not have to stop their involvement even with retirement. Also, combining these opportunities with the open-enrollment aspect of most PME 2020 courses greatly increases the chances for cross-pollination between varied career fields and individual backgrounds. This would help the future military member to cope with frequent career and job changes, and, according to Alvin Toffler, it should improve the strategic vision of future possibilities.[42]

Finally, a third change for PME 2020 concerns future fiscal constraints. PME 2020 must thrive within fiscal constraints by improving results while reducing costs in money and time. PME 2020's potential accomplishments are limitless; however, dollars required to educate and train war fighters are finite. Due to fiscal constraints, there will be fewer high-priced weapon systems developed and more frequent, incremental, technological upgrades to existing systems. Often we'll have to rethink systems' use and retrain users—i.e., the war fighters and their support personnel. For this situation, the virtual reality learning environment is ideal. The simulate-before-you-build principle explores the problems, benefits, and trade-offs of training people to use the new system, educating leaders in employing the systems, and experimenting with possible countermeasures and limiting factors.[43]

In addition, PME 2020's use of interactive technologies for delivery of instruction can reduce costs and improve results. Some studies demonstrate as much as 50 percent or more reduction in time needed to learn compared to conventional delivery.[44] Digital Equipment Corporation reported saving 40 percent of training time by using multimedia instead of traditional classroom teaching. The International Business Machines (IBM) marketing education division reported time savings of 40 percent.[45] Federal Express saved 60 percent of training time.[46]

IBM is a prime example of how the interactive technologies might reduce military costs and provide better results. IBM reported an overall savings of more than $150 million per year, with much of the savings coming from 300,000 employees not traveling to receive their instruction.[47] The military could see similar dramatic savings by eliminating much, if not all, of the physical residency requirement for courses—and thus eliminate much of the TDY, moving, dislocation, per diem, and other costs of students attending resident courses lasting from several days to 10½ months. Virtual residency has the potential to train more military members, more effectively, for less.

Virtual residency, with a core curriculum and consolidated resources, is in fact the most important aspect of PME 2020. It allows PME 2020 to have a core curriculum integrating land, sea, air, space, nonlethal, and information warfare. And it allows the resources of PME 2020 institutions to consolidate where practical and to integrate the newest technological advances within the courses. Finally, virtual residency is the main means of educational distribution.

Objections

> *I think the main failure of culture is the failure of imagination. It's very hard to think outside the boxes—cultural box, institutional box, political box, religious box—that we are all, everyone of us, imprisoned in.*
>
> —Alvin Toffler

As in all new ideas and changes from long-held beliefs and ways of doing things, there will be hurdles to overcome before we can successfully implement a new PME 2020 system. The first hurdle is resistance to change from current training methods to an interactive technology.

What are the most common reasons given for not using interactive technology or for resisting its inclusion in educational programs? According to a study[48] by the Business Research Group of Newton, Massachusetts, the following were the obstacles to implementing multimedia applications:

Obstacle	*Percent*
Cost	51
Equipment	19
Lack of expertise	13
Training	11
Lack of industry standards	8
Management resistance	7
Time	6
Inadequate applications	3
No obstacles	9
Other	4

As previously discussed, the equipment will be affordable. As the equipment becomes more user-friendly, lack of expertise and training will be less significant. Industry is currently developing the standards. Therefore, management resistance seems to be the most significant factor. Promoting the advantages and applications of this technology is the only way to overcome the mindset. For example, a survey of national business leaders and trainers regarding what methods best improved 41 key business skills revealed that 32 of the skills were best taught using experiential exercises and/or simulations. Lecturing was judged best for one skill—listening reflectively. The remaining eight skills were judged best taught using case studies (which also could be done very easily in the virtual seminar environment). The business leaders also rated the skills in importance. The four top-rated skills—to adapt to new tasks, to make decisions, to organize, and to assess a situation quickly—were all considered best taught by simulations.[49] But even with demonstrated strengths of the methodology and technology, there will still likely be resistance on at least some level.

Del Wood, IBM design specialist, stated that among the *Fortune* 500 companies in which he has helped implement multimedia, he has frequently encountered two types of resistance. One type resulted from intolerance of delayed gratification when the users must wait for the payback on investment until after development of lessons and schedules. The other type of resistance was the result of "a fundamental human aversion to change" caused by multimedia lessons requiring a different set of skills, orientation, and commitment.

Mr Wood pointed out that the diverse skills and resources needed for good interactive courseware require "multiple champions and visionaries to implement a change."[50] This need for champions is one the military must address. By fostering a continual, though gradual, conversion of methodologies as the military education system marches toward 2020, the system will grow the champions as the interactive system grows.

The move toward this process has already begun in the military. For example, the Air Force Institute of Technology (AFIT) began its nationwide distance education course in systems planning and management last year. Serving over 7,200 students, it should have a cost benefit of $20 million over six years.[51] Also, AFIT has an ongoing professional continuing education program, making use of satellite links throughout the Air Force. This type of distance learning, in addition to being more cost-efficient, will be more effective in accomplishing joint education and training. The services are looking more and more at sharing education tasks and resources to achieve those cost benefits, especially with distance education.[52] In 1992, Maj Gen Larry Day, deputy chief of staff for technical training in what was then Air Training Command, stated,

> In the next decade, more and more training will occur away from traditional training sites. . . . The concept [distance education] will save on travel and per diem costs and should be a routine training technique for all the services within a decade. . . . The effort [to share training across services] is led by a little-known group called the Interservice Training Review Organization.[53]

Another concern over PME 2020 is the belief that distance learning takes away from personal contact, the key value of PME. However, even without the existence of the virtual reality of 2020, current connectivity has already demonstrated that interactive communication through electronic means may lead to even greater openness and understanding than face-to-face communication. This is due to the entirely egalitarian nature of the interaction, which eliminates many of the intimidating and inhibiting factors of face-to-face communication in the same room. For example, in 1993 one of the top "head hunter" executive recruiting firms, as a cost-cutting measure, began providing videoconferencing technology for client companies to use for interviewing top-level candidates, a situation where "every nuance of face-to-face communications is crucial." The vice-president of the recruiting company was surprised at the results: "Initially we thought they would interview candidates and then fly in the final candidate, but in many cases candidates have accepted the job right over the ConferView. They were more comfortable than we thought they would be."[54] Interpersonal skills apparently can be communicated over the electronic medium. Coincidentally, the above firm estimates it will save clients $135 million this year in reduced travel costs.

Second, by 2020, virtual reality will provide the stimulus of co-location. MIT already is working on computers that will read subtleties of facial expression and voice and duplicate them on computer-generated representations of individuals involved. MIT researchers are even teaching the computer to recognize the difference between a genuine and a fake smile.[55]

Third, the virtual classroom may be supplemented, at least at first, by a physical meeting of the participants. This meeting will likely be of a short-orientation nature. For example, designated virtual seminar mates, spanning services and nations, may meet for two weeks of orientation at the beginning (and perhaps annually) of a three-year virtual seminar course. This physical meeting should enhance and personalize the computer representations of each of the seminar members. Even today's virtual reality simulators already allow participants to quickly dismiss any lingering artificialities. Bruce Sterling reported on Army tank crews and their virtual reality experiences:

> Group by group, the dead tank crews filed into the classroom and gazed upon the battlefield from a heavenly perspective. Slouching in their seats and perching their forage caps on their knees, they began to talk. They weren't talking about pixels, polygons, baud-rates, Ethernet lines, or network architectures. If they'd felt any gosh-wow respect for these high-tech aspects of their experience, those perceptions had clearly vanished early on. They were talking exclusively about fields of fire, and fall-back positions, and radio traffic and indirect artillery strikes. They weren't discussing "virtual reality" or anything akin to it. These soldiers were talking war.[56]

A third concern about distance learning (or for our purposes, virtual residency) is that it reduces student interaction with the faculty. In this case, however, the facts argue that increased connectivity will mean even greater interaction with faculty, with more efficient use of student and faculty time, by using on-line multiparty interactive or virtual conversations. In addition, there will be increased access to experts not on the "resident" faculty but merely available to answer questions in their particular area. This is a critical aspect of PME 2020 when one considers future reductions in the numbers of military experts and in the funds for hiring full-time civilian (including retired military) experts. Will PME schools and courses be able to afford full-time subject matter experts for each particular weapon system, culture, or strategy? The virtual residency, expert systems, and telecommunications aspects of PME 2020 guarantee these experts, or at least their knowledge, will be available on demand for the future war fighter.

Additionally, students can use virtual reality to talk with Caesar and Napoléon.[57] These "virtual" leaders will be programmed with all the anecdotes, paintings, photos (if available), film, video, and books about them. MIT and other labs are working on programs to create "virtual" people that seem alive in virtual reality environments. At MIT, the research project is appropriately named ALIVE.[58] Children's games are already using the beginnings of this technology to introduce students to historical figures. To reduce artificiality, computer software makers in Japan are now producing interactive computer programs in which the characters' lips are in synch with the words they speak.[59]

Looking toward the Future

> *Victory smiles upon those who anticipate the changes in the character of war, not upon those who wait to adapt themselves after the changes occur.*
>
> —Giulio Douhet

PME must begin changing now to ensure that it maintains capability and relevance to positively impact the future war fighters and guarantee their ability to contribute to national security. A successful PME 2020 system depends upon taking advantage of existing or emerging technology and operational exploitation opportunities. The military must now begin planning for PME 2020. First, an office of primary responsibility (OPR) must be appointed to oversee and implement the changes. This OPR will also be a liaison between the PME system and civilian education systems and emphasize usability and commonalities to both worlds. The military needs to immediately establish at least a temporary home for a central repository of military and civilian research and proposed solutions regarding questions raised in this paper about potential technologies. Air University (AU) could be that initial repository, and it could establish an on-line list of people and organizations now researching PME-related areas. AU could then develop this central repository and on-line capability with current technology, needing only computers, large storage devices, and on-line connectivity for incoming and outgoing information and questions. As the military builds toward PME 2020, there will be a continual need to know what the most promising upcoming potential technologies are and how best to apply them. To avoid being placed in a reactive catch-up mode, military educational institutions must take steps now to become proactive—leading the way, instead of being dragged, into the next century.

Second, working groups must be formed to recommend changes to the PME infrastructure. The first requirement for initiating infrastructure changes is continuing to research the educational and technological environment and to determine which structures will lend themselves best to rapid adaptability to technology. PME working groups made up of various career fields, having a variety of skills and interests can serve as the initial catalyst for the forming of PME 2020 to recommend what funds are required to purchase technology and develop points of contact at military and civilian institutions.[60]

Third, emerging technologies need to be monitored constantly for developments that might aid PME programs to teach military members how to effectively and efficiently manage the coming flood of raw data. Continual connections and computers responding to thoughts (although limited at this time)[61] are only two examples of emerging, evolutionary technologies that are allowing knowledge-level information to become largely the responsibility of computers rather than the responsibility of individuals. Regarding continual human-computer connection, "nearly every major computer company is currently developing wearable hardware. . . . The Tender Loving Care PC for paramedics features a screen embedded in a pair of high-tech glasses and a hand-held sensor to measure the patient's vital signs."[62] These devices may not have an immediate application for the PME system, but they nevertheless will have an impact on it.

Finally, the path to a successful PME 2020 will depend upon the quality improvement process to generate better ways to perform the education mission. In fact, some organizations have already started to shift direction to take advantage of the near-term technologies and the operational exploitation opportunities they afford. The Air War College Organizational Plan includes initiatives for a teleconferencing capability and for an interactive simulation link between the senior service schools. However, money is still needed to implement these initiatives. Also, the scope of these actions needs to be extended. The justification for the interactive, linked capability applies to personnel other than just the senior officers, and to subject matter other than just war gaming:

> Given the mandated decline of precious resources and personnel, it is in the best interest of our nation to provide our officers with every opportunity to practice in peacetime the combat decision-making they must employ in time of war. As war fighting continues to become more complex, senior leaders need experience translating national level decisions into operational action. This exercise of operational art requires not only development of plans and campaigns, but more importantly the opportunity to manage and execute those plans and campaigns. Educational wargaming provides this vitally important opportunity, and because it is process oriented, it improves war fighting, combat decision-making methodology. Compared to costly field training exercises, wargaming can provide a low-cost and certainly more efficient environment wherein officers can practice in peacetime the skills they will need in combat.[63]

Conclusion

Our military forces will be much smaller in 2020, yet the world will still be a dangerous place. In addition, space joins land, sea, and air as a conflict medium as competition among nations in space increases. This environment, coupled with the information explosion, the changing characteristics of military personnel, fiscal constraints, and significant technological advances, will require a much more educated and trained force if America is to remain a military superpower in the twenty-first century.

To meet this requirement, we will have to change policies and processes. While technology developments will determine the possible ways of delivering education, educational policies and processes will determine (1) who is educated (everyone or a select few), (2) when military members are educated (at specific times for all, or at appropriate times throughout each individual's career), and (3) where military members are educated (in-residence or through virtual residency).

The primary method of ensuring PME 2020 can meet the above needs and is relevant to the war fighter is through the efficient and effective use of leading-edge technology. As Col John A. Warden III, commandant of the Air Command and Staff College, stated: "PME must be on the cutting edge of technology if it is to survive as an institution in the future." Let us not be like the University of California professor 100 years ago who, in an issue of *Popular Science,* retracted his 1888 statement that self-propelled flying machines were "impossible" by saying that "while possible, the engineering difficulties are enormous and possibly insurmountable." Nine years later he was proven short-sighted at Kitty Hawk.[64] If we fail to take steps now to prepare for what technologies and processes must be developed for future education and training programs, we too will be viewed in future years as short-sighted. ☐

Notes

1. This formula is as follows: 26 years ÷ 2 = 13. $2^{13} = 16{,}384$.

2. Bruce Sterling, "War in Virtual Hell," *Wired*, Premier Issue 1993, 98.

3. Eighteen months goes into 26 years slightly more than 17 times. Working backwards from 2020 yields $\$5{,}000 \times 2^{17} = \$655{,}360{,}000$.

4. "Special Deliverer," *CIO*, 1 June 1992, 71.

5. Bob Metcalfe, "Get Ready for Personalized Newspapers," *InfoWorld*, 5 April 1993, 52.

6. Robin Nelson, "Swept Away by the Digital Age," *Popular Science*, November 1993, 107.

7. Ibid., 93.

8. Joe Flower, "Iridium," *Wired*, November 1993, 72.

9. Sara Hedberg, "VR Art Show at the Guggenheim," *Virtual Reality*, Premier Issue 1994, 73.

10. News item in *Wired*, April 1994, 38.

11. A. J. S. Rayl, "Dress Code: The Ultimate PCs Will Be Worn," *Omni*, December 1992, 20.

12. Bennett Daviss, "Brain Powered," *Discover*, May 1994, 60.

13. Gareth Branwyn, "The Machines Take Over: War in the Age of the Intelligent Machine," *Wired*, Premier Issue 1993, 84.

14. Donald A. Waterman, *A Guide to Expert Systems* (Reading, Mass.: Addison-Wesley, 1986), 289–93.

15. Advertisement by RPI Advanced Technology Group in *Virtual Reality*, Premier Issue 1994, 65.

16. Linda Jacobsen, "Homebrew VR," *Wired*, Premier Issue 1993, 84.

17. Ibid., 125.

18. Joseph V. Henderson, "Virtual Realities as Instructional Technology," Proceedings of SALT Interactive Instruction Delivery Conference, 20–22 February 1991, 121–25.

19. Ibid., 121.

20. Brian Green, "Technology on Five Fronts," *Air Force Magazine* 75, no. 9 (September 1992): 62–66.

21. Ibid.

22. Gen Merrill A. McPeak, "The Key to Modern Airpower," *Air Force Magazine* 76, no. 9 (September 1993): 44.

23. Alvin and Heidi Toffler, *War and Anti-War* (Boston, Mass.: Little, Brown, and Co., 1993), 158.

24. Garrett Culhane, "Mission to Planet Earth," *Wired*, December 1993, 94–97.

25. CNN, "Future Watch," 27 March 1994.

26. Culhane, 94.

27. Ibid., 96.

28. Writing in *Technical Horizons in Education Journal*, ("Connecting with the Future Today," April 1994), Lee Droegemueller, Kansas commissioner of education, gives one view of the education world of the next century:

> Visible transformations in the world of work indicate the future integration of the workplace, home, and school. Responsibilities, functions, and activities that once occurred exclusively within each domain are crossing over into other environments. . . . No longer can the school, the office, and the home be separate from one another. These three once-distinct entities are breaking apart, combining and overlapping in new ways.
>
> The major connector of these three entities—home, school, and work—is technology. . . . Thus the direction for planning must be to build the learning community and to focus upon connectivity. This means that the communication systems, networks or infrastructure among the community partners, and how they are connected to the world, become the top priority.
>
> To avoid a similar fate (to businesses which are over-whelmed by technology), schools must use technology for students to learn. Technologically connecting the school with the home and work will make learning relevant and useful. Learning will have no boundaries, as students can connect with others to access information, ideas and experiences from within the community, across the state and around the world (page 10).

29. McPeak, 43–46.

30. Clarence A. Robinson, Jr., "Powerful Nomadic Devices Offer Global Network Access," *Signal* 48, no. 7 (March 1994): 23.

31. CNN, "Science and Technology Week," 2 April 1994.

32. Jacques Leslie, "Connecting Kids," *Wired*, November 1993, 90.

33. Jacques Leslie, "Mail Bonding," *Wired*, March 1994, 46.

34. For example, the multimedia lessons Air Command and Staff College is integrating into current curriculum may have value at civilian institutions or on the commercial market as well. These or other military-created products could be sold or traded for information or services. As the military develops expertise in authoring in the virtual reality and simulation areas, there no doubt will be opportunities to sell actual or modified products to civilians or to encourage commercial vendors to develop items the military requires by providing a less risky, guaranteed, military market.

35. Toffler, 147.

36. Joseph P. Shapiro, "Just Fix It," *U.S. News & World Report*, 22 February 1993, 53.

37. Policy letter from the secretary of the Air Force, September 1993, 4.

38. Currently, the military has already started new recruitment strategies in over 50 career fields. These strategies are aimed at recruiting individuals who already possess the basic skills needed for various specialties. These individuals require little if any training in the basics of their career field. The attractiveness of PME 2020 technologies will enhance this strategy. PME 2020 will not only help recruit these targeted individuals, these same technologies will help retain them.

39. In a survey referenced in *CIO* magazine, the importance of various factors in attracting and retaining technology-related professionals was rated by those professionals. The opportunity to work with leading-edge equipment was rated as very important by 64 percent of those surveyed, opportunity to work on important projects—62 percent, enthusiasm for the mission of the business—57 percent, and opportunities for promotion into management received only 36 percent.

40. McPeak, 44.

41. Tom Peters, *Thriving on Chaos* (New York: Harper Perennial, 1991), 386.

42. Alvin Toffler interview with Peter Schwartz, "Shock Wave (Anti) Warrior," *Wired*, November 1993, 121.

43. Sterling, 99.

44. Larry Armstrong, Dori Jones, and Alice Cuneo, "The Learning Revolution," *Business Week*, 28 February 1994, 80–85.

45. Del Wood, "Instructional Technology in the Business Environment," *Interactive Multimedia '93 Proceedings*, 25–27 August 1993, 52.

46. Caterpillar used interactive media for language training and saw 50–60 percent savings, and expects to save up to $20 million in US operations alone. Bethlehem Steel uses over 100 interactive courses, including more than 15 as part of their Total Quality Management (TQM) program, and reports 20–40 percent time savings, higher retention, and increased participation in voluntary programs. Ford Motor Credit Company estimates cost savings of 25 percent. Bell South reports one program saved $5 million and 20,000 days of instruction. They also have condensed a five-day conventional course into a seven-hour interactive course. They report an 80 percent time savings with 40 percent higher retention levels. Ibid., 56.

47. Ibid., 57.

48. "Interactive '94" conference announcement.

49. Richard Teach, "What Do We Teach When We Use Games?" *The Simulation and Gaming Yearbook*, 1993, 112–21.

50. Wood, "Instructional Technology," 51–58.

51. G. Ronald Christopher and Robert R. Bergseth, "Meeting Air Force Educational Requirements through Media," *Orlando Multimedia '93 Conference Proceedings*, 24–26 February 1993, 68–70.

52. Philpott, 10.

53. Ibid.

54. Audrey Merwin, "Videoconferencing Goes to Work," *New Media*, November 1993, 64.

55. Richard Lipkin, "A Face by Any Other Name," *Science News*, 2 April 1994, 216.

56. Sterling, 51.

57. A recent CNN news tidbit featured a computer-generated Mark Twain for rent. This Mark Twain responds to almost any question with a witty response that takes into account all of Twain's writings and biographical notes from people who knew him. He's currently being used primarily for promotional events at shopping malls, but he definitely shows the potential for PME 2020 to introduce historical figures and experts in the classroom.

58. Lipkin, 220.

59. "Make Sense of Japanese with Your Own Sensei," *Windows*, May 1994, 90.

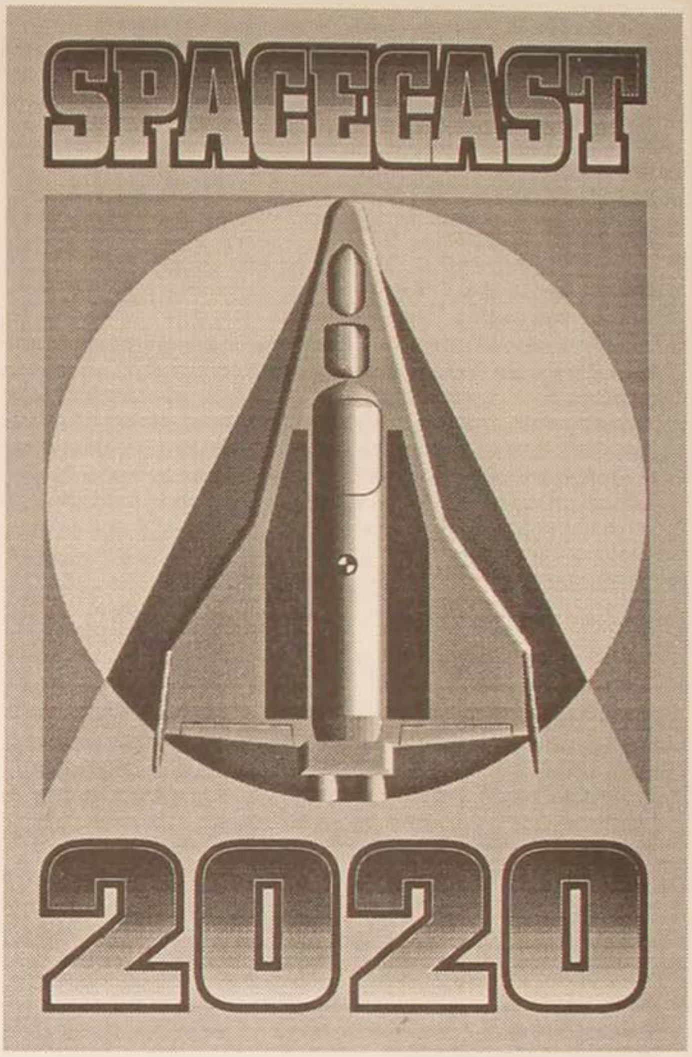
60. The working groups will formulate positions on numerous education related subjects. Questions such as (1) What are the true benefits of resident programs versus nonresident ones? (2) When will virtual residency be advanced enough to replace resident programs? and (3) What taxonomy, if any, should replace Bloom's will need to be answered when the military begins to incorporate emerging technologies into the PME system?

61. Daviss, 60.

62. Rayl, 20.

63. Air War College Organizational Plan, 1 June 1994, Initiatives B93AWCTE-05 and B93AWCTE-04.

64. Candace Golanski, "Looking Back," *Popular Science*, April 1994, 116.



SPACE LIFT

Suborbital, Earth to Orbit, and on Orbit

A *VISION FOR THE FUTURE:* In 2020, aerospace forces will be a reality. A notional composite aerospace wing, based in the continental United States (CONUS), would include a squadron of rocket-powered transatmospheric vehicles (TAV). These Black Horse[1] vehicles, derived from the Question Mark 2[2] X vehicle (fig. 1) and described later in this article, will be fighter-sized airframes capable of placing an approximately 5,000-pound payload in any low earth orbit (LEO) or delivering a slightly larger payload on a suborbital trajectory to any point in the world. Black Horse vehicles could accomplish either task within one hour of completion of mission planning, assuming that the payload was available at the base and the vehicles were on alert. When operating in support of a war-fighting commander in chief (CINC), the aerospace wing will thus have the capability to put mission-specific payloads on orbit (mission-tailored satellites) or on target literally within a few hours of identification of a need. Most missions—except some suborbital operational and ferry/deployment missions—will require aerial propellant transfer from modified KC-XX aircraft. These aerospace craft will use noncryogenic propellants—standard jet fuel and hydrogen peroxide—and will be designed for maximum logistics compatibility with the rest of the wing.

Maintenance and ground operations for the TAV will require no greater specialized skills than those for any other aircraft in the wing. TAVs returning from a mission would normally be serviced and returned to ready-for-flight status in less than a day and could

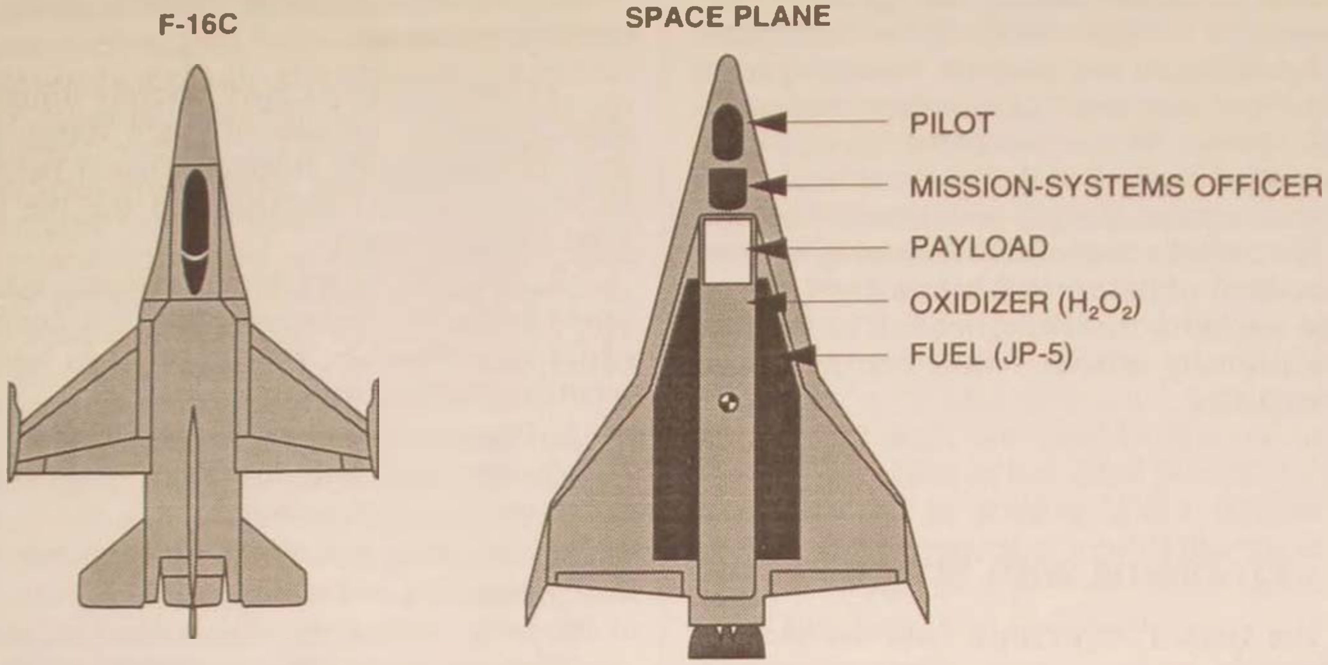


Figure 1. The First Black Horse TAV: "The Question Mark 2" X Vehicle (Planform Comparison with F-16C) (From a conceptual study done by W. J. Schafer and Associates and Conceptual Research Corporation for Phillips Laboratory, January 1994)

be surged to fly multiple missions per day if necessary. If tankers were prepositioned in-theater, TAVs could also fly high-priority, global, cargo-delivery missions.

To fully exploit the TAV's capabilities, designers will adopt a new approach to satellite design—one that maximizes use of advances in miniaturization and modularity. Most space systems' designers thus will take advantage of the vastly lower cost-per-pound to orbit (less than $1,000 per pound) that the TAV concept provides. Orbital payloads that are too large to fit in a single TAV can be designed as modules, launched in pieces, and assembled on orbit.[3] Some high-value satellites will be serviced, repaired, and modernized in space by space tugs, which will move payloads launched on the TAVs to the mission orbit. With space launch and operations made routine by the TAV, multiple new uses for space systems will emerge, and the design cycle for new systems will be greatly reduced. Such systems will be less expensive, simpler, and quicker to make; they will also cause less concern if one does fail and will allow more rapid inclusion of emerging commercial technologies.

The ability to orbit, upgrade, or even retrieve dedicated, special-purpose, space-support capabilities quickly and (relatively) inexpensively will dramatically change space operations. Satellites will perform navigation and most housekeeping functions autonomously. Central ground sites will monitor, update software, and assist these satellites in identifying repair requirements. Theater forces will task the mission payloads on these satellites directly by using deployable ground systems that require less lift into theater than 1990s communications/data-display terminals. The result will be an array of space systems and operations that are fully integrated into global operations.

This description is not science fiction. It is an entirely plausible outcome of the development program described in this article. The initial reaction of many readers to these assertions and to the Black Horse TAV concept in general is that it is too good to be true and that the claims are reminiscent of shuttle or national aerospace plane (NASP) promises. In fact, Black Horse is substantially different in concept from either of those systems, and the numbers and assertions presented here are based on a preliminary but iterated design (i.e., several steps beyond a point design) performed by technically credible engineers. Following a brief discussion of the current lift problem, the article explains the steps needed to produce operationally effective TAVs and associated capabilities.

Problems with Space Lift

The United States must have assured and affordable access to space to expand or even sustain space operations. This means being able to place useful payloads in all relevant earth orbits with high probability of launch success and operation on orbit within hours instead of months or years. It also means the ability to operate flexibly in and through space to accomplish both manned and unmanned missions in support of US national and military objectives.[4] By almost any measure, the current US space-lift (earth to orbit) capability is not sufficiently robust. Worse, it is not improving. Suborbital (operations through space) and orbital maneuvering capabilities are almost nonexistent. If the United States is to make full use of space in the next century, military planners must address these shortfalls.

This article proceeds from the assumption that assured access to space is crucial for many reasons: to enable future innovative ways of supporting combat forces, to counter threats from unfriendly space-faring nations, and to create the conditions for a commercial market that may ultimately support and drive rapidly evolving space technologies. Numerous studies[5] are available to support this assumption. Ultimately, expanded military, civil, and commercial use of space depends on assured and affordable access to space.

A review of the limitations of current launch systems suggests several specific problematic areas:

1. Current systems have severely limited abort capability because of such things as their predominantly intercontinental ballistic missile (ICBM) heritage and the use of solid rocket boosters.
2. Use of disposable hardware, manpower-intensive operations, and the design of US lift systems in general result in large, recurring launch costs.
3. There is little or no standardization of launch vehicles, their interfaces, spacecraft buses, or payload interfaces.[6]
4. Tailoring rockets to fit payloads is costly, wasteful, and unnecessary.[7]
5. Solid rockets and disposable hardware are generally not environmentally friendly.
6. The current huge and highly specialized launch infrastructure (ranges, launchpads, personnel, etc.) causes expensive, lengthy, and unresponsive launch schedules. Unless an alternative is discovered, this launch infrastructure will be archaic well before 2020.
7. Space-launch and operations procedures are overly complex and nonstandard, requiring "white-coat" specialists instead of "blue-suit" operators.
8. Launch operations are "serial" events. One payload and one (dedicated) launch vehicle are readied interdependently and step-by-step, a process that does not allow parallel preparation of spacecraft and launch systems for flexible launch scheduling.
9. The US does not have a flexible, operationally responsive space-launch system or the capability to reconstitute even a limited capability on orbit in response to a crisis or loss (deliberate or accidental) of any US space system.

This article does not propose a new national space policy, a new space-lift policy, or a "silver bullet" solution that provides unlimited or unconstrained lift. Rather, it proposes an alternative architecture of space lift and suborbital and on-orbit vehicle capabilities that will enable the country to perform new missions in space, provide a responsive and resilient space-lift/operations capability that is increasingly acknowledged as militarily essential,[8] permit an escape from the current vicious cycle of cost-weight-size-complexity-risk-delay that frustrates US government space systems, and offer the potential for future commercial exploitation that not only would result in vast new commercial opportunities, but also would logically drive development of even better space-system capabilities.

This article proposes a space-lift system that can put usable payloads on orbit affordably, has extremely high operational utility, is responsive, requires little or no specialized infrastructure, operates like an airplane, and has the potential to change the approach to space as surely as the DC-3 changed air travel. It also addresses potential suborbital missions that such a system would allow; discusses different ways of deploying, servicing, and redeploying space assets once they are on orbit; and explains why this is desirable in some (but not all) cases.

If our nation has no desire for expansion in the use of space (either militarily, scientifically, or commercially), it can no doubt continue tinkering with existing launch systems and gradually refine procedures to gain small, incremental improvements in efficiency. This would commit the United States to an ultimately self-defeating cycle: the continuation of increasingly large and complex space systems—technologically obsolescent as soon as they become operational—and ever fewer yet higher-performance launch systems to put them on orbit. The great risk, cost, and difficulty of replacement associated with failure of one payload during launch or while on orbit demand increasingly burdensome and unwieldy oversight focused on ensuring that nothing can possibly go wrong. In other words, not only will a policy of business as usual not enable a breakthrough in the use of space, it may ultimately cause some existing uses of space to become unaffordable and unattractive.

The SPACECAST lift team recommends that the Department of Defense (DOD) proceed with a modified space-development program that emphasizes the lift and on-orbit operations technologies highlighted in this article. This program must emphasize, above all else, increased operational flexibility and a concomitant reduction in specialized infrastructure. The top priority should be an X program to demonstrate the validity of the Black Horse TAV concept. The entire cost of such a program would be less than $150 million (by comparison, a single Titan IV launch costs $325 million).[9] This type of system, although not capable of meeting all lift requirements, offers great potential for a breakthrough in making space operations routine and introduces multimission capability. It stands above all other space-lift ideas that have been evaluated.

Missions

The TAV, like the airplane before it, has the capability to perform many different types of missions. The TAV concept is not intended to be all things to all people; in fact, SPACECAST explicitly recognizes that one system is unlikely to fully satisfy mission needs in every area. However, the TAV can perform a subset of missions across several mission areas. In this sense, it is like the C-130 aircraft—basically a transport airframe but with AC-, EC-, KC-, MC-, and other versions. SPACECAST believes that the TAV can improve on this by using modular, interchangeable mission modules (satellite or weapons dispensers, for example) so that the same airframe—flying very similar mission profiles—provides a flexible, responsive, multimission capability. This capability provides tremendous leverage in achieving global reach—global power and contributes to the overall SPACECAST concept of "global view."

The core of the proposed space-lift and transportation architecture is an innovative space-access capability that can operate like an air-transportation system. The US space-transportation capability of the future should include systems for moving payloads around, within, or through space (suborbital, orbital, or return from orbit). SPACECAST 2020 proposes pursuing a space-lift development strategy that provides solutions to the country's most pressing problems, while encouraging (but not assuming) future quantum improvements in space-transportation technology.

Space Lift

If launch of a satellite becomes a less complex, less time-consuming, and less costly task, engineers can design spacecraft for shorter lifetimes with ease of upgrade or replacement. Shorter lifetimes would reduce fuel requirements, much of the onboard redundancy, and other elements related to design life. Designers could avoid much of the current cost redundancy and complexity, creating smaller, less expensive, and more technologically up-to-date systems. Evolving toward such systems would make replacements easier to produce and launch, and the consequences of an on-orbit failure could be remedied as soon as a satellite was available. Satellites that must be large (e.g., optics—such as the Hubble telescope—that do not use interferometry) could be designed modularly and assembled on orbit. To take full advantage of this capability, the US would have to revisit most of its basic assumptions about space operations, starting with the type of space-lift system.[10]

It is important to note that a single system will not satisfy all needs, just as variants of a single airframe do not perform all air missions. For example, a Black Horse TAV will probably never launch a military strategic and tactical relay satellite (MILSTAR). Also, transitional measures may be necessary to preserve operational capabilities until new technology systems come on-line. This will undoubtedly include expendable launch vehicles in the near term. SPACECAST believes that the approach outlined below, while not addressing all space-lift problems, provides the maximum potential payoff for 2020 and beyond.

Any proposed lift system must address the operational concerns and problems highlighted earlier. Specifically, to be militarily useful, a future lift system must be responsive (capable of launch on demand), highly reliable, able to abort a launch without destroying the vehicle (soft abort), resilient, flexible, logistically supportable, and easily operated. An overriding concern for all users—military, civilian, or commercial—is that the system be affordable. These factors can be difficult to translate into specific numbers, so—rather than setting quantitative goals—this article seeks a system that offers a recognizable, *qualitative* improvement in the launching of payloads into space. Numbers relating to the initial design of the Black Horse TAV are mentioned here, but they show the capabilities of an X vehicle designed with current technologies and should not be interpreted as the upper limit of the vehicle's capabilities.

Force Application

A version of the TAV contributes to our national military strategy by allowing the United States to rapidly respond worldwide to future threats with overwhelming offensive firepower. It provides the national command authorities (NCA) and the CINC the ability to accomplish strategic-level effects in about an hour without using weapons of mass destruction. Rapid vehicle recovery, rearming, and relaunch on subsequent missions allow the CINC to continue the offensive through decisive follow-on attacks, thereby reducing the effectiveness of enemy interference with reconstitution and recovery attempts. Such a vehicle has the potential to escalate the pace of war fighting beyond SPACECAST's projection of future threat capabilities. The system capitalizes on three specific offensive advantages.

Speed and Surprise. The greatest single advantage of this weapon is surprise. Strategic surprise results from the ability to strike enemy targets at any depth with little or no warning. Because kinetic energy multiplies the effect of weapons delivered from a suborbital trajectory, the weapons themselves can be small (e.g., brilliant micromunitions); therefore, a single vehicle could simultaneously strike a large number of targets. Operational surprise results from the rapidity of the completed attack, which may be timed to catch an adversary in the process of deployment or employment of inadequately prepared forces. Tactical surprise results from a variety of suborbital profiles that these vehicles can use to exploit gaps in an enemy's defense. The speed of the system—the ability to put force on target anywhere in the world in a matter of minutes—also converts the global reach of the system into a form of "presence" that does not require constant forward deployment of forces.

Mass, Economy of Force, and Persistence. This concept can rapidly complete a strategic attack on multiple (perhaps even multithousand) aiming points with a small fleet of appropriately armed TAVs. The exact number will depend on vehicle payload capacity, final weapons designs, and cost. Rapid revisit times allow continued pressure on the enemy. The concept also contributes to solving the current concern of handling a number of major regional contingencies, since the surge rate of the weapon system should allow destruction of at least two widely dispersed regional opponents' key centers of gravity within several days. Finally, the simultaneous presentation of thousands of small reentry vehicles to a surprised and defensively helpless adversary will likely overwhelm him, thus ensuring the success of our nation's objectives.

Synergy. The vehicle's ability to employ a variety of weapons allows tailored effects to prepare the battlefield for other weapon systems or to act as a force multiplier, allowing ground, air, and sea forces unimpeded access to the battlefield to accomplish follow-on missions. Results can also provide synergistic effects for other national instruments of power.

On-Orbit Operations

Putting things on orbit (into LEO, in particular) does not always satisfy operational demands. Some satellites must be lifted to higher orbits, and some key space assets may require redeployment from one operation to the next (altering orbits). Missions to retrieve high-value assets for repair or upgrade (remotely on orbit, at a space station, or back on earth); to resupply space platforms with things like fuel, food, or weapons; or even to collect space debris and "dead" satellites from highly populated orbits are also possible.

As a result, the US may need a system of transportation between LEO and other orbits. This is essentially an extension of concepts already studied by the National Aeronautics and Space Administration (NASA) and DOD. The SPACECAST team believes that these types of systems complement any lift concept, permitting either larger payloads for a given booster or the launching of a given payload on a smaller system. For the TAV concept, postulation of a separate on-orbit transportation system opens up additional missions, but it is not a requirement for the TAV's performance of the basic missions described here.

The Vehicle

Design of a vehicle to accomplish multiple missions is seldom easy. The history of the F-111 aircraft serves as a strong warning, as do our nation's unsuccessful efforts (thus far) to accommodate all space users' launch requirements on a single vehicle.

The critical factor in designing an aerospace vehicle is ensuring that the mission profile (range, maneuverability, type of payload, etc.) and the performance requirements (speed and amount of payload, among others) of the proposed multimission vehicle are compatible. If they are, increased operational flexibility and cost savings through common logistics and operational procedures become possible. The SPACECAST team believes that this *is* the case with Black Horse vehicles for both the launch of spacecraft and the suborbital delivery of weapons or cargo. As mentioned earlier, the C-130 is a good analogy in terms of design philosophy: simple and as rugged as possible, not necessarily the highest-performance system, but inherently capable of multiple missions.

Space-lift Options

The size of the payload put into orbit by a launch vehicle should not drive the launch-system design. In fact, small spacecraft have many potential advantages, mentioned earlier. Cost-per-pound to orbit should be a key measure, and if the cost is low enough, almost any mission payload can be repackaged to fit a smaller launch envelope or accommodated on several launches, if need be. Those payloads that absolutely must have a launch vehicle of a specific size will probably never be affordable, although overriding national security concerns may still require their launch.

The strategy advocated here—reducing payload size for a system that produces low operating costs—rests on four assumptions. First, the technology that drives space payloads (sensors, electronics, software, etc.) is advancing rapidly—even accelerating. This makes large, complex satellites (because of their lengthy cycles of design and construction) more vulnerable to obsolescence on orbit and favors an approach that regularly places more up-to-date systems on orbit. Second, these same technological advances increasingly allow more capability to come in smaller packages. Modularity, interferometry, bistatic radar techniques, and other technologies may even allow things traditionally believed to require large, monolithic platforms to be put in space incrementally and either assembled on orbit or operated as a distributed system. Third, economies of scale have proved elusive in space systems. Large boosters are not appreciably (an order of magnitude) more cost-effective (dollars-per-pound on orbit) than small boosters, and no projected demand or incremental improvements will significantly (again, by an order of magnitude or more) reduce the cost of current boosters. Finally, military space operations will be increasingly subject to fiscal constraints because many national security requirements may no longer justify performance at any cost.

Despite these assumptions, several possible alternative systems exist, most of which are familiar. They include Pegasus; Taurus; other light, expendable launch vehicles; converted sea-launched ballistic missiles; hybrid (mixed solid-liquid propellant) rockets (also expendable); a variety of reusable vehicles from NASP-derived systems to DC-X-derived single stage to orbits (SSTO); carrier-orbiter concepts such as the German Sänger and Boeing's reusable aerospace vehicle (actually a trolley-launched system); and even cannon or rail-gun launch (table 1).

Which System Is Best?

Most alternative systems actually do not offer a qualitative difference in the launching of satellites. Pegasus, Taurus, other expendables, and hybrid rockets fall into this category. A qualitative difference is important because even the most ambitious recommendations for improved conventional (expendable) boosters do not offer more than a 50 percent reduction in cost-per-pound to orbit[11] and in most cases still rely on antiquated range-support systems and—to a lesser extent—launch procedures. Small expendables, though more flexible and more operationally effective than large boosters, typically cost even more per pound to orbit. In making a system-acquisition decision, planners must carefully compare the life-cycle costs of reusable systems with those of mass-produced expendables—a comparison that is beyond the scope of this article. It is worth mentioning, however, that one of the hidden costs of expendable rockets—particu-

Table 1

Qualitative Comparison of Launch Systems

System Capability	DC-X SSTO	Black Horse	Pegasus	Taurus	Sea Launch	Gun Launch
Responsiveness	Good	Excellent	Good-Excellent	Poor-Good	Poor-Good	Excellent
Flexibility	Good	Excellent	Fair	Poor	Fair	Poor
Soft abort	Fair-Good	Excellent	None	None	None	None
Resilency	Fair	Good	Fair	Fair	Fair	Good
Logistics	Fair	Good	Fair	Fair	Fair	Poor
Reliability	Unknown	Unknown	Fair	Fair	Fair	Unknown
Ease of operations	Good	Excellent	Fair	Fair	Fair	Fair
Environmental	Excellent	Good-Excellent	Poor	Poor	Poor	Fair-Excellent
Cost (lbs to orbit)	Good-Excellent	Good-Excellent	Poor	Poor	Poor	Excellent

larly those using solid propellants–is environmental. Although difficult to assess, adverse environmental impact may be an overwhelmingly negative factor in the mass use of small, expendable launch vehicles.

Cannon/rail-gun systems may be attractive in terms of cost-per-pound to orbit but have some severe limitations. Payloads must withstand accelerations of 1,000 Gs or greater (this does not facilitate building less costly satellites with fewer constraints on the use of commercial parts), and the US would become more–not less–dependent on specialized infrastructure. Barring a revolutionary advance in propulsion technology (which is as unlikely in the next 20 years as it is unforeseeable), the SPACECAST team believes that fully reusable lift systems integrated with mainstream aerospace operations offer the best hope for qualitative change in space lift.

Problems with Reusables and General Design Goals

From basic intuition through the justification for the space shuttle to the most recent studies,[12] fully reusable systems offer the greatest operational flexibility and potential cut in launch costs. Three problems continually recur: (1) how to build a system that is completely reusable and has acceptable performance; (2) how to justify the nonrecurring costs (infrastructure investment as well as hardware development) to get the eventual benefits of lower recurring costs; and (3) how to reduce recurring costs to the point that one can expect an eventual payback. The space shuttle's problems in these areas and others have disillusioned people, but a radically different design may finally vindicate the notion of a reusable launch system.

Problems with fully reusable launch vehicles may stem from misplaced attachment to old paradigms of space systems (e.g., at least 20,000 pounds of lift capacity are needed to place useful payloads in orbit). The reason for this is twofold: first, it reflects assumptions about satellite design that do not account for advances in miniaturization and modularity (i.e., what has become possible) and second, it assumes that payload size is the primary determinant of a launch system's utility (as opposed to, say, cost-per-pound of payload in orbit or the ability to launch on extremely short notice). This mind-set drives performance to the edge of the envelope, creates tremendous development costs and dependence on immature technologies, usually fails to address operational implications sufficiently, and produces huge specialized infrastructure requirements that further drive up recurring and nonrecurring costs. These crippling problems can be overcome if designers challenge the old assumptions about space lift.

Space authorities have now acknowledged the negative relationship between trying to get the maximum number of pounds of payload onto a given rocket and optimizing cost/reliability.[13] Further, as discussed above, the vicious cycle of large satellite design and the opportunities provided by miniaturization and other advancing technologies argue in favor of smaller, standardized satellite designs.[14] Finally, authorities on military space have expressed frustration with the "custom rocket" approach that comes from attempting to squeeze every last ounce of lift out of a given booster.[15] The time is ripe to design an operationally sound launch vehicle—one that utilizes existing, common infrastructure; one that can be maintained by well-trained high school graduates; and one that can be operated by well-trained college graduates without scientific expertise. One can then build payloads to fit it.

Development costs and dependence on immature technologies are linked to the performance issue. Because performance requirements are so high, only exotic fuels, engines, or design concepts can possibly meet them. As a result, billions of dollars in research and development are required to validate (and sometimes invent) the enabling technologies. All too often, the success or failure of a given approach cannot be determined until the system is actually built, and even a prototype incorporating many advanced technologies may be prohibitively expensive. As an alternative, the SPACECAST team proposes an affordable X-vehicle development program that has clear, near-term military relevance and traceability to an operational system.

Failure to take into account the operational implications of a launch system—not just the launch crew but the support infrastructure for such things as fueling, maintenance, logistics, or basing—has been crippling in terms of cost and the eventual utility of systems. NASP-derived and two-stage (carrier vehicle and space plane) concepts seem particularly vulnerable to this shortcoming, although they still represent an improvement over the huge, archaic, expensive, inflexible, and manpower-intensive procedures required for current lift systems.[16] From the start, operational and infrastructure considerations must have top priority. Space operations must become as routine and nonexotic as air operations.

Black Horse TAVs

To address these concerns, we can assume that maximum performance (in terms of specific impulse for rockets) is not necessary or even desirable. This assumption permits consideration of noncryogenic propellants, which offer several advantages. If these propellants are sufficiently dense, a workable lift system can be designed. The British did so with the Black Arrow and Black Knight programs, using 1950s technology, because factors such as a reduction in tankage volume, a decrease in engine complexity, and an improved engine thrust-to-weight ratio make up for much of the (propellant) performance loss (fig. 2). Interestingly, one of the most attractive combinations of noncryogenic propellants is jet fuel (nominally JP-5) and hydrogen peroxide.[17]

The real attraction of this propellant combination is in the operational arena. The propellants are easily available (hydrogen peroxide is commonly sold for industrial uses at 70 percent purity; vendors could provide higher purities, or the commercial product could be refined on-site), storable, and pose no significant logistics problems. Rocket engines using these propellants also have excellent reliability histories, both on the Black Arrow and Black Knight programs and on the NF-104D research aircraft. The NF-104D program started such an engine (using JP-4 and H_2O_2) at least two times on every flight, experienced no rocket-engine-related emergencies during 11 years of operation, and was serviced and maintained with "essentially conventional maintenance procedures and normally trained personnel."[18] Storage and handling of high-purity H_2O_2 is not inherently dangerous and requires primarily discipline—not extensive safety equipment.[19] The Black Arrow and NF-104D programs routinely used 85–90 percent pure hydrogen peroxide; there are no known chemical reasons why operations with higher purities would be any more difficult. Finally, servicing a vehicle that uses cryogenic propellants requires many more steps (and is thus much slower) than servicing a noncryogenic-fueled (such as JP-5 and H_2O_2) vehicle. Even on the DC-X SSTO demonstrator, which had ease of operations as a design goal, fully 80 percent of the preflight checklist items were cryogenics-related.[20]

If readily available and easily stored propellants are used, the only reasons why a reusable vehicle could not operate from any location would be specialized requirements for assembly/loading, launch, and landing. Although a vertical takeoff and landing system has advantages in terms of empty

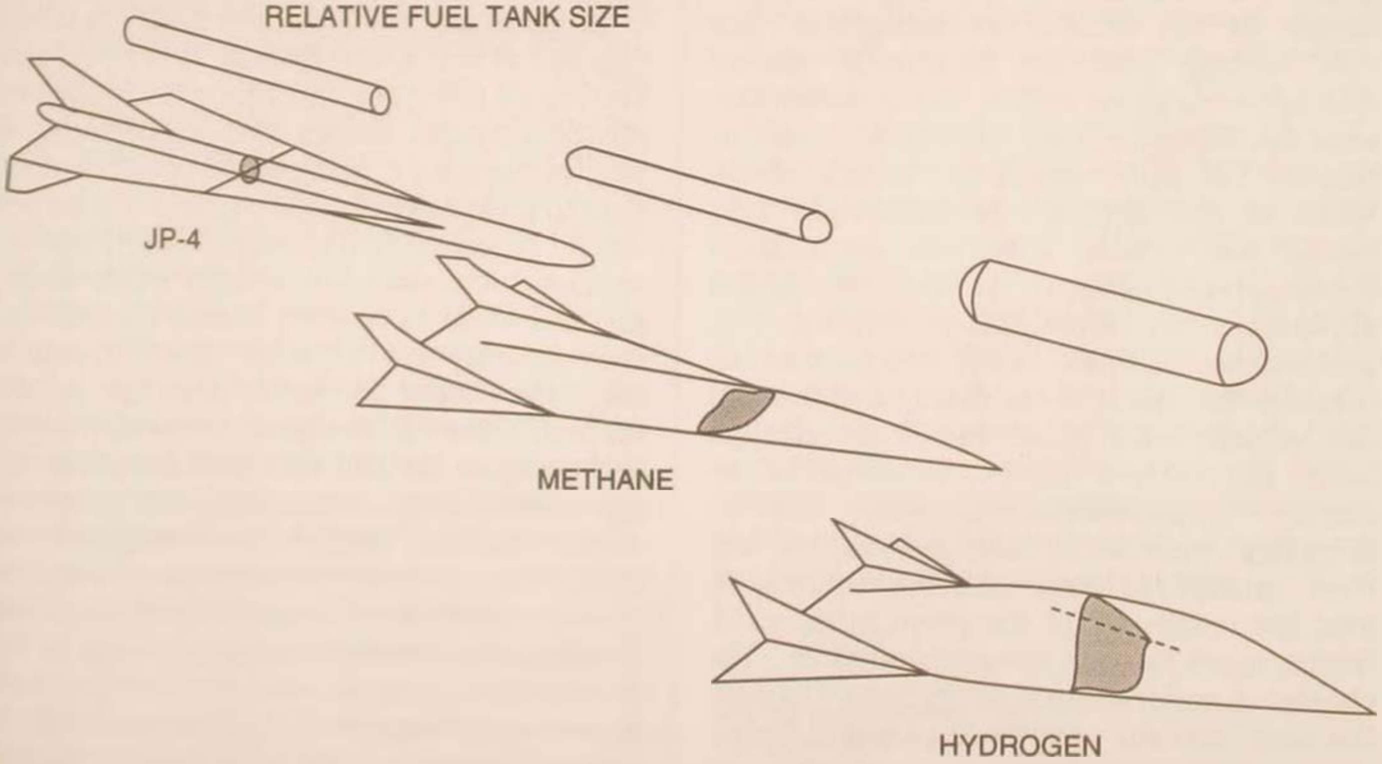


Figure 2. Notional Vehicle Cross Sections for Different Fuels (From Bill Sweetman, *Aurora: The Pentagon's Secret Spy Plane* (Osceola, Wis.: Motorbooks International Publishers and Wholesalers, 1993)

weight and choice of launch/landing sites (theoretically it needs only a small pad), the SPACECAST lift team believes that a horizontal takeoff and landing system is a better near-term approach.

A horizontal takeoff and landing space-launch system has many advantages. First, sufficient airfields are available for any conceivable mission. Second, fuel supplies and logistics infrastructure (crew equipment, administrative support, ground transportation, and maintenance and other ground personnel) are already located at airfields. Finally, a horizontal takeoff and landing vehicle would almost certainly be more robust. Its advantages include a larger abort envelope, the ability to land with all engines out, and greater cross-range on reentry. Although there is a performance penalty associated with this approach (hence, the DC-X design), there is also an ingenious way to compensate for it—aerial propellant transfer.[21]

True SSTO vehicles must lift all the propellant they need to reach orbit from the ground. This in turn drives the gross takeoff weight of the vehicle (including the wing and landing gear for horizontal takeoff and/or landing), as well as the vehicle's size and the engine and structural margins needed for safe takeoff or launch abort. Much of this structure is deadweight long before the vehicle leaves the atmosphere (hence, staged designs). To date, two design approaches have attempted to eliminate this problem for SSTOs: NASP, which is an air breather for much of its flight, and the carrier vehicle/space plane two-stage concept. Both approaches have numerous drawbacks.[22] However, if the TAV can be launched with minimum propellants and then rendezvous with an aerial refueler to load the remainder of the propellants, a different, more flexible design is possible. The choice of noncryogenic propellants is essential here, and the properties of a JP-5 hydrogen peroxide engine (H_2O_2 is almost twice as dense as jet fuel, and the engine operates at a 1:7 fuel-to-oxidizer mix by weight) make it attractive for transferring the bulk of the oxidizer after takeoff.

At least initially, designers have conceived the Black Horse TAV as a manned system. Without addressing whether or not a crew is or always will be necessary, designers have planned for a crew for these reasons: A crew is essential for the initial X-vehicle development program, although that same program could test technologies that would enable later unmanned versions (unmanned aerial refueling, for example); a crew is desirable for several of the suborbital missions described below; and a crew may be desirable for some operations in space. If the vehicle has an austere (U-2-like) cockpit and is not designed for long-duration orbital missions (as will almost certainly be true for the X vehicles), the effects of loss of payload weight will be minimized. The issue of whether manning the system causes unacceptable costs is not a valid concern since this system is not a piece of long-range artillery (e.g., an ICBM) converted for transport use. It is, essentially, a fast, high-flying aircraft with no greater risks to crewmembers than any other developmental system.[23]

In summary, the Black Horse TAV is a new concept of aerospace vehicle. It is not a new version of the space shuttle or NASP and explicitly contains design choices in terms of size, performance, and mission profile to ensure that experiences with those vehicles will not be repeated. Specifically, Black Horse is a small vehicle with low weight when empty and low weight on orbit, factors that historically correspond to cost. Black Horse—at least the initial X-vehicle concept as described below—is designed around existing technologies for full reusability (unlike the space shuttle) and ruggedness at the expense of the highest possible performance. Any comparison to NASP is particularly inappropriate: aside from horizontal takeoff and landing, no similarity exists. Because of the air-breathing engine, the low-density fuel, and the requirement to fly hypersonically in relatively dense air, NASP required multiple technological breakthroughs in propulsion and materials. By comparison, the thermal and structural requirements of Black Horse are much less stringent.

The structure of the Black Horse was designed according to standard aircraft practice. That is, given the factors of maximum propellant off-load from a KC-135 tanker; estimated structural weight (from the volume required to enclose fuel, crew, payload, etc.); and assumed weights for payload, crew, thermal protection, and other subsystems, engineers designed a wing to provide sufficient lift throughout the flight envelope. This design was then iterated to ensure internal consistency. The resulting design has a relatively low structural-mass fraction when compared to that of other orbital vehicles. This is true for two reasons. First, the propellants are substantially denser than "traditional" rocket fuels; thus, the enclosed volume of the vehicle (hence, the structural weight) is low. Second, by transferring the bulk of the propellant, the designers avoid the penalty of sizing the wing, landing gear, and supporting structure for a fully loaded takeoff. This technique results in a savings of 4,200 pounds for the landing gear alone,[24] and essentially makes the concept possible. Critics of the concept have expressed doubts about the numbers, but others—including Burt Rutan of Scaled Composites—have no doubts about the technical feasibility of the structure. Indeed, Rutan believes that the structure could be made even lighter using composites instead of aluminum, as the designers assumed.[25]

Other structural issues include the design of the payload bay and the thermal protection system. Although the payload bay was not designed in detail, additional structure was assumed, based on aircraft requirements for internal cargo or weapons carriage. A thermal protection system of blanket-insulating material and carbon-silica carbide (for the nose and leading edges) with a weight of 1.1 pounds per square foot was included in the design.

The baseline design is for a vehicle weighing 48,450 pounds at takeoff (and 187,000 pounds after aerial refueling), powered by seven rocket engines. Two engines suffice for takeoff and the full refueling profile and are optimized for performance in lower altitudes; the remaining five provide the additional thrust necessary for global reach or orbital insertion.[26]

The performance of the engines and fuel (JP-5 and hydrogen peroxide) was estimated using NASA standard codes and incorporating losses from geometry, finite-rate chemistry, viscous drag, and energy-release efficiency. This results in a specific impulse of 323 seconds for the low-altitude engines and 335 for the orbital-insertion engines.[27] In terms of thrust-to-weight ratio for the engine itself, the performance is no higher than what the British obtained from the Gamma engines (using kerosene and hydrogen peroxide) designed and built in the 1960s. The designers believe that this is a conservative estimate of potential performance.

The final element of the design is the payload deliverable on orbit. This depends on several factors, but—as a figure of merit—the designers chose a 1,000-pound payload in a 35-degree-inclined, 100-nautical-mile circular orbit (due-east launch from Edwards AFB, California, from a refueling track at 40,000 feet and .85 Mach). This assumes, of course, that the TAV also goes to orbit; flying a suborbital trajectory allows a significantly greater payload (6,600 pounds) to be placed in orbit, even after the weight of an upper stage (a 4,765-pound STAR 48V) is subtracted. If weapons or cargo delivery is the goal, 5,000 to 10,000 pounds could be delivered on a suborbital trajectory to almost any point on the globe, using the baseline design.[28] The designers believe that all these numbers can be improved through better engines, lighter dry weight, potential fuel additives, and a bigger vehicle (if so desired for an eventual operational system).

Design Requirements for Weapons Delivery

There are several alternatives for delivering weapons, including the TAV described previously, ICBMs, satellite basing, and intercontinental cannons. The SPACECAST lift team believes that operational flexibility greatly favors the TAV approach.

An appropriately configured version of the TAV can perform both ground- and space-force application missions with near-term technologies. Some key characteristics of the air-refuelable, rocket-powered TAV that are particularly relevant are the ability to operate as flexibly and responsively as an aircraft (with similar operations, maintenance, and logistics infrastructures), an inherently low-observable nature from most aspects (no inlets, blended surfaces), and the ability to conduct manned missions. The vehicle can also exploit the advantages of space basing (low reaction times and high energy states) with far greater operational flexibility and additional defensive capabilities to survive future threats. Although the ideas presented here were conceived independently, this concept is not new. Several other studies recommend similar vehicles.[29]

The system must have specific characteristics to accomplish the force-application mission. First, it must be able to launch from a quick-reaction alert status. This ability enables the short response times critical to the success of any future weapon system. The Black Horse TAV is capable of fulfilling this requirement in large part because of its use of noncryogenic fuels.

Second, the vehicle must be designed to incorporate modular weapon systems sized to fit the payload bay of the TAV. This concept allows use of the vehicle for a variety of military missions, from force enhancement through force application, thereby increasing cost-effectiveness. The TAV should be hard-wired to provide necessary infrastructure requirements (for example, basic power and communication links) to the module while the module reports fault/degradation information to the operator or controlling computer on the TAV. Note that these interfaces would not be significantly different from those required to launch a satellite. The largest part of the necessary weapons-delivery infrastructure should be designed, as much as possible, into the clip-in module rather than the carrier vehicle.

The idea of weapon modules serves several purposes. With this approach, the vehicle is able to accomplish force-enhancement missions until it is needed for weapons delivery; in other words, it is rapidly reconfigurable for different missions. In addition, the weapons modules can be preloaded with "wooden rounds," stored until needed, and then quickly loaded on the vehicle. Maintenance or upgrades can be performed on the ground-based weapons, ensuring maximum reliability and capability. Finally, the module concept offers quick reloads, which facilitate rapid turn-times and sustainability. By analogy with current dispensing systems, the deliverable payload should be approximately 75 percent of the vehicle's total payload capacity.[30]

Third, for survivability and maximum offensive potential, the vehicle must have global reach from a suborbital flight path. Global reach provides operational flexibility while allowing the vehicle to launch and recover from secure areas. The suborbital requirement contributes to self-protection tactics. Additionally, since the suborbital flight path requires less propellant than does orbital insertion, greater weapon loads than those for orbital payloads should be possible. Since weapons will generally be denser than spacecraft, this should mean that an efficient, multipurpose, payload-bay design is possible. Again, the Black Horse TAV satisfies this requirement.

Fourth, the TAV must allow rapid turnaround to follow-on missions. This maintains the initiative and offensive advantage for the CINC and allows rapid follow-on targeting. It is unrealistic to assume that the military will have enough vehicles to engage all possible target sets with a single mass launch. Actual requirements for turnaround times will depend on the number of vehicles, the payload capacity for each, the number of aiming points, and the threat. Any attempt to fix a hard number in relation to these requirements requires some detailed operations analysis, but a 12-hour cycle rate seems a reasonable minimum. The TAV and associated aircrew-to-airframe ratios should meet this requirement.

Fifth, the system should maximize the use of existing military infrastructure. This requirement is levied to allow launch and recovery from the widest possible number of bases, which—in turn—provides some measure of survivability through dispersion and mobility. The TAV provides a limited solution to this requirement and is restricted only by airfield length/capacity and refueling support.

Sixth, the issue of designing this vehicle for humans is important only in the near term. Technology has not progressed to the state whereby a computer can replace humans in all operations—specifically, those in unpredictable environments or in degraded equipment modes. The SPACECAST lift team recommends designing early vehicles for human operators. Although such a design will result in higher weight and lower G capability (the latter is probably not an issue for typical mission profiles), a human operator allows for rapid, autonomous (in accordance with the commander's intent) decision making when confronting the technologically advanced threat of the twenty-first century. When the database is developed and hardware and software technologies are sufficiently proven, human operators theoretically could be removed from the vehicle. Virtual reality is not a solution in the interim. Communications links are vulnerable to an advanced enemy, who could jam or exploit them. Taken together, all these reasons argue that human pilots and human systems operators will continue to provide significant advantages—at least in the near term.

Finally, payload size may be a limiting factor in some specific employment scenarios. SPACECAST believes that the Black Horse TAV concept offers sufficient payload potential to perform a number of militarily useful missions. As mentioned earlier, a TAV capable of putting itself and 1,000 pounds of payload on orbit can deliver significantly more payload on a suborbital trajectory; further, the significant growth potential in the basic design (sizing the vehicle around the fuel off-load from a tanker larger than the KC-135, for example) could lead to larger deliverable payloads.

Weapons Options

Three classes of weapons are appropriate for this vehicle: kinetic-energy, high-explosive, and directed-energy. In general, all weapons should be palletized or containerized to ensure maximum flexibility in switching missions and to allow incremental upgrades and maintenance while the weapons are in storage.

In summary, a TAV capable of employing modular military payloads would provide the United States a sustained counterforce capability for use against a wide variety of targets defended by increasingly capable threats.

On-Orbit Operations Vehicles

As mentioned earlier, the ability to maneuver payloads on orbit provides enhancements to any lift system. This section addresses some general issues but does not assume the use of any specific vehicle design (for example, the STV of NASA's Marshall Space Flight Center) or associated operations concepts. In other words, SPACECAST is not advocating that on-orbit operations vehicles be tied to any specific satellite architecture. However, the lift team does recognize that trade-offs will be an integral part of any decision to pursue on-orbit operations vehicles (i.e., Is it better to repair/service/upgrade a particular satellite or replace it?).

Two key issues are important to this concept: the utility of reusable on-orbit transportation systems and the utility of on-orbit satellite servicing and repair. With regard to transportation systems, a study by the Directorate of Aerospace Studies (DAS) of Air Force Systems Command (now Air Force Materiel Command) in 1989 identified two basic vehicle configurations or capabilities: an orbit transfer vehicle (OTV) for moving things from LEO to higher orbits and an orbital maneuvering vehicle (OMV) for moving things around within a designated orbit and docking with and servicing satellites. This architecture is superior to the current approach (expendable upper stages and/or propulsion systems integral to the spacecraft bus) for several reasons. Expendable upper stages are, by definition and design, thrown away after use and become "space junk." More importantly, however, although unit costs of expendable systems are less than those of reusable vehicles, reusable systems are "generally less expensive on a per mission basis" over their lifetime.[31]

The DAS study also addressed the issue of whether or not it is more advantageous to use an on-orbit transportation capability to service and/or repair satellites or to continue fielding expendable satellites. As expected, there is no clear answer. On the one hand, the authors of the study conclude that "it is reasonable to believe that there will be future circumstances which offer cost advantages to repairable satellites."[32] On the other hand, the analysis was sensitive enough to the estimated characteristics of future satellites (e.g., mission duration, mass, cost, subsystem reliability, and launch costs) that the results were not conclusive for all satellites in all orbits. In general, satellite repair becomes more attractive as constellation size and satellite mass, cost, and mission duration increase and as launch costs and satellite reliability decrease. It is much more attractive from a cost standpoint if satellites use modular, standardized/common subsystems.

The utility of reusable on-orbit transportation systems for satellite servicing and repair in 2020 depends heavily on the types and quantities of satellites in orbit at that time, as well as on the capabilities and costs of US launch systems. Given our assumptions of increasingly capable small packages and the ability to put them responsively on orbit, it is not at all clear that either repair or resupply of existing satellites is an attractive mission. On the other hand, if smaller but more cost-effective launch vehicles make on-orbit assembly and fueling of larger satellites desirable, many of the technologies discussed below will be needed. Ironically, the present large-satellite paradigm and its associated high cost-per-pound to orbit prevent testing the on-orbit repair concept.

Operations Concept

The TAV would be readied for flight at an aerospace base differing from an air base only by the H_2O_2 storage and first-level maintenance equipment, all of which could be deployed. It would be fueled with 100 percent of its JP-5 and approximately 7 percent of its H_2O_2 capacity. It would then be loaded with its payload, taxi and take off, rendezvous with a tanker and load the entire tanker's capacity of H_2O_2, turn to the correct heading, and depart for orbit. The time from push-back to orbit would be less than an hour.

After completing its orbital mission, the TAV would deorbit and return to its own or any other suitable base—again, a very short process. A suborbital mission would be similar, and there would probably be no need to refuel before returning to base. Turnaround time is somewhat speculative at this point (the X-vehicle program would provide an answer), but a preliminary look at the technologies (rocket engine, thermal protection, etc.) suggests it will be a matter of hours or—at worst—no more than days. Unlike the space shuttle, the TAV would be designed so as not to require extensive refurbishment between flights.

Two technical areas are key to the ability to "turn" the TAV quickly: thermal protection and engines. For the former, the combination of the aerothermal environment (less stressful than that for the space shuttle, due to Black Horse's low wing loading and deceleration high in the atmosphere) and advances in materials since the space shuttle was designed should make a fully reusable system possible. For the engines, the AR-2 used on the NF-104D provides a baseline: it routinely operated with two hours of firing time (and numerous restarts) between overhauls[33]; the Black Horse designers believe that an improved design could do better. Although one of the purposes of an X program would be to test the limits of reusability of a TAV, the SPACECAST team does not believe there are any showstoppers here.

This concept will provide vastly increased flexibility and responsiveness in launching spacecraft and performing suborbital missions, tremendously reduced operations and logistics infrastructure compared to other lift concepts, increased reliability, suitability for manned flight, and significantly reduced cost of space launch. It also builds on aerial refueling—currently an operational strength of military aviation, performed hundreds of times a day—versus airborne separation of large manned vehicles, performed only a few hundred times in history in the development of new space-launch capability. A squadron of eight Black Horse vehicles, each flying only once per week, would provide access to space *hundreds* of times per year, making space operations truly routine.

A Threat-based System

Future threats to the United States would have a far greater effect on offensive operations than would current threats. Several types of threats are possible: hostile satellites, ground- and space-based directed-energy weapons, ICBMs, third world nuclear weapons, and other weapons of mass destruction. An armed TAV could negate future threats through a combination of countermeasures, tactics, and survivable basing.

First, the construction of the vehicle should include as many low-observable techniques as possible. Although today's low-observable technologies will gradually lose their utility, they will force adversaries to confine defensive systems to particular (and therefore predictable) techniques. They have the further benefit of reducing the detection envelope of enemy acquisition systems and therefore making the adversary's targeting problem more difficult.

Second, this system permits the use of onboard, active defensive systems. By using a suborbital trajectory during the attack profile, a TAV may use such disposables as chaff, flares, towed decoys, and active defensive munitions to defeat weapon systems without creating hazardous space junk. The design of the operational TAV could also accommodate modular electronic countermeasures (ECM) systems—weight and power budgets permitting.

Third, the TAV concept permits surprise. Even if an adversary has spies operating in the vicinity of airfields or if commercial media satellites detect operations in progress or if the enemy detects unusual launch activity, the specific aiming points, axes of attack, and timing of attack are less easily predictable. Launch to a single, suborbital weapons-delivery pass followed by reentry and landing compresses the time the adversary has to respond—especially an adversary with neither space-surveillance capability nor intercontinental-launch detection. The enemy has minutes to observe the mission, assess intentions, make the appropriate decision, get the defensive capabilities in place, and complete the intercept. Multiple, simultaneous, inbound trajectories compound surprise.

Fourth, the inherent flexibility of a TAV enhances unpredictability. Again, the single suborbital pass serves as an example. Since the vehicle starts from ground alert, the enemy cannot predict the mission's time over target. The vehicle's ability to establish a variety of suborbital trajectories, as well as approach the target from differing orbital planes, also confounds the adversary's predictive ability and may negate many of his defensive systems.

Fifth, a squadron of TAVs translates into mass. The United States will more than likely have a small fleet of these reusable vehicles. The ability to mass several vehicles from single suborbital passes at the time and place chosen by the CINC allows the commander to overwhelm the enemy's defensive systems as well as concentrate the appropriate amount of firepower to achieve required effects. In the absence of great numbers of vehicles, the same mass effect is maintained through the ability of each vehicle to deliver a large number of weapons.

Sixth, assuming the existence of an appropriate family of weapons with sufficient crosstrack (to the sides of the delivery vehicle's trajectory), the TAV will have standoff capability. Thus, the vehicle can release its payload outside the range of many possible threat systems.

Seventh, several vehicles working in concert can use advanced countermeasures as well as suppress threats for each other. The clip-in module for one vehicle, for example, might be a countermeasures suite, while the clip-in modules for other vehicles in the flight would be weapons.

Finally, TAV bases can easily be dispersed. Although threat systems surely will have the ability to find and target aiming points in the United States by the year 2020, their capabilities can be reduced through dispersion of the TAVs to a wide number of bases, through mobile operations, and through good deception plans. (An enemy's problem would be compounded if a large number of commercial TAVs also exists.) Any attempt to force this system to consolidate operations at a single, fixed location would be unnecessary and should be resisted because it obviously provides the adversary a fixed, high-value target. Logistics concerns can be adequately addressed by designing a vehicle that shares existing aircraft infrastructure to the maximum extent possible.

In summary, the ability of the TAV to accomplish its weapons-delivery mission from a single suborbital pass, while using both passive and active countermeasures, compresses the adversary's decision loop and results in increased survivability. The addition of low-profile basing complicates the threat's targeting problem and ensures that fewer assets are placed at risk during enemy attack. This combination results in a survivable system able to fight in the high-threat environment of the twenty-first century.

On-Orbit Operations

To a large extent, the types of operations performed on orbit will be determined by the capabilities that new vehicles provide, whether OTV, OMV, or TAV. Orbit-transfer vehicles could reduce the need for upper stages on launch systems and increase the amount of payload delivered to orbit. Maneuvering vehicles could provide some repositioning or on-orbit shuttle capabilities, a function that would help make orbital operating bases (space stations) functional. Both of these vehicles will facilitate on-orbit maintenance and upgrades to extend satellite lifetimes and combat technological obsolescence.

Even the TAV has implications for orbital operations. Besides capturing satellites and returning them to earth, the TAV may be the best means of changing a satellite's inclination. Assuming it is not easier to launch a new satellite to the relevant orbit, the TAV could go to orbit without cargo (to conserve fuel), capture a satellite, reenter, perform an aerodynamic maneuver to align itself with the new orbit (perhaps in extreme cases, even refueling again), and then return the satellite to space. Although the Black Horse studies to date have not included calculations of the fuel required for on-orbit rendezvous, this is a potential mission if the vehicle does not go to orbit fully loaded; unlike shuttle operations, launching an empty vehicle would not be a cost-prohibitive operation.

Links to Other SPACECAST Areas

The concept of the TAV connects many SPACECAST proposals. The logistics of space lift with a militarily capable TAV are now linked to the proposal on global view. This combination uses the proposed architecture to identify and pass coordinates of critical targets to the TAV prior to its weapons-release point, cutting to an absolute minimum the time from initial target detection to destruction. This ensures that the TAV uses the most effective targeting intelligence to gain the greatest possible strategic effects.

SPACECAST's proposals for force application address various weapons and their suitability. The TAV offers a platform for their use with significant military advantages over other techniques, such as satellite basing. System architectures are compatible with the weapons-delivery vehicle. Finally, proposals for offensive counterspace benefit from a TAV-based weapon system that could use directed-energy weapons without our building, deploying, operating, and defending an orbiting "battlestar."

Other linkages include the ability of the vehicles described here to support the "motherboard" satellite concept described in SPACECAST's space modular systems proposal, as well as the utility of a space traffic control system in accommodating both the TAVs and increased on-orbit activity. Finally, many of the concepts in SPACECAST depend heavily on improving and reducing the cost of access to space—the heart of the concept of the Black Horse TAV.

Potential Technologies

Although a working TAV in the form of an X vehicle can be built with existing technologies, improved technologies and/or supporting capabilities will enhance performance in several areas.

Structures

The initial study on the feasibility of an aerial-refueled space plane[34] concluded that an F-16-sized X-vehicle TAV built according to standard fighter-aircraft design criteria and incorporating aluminum structures could place itself, a crew, and 1,000 pounds of payload into orbit. However, further analysis of structural requirements and application of modern design techniques and materials could significantly reduce structural weight. As mentioned earlier, Burt Rutan of Scaled Composites believes that this possibility is within current design and fabrication capabilities. Since Black Horse is a single-stage-to-orbit vehicle, every pound of dry weight saved is an extra pound of payload.

Engines

The same study baselined an engine no more sophisticated or efficient than the one used by the Black Arrow/Black Knight program (1950s technology).[35] A modest development program could certainly improve this level of performance (efficiency and thrust-to-weight ratio) while improving reliability and maintainability. Further, a hybrid engine such as a ducted rocket[36] (admittedly a separate development program) could offer both increased performance and reduced noise—both potentially critical factors for widespread commercial use of TAVs.

Propellants

Although the intent of the program is to stay away from exotic or hazardous materials, certain options increase specific impulse without sacrificing operability. Some possibilities are fuel additives such as quadricyclene, denser hydrocarbons (JP-8 or -10 instead of JP-5), or—in the far term—high-energy-density substances such as metastable fuels. As long as the fuel continues to meet operability and logistics concerns, this area has tremendous potential payoff. An increase of one second in specific impulse would increase payload on orbit by 128 pounds for the initial Black Horse design.[37]

Thermal Protection System

The feasibility study mentioned above baselined durable tailored advanced blanket insulation (DuraTABI) material, which weighs 1.1 pounds per square foot, for area ("acreage") coverage and carbon-silica carbide (C/SiC) for the nose, wing, strake, and rudder leading edges. Detailed aerothermodynamic reentry calculations may indicate a less stringent requirement for thermal protection than was assumed in the initial design, possibly even allowing an all-metal skin (Rene 41 or Iconel 617). On the other hand, retaining excess thermal protection—perhaps by applying more advanced thermal protection systems—could give the vehicle a larger reentry envelope and even more operational flexibility.

Refueling Vehicle

Designers sized the TAV around the maximum amount of propellant that a single KC-135Q could transfer. These aircraft are in the inventory and already have separate aircraft fuel tanks and off-loadable propellant tanks. Thus, they would require minimum modification. The availability of a modified KC-10 or large commercial aircraft derivative to off-load H_2O_2 would greatly increase the potential size and payload of the TAV without significantly changing (except perhaps to reduce) the cost-per-pound to orbit. Although this is more a programmatic than a technical issue, there are potential areas for investment in higher-capacity pumps and perhaps a dual-tube boom refueling system to transfer both fuel and oxidizer at once.

On-Orbit Operations Vehicles

As mentioned earlier, on-orbit operations vehicles complement most lift concepts. These vehicles have distinct technology development, demonstration, and validation needs.

Technologies required to implement on-orbit operations architecture include high-efficiency, reusable, space-propulsion systems. Cost, performance, and operational-utility analyses are needed to select from among the various potential technologies. Candidates include conventional chemical, electric, nuclear, and solar-thermal propulsion systems. Issues to be addressed would include power sources for electric propulsion concepts; radiation shielding, high-temperature materials, launch safety, and waste disposal for nuclear-propulsion concepts; solar concentrator fabrication and high-temperature materials for solar-thermal propulsion concepts; and long-life performance/reliability demonstrations for all concepts.

The on-orbit operations vehicles will require robotics for docking, grasping, repair, and resupply operations and/or telepresence/virtual reality/artificial-intelligence technologies in some combination for on-orbit operations. Planners need analyses to determine the extent to which humans must participate in repair/servicing operations. Considering the technologies expected to be available in 2020, planners need to know what tasks can be done only by human beings, what tasks can be done remotely with humans in the loop, and what tasks can be done autonomously. Artificial-intelligence technologies could reduce the requirement for human-in-the-loop operations in circumstances in which this would be difficult or present technical challenges. Again, this requires further analysis.

Spacecraft design would have to change significantly to obtain maximum utility from the TAV concept. Docking operations would require some degree of spacecraft bus standardization. Refueling operations would require standardization of the propellant-feed system. Such design approaches as standard spacecraft buses and standard, modular, miniaturized subsystems and interfaces would facilitate repair/upgrade operation. External structures such as solar arrays and antennae might have to fold to withstand the accelerations associated with high-impulse spacecraft maneuvers or to stow the spacecraft in the bay of a TAV for redeployment. It is important to note that many of these changes will happen with or without the development of on-orbit servicing. They are driven by the need to reduce the costs and timelines associated with the earth-to-orbit segment of the transportation system.

OTVs may need supporting "bases" in certain critical locations. For transportation to high-altitude, low-inclination orbits, unmanned coinclination platforms in LEO would serve as cargo-transfer and jumping-off points for OTVs. Orbits containing large numbers of higher-cost satellites or fewer extremely expensive satellites would require co-orbital, unmanned platforms where OTVs could transfer payloads to OMVs for final orbit insertion or docking/repair.[38]

Near-Term Technologies and Operational Exploitation Opportunities

Designers can use existing and proven technologies—aluminum structure and DuraTABI thermal protection—to develop and fly an X vehicle to demonstrate the feasibility and operational utility of the Black Horse. As an interim step, existing AR-2 engines could be used to fly the vehicle through all of its atmospheric flight profile, testing handling, formation flying, refueling, and suborbital trajectories, while a concurrent engine-development program produces the higher-performance engines needed to reach orbit. The basic concept is for a crewed vehicle approximately the size of an F-16 (but with only 70 percent of its dry weight) that could take off from and land on virtually any runway, load the bulk of its propellant (all oxidizer) from a KC-135Q (or T) tanker at approximately 40,000 feet and Mach 0.85,[39] and then carry out an orbital or suborbital flight. An experimental program could allow testing of the TAV as the US has tested aircraft for decades, with a gradual expansion of the performance envelope to meet the necessary objectives.[40]

The primary areas for design and development are the vehicle aerodynamic configuration, higher-performance rocket engines, and the vehicle structure. A study by W. J. Schafer and Associates and Conceptual Research Corporation[41] indicates that there are no technological roadblocks in this area and that a vehicle could be designed and tested with existing technologies, although there is room for improvement using advanced materials.

Areas that require some careful design work but no technological breakthroughs are the need for thermal protection, the need to cycle landing gear through the thermal protective surface, and the use of structural composites. It therefore appears that an X-vehicle program could proceed *with existing technologies.*

Although cost is not the single driving issue in this study, several comparative estimates of a two-TAV, 100-flight (including orbital) X-vehicle program suggest that the military could conduct such a program for a reasonable amount of money. Using actual X-29 and X-31 cost data, the Question Mark 2 TAV X-program would cost about $78 million (M). A cost model for the Lockheed Skunkworks program yielded $96M. The Rand Corporation Development and Procurement Costs of Aircraft (DAPCA) IV model gave a total program cost of $118M. Finally, a cost estimate by an Aerospace Corporation analyst came up with $120M.[42] Although these are rough estimates and although a vehicle of this type has never been built before, the fact that differing methodologies independently came up with similar numbers is somewhat encouraging.

Initial estimates, using a cost model based on actual expense data for the SR-71, suggest that a Black Horse vehicle could place payloads into LEO at a cost of less than $1,000 per pound (the model yields costs between $50 and $500 per pound, depending on assumptions), with a per-sortie cost of around $260,000 and an annual operating budget for an eight-TAV unit (with support) of approximately $100M. This model may be particularly appropriate because the operations of an air-refuelable TAV and the SR-71 would be similar in several ways, not the least of which is use of the same tanker. The model includes—and is sensitive to—overhead costs (assumed to be the same as for the SR-71), number of vehicles and sorties, payload (assumed to be 1,000 pounds), and fuel costs. A key point is that this system is not "cheap" to operate relative to most aircraft; in fact, the numbers are comparable to SR-71 operating costs. The cost-per-pound to orbit, however—even under fairly pessimistic assumptions (smallest payload, relatively few flights, and high nonflying-operations cost)—is still quite low, compared to that of other launch systems. Perhaps this shows just how expensive our current space operations really are (at $10,000 per pound to orbit and up) and how large the potential for improving that figure is with reusable launch vehicles. Cost-sensitive basing schemes and logistics concepts—such as the USAF's "Rivet Workforce," which consolidates maintenance skills—could further reduce recurring operations-and-maintenance costs.

On-Orbit Operations

There are several near-term programs that would expand our ability to provide on-orbit services. These include the space surveillance tracking and repositioning (SSTAR) experiment (formerly called the electric insertion transfer experiment [ELITE]), an Air Force–TRW cooperative research-and-development agreement, a potential flight test of the ex-Soviet TOPAZ nuclear reactor, and the space nuclear thermal propulsion program. These deal primarily with propulsion systems but—particularly in the case of SSTAR—also with supporting technologies such as navigation, autonomous operation, and potential mission-oriented payloads. Unfortunately, all of these programs have suffered funding setbacks and are on hold or in danger of cancellation.

Commercial Opportunities

Cheap, reliable transport to, from, and through space offers innumerable possibilities.[43] It is the enabler for everything anyone does in the future in space. All of the technologies and techniques described above have potential commercial application, but a prescription for their use is beyond the scope of this study. Instead, this article highlights some of the opportunities they may create and reasons why a robust commercial space market is ultimately essential for government use of space.

Cheap space lift is a market enabler that will open up the use of space for things not currently practical or even anticipated. Some obvious possibilities include the extremely rapid delivery of people and cargo from one point on the earth to another, while the ability to carry passengers safely and at a reasonable cost could open a new market for space tourism. Availability of technology that enables the economical use of space will, in turn, spur development of a true commercial market for all things related to spaceflight and operations. This will eventually drive the real cost of access to and operations in space down even further, as jet transport has done in the commercial aviation market.

If US manufacturers of launch vehicles pursue innovative technologies with true market-creating potential, they could find themselves in a globally dominant position, just as the US aircraft industry did following the introduction of the Boeing 707 and the DC-8. Dramatic expansion of the market for space transport, which will not happen without dramatic reductions in the cost of space access, is also absolutely necessary if the US launch industry is to remain commercially viable. The alternative is to risk becoming like the current US shipbuilding industry. Increasingly inefficient and shrinking, this industry is unable to compete with low-cost and/or subsidized foreign producers and stays alive only because of government subsidies.

Government support in the initial stage of development is vital. The market for space is not large enough to drive the kind of productive and creative explosion in space-related hardware that has occurred in electronics, for example. The main prerequisite for this market—rapid, reliable, affordable space lift—is missing. Government and the military, whose performance requirements for launch on demand are the most stressing now, must take the lead in this area and produce the technological/operational breakthrough that will enable expanded future exploitation of space and the development of a large market to unleash the powers of commercial development. Industry cannot and will not make the investments needed for such breakthroughs on its own. It faces a market similar to that for air transport prior to the introduction of the DC-3, while development of a TAV will require an effort much like the one that produced the first jet transports. Development of jet transports would not have been possible without government investment in jet-engine technology and large aircraft (e.g., the B-47 and B-52), despite an air-transport market that was already fairly large.

Summary

The core concept of this article is the Black Horse TAV. The initial reaction of most people to the concept is, It sounds great, but if it would really work, why hasn't anyone thought of it before? There is no simple answer to this question. The United States did flirt with transatmospheric vehicles in research and X-vehicle programs but decided in favor of expendable boosters because of a combination of materials limitations, engine-performance requirements, and other technical factors, coinciding with rapidly increasing satellite weights. It seemed that only large boosters could put the required payloads in orbit. The rocket community discarded noncryogenic propellants for similar reasons. The rocket equation dictates that noncryogen-fueled vehicles have a propellant mass fraction of about 95 percent; cryogens reduce this to about 90 percent. Since all the structure, as well as the payload, must fit in the remainder, vehicles fueled with noncryogens did not seem able to orbit useful payloads.

Since then, however, much has changed. Miniaturization and other technologies now allow smaller satellites to do more than they once could, while large, complex systems have become increasingly unaffordable. In other words, it is now possible to get away from the tyranny of the payload and think first about designing a launch vehicle for operability and even cost, and then building satellites to fit it. In turn, by assuming a reduced payload requirement; adding 20 years of additional knowledge in materials science, structural design of aerospace vehicles, and lifting-body research; and recognizing that the greater density of noncryogenic fuels compensates somewhat for their reduced performance, the outline of a TAV concept begins to emerge. The final key element is the transfer of aerial propellant.[44] Putting air refueling together with the other elements—in many ways a classic example of what John Boyd calls "destructive-creative" thinking[45]—led to the Black Horse concept.

Black Horse vehicles have the potential to revolutionize the way the military (and perhaps eventually the commercial world) uses and even thinks of space. They are true aerospace vehicles, with tremendous operational implications. A first-cut analysis indicates not only that the concept is feasible, but also that it can be done with no new technologies. We must now perform a more rigorous and detailed design and then press ahead with a Question Mark 2 X-vehicle program to validate the system.

Notes

1. The name *Black Horse* has multiple origins. It is first a tribute to the British Black Arrow and Black Knight programs, which demonstrated the basic propellant concept many years ago. The name also is a link to the SR-71 Blackbird, which provides the tanker aircraft and the basis for the operations-cost model. These connections are explained in more detail later in the article. The *Horse* part of the name honors an animal that has carried cargo and people in peace and in war. Finally, *Black Horse* sounds a lot like *dark horse*, which is certainly true of this system in the launch-systems race.

2. In honor of the first aircraft to demonstrate aerial refueling. Thanks to Dr F. X. Kane for reminding us of the lineage of experimental programs and for suggesting this name.

3. For example, much monolithic satellite design (sizing, folding/deployable elements, and so forth) is based on making maximum use of a single launch-vehicle envelope. In contrast,

under this approach, a prewired structure, solar panels, subsystem modules, and payload modules could be designed with relatively simple, quick-connect interfaces (work on the space-station assembly process would probably be used here) for manual or automated assembly. Active structural control would ensure that necessary alignment tolerances were met after assembly.

4. See, for example, Air Force Mission Need Statement 202-92, *Military Aerospace Vehicles.*

5. The "Visions" study of the US Air Force Space and Missile Systems Center (SMC/XR), for example. Almost all space panels conclude that space lift is the critical element in developing space applications.

6. Hon Sheila E. Widnall, secretary of the Air Force, speech to the National Security Industrial Association, 22 March 1994.

7. Ibid. This situation is often referred to as "the tyranny of the payload."

8. Senate Armed Services Committee, statement of Gen Charles A. Horner, CINC, United States Space Command, 22 April 1993.

9. DOD Space Launch Modernization Plan, April 1994.

10. Ibid. See also "Space Traffic Control: The Culmination of Improved Space Operations," in *Spacecast 2020,* vol. 1 (Maxwell AFB, Ala.: Air University, June 1994), D-1.

11. See the Vice President's Space Advisory Board, "The Future of the US Space Launch Capability: A Task Group Report," November 1992 (the Aldridge report) for cost goals for Spacelifter. Other sources (cited in Air Force Institute of Technology alternative lift briefing) generally give higher costs-per-pound to orbit for the small, expendable lift systems than for large expendables.

12. Aldridge report, NASP studies, Delta Clipper studies.

13. Edward C. Aldridge, interview with author during first Advisory Group visit, January 1994.

14. For example, the Defense Advanced Research Projects Agency's (DARPA) Advanced Space Technology Office has produced several articles on the capabilities, operational benefits, and potential cost savings of small, modular satellites.

15. Horner; Widnall.

16. Operations costs for Kennedy Space Center, Florida, and Vandenberg AFB, California, run into billions of dollars per year, and it takes weeks to months to refurbish a launchpad following a launch for the next event.

17. Clapp and Hunter, "A Single Stage to Orbit Rocket with Non-Cryogenic Propellants."

18. Ibid.

19. David Andrews, "Advantages of Hydrogen Peroxide as a Rocket Oxidant," *Journal of the British Interplanetary Society,* July 1990. See also "Propellants for Supersonic Vehicles: Hydrogen Peroxide," Project Rand, RA-15046 (Douglas Aircraft Company, 12 August 1947).

20. Capt M. Clapp, DC-X crew member, interview with author, January 1994.

21. Of course, this technique is not limited to horizontal takeoff and landing vehicles; it was even considered for the Apollo mission, according to Dr F. X. Kane. However, a winged horizontal takeoff and landing vehicle offers the best performance match (hence, the least expensive option) to existing tanker assets.

22. For NASP, drawbacks include structural design and materials problems due to sustained hypersonic air-breathing flight, fuel tankage, and engines. For carrier/orbiter concepts, they include a large, expensive, unique carrier vehicle with considerable development costs of its own.

23. The environment in which a TAV must operate is no more hostile to human life than the environment in which a U-2 or TR-1 routinely operates.

24. Conversation with Capt M. Clapp, USAF Phillips Laboratory, May 1994. The number comes from the rule of thumb that landing gear will weigh approximately 3 percent of gross takeoff (or landing, whichever is greater) weight.

25. Ibid.

26. Full details are contained in the paper and briefing from W. J. Schafer and Associates and Conceptual Research Corporation, January 1994.

27. Ibid.

28. Briefing, USAF Phillips Laboratory (Capt M. Clapp) to SPACECAST team, Maxwell AFB, Ala., 29 April 1994. Performance numbers and flight profiles were validated using NASA's Program to Optimize Simulated Trajectories (POST).

29. *Project Forecast II* (U), 6 vols. (Andrews AFB, Md.: Project Forecast II Office, June 1986); Mission Applications Document (22 July 1990); and Force Applications Study (13 June 1991).

30. Technical Order 1-1M-34, SUU-64/B, *Tactical Munitions Dispenser,* 31 May 1991, 1-110.

31. DAS-TR-89-1, *Comprehensive On-Orbit Maintenance Assessment (COMA)* (Kirtland AFB, N.Mex.: Directorate of Aerospace Studies, 31 March 1989), 61.

32. Clapp interview.

33. Briefing, Rocketdyne, subject: NF-104D Program, undated (on file at Phillips Laboratory).

34. Paper and briefing from W. J. Schafer and Associates and Conceptual Research Corporation.

35. The design assumes an injector that is 98 percent efficient, for example. Current engine designs (the main engine of the space shuttle, for example) achieve 99.8 percent efficiency.

36. A ducted rocket uses the combustion and exhaust mechanisms of a conventional rocket but gets its oxidizer (atmospheric oxygen) by using air intakes instead of an onboard supply. This has particular advantages at lower altitudes and speeds. Martin Marietta Corporation, among others, has design concepts for this type of system.

37. Based on Phillips Laboratory parametric studies.

38. AFSC/DAS study.

39. According to figures in the KC-135Q "Dash-1," the tanker will be volume constrained (not by weight or center of gravity) in the amount of hydrogen peroxide it can carry. This restriction results in a maximum load of about 147,000 pounds. The entire amount can be transferred in approximately 11 minutes. The KC-135Q off-load rate is 1,200 gallons per minute, and since hydrogen peroxide (at 11.92 pounds per gallon) is substantially denser than jet fuel, this results in a propellant-weight transfer of about 14,300 pounds per minute.

40. Clapp and Hunter.

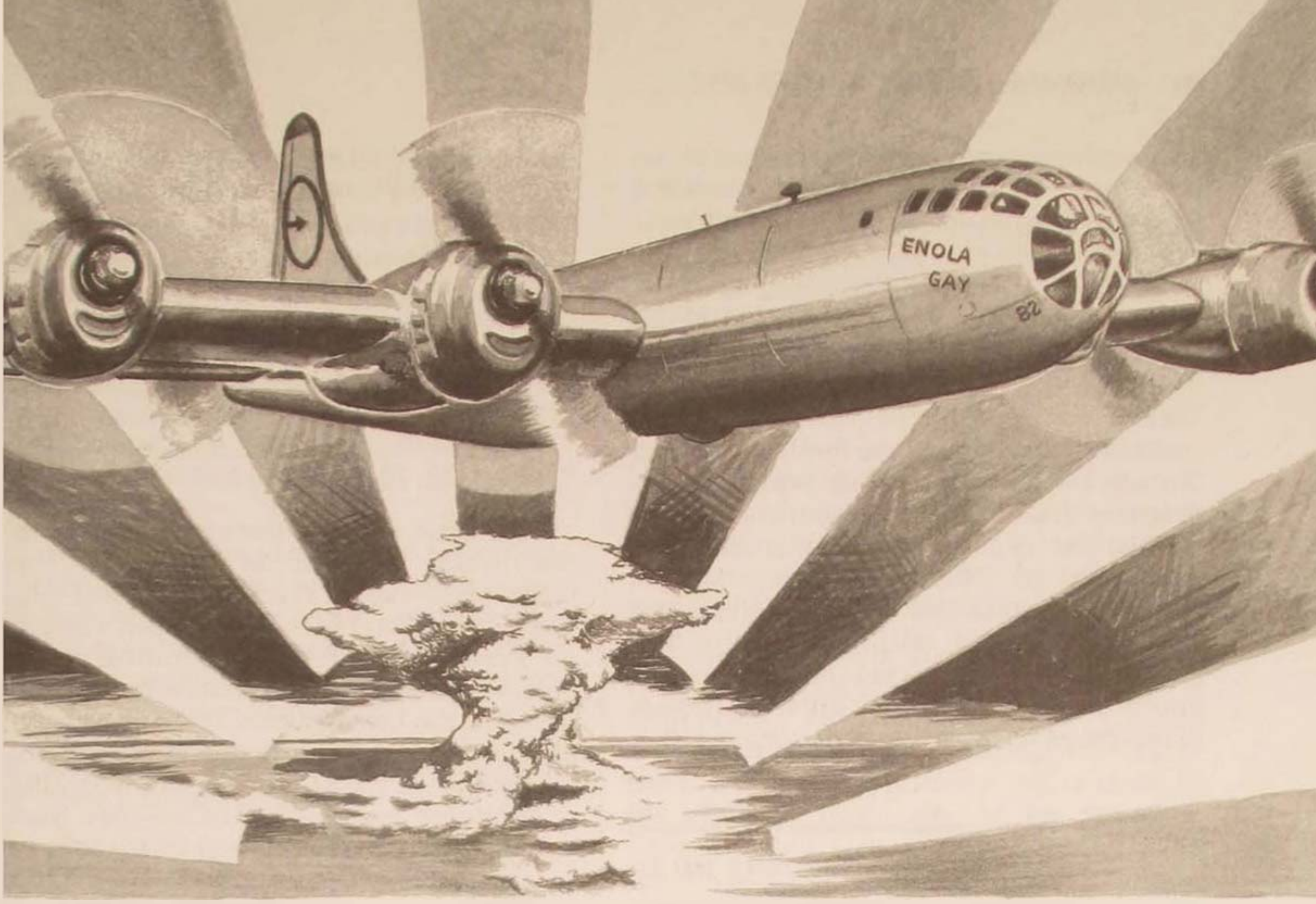
41. Paper and briefing from W. J. Schafer and Associates and Conceptual Research Corporation.

42. Phillips Laboratory XPI, memorandum, 20 March 1994.

43. See, for example, briefing, G. Harry Stine and Paul C. Hans, The Enterprise Institute, subject: Economic Considerations of Hypersonic Vehicles and Space Planes, 1990.

44. Aerial refueling is now as common in military air operations as beverage service is on commercial flights, and it is usually (and rightly) thought of as a way to extend the range and endurance of aircraft. What hasn't been fully appreciated is the fact that aerial refueling has also affected the design of aircraft (i.e., a fighter can have global range—if it can refuel often enough—without carrying all that fuel at takeoff). What's new is applying this concept to a space-faring vehicle. For the concept to become commercially viable, commercial operators will also have to embrace air refueling as a routine operation, though this leap should be no greater than that of the first commercial aircraft or the first commercial jets.

45. John Boyd, "SPACECAST," lecture, Maxwell AFB, Ala., October 1993.



THE ATOMIC BOMBINGS OF JAPAN

A 50-Year Retrospective

COL RALPH J. CAPIO, USAF

> *Know then thyself, presume not God to scan;*
> *The proper study of Mankind is Man.*
> *Placed on this isthmus of a middle state,*
> *A Being darkly wise, and rudely great:*
> *With too much knowledge for the Sceptic side,*
> *With too much weakness for the Stoic's pride,*
> *He hangs between. . . .*
>
> —Alexander Pope
> *Essay on Man*

IF 7 DECEMBER 1941, a date "which will live in infamy,"[1] conjures up a vision for Americans of treachery,[2] death, and destruction, then Hiroshima and Nagasaki are two names synonymous the world over with horrific power that, having been unleashed, still threatens mankind's fragile grip on survival. ("Cry 'Havoc!' and let slip the dogs of war."[3]) If we were to do the same thing today, the consequences would likely be "as much a punishment to the punisher as to the sufferer."[4]

Hiroshima and Nagasaki represent an experience of multiple dimensions. What happened? What led up to the bombings? Why was it done at all? What does it say about the character of the nation that did it and the nation that received it? What are the implications? These issues have fascinated historians, military scholars, and, indeed, the whole world for the past 50 years.

The events leading up to President Harry S Truman's decision to use weapons of unprecedented mass destruction against Japan are curious and—even now—controversial. As we approach the 50th anniversary of the bombings, a great deal of study, debate, and global attention will be paid to the circumstances that affected the decision. It is imperative that US military officers be aware of the issues surrounding this singular event.

The events leading up to President Harry S Truman's decision to use weapons of unprecedented mass destruction against Japan are curious and—even now—controversial.

No doubt, 6 August 1945 began as any other day. Before it ended, something dramatic occurred that would change the way nations dealt with each other—perhaps for all time. On this day at 8:15 A.M., the *Enola Gay*—a B-29 Superfortress named after its pilot's mother—opened its bomb-bay doors over Hiroshima—at the time, a military center and the seventh largest city in Japan[5]—and dropped a single weapon with a destructive capacity of apocalyptic proportions. The crew on board and the team of scientists who developed the bomb were not sure whether the weapon would detonate. Nor were they sure what would happen if it did.[6] In the split second in which a blinding flash of light told the crew of its success, approximately 70,000 souls[7]—who, until that fateful moment, had been going about their normal, everyday lives—perished, and the world changed:

> It was a kind of hell on earth, and those who died instantly were among the more fortunate. Thousands died—vaporized, crushed, or burned. But there were tens of thousands more who were still alive and those who could move began to mill about the city, seeking relief from shock, fire, and pain. Thousands threw themselves into the Ota River, which would be awash with corpses by the end of the day.[8]

The bomb dropped that day had been in the making at top-secret laboratories, by order of President Franklin D. Roosevelt, since December 1941—before Japan's attack on Pearl Harbor.[9] This $2 billion crash program, code-named the Manhattan Project, began in the United States at the suggestion of physicists Albert Einstein and Leo Szilard, refugees from Nazi Germany. The scientific community feared—rightly so—that Nazi scientists were mastering new technology in physics necessary to manufacture such a weapon.

The single weapon ultimately dropped on Hiroshima,[10] nicknamed Little Boy, produced a yield of approximately 20,000 tons of TNT—roughly seven times greater than all of the bombs dropped by all of the Allies on all of Germany in 1942. It produced an airburst approximately 1,000 feet above the city, creating a fireball with a diameter greater than the length of three football fields. The temperature at ground zero reached 5,000 degrees centigrade. The shock wave and its reverse effect reached speeds close to the speed of sound. A mushroom cloud rose to 20,000 feet in the air, and 60 percent of the city was destroyed.[11] Three days later, on 9 August, the United States dropped a second atomic bomb. The target, Nagasaki—a port city in southern Japan—was 30 percent destroyed, and approximately 40,000 of its citizens were killed.[12] On 15 August, Japan surrendered—unconditionally—thus ending a world conflagration in which 50 million people died.[13]

One of the threshold issues presented by the bombing of Hiroshima and Nagasaki is the nature of the target itself. Many people have asked how it came to be that whole civilian populations could become the proper object of direct and purposeful military action. That is, the target at Hiroshima and Nagasaki was principally the civilian population itself.[14] There was no "militarily" significant target to speak of beyond that, although Hiroshima did support an army headquarters. The answer has to do, in part, with the changing concept of modern warfare:

> World War I ushered in the period of total war, a type of war consisting of the combination of many allies, enormous cost, unlimited use of highly destructive weapons, and unlimited war aims. Hostilities were conducted over greater territory . . . than ever before.
>
> More troops were employed, supported by the home front population.[15]

As a consequence, the age-old distinction between enemy combatants and noncombatants began to blur.[16] It became clear that the civilian population was absolutely necessary if a nation were to successfully prosecute a total war effort. Without economic and war-production aid from the "civilian front," military war fighters would be less able to continue their efforts.[17] Thus, a gradual escalation of war fighting occurred, which included a nation's war-fighting sustainment capability and its civilian population. This trend manifested itself in the firebombing attacks on Dresden and Tokyo, the V-weapon attacks against London, and—eventually—the atomic attacks at Hiroshima and Nagasaki.

The rationale most often proffered to justify the use of such awesome weapons is "military necessity."[18] That is, dropping the bombs actually served to save lives. One must consider that the immediate military context of the decision to use atomic weapons was the Okinawa campaign—the last major battle of the war. Located 350 miles off the coast of mainland Japan, Okinawa "was to be used as a jumping-off place for the long-anticipated invasion of Japan." During the Okinawa campaign, 49,151 US servicemen were killed or wounded.[19]

Okinawa was the first campaign in which the notorious kamikaze appeared. Over 5,000 American sailors died[20] as a result of approximately 350 kamikaze missions[21]—the heaviest toll the US Navy had suffered in any episode of the war, including Pearl Harbor.[22] More than just militarily significant, the kamikaze represented the totally committed enemy—even to the point of fanaticism. If a full-scale invasion of the Japanese home islands became necessary, the kamikaze was a harbinger of the degree of military difficulty that, in all likelihood, awaited an invasion force.

In the aftermath of the bitterly fought Okinawa campaign, the president was clearly concerned that an invasion of the well-defended Japanese homeland could give rise to an "Okinawa from one end of Japan to the other."[23] Years later, in his memoirs, Truman cited Gen George C. Marshall's observation that approximately 1.5 million soldiers would have been required to invade Japan. Of this number, 250,000 would likely have been casualties, and an equal number of Japanese would have died.[24] However, some people suggest that recently declassified documents indicate that no such "official" estimate existed and that estimations of casualties ranged from a low of about 25,000 to a high of 46,000.[25] If true, this would make the figure of 250,000 nothing more than a "postwar creation"—an effort to justify, in some measure, the use of this weapon on the grounds of military necessity. Truman also went on to say, perhaps tellingly, that "the need for such a fateful decision never would have arisen had we not been shot in the back by Japan at Pearl Harbor in December 1941."[26] Moreover, it has been further suggested that American citizens

> recognize that pre- and post-Hiroshima dissent was rare in 1945. Indeed, few then asked why the United States used the atomic bomb on Japan. But had the bomb not been used, many more, including numerous outraged American citizens, would have bitterly asked that question of the Truman administration.[27]

Was the decision militarily justifiable as a "numbers" analysis? By this time, was the world so numbed to killing that the bombings were just one more step in an ongoing process? Or was the decision militarily unnecessary? Were we trying to "communicate" with the Russians for a better postwar environment? Even worse, was it an act of vengeance,[28] complicated by overtones of racism[29] and fanned by home-front propaganda?[30] From our vantage point, we may now be far enough away from these events to draw conclusions dispassionately yet still close enough to remember them as contemporary.[31] Thus, I believe it is entirely appropriate for us to consider these truly difficult—even painful—questions. At the same time, we must keep in mind that this matter—like other complex issues—is subject to different interpretations, depending upon the perceptions and biases of the people being asked about it.

To be sure, servicemen who would have been tasked with the invasion of Japan were relieved by the bombings. It meant, quite simply, that now they could hope to "grow up to adulthood after all."[32] The following account, written by a British soldier in 1945, illustrates the point:

> I was all set to fly to Okinawa . . . and, since the Japanese had almost no air defenses, we were to bomb, like the Americans, in daylight.
>
> I found this continuing slaughter of defenseless Japanese even more sickening than the slaughter of well-defended Germans. But still I did not quit. By that time I had been at war so long that I could hardly remember peace. No living poet had words to describe that emptiness of soul which allowed me to go on killing without hatred and without remorse. But Shakespeare understood it, and he gave Macbeth the words:
>
> . . . I am in blood
> Stepp'd in so far that, should I wade
> no more,
> Returning were as tedious as go o'er.
>
> I was sitting at home, eating a quiet breakfast with my mother, when the morning paper arrived with the news of Hiroshima. I understood at once what it meant. "Thank God for that," I said. I . . . would never have to kill anybody again.[33]

The bombings meant something else to the scientists and other people associated with the development effort.[34] Originally tasked with beating Nazi Germany to the punch, they clearly achieved this objective. However, as the war in Europe ended before Germany could develop the bomb and before we had any need to use it there, questions began to arise about whether or not it was necessary— or appropriate—to use the bomb in Japan:

> Most of the Manhattan Project scientists, including J. Robert Oppenheimer, director of the Los Alamos laboratory, tended to favor use of the bomb. But as the war drew to a close, a growing minority questioned whether Japan should be the target of the terrible weapon that had been developed—they felt—mainly as insurance against a Nazi bomb.[35]

Leo Szilard was this group's most emphatic dissenter. To his credit, he continued expressing his concerns about the morality of using such indiscriminate weapons long after the end of the war. After Japan's surrender, even Oppenheimer became well aware of the implications for mankind:

> Today . . . pride must be tempered with a profound concern. If atomic bombs are to be added as new weapons to the arsenals of [the] world . . . then the time will come when mankind will curse the names of Los Alamos and Hiroshima.
>
> The peoples of this world must unite, or they will perish. This war, that has ravaged so much of the earth, has written these words. The atomic bomb has spelled them out for all men to understand.[36]

From the perspective of US government officials who made decisions regarding the development and use of atomic weapons, the bombings aided in bringing about the surrender ceremony aboard the *USS Missouri*.[37] While he was still at the Potsdam Conference with Churchill and Stalin,

In November 1944, B-29 Superfortresses like the ones pictured above began bombing Tokyo. Nine months later, on 6 August 1945, the Enola Gay, *piloted by Paul Tibbets (below), dropped an atomic bomb on Hiroshima. Three days later, on 9 August, the US dropped a second atomic bomb on Nagasaki (left).*

President Truman found out that that the atomic bomb had been successfully detonated at Alamogordo, New Mexico. The conference itself was a difficult give-and-take among the Allies over the terms upon which the war should be ended and the conditions for the postwar peace. Buoyed by the Alamogordo success, Truman had decided upon and issued a harsh ultimatum—the Potsdam Declaration—that called upon Japan to surrender unconditionally or face "prompt and utter destruction."[38] Japan had been subjected to overwhelming aerial bombardment, including firebombing and carpet bombing of most of its cities and civilian population, as well as devastating naval blockades by long-range submarines and surface vessels. Consequently, despite opposition from the imperial army, Japan began to realize that it had lost the war. Clearly defeated, the Japanese made peace overtures through the Russians, who had not yet entered the Pacific war. Their only request was that they be allowed to keep their emperor.[39]

Did we explore adequately the diplomatic channels that were clearly open to us?

The Japanese were ready to surrender. However, they hesitated in accepting Truman's Potsdam Declaration because it was silent—or, at least, ambiguous—on the subject of the emperor's status. Indeed, many people think that the United States's insistence on unconditional surrender amounted to "the chief obstacle to an early Japanese surrender,"[40] which then rose to the level of "tragedy."[41] In response to the Potsdam Declaration, the Japanese government issued a statement to its people, which led to one of history's most consequential "failures to communicate." While posturing with the Russians, the Japanese suggested that they were "withholding comment"[42] on the Potsdam Declaration. From reports in Japanese newspapers, the United States concluded that the Japanese believed that the declaration was of "no great value" and was being "ignored."[43] Taking this response to be a rejection, Truman ordered that the atomic bombs be dropped as a means of ending the war promptly (and on favorable terms) and of "influencing" Stalin.

Was this an honest misunderstanding? Did we explore adequately the diplomatic channels that were clearly open to us? Did we hear only what we, for some reason or another, wanted to hear? Were we so concerned about Russia and the postwar peace that we were willing to sacrifice thousands of Japanese men, women, and children to this awful weapon? Was our insistence on unconditional surrender driven only by some vague domestic notion—inherited from our own Civil War,[44] perhaps—that this was the only true end to a war of this magnitude? Certainly, these are difficult questions. But some things seem clear: we did achieve a quick end to the war on favorable terms; an invasion of Japan was unnecessary; President Truman never publicly regretted[45] his fateful decision;[46] and the United States and the Soviet Union were thrust into what was to become the cold war:

> Never had any nation attained such immense power as had the United States at the end of the Second World War. It had a strong battle-tested army, a navy more powerful than all the other fleets combined, the world's greatest air force . . . and in the atomic bomb held the secret of a weapon capable of such vast destruction that no one had a defense against it.
>
> Just as Americans were dismayed by Russia's politics . . . Russians were alarmed by American politics . . . and by efforts . . . to confine the secret of the atom bomb to themselves.[47]

The single most gripping characteristic of our time has been the reality of life in the shadow of potential nuclear devastation. We learned to live with theories of strategic "deterrence," such as mutual assured destruction (MAD). Just as the arms race escalated, so did uncertainty:

> Armed with tens of thousands of nuclear weapons capable of being launched from land, sea, and air, the United States and the Soviet Union became prisoners of a cold war process that neither controlled. Locked into a nuclear arms race justified by national security, they increased their peril, diminished their economies, and promoted an international atmosphere of impending catastrophe.
>
> How to prevent the nuclear system from becoming a way of death was the question that dominated the debate over nuclear weapons from their inception.[48]

Such was one of the legacies of the bombs dropped on Hiroshima and Nagasaki.

From the Japanese perspective, the bombings have had profound implications. The entire postwar era has been driven, to a large extent, by what happened to Japan—not only as a vanquished nation, but also as the only nation in the world to have suffered an atomic attack:

> As victims of the advent of atomic weapons, the Japanese people could argue convincingly that wars were ever more destructive, that a new age in international affairs was accordingly at hand, and the sovereign prerogative to go to war must be renounced. No other nation embraced the liberal hope of the future world order with the enthusiasm of Japan, for no other nation's recent experiences seemed to bear out the costs of the old ways.[49]

Consequently, Japan developed an attitude that it could grow into a "modern industrial nation . . . without arming itself" and, further, that its recent past "justified devoting national energies entirely to rebuilding the national livelihood."[50] That Japan has been able to achieve astounding postwar economic growth is clear—so much so, in fact, that because of this success (attributable, some say, to the government's "favorable" attitude towards its businesses), the term *Japan, Inc.*[51] has been used, somewhat pejoratively, to describe the phenomenon. As a corollary, some people believe that Japan has taken unfair advantage of its attitude against rearmament in general and nuclear weapons in particular. In fact, some of them think that Japan has had a "free ride":

> Criticism grew particularly vocal around the time that Japan's economy emerged as the third largest in the world. Some critics, in fact, attributed Japan's economic success to the abnormally low defense burden it carried, arguing that its remarkable growth was only made possible by US assumption of the lion's share of the defense burden.[52]

As the 50th anniversary of the atomic bombing of Japan approaches, the debate over whether or not the Japanese somehow qualify as "victims" of the war has already begun. The Smithsonian Institute announced plans to commemorate the event by holding a special exhibition, including the display of the *Enola Gay.* Plans for the exhibition were circulated for public comment and drew an immediate and adverse reaction, principally from US veterans groups who felt that the Japanese, by being cast as victims, were escaping from their responsibility for waging aggressive war and that such an exhibition amounted to revisionist history. The Smithsonian took these comments under advisement and cancelled its originally planned exhibit. It now intends simply to exhibit a portion of the fuselage of the *Enola Gay* and write a brief explanatory text.[53]

Clearly, the bombing of Hiroshima and Nagasaki has had a profound effect—not only on Japan, but on mankind.

Clearly, the bombing of Hiroshima and Nagasaki has had a profound effect—not only on Japan, but on mankind. Although it stands as historic testament to our intellectual capacity to discover and harness immense power, it also demonstrates the fragility of life. We can no longer be certain that such forces could never destroy us. In exhibiting our willingness to use such power in war, we have shown a capacity towards self-destruction that bears constant vigilance. Thus, the advent of the nuclear age forever changed the relationship among nation-states. Hiroshima and Nagasaki have shown us that there is, ostensibly, a point beyond which we will not allow ourselves to be pushed without exhausting all military resources available to us and that, no matter how costly the consequences, we are prepared to justify those actions accordingly. Therefore, we now have "no more important challenge . . . than how to prevent the unprecedented catastrophe of nuclear war."[54] It is critically important that US military officers carefully consider the lessons of Hiroshima and Nagasaki. □

Notes

1. President Franklin D. Roosevelt, address to a joint session of Congress, 7 December 1941.

2. On 22 November 1994, the government of Japan (GOJ) acknowledged, for the first time, that its surprise attack on Pearl Harbor was conducted while the negotiations process was still technically ongoing. Without actually apologizing, the GOJ indicated that it had instructed its ministers in Washington to deliver a diplomatic note indicating that the talks then being conducted between the US and Japan were terminated. The note was not delivered until after the attack on Pearl Harbor. The GOJ's recent statement seemed to offer as an explanation that their ministers did not recognize the urgent need to deliver the note. Cable News Network television report, 22 November 1994.

3. *Julius Caesar,* act 3, sc. 1, line 273.

4. Adrienne Koch and William Peden, eds., *The Life and Selected Writings of Thomas Jefferson* (New York: The Modern Library, 1944), 529.

5. *Kodansha Encyclopedia of Japan,* vol. 3 (Tokyo: Kodansha, Ltd., 1983), 149.

6. Some scientists feared that a nuclear chain reaction, once set in motion, might ignite the earth's atmosphere or crack the earth's crust at the point of the bomb's detonation. Peter Wyden, *Day One: Before Hiroshima and After* (New York: Simon and Schuster, 1984), 51.

7. "The Effects of Atomic Bombs on Hiroshima and Nagasaki," in *The United States Strategic Bombing Survey,* vol. 7, ed. David MacIsaac (New York: Garland Publishing, Inc., 1976), 3.

8. William Sweet, *The Nuclear Age: Power, Proliferation and the Arms Race* (Washington, D.C.: Congressional Quarterly, Inc., 1984), 10.

9. For an excellent rendition of the facts and circumstances leading up to the making and use of the atomic bombs on Japan, see Wyden.

10. *The Outline of Atomic Bomb Damage in Hiroshima* (Hiroshima: The Hiroshima Peace Memorial Museum, March 1990), 4.

11. Wyden, 9–10.

12. *The New American Desk Encyclopedia* (New York: Signet Books, 1984), 808.

13. *Chronicle of the 20th Century,* ed. Clifton Daniel (Mount Kisco, N.Y.: Chronicle Publications, 1987), 598.

14. Certain Japanese cities had been "exempted" from bombing and "reserved" for a nuclear weapon. Hiroshima had been selected as one of these for several reasons (e.g., its size ["a large part of the city would be destroyed"] and its adjacent hills [to "focus" the blast effect]). Wyden, 197.

15. Headquarters, Department of the Army, *International Law,* vol. 1 (Washington, D.C.: Government Printing Office, 1962), 11.

16. Barton J. Bernstein, "The Atomic Bombs Reconsidered," *Foreign Affairs* 74, no. 1 (January–February 1995): 135. Some people will contend that Professor Bernstein argues with a revisionist's logic. Nevertheless, it is important that military officers be aware of the issues and their presentation.

17. Hiroshima had "home factories" that produced artillery, aircraft parts, and machine tools. Wyden, 197.

18. William Lanouette, "Why We Dropped the Bomb," *Civilization* 2, no. 1 (January–February 1995): 28.

19. "Outlook: Database," *U.S. News & World Report,* 3 April 1995, 12.

20. John Keegan, *The Second World War* (New York: Penguin Books, 1989), 572.

21. "Outlook: Database," 12.

22. Keegan, 561.

23. Ronald H. Spector, *Eagle against the Sun: The American War with Japan* (New York: Free Press, 1985), 543.

24. Keegan, 574.

25. Eric Foner and John A. Garraty, eds., *The Reader's Companion to American History* (Boston: Houghton-Mifflin Co., 1991), 799.

26. *Chronicle of the 20th Century,* 811.

27. Bernstein, 152.

28. Soon after the Hiroshima bomb was dropped, President Truman received a number of entreaties that such weapons not be used again. In response to one such request by the Federal Council of Churches of Christ in America, President Truman articulated what was quite probably the existing sentiment among most Western nations at the time when he said, "Nobody is more disturbed over the use of the atomic bomb than I am, but I was greatly disturbed over the unwarranted attack by the Japanese on Pearl Harbor and their murder of our prisoners of war. The only language they seem to understand is the one we have been using to bombard them. When you have to deal with a beast, you have to treat him as a beast." Wyden, 294.

29. The internment of Japanese-Americans at the outbreak of hostilities is, of course, a well-known event in American history. Additionally, American attitudes during the war have been described as follows: "The Americans never seemed to be as morally sensitive about bombing Japan as they were about attacking Germany. The attacks on Japan were ferocious and indiscriminate. There were several reasons for this. In the first place, in the war with Germany, the Americans distinguished between the Nazis, who were the real enemy, and the German people, who were at least partly victims. No such distinction was made when considering the Japanese; the entire population of Japan was perceived as the enemy. Further, there was a racial prejudice against the Japanese that the Americans did not feel towards the Germans." Louis A. Manzo, "Morality in War Fighting and Strategic Bombing in World War II," *Air Power History* 39, no. 3 (Fall 1992): 35–50.

30. In commemoration of the 50th anniversary of the United States's participation in World War II, the National Archives conducted a spectacular exhibit entitled "Powers of Persuasion," from February 1994 to February 1995. It was an exhibition of poster art from World War II advocating bond drives, scrap drives, ration plans, and patriotism. This latter concept sometimes took the form of very aggressive posters sensationally depicting the "evils" of Japan and Germany. One such poster characterized the

Japanese and Germans as vermin, the clear implication being that they should be "exterminated." Archibald MacLeish—at the time, director of the forerunner of the Office of War Information—described the power and purpose of such World War II "information" campaigns as follows: "The principal battleground of this war is not the South Pacific. It is not the Middle East. It is not England, or Norway, or the Russian Steppes. It is American opinion." Stacy Bredhoff, *Powers of Persuasion* (Washington, D.C.: Government Printing Office, 1994), i.

31. Indeed, the timing of such an inquiry is important. As Thucydides instructs us, it is difficult "because of its remoteness in time, to acquire a really precise knowledge of the distant past or even of the history preceding our own period." Thucydides, *History of the Peloponnesian War*, trans. Rex Warner (Baltimore, Md.: Penguin Books, 1954), 13.

32. Spector, 559.

33. Freeman Dyson, *Weapons and Hope* (New York: Harper & Row, 1984), 121.

34. For a complete and current description of Dr Oppenheimer's role in the Manhattan Project and the attitudes he and his fellow scientists developed towards the atom bomb and its use, see "Oppenheimer Investigated," *The Wilson Quarterly* 18, no. 4 (Autumn 1994): 34.

35. Sweet, 14.

36. Dyson, 16.

37. Alexander DeConde, *A History of American Foreign Policy*, 3d ed., vol. 2, *Global Power: 1900 to the Present* (New York: Charles Scribner's Sons, 1978), 200–203.

38. Wyden, 226.

39. Charles Strozier, "The Tragedy of Unconditional Surrender," in *Experience of War: An Anthology of Articles from MHQ: The Quarterly Journal of Military History*, ed. Robert Cowley (New York: W. W. Norton & Co., 1992), 505–10.

40. Spector, 545.

41. Strozier, 505.

42. The Japanese word *mokusatu* was used by Prime Minister Suzuki to describe his government's reaction to the declaration. This word could be interpreted to mean anything from "ignore" to "treat with contempt." Wyden, 233.

43. Spector, 549.

44. For an interesting discussion of the importance of unconditional surrender, see Garry Wills, *Lincoln at Gettysburg: The Words That Remade America* (New York: Simon & Schuster, 1992), 135.

45. Spector, 554.

46. Cabell B. H. Phillips, *The Truman Presidency: The History of a Triumphant Succession* (New York: Macmillan Co., 1966), 57.

47. DeConde, 204.

48. Foner and Garraty, 798.

49. Daniel Okimoto and Thomas P. Rohlen, eds., *Inside the Japanese System* (Palo Alto, Calif.: Stanford University Press, 1988), 236.

50. Ibid.

51. Ibid., 172, 217.

52. "The Common Security Interests of Japan, the United States, and NATO," in *Joint Working Group of the Atlantic Council of the U.S. and the Research Institute for Peace and Security* (Cambridge, Mass.: Ballinger Publishing Co., 1981), 109.

53. David Umansky, director, Office of Public Affairs, Smithsonian Institute, Washington, D.C., telephone interview with author, 4 May 1995. Umansky distinguishes between a "commemorative" exhibit and an "informational" exhibit. He states that the institute's original plans impermissibly blended the two and, upon reflection, the exhibit was cancelled and a new commemorative-only exhibit will be conducted.

54. National Academy of Sciences, Committee on International Security and Arms Control, *Nuclear Arms Control: Background and Issues* (Washington, D.C.: National Academy Press, 1985), ix.

CONTEMPORARY CIVIL-MILITARY RELATIONS

IS THE REPUBLIC IN DANGER?

CAPT EDWARD B. WESTERMANN, USAF*

RICHARD KOHN, FORMER chief of the Office of Air Force History, catalyzed an increasingly heated debate concerning the alleged politicization of the American military. In an article entitled "Out of Control: The Crisis in Civil-Military Relations," Kohn identifies "warning signs" indicative of the increasing alienation of the US military from its civilian leadership.[1] He lists a series of actions demonstrating that "the U.S. military is now more alienated from its civilian leadership than at any time in American history, and more vocal about it."[2] Kohn supports his charge by citing several examples: an Air Force major general making disparaging remarks about President Clinton during a basewide briefing, the "jeering" of a congressman during a speech to the Army's Command and General Staff College, and the alleged deliberate undermining of former secretary of defense Les Aspin by military officers in the wake of the Somalia disaster. Perhaps more seriously, Kohn suggests that the armed forces are becoming "Republicanized"—that is, dominated by supporters of a single political party.

---

*The author would like to express his appreciation to Dennis Showalter and Dave and Jeanne Heidler for their suggestions and comments in the preparation of this article.

Civil-Military Relations in Historical Perspective

Friction between the American military establishment and its civilian leadership is not a contemporary phenomenon. The debate concerning civil-military relations—in particular, the maintenance of civilian control of the military—has been a fundamental issue in the American body politic from the American Revolution to the present day. Tension between members of the military and civilian leaders existed from the founding of the United States. The Newburgh Conspiracy of 1783 involved a threatened coup by officers and soldiers of the Continental Army who were disgruntled over pay and pension issues. The conspiracy, headed by Horatio Gates, the "Hero of Saratoga," foundered only after a personal appeal by George Washington.[3] Although the Newburgh conspirators did not embrace an antidemocratic ideology, they were certainly willing to employ antidemocratic methods to obtain their objectives.

Kohn suggests that the armed forces are becoming "Republicanized"—that is, dominated by supporters of a single political party.

The initiative by the Newburgh conspirators to bring about the end of the Republic through the force of arms, although unsuccessful, demonstrated that within a significant segment of the military there existed a pervasive feeling of distrust and open disdain for civilian authorities. That the civil authorities reciprocated these feelings of antipathy, if not outright distrust, was clearly seen in 1783 in their protesting the efforts of Henry Knox and Baron Frederick von Steuben to found the Society of the Cincinnati, a fraternal organization for former Revolutionary War officers. Critics of the society protested that it was "inherently unrepublican" and that it "smacked of tyrannical designs."[4]

The debate surrounding the creation of a professional standing army versus the reliance on a militia of citizen-soldiers constituted another major point of contention in the early years of the Republic. The enduring myth of the effectiveness of the militia during the Revolution would later be championed by Jeffersonian Republicans intent on preventing the "subversion" of the Republic at the hands of despotic militarists. In fact, the historian Theodore Crackel argued that "the army Jefferson inherited in 1801 had a Federalist character . . . a product of the critical and intensely partisan years of 1798–1800 . . . composed almost totally of men with Federalist sympathies, many of whom had openly expressed contempt for the political philosophy of the new administration."[5] A remarkable aspect of Jefferson's presidency involved his ability to remake a hostile "monarchical Federalist" officer corps into a republican force. Even more remarkable was the role played by Gen James Wilkinson, a staunch Federalist, in supporting Jefferson's fundamental transformation of the officer corps.[6]

Distrust of the professional military establishment found renewed expression in the twentieth century in the antimilitarist writings of proponents of both reform liberalism and business liberalism. Indeed, the proponents of business liberalism argued in the 1920s that the military was a "vestigial hold-over from a barbarous past"—an anachronism in the wake of the "war to end all wars."[7] The philosophies of both reform and business liberalism continue to exert a considerable influence on contemporary American liberal thought. Twentieth-century American liberals have regularly sought to establish mutual exclusivity between liberal thought and military institutions. This overtly adversarial relationship found its most extreme expression in the pacifist movements prior to the First and Second

World Wars and, subsequently, in the peace movement during the Vietnam War.

The Second World War proved a watershed event for the American military. The sweeping power given to members of the military in the formulation of policy coincided with the increasing participation of the military in the decision-making process. By the end of the war, the American military—in particular, the Joint Chiefs of Staff (JCS)—had become "the alter egos of the President in the conduct of war."[8] The growth in the powers of the joint chiefs mirrored a corresponding increase in the power and importance of the military in the post–World War II world.

In his article, Kohn argues that "the roots of the crisis go back to the beginning of the Cold War, when the creation of a large, 'peacetime' standing military establishment overloaded the traditional process by which civilian control was exercised."[9] The opening of the atomic Pandora's box created a paradigm shift in the operational and strategic considerations of warfare and introduced an apocalyptic element to warfare, which—according to Kohn—"required civilians to invade traditional military operational authority."[10] Kohn's argument mirrors the contention of Samuel Huntington concerning the changing attitude of the military toward civilian control. In his classic work, *The Soldier and the State*, Huntington argues that the members of the JCS sought to institutionalize and perpetuate the role of the joint chiefs and their access to the president in the postwar period. In the area of foreign affairs, the political leaders determined the "what," and the military leaders decided on the "how."[11]

Kohn contends that the spectre of the "atomic genie" required civilian authorities "to take away these weapons from the military, lest operational commanders displace Congress and the President in determining whether the country would go to war."[12] The military certainly did not object to the subordination of these weapons to presidential control. Kohn, however, argues that the US-Soviet standoff "now required civilians to invade traditional military operational authority."[13] He further details a process of bureaucratization of the military after 1950 that "increasingly blurred" the line between military and civilian counterparts. In effect, he argues that the military began to emphasize business management while its civilian counterparts became increasingly "versed in military strategy and operations."[14] This transformation of civilian leadership and its increasing encroachment into operational decision making found its ultimate expression in the actions of Secretary of Defense Robert S. McNamara and his "whiz kids."

Kohn correctly emphasizes the heightened tensions between the military and its civilian leadership as a result of limited wars in Korea and Vietnam. The firing of Gen Douglas MacArthur, however, far from being a warning sign of a fundamental schism between the two, was in fact a clear reaffirmation of the primacy of civilian control. Likewise, President Lyndon B. Johnson's micromanagement of the bombing campaign in North Vietnam and his boast that the Air Force could not bomb an outhouse without his approval, although unpopular with military planners, remained an uncontested presidential prerogative. In fact, Johnson's behavior had clear historical precedents, including Abraham Lincoln's continuous involvement in strategic decision making during the Civil War.[15]

The collective post-traumatic stress syndrome experienced by the American military establishment in Vietnam's aftermath was a reaction in part to "McNamara's rigid decision-making methods and peremptory dismissal of military judgement."[16] One clearly overstated allegation, however, is that a military-congressional alliance emerged in response to the McNamara era, spearheaded by the Republican administrations between 1963 and 1993. The stigma of military defeat did lead military and civilian defense officials to question the structure of forces

Does Gen Colin Powell represent a new breed of military planner? During his tenure as chairman of the Joint Chiefs of Staff, he was described as "the most powerful military leader since George C. Marshall . . . and the most political since Douglas MacArthur." In a world in which military issues are inseparable from geopolitical and domestic ones, the role of the chairman has in fact become a political position.

and the strategy employed in Vietnam. The ability of a defeated military to draw lessons from its past failures by changing doctrine, force structures, and technology is a vital step for ensuring success in subsequent campaigns. Harry G. Summers's *On Strategy: A Critical Analysis of the Vietnam War* is one of the clearest manifestations of the postwar debate within the military in attempting to come to grips with the causes for the US defeat in Southeast Asia.[17] The existence of a contemporary "stab-in-the-back" theory primarily implicating Johnson and his conduct of the war is without question. However, the wide dissemination of the argument does not, ipso facto, reflect a wide acceptance of it within the military community.[18] More remarkable still was the continued acceptance of the basic premise of civilian control by the military in the very shadow of a humiliating defeat and the subsequent downsizing of American forces in the 1970s.

The debacle in Vietnam did lead to a vocal effort by senior military leaders for clearer political objectives capable of being aligned with existing military capabilities (a patently Clausewitzian concept). Indeed, the perceived failures of both American political and military policy in Vietnam proved the pivotal experience for most of the contemporary military leadership. That this concept received bipartisan support in Congress should neither surprise nor alarm Kohn. What would have merited alarm was a refusal to learn from the Asian debacle.

The debacle in Vietnam did lead to a vocal effort by senior military leaders for clearer political objectives capable of being aligned with existing military capabilities.

Additionally, Kohn's contention that during the 1970s "the professional military became politicized, abandoning its century-and-a-half tradition on nonpartisanship" is both misleading and historically debatable. Grover Cleveland narrowly lost the 1888 election to Benjamin Harrison in large part due to the reaction of former soldiers disgruntled by his veto of a measure designed to provide pensions to disabled Civil War veterans.[19] Furthermore, growing historical consensus indicates that support of the military proved crucial in the presidential election of Abraham Lincoln in 1864 and of U. S. Grant in 1868.

Kohn rightly points out that the end of the draft diminished the "ideological diversity" of the officer corps. However, he neglects to credit the military's arguments against the institution of an all-volunteer force—largely a liberal initiative in response to the American experience in Vietnam. Senior military leaders, supported by civilian analysts such as Morris Janowitz, argued that an all-volunteer force forfeited the principle of "democratic participation" within the armed services.[20] In addition, opponents of the volunteer force feared higher operating costs, a decrease in the quality of recruits, and increased discipline problems.[21] It is, however, significant that senior military officers provided clear support for the initiative once the civilian leadership decided to adopt the all-volunteer force.

In the face of President Jimmy Carter's "contemptuously anti-military administration," Kohn finds the emergence of a "Republican," "conservative," and "politicized military."[22] Kohn fails to provide any significant evidence to support this statement. He neglects to mention the prohibitions imposed on military members with respect to holding political office, actively campaigning in uniform, or taking advantage of one's military position to campaign. The fact that most military members are conservative is certainly no surprise. This orientation reflects the overwhelming middle-class composition of the military.[23] It is also a direct consequence of a volunteer military correspondingly likely to attract men and women imbued with conservative values and, oftentimes, family traditions of armed service. Indeed, over 22 percent of the last five entering classes of the United States Air Force Academy were either sons or daughters of a retired or active duty military parent.[24] Again, the implied pejorative associated with the "Republicanization" of the military is unsupported by statistical evidence and plays to the spectre of an illusory military power play, à la *Seven Days in May*.

The renewed emphasis on increasing military capability during the 1980s was less a testament to the rising power of the military community than a reflection of a fundamental *political* objective of the "Reagan Revolution." It is equally clear that the military benefited from the Reagan buildup and was not averse to taking full advantage of the opportunities offered during the Reagan and Bush presidencies. The buildup of the military did not, however, take place in a vacuum. President Reagan's request for increased military spending in the 1980s required broad-based congressional support. The willingness of members of Congress to support the president's military program reflected in large part a perception of the "mandate" the American people demonstrated in Reagan's overwhelming election victories.[25]

The Colin Powell Argument

Kohn is particularly harsh in his criticism of Gen Colin Powell, former chairman of the JCS (CJCS), for his "intrusion into foreign policy" and for "reversing the relationship between the national goals and military means, turning the age-old Clausewitzian formula about war being an extension of policy on its head."[26] There is no doubt that General Powell's experience in Vietnam influenced his views on the necessity for clear political objectives and the use of "overwhelming force."[27] Additionally, Powell's earlier experience as head of the National Security Agency (NSA) involved him, by definition, in the policy-making process. Support or advocacy of proposed foreign policy initiatives was an inherent element of Powell's position within the NSA. The final decision concerning a proposed course of action, however, always rested with civilian authority, namely the commander in chief.

With his appointment as CJCS, Powell inherited a position vastly strengthened by the Goldwater-Nichols Defense Reorganization Act of 1986, which mandated the extension of the role and power of the chairman within the joint chiefs. In fact, "Powell was empowered by Goldwater-Nichols to give his military opinion to the President, no matter if the Chiefs agreed with it or not. That made the Chairman *the* military adviser to the President in fact, not just in theory" (emphasis in original).[28] It did not, however, restrict or limit the final authority of the president.

Kohn criticizes Powell's efforts in the fall of 1989 to proceed "without any authorization from superiors" in developing "a set of concepts designed to reconfigure the entire military establishment . . . a new national strategy and significantly reduced and revamped military services."[29] The implication that it is inappropriate for America's senior military leadership to consider force restructuring in the face of changing defense commitments is patently ludicrous. Abundant examples exist involving the participation of military members in the process of remolding forces in consonance with changing national strategy objectives. For example, Gen George Marshall told President Franklin D. Roosevelt at the start of the Second World War that the political/military goal of American involvement had to include unconditional surrender of the enemy and the destruction of his military capability.[30] Powell's formulation of a national strategy blueprint does not "turn Clausewitz on his head." Rather, it recognizes the role of military leadership in offering suggestions for military reform. Military officers cross the line when they attempt to achieve direct control over, or usurp, the constitutionally guaranteed powers of civilian leadership in the policy-making process.

This concept of civilian control of the military finds expression in Huntington's discussion of a Clausewitzian dictum that "war does not have its own logic and purpose. The soldier must always be subordinate to the statesman." In fact, Huntington accepts the Clausewitzian contention that misguided or self-serving policy on the part of the civilian leaders "does not concern the military man."[31] Huntington's contention, however, does not necessitate the exclusion of the military from the initial policy formulation but demands military obedience in support of the final decision of civilian policymakers.

Kohn is correct to criticize Powell's op-ed article in the *New York Times* concerning his opposition to American action in Bosnia. The general's public advocacy in that newspaper and in *Foreign Affairs* of his views for a new national strategy in the wake of the cold war is problematic. As CJCS, Powell did not surrender his First Amendment rights; however, he acted inappropriately in preempting the political decision-making process. Direct entry of military officers into the arena of public discourse should occur only after their resignation or withdrawal from military service. The fact that President Clinton had not taken the oath of office is a legalistic point.

Powell's public advocacy, although inappropriate, can most probably be traced to his previous role in the policy-making process during the Bush presidency. In addition, the fact that the 1992 elections had concentrated on domestic policy at the expense of foreign policy was certain to cause concern within a military establishment facing cataclysmic change and restructuring. The perceived lack of foreign policy expertise within the Clinton White House, whether accurate or not, certainly played a role in Powell's decision to publish his views on the Bosnian situation.

Powell's tenure as CJCS can be seen from two very different perspectives. Kohn describes Powell as "the most powerful military leader since George C. Marshall . . . and the most political since Douglas MacArthur," a man who contravened the traditions of civil-military relations as they had existed since the advent of the Republic.[32] Was Powell the exception to the rule, a man who became accustomed to the formulation and exercise of political authority? Or is it possible to see Colin Powell as representing a new breed of American military planners? In a world in which the US military faces taskings from coalition warfare in the Gulf, limited air strikes in Bosnia, and humanitarian assistance in Somalia and Rwanda, perhaps it is time to recognize that the role of the CJCS has in fact become a political position, which is "simply a function of the complex modern world that chairmen operate in—a world in which military issues are inseparable from geopolitical and domestic ones."[33] The contemporaneity of the events surrounding Powell's tenure as CJCS prohibits a definitive assessment of his impact on the office or its future role. It is clear, however, that the chairman's role is still evolving and that the debate will continue.

Conclusion

Forty years ago, Huntington described the inherent conflict present between the "functional and societal imperatives" of civil-military relations. He argued that

> one of the more basic and obvious facts of our time is that changes in technology and international politics have combined to make security the final goal of policy rather than its starting assumption. The functional imperative can no longer be ignored. Previously the primary question was: what pattern of civil-military relations is most compatible with American liberal democratic values? Now this has been supplanted by the more important issue: what pattern of civil-military relations will best maintain the security of the American nation?[34]

Huntington clearly identified the intrinsic dichotomy between a standing professional military and its relationship to American liberal philosophy. It is a dichotomy that continues to produce impassioned defense on both sides.

In the end, the framers of the Constitution successfully integrated a standing military capable of defending the Republic against enemies, both foreign and domestic. The professional military of today—like the soldiers of the early Republic—remains strongly rooted in the concept of the subordination of the military to civilian control.[35] The ultimate irony, perhaps, is that the conservatism of the military, so stridently criticized in liberal philosophy, acts as the very bulwark that ensures the continued adherence of the military to the concept of civilian control. Marcus Antony does not stand outside the gates of Rome—there is no danger to the Republic. □

Notes

1. Richard H. Kohn, "Out of Control: The Crisis in Civil-Military Relations," *The National Interest*, Spring 1994, 3.

2. Ibid.

3. James K. Martin and Mark E. Lender, *A Respectable Army: The Military Origins of the Republic, 1763-1789* (Arlington Heights, Ill.: Harlan Davidson, 1982), 186–94.

4. Ibid., 203.

5. Theodore J. Crackel, *Mr. Jefferson's Army: Political and Social Reform of the Military Establishment, 1801-1809* (New York: New York University Press, 1987), 180.

6. Ibid., 181.

7. Samuel P. Huntington, *The Soldier and the State: The Theory and Politics of Civil-Military Relations* (Cambridge, Mass.: Belknap, 1957), 289–90.

8. Ibid., 333.

9. Kohn, 4.

10. Ibid., 5.

11. Huntington, 336, 342.

12. Kohn, 5.

13. Ibid.

14. Ibid.

15. For a complete discussion of Lincoln's role in strategic planning during the Civil War, see T. Harry Williams, *Lincoln and His Generals* (New York: Alfred A. Knopf, 1952).

16. Kohn, 6.

17. Harry G. Summers, Jr., *On Strategy: A Critical Analysis of the Vietnam War* (Novato, Calif.: Presidio Press, 1982).

18. This myth appears far more frequently in the writings of civilian historians with reference to the Vietnam War. See Stanley Karnow, *Vietnam: A History* (New York: Viking Press, 1983).

19. Richard E. Welch, Jr., *The Presidencies of Grover Cleveland* (Lawrence, Kans.: University of Kansas Press, 1988), 97; and Henry J. Ford, *The Cleveland Era*, The Chronicle of America Series (New Haven, Conn.: Yale University Press, 1919), 154.

20. Morris Janowitz, "Volunteer Armed Forces and Military Purposes," *Military Review*, July 1972, 15-22.

21. Jack R. Butler, "The All-Volunteer Armed Force—Its Feasibility and Implications," *Parameters*, Spring-Summer 1972, 17-29; and "A Volunteer Army Cannot Be Recruited 'On the Cheap'," *Armed Forces Journal*, June 1972, 44–46.

22. Kohn, 7.

23. The preponderantly middle-class makeup of the US officer corps dates from Jefferson's military reforms at the turn of the nineteenth century. See Crackel, 182.

24. US Air Force Academy admissions office, Colorado Springs, Colo.

25. See John Kenneth White, *The New Politics of Old Values* (Hanover, N. H.: University Press of New England, 1988).

26. Kohn, 11-12.

27. Howard Means, *Colin Powell: Soldier/Statesman, Statesman/Soldier* (New York: Donald I. Fine, 1992), 293.

28. Ibid., 300–301.

29. Kohn, 9.

30. Means, 303.

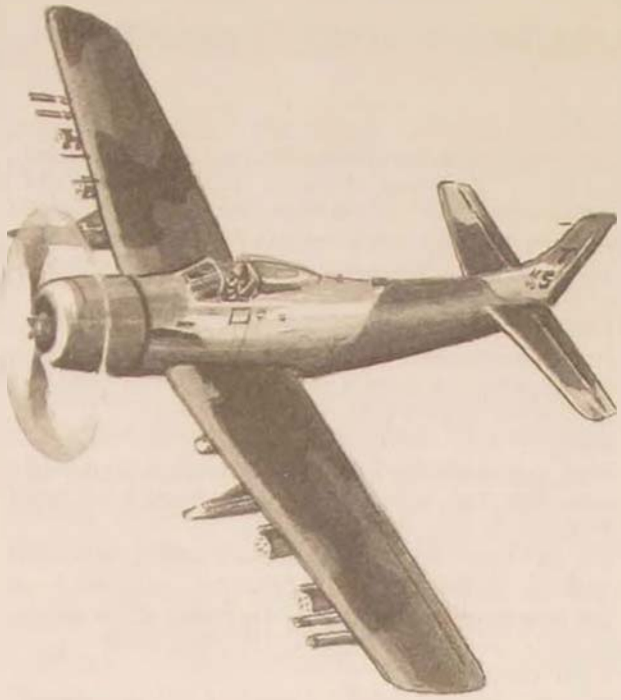
31. Huntington, 57–58.

32. Kohn, 9.

33. Means, 264.

34. Huntington, 3.

35. Ibid., 205–8.



ORGANIZING FOR SEARCH AND RESCUE

Force Structure in a Joint Environment

2d Lt Dave Meggett, USAF

THE LETHALITY of air defenses has increased exponentially since the conclusion of World War II. Even with the advent of stealth technology, aircraft in combat face an undeniable risk of being forced down. With increased training costs and budget constraints, the military cannot afford to lose aircrew members who could otherwise return to fight again. Cost aside, the US must do everything possible to protect its military personnel. A pilot forced to eject over enemy territory should have confidence that help is on the way. Therefore, we need renewed emphasis on aerial combat search and rescue (CSAR) forces. The CSAR mission, however, tends to be overlooked, and its doctrine is not keeping pace with the increasing CSAR capability available within today's joint forces. While the 1986 Goldwater-Nichols Department of Defense Reorganization Act made the unified commands the model for organization, CSAR forces are distributed unevenly, nonfunctionally, and redundantly at best—greatly reducing the theater commanders' ability to support their forces with vi-

able rescue units. Remedying the situation will require the military to rethink the way we organize and implement CSAR forces.

Concentrated efforts at recovering downed aircrews began after the entry of the United States into World War II when Gen H. H. ("Hap") Arnold forged an agreement with the Royal Air Force to conduct combined search and rescue operations in the North Sea and English Channel.[1] These missions relied heavily on Catalina seaplanes and converted B-17 Flying Fortresses to drop rescue equipment to the crews. Land-based operations came about soon after in South Asia, consisting initially of ground teams but increasingly employing helicopters to effect rescues. Helicopters provided a quantum leap for rescue forces, and, despite their entry late in the war, their effectiveness helped fashion CSAR units of the future. The Air Rescue Service was formed soon after the end of the war, and it had rapidly developed its capabilities by the end of the Korean War. By the early 1960s, it was responsible not only for worldwide SAR activities in war and peace but for recovery of space vehicles after splashdown and for local base rescue teams as well.[2]

None of these missions, however, prepared the Air Rescue Service for the challenges it would face in Vietnam. The Air Force was reluctant to send additional units at the beginning of the war in an attempt to maintain the covert posture of its Farm Gate assistance operation (the US Air Force advisory support of the South Vietnamese Air Force early in the war). Any pilots unfortunate enough to be shot down had a better chance of being rescued by a passing Air America flight than they did by military forces.[3] As losses mounted, the equipment and units in place were deemed to be inadequate, and the mission was reevaluated. It was at this time that CSAR really began to find its legs. HH-43 helicopters were refitted with armor plating, door guns, and additional fuel tanks to increase their range; and they were soon augmented by the arrival of the much more capable HH-3 Jolly Green Giant. Although well suited for extraction, the helicopters were extremely susceptible to fire from ground forces, who commonly surrounded downed pilots, set up "flak traps," and waited for the rescue helicopters to come in before firing. Help came in the form of the Douglas A-1 Skyraider, a small, rugged aircraft capable of extended loiter in target areas and capable of carrying a vast array of munitions. The Navy agreed in 1965 to provide the Air Rescue Service with A-1s on a rotating basis for escort duties.[4]

Typical rescue missions had a pair of Skyraiders, "Sandy High," providing escort for the helicopters and commanding the mission until arrival on scene. A second pair of A-1s, "Sandy Low," orbited the crash site to determine the crew's condition and location and the composition of enemy forces in the area. Sandy Low was often assisted by forward air controllers who were typically familiar with the terrain and enemy strength in the area. Once the team arrived, Sandy Low assumed control and cleared the helicopters into the area. The pickup helicopter, "low bird," moved in while the "high bird" backup helicopter remained in orbit.[5] While there were some variations for terrain and equipment available, this served as the military's model for CSAR for the entire war.

While rescue forces in Vietnam have rightfully been commended for their performance, there were definite shortcomings in our rescue abilities. Forces lacked a long-range rescue vehicle for missions into North Vietnam. During Linebacker II, for instance, not a single aircrew member was recovered from beyond the border. Time was also a critical factor. Slow-moving helicopters traveling long distances left crews on the ground for extended periods of time. This led to a disturbing statistic: a pilot's chances of being rescued were good if picked up within 15 minutes but dropped off sharply after 30.[6] Of the 2,254 US Air Force aircraft lost over Vietnam, only 635 crew members were recovered.[7]

Certainly there are many lessons to be learned from our experience in Vietnam. First, even peacetime forces must be prepared to engage in CSAR in varied situations. The Air Rescue Service, later the Aerospace Rescue and Recovery Service, had focused so much on emergency and space recoveries that they were ill equipped to deal with extraction under combat conditions. The vehicles were unarmed, unarmored, and they lacked the range and durability needed for combat.[8] It took nearly five years of combat experience to turn the ad hoc grouping of secondhand equipment into a professional combat rescue service, a luxury we could not afford then and certainly will not have in future conflicts.

Second, forces must be tailored to peculiarities of their operational areas. In several cases, extensive modifications had to be made to existing aircraft in an attempt to find a suitable rescue platform, including fuel tanks, weapons systems, and armor. The H-5, the first helicopter sent to Vietnam, had wooden rotors that deteriorated rapidly in the humid climate. The original extraction cables were too short to reach through the dense triple canopy of Vietnamese and Laotian rain forests. Had forces been trained and stationed in country, they would already have prepared for these contingencies.

Third, joint efforts produce better results. When the Air Force saw it needed armed escorts, the Navy had the capability to provide them. When the Air Force needed additional helicopters, Army helicopters were made available. The result was a combination of capabilities more efficient than any service could have provided on its own. No one service had enough resources to spare for a separate CSAR unit.

Finally, tactics have to be modified to suit the nature of the rescue. Prior to Vietnam, formal doctrine on combat rescue was virtually nonexistent, leading to experimentation with techniques and equipment. It was not the doctrine of the individual services that made CSAR effective in Vietnam but rather the ingenuity of the rescue forces, which made do with impromptu arrangements of whatever forces happened to be in the area at the time. While Vietnam provided the most experience for our forces, the shortcomings mentioned above should keep it from being accepted as our model for CSAR.

It was nearly 20 years before a CSAR operation of Vietnam's magnitude would be seen again. In Operation Desert Storm, Special Operations Command (SOCOM) was tasked with providing all rescue forces in-theater. While SOCOM was well equipped with helicopters and pararescue forces, it lacked escort planes for them. The Sandy mission was turned over to Air Force A-10s, which were assigned to specific rescue units. Coordination between the two was more difficult because SOCOM was loathe to reveal many of its covert tactics to regular forces. On 21 January, a Navy F-14 pilot, Lt Devon Jones, and his radar intercept officer, Lt Lawrence Slade, were shot down over Iraq by a surface-to-air missile. Slade was captured immediately, but Jones landed far enough away to avoid detection. Digging himself a foxhole in the sand, Lieutenant Jones waited as several Iraqi farmers passed within a few feet of his position. When he finally turned on his survival radio, he found that rescue forces were already looking for him. Two A-10s were sweeping the area, trying to pinpoint his location. They did so, then returned to their base to refuel and escort a helicopter in. Jones waited anxiously, then noticed an Iraqi truck headed directly for his position. Before it reached him, however, the truck erupted in flames. The A-10s had returned, destroying the truck with their 30-mm guns. Lieutenant Jones was rescued after spending eight hours on the ground.[9]

The tactics of the mission bear a striking resemblance to Vietnam. In the CSAR community, the leadership was very much a remnant of Vietnam. However, there were certainly differences. The terrain of Iraq provided much less cover than did Vietnam, necessitating rapid response of rescuers to prevent capture. Lieutenant Jones spent eight hours on the ground waiting for rescue forces to get a helicopter to a known location. Had SOCOM been more willing to integrate with regular forces, the rescue time could have been shortened dramatically. Iraq's terrain also provided less cover for enemy ground troops, preventing the "flak traps" so prevalent in Vietnam. This allowed helicopters to enter the scene without fear of an ambush, which had hindered so many rescues in Southeast Asia. Organizationally, rescue forces were consolidated under the command of the joint forces air component commander (JFACC) rather than an Air Force agency, giving the rescue crews the ability to organize and plan their missions more effectively. However, the fundamental tactics of CSAR hadn't changed much, and neither had the prevailing attitude of the services that rescue was a contingency mission to think about once hostilities had already begun, and one that they could handle on their own.

Air Force doctrine concerning CSAR reflects this afterthought attitude, as well as the lack of joint consideration. Air Force Manual (AFM) 2-36, *Search, Rescue, and Recovery Operations,* states that "operational control of specific SAR forces may be passed to the air component commander of a joint force,"[10] indicating that the Air Force is willing to turn over control of SAR forces, such as in Desert Storm. However, it furthers the view that rescue is a secondary mission by stating that "it is impractical to establish a static SAR force structure of sufficient strength to have forces close at hand, regardless of area."[11] Some A-10 pilots do receive special SAR training, but not all. What happens when SAR qualified pilots are shot down and only pilots unfamiliar with SAR operations are left to rescue them?[12]

The Navy doesn't have a single text to deal with CSAR; it deals with it as an extension of other missions. On a typical aircraft carrier, only three helicopter crews (out of eight) are trained to perform SAR missions.[13] The Marine Corps places even less emphasis on rescue missions because the time spent diverting forces to conduct a search detracts from a unit's primary function.[14] Because CSAR is so dependent on a conflict to be implemented, it is not likely to receive the attention it deserves until a more cost-effective means of maintaining an active rescue force is accepted.

Services have also resisted the integration of their equipment into a joint package on anything less than an emergency basis. The Navy's reason for doing so is to retain independence: "Battle Group Commanders want the capability to do CSAR . . . with organic battle group forces."[15] It shows its true nonjoint mentality in stating that "existing [CSAR] texts are from other services and not always compatible with Navy operating procedures."[16] The services are unwilling to sacrifice their own CSAR capabilities despite the fact that all rescue operations in every major conflict in the past 30 years have been conducted by joint forces.[17] The Air Force is currently tasked with providing CSAR forces for the entire military, but the other services were unwilling to elevate the status of the joint rescue coordinator to joint rescue commander, fearing that it would give the Air Force another vote (with the JFACC) on the unified commander's staff.[18]

The current force structure is limited in its range and scope. There are approximately 200 Air Force aircraft dedicated to the SAR mission, and the majority fall under the Air Force's only SAR wing, the 39th Aerospace Rescue and Recovery Wing (ARRW) based at Eglin AFB, Florida.[19] These forces consist mainly of HH-3, CH-53, and -60 helicopters, with HC-130 aircraft acting as command and communication platforms. Several problems arise in adapting this structure to an effective CSAR force. First, the wing does not possess any rescue escort aircraft, such as A-10s, so training for CSAR is sporadic at best.[20] Also, by having only one dedicated ARRW, the Air Force is limiting its ability to react to overseas crises. The Navy has limited shipborne rescue capability but does have two Naval Reserve squadrons dedicated to CSAR. The continued acquisition of HH-60s is expected to upgrade the overall capability of Navy rescue forces.[21] This lack of attention to CSAR projection seriously degrades the ability of the services to construct an effective force in a regional conflict, and this was seen in the reaction time of rescue forces in Desert Storm.

This attitude is changing, but slowly. Joint Publication 3-50.2, *Doctrine for Joint Combat Search and Rescue,* was due for final approval in September 1993, but it is still undergoing changes. The very fact that it is being drafted as a joint publication is a quantum leap from the current lack of cooperation among recovery forces.

The importance of CSAR is being noted as well. A single captured pilot can cause national furor, as was witnessed recently in the case of Army Warrant Officer Michael Durant in Somalia. The public will not stand for Americans being held as prisoners, and this concern for American prisoners of war (most of whom can be expected to be aviators in a Desert Storm scenario) has forced the services to take a hard look at how they train for rescue. Some A-10 and all OA-10 forward air controller pilots receive routine training in CSAR, and the Navy is trying to expand their helicopter rescue capabilities, favoring the rugged HH-60 over the much larger (and expensive) tilt-rotor V-22 Osprey. The Osprey, although much faster and having longer range, is a larger target for antiaircraft fire and is already far over budget and behind its development time line.[22] Budget constraints are likely to limit procurement of any pure rescue equipment, which helps explain the Air Force's reliance on special operations to take on CSAR responsibilities, allowing helicopter technology to receive funding in one place. Trying to reemphasize the CSAR mission in light of dwindling resources requires an organizational change to do more without expanding the size of the force.

In 1986, the Goldwater-Nichols Act placed the impetus of joint operations on the unified commands. A single commander was placed in charge of all Air Force, Army, Marine, and Navy assets in his theater of operations. CSAR forces, however, were not incorporated into the command force structure, remaining under the owning service's control. This seriously limits a commander's choices when confronted with a mission requiring CSAR support. The commander does not have a designated rescue unit available for immediate response to a crisis. What forces are available are spread among the various services, have had little experience working together, and have no defined CSAR chain of command. However, the unified command structure does provide a model for a better CSAR organization, and with minimal difficulty. In order to make our CSAR forces more capable and efficient, it will be necessary to organize them at the theater level.

First, those units with the best CSAR capability in-theater must be identified by the command. This may be any combination of service components, including fixed- and rotary-wing aircraft. These units would then be tasked with providing CSAR for the entire theater as a primary mission. In Pacific Command (PACOM), for example, Army helicopters, Air Force OA-10s, and fighter support units are all based within 20 miles of Seoul, South Korea. If a squadron of each was tasked with CSAR, they could be immediately employed by PACOM as an organic joint rescue unit under direct control of the commander in chief (CINC). This would allow them to react rapidly with a known command structure in place. Similar conditions exist in Germany, England, Panama, Japan, Turkey, Hawaii, and on both coasts of the US. Being region-specific units, each would be prepared, trained, and equipped to deal with peculiarities of terrain, weather, and enemy threats. Units in the Middle East would certainly use different tactics and equipment than those in Central America. This would also prevent the need to deploy an outside, inexperienced CSAR force because the local unit would be responsible for operations in their theater. The proximity of these forces would allow joint training for CSAR on a regular basis. As the training would not require the units to relocate or deploy elsewhere, they would still be free to train as usual for other service-specific missions. The frequent training would help remove the obstacles that have hindered smooth joint CSAR operations in the past, obstacles such as inconsistencies in tactics and breakdowns in logistics and in communication, command, and control. In effect, this arrangement emphasizes CSAR as a vital mission but does not force the commands to form a separate, dedicated rescue group.

While such a group would be extremely effective, it is also cost-prohibitive. It would require a command to train aircrews and operate and maintain aircraft specifically for the CSAR mission, all the time wondering when a conflict would arise in which the group could be utilized. Tasking separate units helps to highlight the importance of CSAR without detracting from service capabilities, allowing them to do more with the same amount of resources.

Budgeting constraints must be considered as well. Because training for CSAR would fall under the direction of the unified commands rather than under the individual services, the funding would be provided by the commands themselves. USSOCOM would receive less money for rescue training but would still maintain mission-specific rescue capability, including hostage rescue and forced extradition, and would have forces available to augment the theater-level forces in extreme circumstances. Likewise, the individual services would keep their organic forces for noncombat rescue but would not field a fully capable CSAR unit, thus preventing redundancy. This is likely to cause some grumbling at the service level, but this is precisely the attitude that has to be overcome if we are serious about maintaining our combat effectiveness during a drawdown. New rescue-specific equipment is not likely to receive funding, so it is critical to get the most out of the resources we already possess and to investigate the CSAR applications of new technologies already being brought into the services, such as global positioning system (GPS) tracking.[23] The financial posture of the military relies on its ability to justify expenditures, and joint organization will provide the most efficient way of spending our defense dollars.

The military is at a critical juncture. Simply downsizing the forces we possess to save money will likely result in a decrease in effectiveness. A real drawdown requires a rethinking of the way we organize, a new paradigm around which to base our force structure. The current CSAR capability reflects the lack of attention and thought given to it by the services. It is inefficient and, if not seriously reevaluated, will find itself ineffective as well. The resources are available in-theater, but are not organized into an effective joint force. The current organizational structure and the attendant interservice rivalries are preventing us from realizing the true potential of these resources and will continue to hinder effective CSAR force utilization until there is a serious effort to realign them. □

Notes

1. Earl H. Tilford, Jr., *Search and Rescue in Southeast Asia, 1961-1975* (Washington, D.C.: Office of Air Force History, 1980), 6.
2. Ibid., 18.
3. Ibid., 47.
4. Ibid., 66.
5. Ibid., 94.
6. Brian Lewis, "Helicopters and Search and Rescue: Doctrine Driving Technology Driving Tactics," research report (Colorado Springs, Colo. : US Air Force Academy, 1993), 6.
7. Tilford, 155.
8. Lewis, 5.
9. Kerry DeRechi, " 'I Got Lucky,' Says Pilot Rescued in Iraq," *Norfolk* (Va.) *Pilot*, 27 March 1991.
10. Air Force Manual (AFM) 2-36, *Search, Rescue, and Recovery Operations*, 1967, 9.
11. Ibid., 2.
12. Bill Steiger, "Pilots Heroes at Home," *Charleston* (S.C.) *News and Courier*, 23 January 1991.
13. Joint Publication 3-50.2, *Doctrine for Joint Combat Search and Rescue*, 18 May 1993, B-16.
14. Ibid., C-1.
15. Comdr John B. Mills, "Navy Combat Search and Rescue: Past, Present, Future," research report (Maxwell AFB, Ala.: Air War College, April 1988), 25.
16. Ibid., 26
17. Tom Fielder, "Downed Pilot Snatched from Iraq," *Miami Herald*, 22 January 1991.
18. Comdr John Keiselbach, USN, telephone interview with author, 2 December 1993.
19. Bill Yenne, *The United States Air Force Today* (New York: Gallery, 1986), 71.
20. Michael Roberts, *The Illustrated Directory of the United States Air Force* (New York: Crescent, 1989), 58.
21. Joint Pub 3-50.2, B-2.
22. Mills, 26.
23. C. C. Hobdy, "Search and Rescue as an Instrument of National Policy," Research Report no. 3931 (Maxwell AFB, Ala.: Air War College, April 1970), 90.

Spring 1995

IRA C. EAKER AWARD WINNER

Maj Scott A. Fedorchak, USA

for his article

Air Operations Must Be Joint

Congratulations to Maj Scott A. Fedorchak on his selection as the Ira C. Eaker Award winner for the best eligible article from the Spring 1995 issue of the *Airpower Journal*. Major Fedorchak receives a $500 cash award for his contribution to the Air Force's professional dialogue. The award honors Gen Ira C. Eaker and is made possible through the support of the Arthur G. B. Metcalf Foundation of Winchester, Massachusetts.

If you would like to compete for the Ira C. Eaker Award, submit an article of feature length to the *Airpower Journal*, 401 Chennault Circle, Maxwell AFB AL 36112-6428. The award is for the best eligible article in each issue and is open to all US military personnel below the rank of colonel or equivalent and all US government civilian employees below GS-15 or equivalent.

Ricochets and Replies
continued from page 3

RE SACRED COWS

I want to congratulate you on the much-needed change in direction of the *Airpower Journal.* You are right—the Air Force is hungry for ideas. After all, its professional journal has been on a self-imposed, seven-year fast.

That said, there have been areas of significant progress at Air University and in the Air Force generally since 1987. The reorganization of the USAF, led by Gen Merrill A. McPeak, was an absolute necessity after the end of the cold war. Nevertheless, it took integrity and courage. The establishment of the School of Advanced Airpower Studies (SAAS) is another encouraging sign. The "Warden Revolution" at Air Command and Staff College is indicative of the potential inherent in ideas. If there is an intellectual revolution in the Air Force, no one is happier about it than those few of us who, quite literally, were the intellectual insurgents of the 1970s and 1980s.

War is, above all, an intellectual endeavor. Before planes drop bombs, soldiers march, tanks roll, or ships sail, war exists as an idea in someone's mind. Ideas lead to strategy, and if the strategy is flawed, the war will be lost. Bad strategy cannot be saved by heroism, increased bomb tonnages, technological silver bullets, or a plethora of human suffering. (I commend to you Prof Larry E. Cable's *Unholy Grail* for an elaboration on the above.) Meanwhile, I hope the new direction undertaken by the *Airpower Journal* means that the Air Force's unilateral disarmament in the war of ideas has ended.

Earl H. Tilford, Jr.
(former editor of *Air University Review)*
Carlisle, Pennsylvania

Net Assessment

Reading furnishes our mind only with materials of knowledge; it is thinking that makes what we read ours.

—John Locke

Certain Victory: The U.S. Army in the Gulf War by Brig Gen Robert Scales, USA; Lt Col Terry Johnson, USA; and Maj Thomas Odom, USA. Government Printing Office, Superintendent of Documents, P.O. Box 371954, Pittsburgh, Pennsylvania 15250-7954, 1993, 435 pages, $115.00.

Certain Victory—an expensive, full-color, 435-page celebration of the US Army's triumphant emergence from the malaise of Vietnam into the oil fields of Kuwait—takes the reader on a fast-paced journey through the 100-hour ground war in the Gulf. Six of its seven chapters begin with very readable personal accounts of the Gulf War or events leading up to it. The personal stories are presented in italics and run three to five pages. Chapter 7 begins with a personal account of a sergeant major's recollection of his return to the States from Vietnam in 1969. It is part of the writers' attempts to frame the book in the light of a vastly improved, necessary, and war-winning Army of the 1990s.

The primary authors—a three-man team led by Brig Gen Robert Scales—are not shy about giving total credit to the Army for the success of the campaign against Iraq. The authors even view something as benign and self-evident as the airlift and sea lift of combat and support forces from the US and Europe as an all-Army show: "In Desert Shield the Army created a military metropolis half a world away in less than 90 days" (page 383).

The detailed—in some cases, hour-by-hour—description of the ground war shows numerous tank battles against well-equipped, motivated, and highly trained Iraqi forces who—allegedly—had hardly been touched by the 41-day coalition air campaign that preceded G day:

> Though battered by the Coalition for 41 days, the Iraqi GHQ [general headquarters] had retained control of its forces in the KTO [Kuwaiti theater of operations]. Emergency crews swiftly repaired the communications system when it was damaged by bombing. . . . The 50th Armored Brigade still had plenty of fighting machines. Air attacks since January 17 had caused few losses. Ninety of his original 108 tanks remained serviceable, as did most of his MTLB personnel carriers. (Pages 232–35)

Throughout the book, the authors consistently maintain that air did little to affect the outcome of the war. Ground forces did the real job, especially in the area controlled by General Frederick J. Franks, VII Corps commander:

> Under the American guns, the remaining combat vehicles in the Iraqi security force died quickly. The defending Iraqi commander later remarked that after losing 2 of his 39 T-72s in five weeks of air attack, the 2d Cavalry had annihilated his entire command in fewer than six minutes in what later came to be known as the Battle of 73 Easting. (Pages 261–62)

However, the authors' criticism of airpower does not extend to rotary-wing craft. These they judge to be extremely effective force multipliers, capable of enormous and timely destruction of enemy ground forces and personnel:

> Stockhausen noticed that the dark night and the very steep angle of the missiles' trajectories completely surprised and confused the enemy. As they ran aimlessly among the burning vehicles, the hapless Iraqis obviously had no idea of what was hitting them. Hatch had joined the engagement as a copilot-gunner. He was so absorbed in his Hellfire sight that he failed to notice a rumble of explosions below him until the pilot in an adjacent aircraft broke in on his radio. The pilot told Hatch that he had just chewed up about a dozen Iraqi soldiers armed with AK-47s who had collected below Hatch's Apache and were ready to shoot him down. His wingman's 30mm gun had saved Hatch's life. . . . Later, gun camera videotape confirmed that the single Apache battalion had killed 38 T-72s, 14 BMPs, and 70-odd trucks. (Pages 271–72)

The authors blame fixed-wing aircraft and the men who commanded them for letting the Republican Guard escape during the last hours of the ground war. Further, they can't resist taking a swipe at the work of American air forces in the much publicized "Highway of Death," accusing them of doing little but shooting up stolen trucks, buses, and cars, and in the process allowing the main Iraqi battle force to escape into the desert:

> The decision to leave everything east of 20 Easting to air power rather than mount a series of Apache attacks against the retreating armor gave the Iraqi tanks the opportunity to run a rather porous gauntlet and seek sanctuary within the Basrah pocket. Close examination of the "Highway of Death," created by the Coalition air forces along the main road from Kuwait City to Basrah, showed the vast majority of the destroyed vehicles to be trucks, cars, and buses looted from the Kuwaitis, none of which were capable of off-road movement. Saddam's armor, able to fan out across the desert, merely sidestepped to the east and retreated into Basrah. (Page 315)

Certain Victory is filled with other equally damning remarks about airpower. Air tasking orders took too long to build, weren't responsive to the corps commander's needs, and so forth. The book slowly works its way up to one of the Army's key concerns both during and after the Gulf War—determining the exact role of airpower in this new age of precision weapons and increased intelligence capabilities. According to *Certain Victory,* airpower's only role is to support the ground commander's scheme of maneuver and to assist in shaping the battlefield. The real work will be done the old-fashioned, "dirty" way by ground forces:

> Air planners have long sought to vindicate the view that the ever-increasing accuracy of air-delivered munitions has made it possible to win war the "clean" way—through strategic targeting. In this view, the application of air power then becomes a campaign—if not a separate war—distinct from ground combat. The Army, on the other hand, does not recognize the distinction. Instead, ground commanders see air power as the means to weaken the enemy and shape the battlefield. (Pages 175–76)

The authors interviewed 99 Army people, including 94 officers and five enlisted men. However, the commander of the Desert Storm coalition, Gen H. Norman Schwarzkopf, was not among them. While there could be a myriad of reasons why the *Certain Victory* research team did not interview this most popular of four-star Army generals, his omission is glaring, nonetheless.

Even without Schwarzkopf, one must view *Certain Victory* as a full-court press by the United States Army to convince everyone within its reach that heavy armor and ground forces have been and still are the decisive elements in warfare. By belittling the contributions of airpower and scarcely mentioning sea power, the authors would have us believe that "only tanks kill tanks" and "only armies win war" and "that's the way it will always be." The real danger in books like *Certain Victory* is that after a while, the uninitiated begin to believe them. With enough time, a whole generation could come to the conclusion that it is possible to fight a 100-hour war with nothing more than tanks and soldiers and suffer little loss of life. Readers could come to believe that armies cross oceans by themselves and fight fully functioning adversaries with only the tiniest bit of assistance from their brothers and sisters in the sky. They could embrace such nonsense as truth and in the process lose their freedom and themselves. *Certain Victory* could unwittingly lead to certain defeat.

Col Rich Reynolds, USAF
Brussels, Belgium

Paper Soldiers: The American Press and the Vietnam War by Clarence R. Wyatt, W. W. Norton and Company, 500 Fifth Avenue, New York 10110, 1993, 272 pages, $22.95.

The relationship between the press and the military is a subject sure to evoke vivid mental images and strong emotions—especially in regard to Vietnam. For example, I was turned off by the endorsement on the back of the dust jacket of this book by the infamous "Baghdad Peter" Arnett, even though he has valid credentials as an experienced Vietnam War reporter. In any case, whether viewed as villain or savior, biased or objective, adversarial or cooperative, the press is almost unanimously thought of as a major, maybe even a decisive, factor in the United States's failure in Vietnam. Did the noble press "pull aside the veil of righteous wrath to bring the war to an end," or did it "misrepresent the nature and progress of the war, thus leading the American people to turn their backs on a 'noble cause' "?

Wyatt observes that "creators of such images have made a simplistic morality play out of what is a complicated, important story" and maintains that neither of these views is accurate since each is based on a false belief that "the press was a powerful adversary of the government and the military." Wyatt supports his thesis through a well-researched, very readable examination of exactly how the press covered the Vietnam War (e.g., resources allocated and sources relied upon). A rework of Wyatt's doctoral dissertation, which was written under the very able direction of George C. Herring, author of *America's Longest War: 1950–1975,* this book is also the story of the changing, often stormy, relationship between the press and the American government in general and the US military in specific.

According to Wyatt, the physical and intellectual demands of journalism motivated Vietnam reporters and their superiors back in the United States much more than political or ideological beliefs. Shoestring budgets, rampant ethnocentrism, and an intense focus on spot reporting of day-to-day American combat activity all combined to shape what Americans knew or, more important, did not know about the Vietnam War. At the same time, "the relationship between the press and the government/military was based on a fluctuating mix of confrontation and cooperation." At times, particularly in the early and late years, press access to official information about the war was rigidly restricted. At other times, such as during President Lyndon Johnson's "Maximum Candor" approach, the press was virtually flooded with information concerning the daily activities of American forces. During each of these periods, Wyatt asserts that "content analyses of newspaper and television coverage show that, more often than not, the press reported official information, statements, and views with relatively little dissent." All of these factors combined to make "Vietnam 'the most covered but least understood' war in American history."

While Wyatt does a credible job of discussing and supporting his thesis concerning the press and the Vietnam War, he does a very poor job of analyzing and discussing exactly how the relationship between the government and the press should work. This omission would not have bothered me except that Wyatt criticizes the American government when it restricts information (obviously hiding something) and when it provides open access (obviously spreading propaganda). His true colors come to light in his conclusion, where he states that "a cult of secrecy that goes far beyond legitimate security considerations has evolved in American government. As the Vietnam War showed, the ability and inclination of the executive branch to restrict and to manipulate information is largely beyond the press's ability to resist." Such thoughts permeate this book and detract from an otherwise insightful treatise. If you are planning to read this book, I suggest you read the conclusion first so that you will be aware of and prepared to deal with Wyatt's biases.

Even with its faults and in spite of Baghdad Peter's endorsement, I highly recommend this book. It certainly convinced me that during the Vietnam War, "the press was more a paper soldier than an antiwar, antigovernment crusader."

Lt Col William F. Furr, USAF Retired
Montgomery, Alabama

The Origins of U.S. Nuclear Strategy, 1945–1953 by Samuel R. Williamson, Jr., and Steven L. Rearden. St. Martin's Press, 175 Fifth Avenue, New York 10010, 1993, 275 pages, $45.00.

The United States's nuclear strategy from the Korean War to the end of the cold war was based on the simple concept of having enough nuclear weapons pointed at the Soviet Union to keep it from unleashing a preemptive nuclear attack on the United States or its allies. But how did the US come to adopt such a policy? In *The Origins of Nuclear Strategy, 1945–1953,* Samuel R. Williamson and Steven L. Rearden very persuasively argue that this deterrent strategy only slowly evolved into doctrine, driven not so much by military or political planning as by budgetary demands.

Using extensive original source material, Williamson and Rearden skillfully relate how the United States came to rely on its huge nuclear arsenal for both national and international security. Somewhat surprisingly, however, this policy was not a foregone conclusion until nearly the end of the Truman presidency. In fact, until 1948 there was no consensus on the role of atomic weapons because "neither the military nor the civilian leadership was sure what exactly to make of the atomic bomb" (page 29).

While the military wanted significant input into atomic policy in the postwar period, massive demobilization affected how it proposed to use atomic weapons. As late as October 1947, the Air Force had only 18 operational B-29s modified to drop atomic bombs, with only 11 qualified crews and two bomb assembly teams. Even a year later, when Gen Curtis LeMay assumed command of the Strategic Air Command (SAC), there was still only one functional atomic bombardment group, not the six that the Air Force had hoped for. Perhaps most telling, military leaders had not yet even attempted to integrate atomic weapons into American war plans.

Civilian attempts at control of atomic policy suffered also. When the Atomic Energy Act transitioned control of atomic energy from the War Department to the Atomic Energy Commission (AEC) on the last day of 1946, the program was in disarray. With the sense of wartime urgency gone, many scientists had left the project for other endeavors. Facilities were starting to deteriorate. Of the three graphite reactor piles at Hanford, Washington, for example, one had to be shut down and power to the others reduced. Confirmation hearings for AEC chairman David Lilienthal and the other members dragged on for six months, denying the AEC any effective leadership from October 1946 to April 1947. And above all else, the US had produced only a half-dozen operational bombs by mid-1947.

The 1948 Berlin crisis proved crucial to the creation of an effective US nuclear strategy with civilian and military cooperation. When the Soviet Union began its blockade of Berlin in June of that year, the US response included the possible use of atomic weapons. Though no atomic bombs were sent to Europe, Great Britain agreed to allow two US bomb groups to deploy there. Designed as a temporary measure, the deployment soon became permanent, setting the stage for future US nuclear weapon stockpiling in England. The Berlin crisis also forced the president and his advisors to confront the reality of including nuclear weapons in future US war plans.

Clearly, though, Williamson and Rearden believe that the most important factor in convincing President Truman to adopt a military strategy dependent on nuclear power was the federal budget. Until Berlin, Truman wanted to reduce American dependence on nuclear power and perhaps even have it internationally controlled or banned. But in the wake of the Berlin crisis, the 1948 debate over the 1950 budget finally convinced Truman that America's nuclear monopoly would be a cost-efficient way to deter Soviet aggression. Though he remained uneasy over including atomic weapons in defense planning, the existing nuclear technology and production potential made it cheaper than building and maintaining conventional forces. A fiscal conservative who wanted to keep defense spending as low as possible, Truman all but forced the Defense Department to adopt an active reliance on strategic airpower and nuclear weapons because it could be done and still meet his $15 billion defense ceiling.

The 1951 budget entrenched the nation's less costly nuclear strategy, reducing the defense budget by $2 billion to help offset the growing federal deficit. Despite the successful Soviet atomic test in the summer of 1949, Truman and his military advisors felt America's numerical advantage and delivery capabilities would continue to outpace Soviet advances for several years, until the budget could allow for greater conventional forces.

The Korean War ended frugal defense appropriations, with the 1951 and 1952 defense budgets soaring to $48 and $55.5 billion, respectively. But it did not end America's growing dependence on strategic nuclear deterrence, although it did force the US to maintain larger and more potent conventional forces, a duality in line with Secretary of State Dean Acheson's overtures since 1949 regarding the priority of European security. But with the advent of a successful and relatively inexpensive thermonuclear weapons program by 1952 and the emergence of General LeMay's vastly strengthened SAC, the US was not about to back away from its now firm belief in the necessity of a strong nuclear backbone. As a corollary to this doctrine, the Air Force in the 1950s became America's first line of defense, assuming the bulk of the responsibility for fighting both nuclear and general wars.

Although President Truman and the country had a variety of options available concerning the use of nuclear weapons, Williamson and Rearden clearly saw it as an instrument of national power that would inevitably become a part of American war plans. Ironically, the United States faces a similar dilemma today. With the end of the cold war and the demise of the Soviet Union, we look to stealth aircraft and "smart bombs" to give us the technological advantage necessary to win regional wars as we simultaneously pare our current military budget, the size of our uniformed services, and the nuclear arsenal built since the Truman years. But the authors point out that we must still adhere to realities similar to those faced by Truman because "he . . . left a way of thinking about national security, a mindset that for the first time in American history accorded primacy to maintaining a large and ready defense establishment" (page 184). This well-written and documented book provides insight into how this particular mind-set was created.

Maj William L. Coode, USAF
Starkville, Mississippi

Mission Debrief

I Can Write Better than That!

OK, THEN DO IT! *Airpower Journal* is always looking for good articles written by our readers. If you've got something to say, send it to us. We'll be happy to consider it for publication.

The *Journal* focuses on the operational and strategic levels of war. We are interested in articles that will stimulate thought on how warfare is conducted. This includes not only the actual conduct of war at the operational and strategic levels, but also the impact of leadership, training, and support functions on operations.

We need two typed, double-spaced draft copies of your work. We encourage you to supply graphics and photos to support your article, but don't let the lack of those keep you from writing! We are looking for articles from 2,500 to 5,000 words in length—about 15 to 25 pages.

As the professional journal of the Air Force, *APJ* strives to expand the horizons and professional knowledge of Air Force personnel. To do this, we seek and encourage challenging articles. We look forward to your submissions. Send them to the Editor, *Airpower Journal*, 401 Chennault Circle, Maxwell AFB AL 36112-6428.

. . . But How Do I Subscribe?

EASY . . .

- Just write New Orders, Superintendent of Documents, P.O. Box 371954, Pittsburgh PA 15250-7954.

- Say that you want to subscribe to AFRP 10-1, *Airpower Journal*, stock number 708-007-00000-5.

- Enclose a check for $13.00 ($16.25 for international mail).

- Spend a year enjoying four quarterly issues mailed to your home or office.

Basis of Issue

AFRP 10-1. *Airpower Journal*, is the professional journal of the Air Force. Requirements for distribution will be based on the following:

1 copy for each general on active duty with the US Air Force and Air Reserve Forces.

1 copy for every 5 (or fraction thereof) active duty US Air Force officers in grades second lieutenant through colonel.

1 copy for each US Air Force or Air Reserve Forces office of public affairs.

3 copies for each Air Force Reserve Forces unit down to squadron level.

3 copies for each air attaché or advisory group function.

1 copy for each non-US Air Force, US government organization.

1 copy for each US Air Force or US government library facility.

If your organization is not presently receiving its authorized copies of the *Airpower Journal*, submit a completed AF Form 764a to your publications distribution office (PDO).

The Editor

Our Contributors

Gen Michael P. C. Carns, USAF, Retired (USAFA; MA, Harvard University) served as Air Force vice-chief of staff from 1991 until his retirement in 1994. He flew 200 combat missions over Southeast Asia in the F-4E. During Desert Shield/Desert Storm, he served as the director of the Joint Staff. Other assignments during his distinguished Air Force career included deputy commander in chief and chief of staff, US Pacific Command; commander, Thirteenth Air Force; deputy chief of staff for plans and later deputy chief of staff for operations and intelligence, Headquarters PACAF; director of operations, J-3, Rapid Deployment Joint Task Force; commander, 57th Fighter Weapons Wing, Nellis AFB, Nevada, and the 354th Tactical Fighter Wing at Myrtle Beach AFB, South Carolina. General Carns also served as special assistant to the chief of staff, Supreme Allied Commander, Europe.

Col Ralph J. Capio (BA, Rutgers University; MPA, State University of New York, Albany; JD, Union University, Albany Law School; LLM, George Washington University; MIBS [in progress], Saint Louis University) is an Air Force judge advocate assigned to Headquarters Air Mobility Command as chief, Contract and Air Law Division, Office of the Staff Judge Advocate. Colonel Capio is a distinguished graduate of Squadron Officer School, as well as a graduate of Air Command and Staff College and the national security management program of National Defense University.

Capt Edward B. Westermann (USAFA; MA, Florida State University) is an assistant professor of history at the USAF Academy. He has previously served as a combat search-and-rescue helicopter aircraft commander and as an exchange instructor pilot with the German air force. Recently selected as the USAF Academy's outstanding academic educator in history, Captain Westermann will soon attend the Free University of Berlin on a Fulbright-Hays Fellowship.

2d Lt Dave Meggett (USAFA) is a student pilot in the 8th Flying Training Squadron, Vance AFB, Oklahoma.

Please Recycle

Tear Out and Remove

Superintendent of Documents **Subscription** Order Form

Order Processing Code:
***5600**

☐ **YES,** enter my subscription(s) as follows:

____ subscriptions to ***Airpower Journal*** (AURE) for $14 per year.

The total cost of my order is $______. Price includes regular shipping and handling and is subject to change. International customers please add 25%.

____
Company or personal name (Please type or print)

____
Additional address/attention line

____
Street address

____
City, State, Zip code

____
Daytime phone including area code

____
Purchase order number (optional)

For privacy protection, check the box below:
☐ Do not make my name available to other mailers

Check method of payment:
☐ Check payable to Superintendent of Documents
☐ GPO Deposit Account ☐☐☐☐☐☐☐ – ☐
☐ VISA ☐ MasterCard
☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐
☐☐☐☐ (expiration date)

____
Authorizing signature 6/95

Mail To: Superintendent of Documents
P.O. Box 371954, Pittsburgh, PA 15250–7954

Charge your order. It's easy!

MasterCard

VISA

S3S

To fax
your orders
(202) 512–2250

To phone
your orders
(202) 512–1800

Thank you for your order!

Want a Subscription to the *Airpower Journal?*

Detach this card, fill it out, and mail it along with a check, VISA, or MasterCard number to:

Superintendent of Documents
P.O. Box 371954
Pittsburgh PA 15250-7954

Superintendent of Documents
P.O. Box 371954
Pittsburgh, PA 15250-7954

Tear Out and Remove

AIRPOWER JOURNAL COMMENT CARD

We are always interested in hearing from our readers. Please
this card to comment on this issue ______________

Issue Article

Rank/Title First Name Initial Last Name

PLEASE PRINT

Street City State/Country Zip

AIRPOWER JOURNAL COMMENT CARD

We are always interested in hearing from our readers. Please
this card to comment on this issue ______________

Issue Article

Rank/Title First Name Initial Last Name

PLEASE PRINT

Street City State/Country Zip

FEEL LIKE SPEAKING UP?

Fill out one of the attached comment cards and drop it in any mailbox.

OWER JOURNAL
hennault Circle
ell AFB AL 36112-6428

OFFICIAL BUSINESS
LTY FOR PRIVATE USE, $300

NO POSTAGE
NECESSARY
IF MAILED
IN THE
UNITED STATES

BUSINESS REPLY LABEL
FIRST CLASS PERMIT NO. 200

POSTAGE WILL BE PAID BY ADDRESSEE

AIRPOWER JOURNAL
Airpower Research Institute
401 Chennault Circle
Maxwell AFB AL 36117-8930

OWER JOURNAL
hennault Circle
ell AFB AL 36112-6428

OFFICIAL BUSINESS
LTY FOR PRIVATE USE, $300

NO POSTAGE
NECESSARY
IF MAILED
IN THE
UNITED STATES

BUSINESS REPLY LABEL
FIRST CLASS PERMIT NO. 200

POSTAGE WILL BE PAID BY ADDRESSEE

AIRPOWER JOURNAL
Airpower Research Institute
401 Chennault Circle
Maxwell AFB AL 36117-8930

The *Airpower Journal* (ISSN 0897-0823), Air Force Recurring Publication 10-1, is published quarterly. Subscriptions may be ordered from New Orders, Superintendent of Documents, P.O. Box 371954, Pittsburgh PA 15250-7954. Annual rates are $13.00 domestic and $16.25 outside the United States. The GPO stock number is 708-007-00000-5.

The *Journal* welcomes unsolicited manuscripts. Address them to Editor, *Airpower Journal*, 401 Chennault Circle, Maxwell AFB AL 36112-6428. Submit double-spaced, typed manuscripts in duplicate. All submissions will be edited in accordance with the standards set forth in the *Air University Press Style Guide*. *Journal* telephone listings are DSN 493-5322 and commercial (334) 953-5322.

Coming in the Fall

A World War II Bibliography

AU PRESS

AIRPOWER JOURNAL

Fall 1995