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United States Air Force Scientific Advisory Board



Report on System-Level Experimentation

Executive Summary and Annotated Brief

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Foreword

This study is about system-level experimentation (SLE) – campaigns of genuine discovery experiments - and how SLEs can be used to drive disruptive innovation.

SLEs support the discovery, exploration, and understanding of new operational and system concepts and the technology needed to support those concepts in future environments. As such, SLEs are complimentary to, but different from ATDs or JEFX (focus on early discovery versus later demonstration), Battleregions (focus on game changers versus near-term needs), or Big Safari or the Rapid Capabilities Office (focus on discovery in future environments versus fast fielding to meet high priority needs). Similarly, SLEs are not wargames (e.g., the AF/A8 Futures Game), but SLEs could be conducted in the futuristic scenarios of such games.

Disruptive innovations often arise from the “friction of war.” To mimic that effect, SLEs must incorporate a challenge-competitive environment to maximize depth of innovation and exploration, with an unfettered, highly skilled adversary with no cultural limitations and with technical restrictions imposed only by physics. The experiments should be staffed with carefully selected individuals who have attributes conducive to “out of the box” exploration. Experiments can be conducted in gaming environments ranging from simple “seminar explorations” to networked gaming to being in the field. The SLE approach developed in this study also integrates recently codified industry innovation practices (e.g., innovation starts with the CEO).

The study identifies four essential components in the development of disruptive innovation by means of system-level experimentation: ideas, people, venue, and experiments.

- Ideas: Innovation occurs throughout an organization and must be sought out. It is critical to identify ideas that challenge standard ways of doing things.
- People: Not all people are innovative. Those that are must be identified, supported, protected, and valued.
- Venue: A venue is not a specific place or facility. It is an exploration space, which might be a virtual environment or the battlefield of a war game.
- Experiments: The only way to explore the complexities of a system is through campaigns of experiments, based on the proper venue, people, and ideas. Combining these into a rigorous program of technology and CONOPS will create a deep understanding of what the future may be and how to best meet it.

A case study based on the development of the armed Predator is used to illustrate the SLE approach. The single recommendation is to replicate this case study through the auspices of a Chief of Innovation reporting to the CSAF. The recent creation of an Air Force Futures Program between AF/A8 and AU/CC provides a near-term means to implement this recommendation without creating a new organization. Over time, the Air Force might consider creating a civilian IPA position for someone who served as a Chief of Innovation in industry.



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Executive Summary

Introduction

... any air force which does not keep its doctrines ahead of its equipment, and its vision far into the future, can only delude the nation into a false sense of security.

General Henry “Hap” Arnold
November 1945

Sixty-one years ago General Arnold, as the Chief of the Army Air Forces, recognized the importance of understanding technology and tactics required to dominate in future environments. In today’s parlance, General Arnold was talking about maintaining the Air Force’s combat edge through innovation (e.g., pursuing revolutionary, game-changing systems). In the commercial world, innovation is a means to stay competitive; in the military world it is a means for achieving and maintaining dominance.

This is a Quick Look report on System-Level Experimentation (SLE). Quick Look studies are conducted by a smaller study team in a shorter period of time than a full Scientific Advisory Board (SAB) study. This study is about provoking disruptive innovations through system-level experimentation. There are five key points in this study.

1. SLE is an approach to unfettered exploration of alternative system concepts focused in future environments to aid in earlier discovery of game changing ways to “fly and fight.”
2. Our adversaries innovate while we merely react - a more proactive approach would support system-level discovery experiments focused on disruptive ideas, thus increasing the likelihood of finding game-changing ways to “fly and fight” BEFORE the fight, forcing our adversaries to react to our innovations.
3. At one time the USAF aggressively searched for “game changers;” arguably it has not done so for many years.
4. The USAF is not alone. Innovation is also an important national issue for U.S. industry. There has been impressive progress in the last year, and there are lessons learned the USAF can apply now.
5. Ad hoc groups (e.g., “innovation task forces”) drawn from Air Force organizations can be formed to do SLEs and would need to be supported by a small group of facilitators. These “innovation task forces” need to be resourced, protected, and visibly important to the Chief of Staff.

The Air Force faces a world rapidly increasing in complexity, with adversaries ranging from emerging super powers to elusive terrorist organizations. With the quickening pace of technological change and its commercial availability, as well as the ability of our adversaries to take advantage of that technology in innovative ways, the Air Force can no longer solely rely on its current approach to developing new technologies and tactics. The Air Force must become more adaptable and able to respond rapidly to opportunities afforded by technological advances. Indeed, the Air Force must take a leadership role in driving the development of new technology

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and in creating the tactics, techniques, and procedures to use that technology. In short, the Air Force must become more innovative.

Technology and tactics are inseparable, so that the Air Force must embrace an approach for innovation that links technologists and operators from its inception. The Air Force also needs to focus on an uncertain future, with unforeseen requirements. To best meet that future, the Air Force must embrace a culture of experimentation, in which technology and tactics are developed and tested in a diverse range of environments – the experiments should be focused at the system level. Experimentation alone is, however, not sufficient. The Air Force must also develop a strong culture that fosters and nourishes innovation. This quick look study examined how the Air Force can employ system-level experimentation to help provoke the innovation needed to meet its future challenges.

Experimentation

This study is about system-level experimentation and how it drives innovation. By system we mean the integration of technology, process, people, and organization to accomplish some set of functions. In the context of this study, a system is the combination of the components necessary to carry out the missions of the Air Force.

Alberts and Hayes [1] describe three types of experimentation:

Discovery experiments are designed to generate new ideas or ways of doing things. Hypothesis testing experiments are the classic type used by scholars and researchers to advance knowledge by seeking to falsify specific if/then statements or to discover their limiting conditions. Demonstration experiments create a venue in which known truth is recreated.

Most Air Force “experiments” are demonstrations in that they are used to train or show that expected results are true. For the purposes of this study, the focus is only on discovery and hypothesis testing experiments.

Campaigns of experiments are groups of experiments designed for a given purpose. In a typical campaign, there are a series of coordinated experiments, with each experiment informing the next. Such campaigns iterate to an outcome or explore a wide range of alternatives, as will be discussed in more detail below.

System-level experimentation involves campaigns of discovery experiments that combine technology (both developed and envisioned) and concept of operations (CONOPS) to develop new capabilities. SLEs explore a wide range of possible future environments and conditions.

Innovation

Clayton Christensen, in his 1997 book The Innovator’s Dilemma, [2] introduces the concept of a disruptive technology to describe a new technological innovation, product, or service that eventually overturns the dominant technology or product existing in the market. He broadened that concept to disruptive innovation in his sequel The Innovator’s Solution, [3] where he notes that few technologies are intrinsically disruptive; it is their *use* that creates their

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disruptive impact. He describes sustaining innovation, on the other hand, as successive incremental improvements to performance that are incorporated into existing products.

Sustaining innovation is the most common form of innovation. One example is the automobile, which today is only different in degree from Henry Ford's Model T. The personal computer is faster with more memory and disk space today than in the early 1980s, but its functionality is no different. Most Air Force technologies under current development fall into the category of "sustaining innovation."

Disruptive innovation arises not just from the introduction of a new technology, but also through changes in the use of those technologies. Disruptive innovations often impact the market broadly, creating entirely new industries while destroying others, when first introduced. The automobile changed the world by eliminating horses as the principle mode of transportation, with similar impacts in all the subsidiary businesses associated with them. In the late 1970s, computing changed in a disruptive manner with the introduction of the personal computer. At first PCs were slow, had no memory or software, and their utility for almost anything was questioned. Their performance was far less than the mainframe computers they eventually replaced. They were, however, relatively inexpensive and, more importantly, could be run and managed by an individual, not requiring an extensive organization. Suddenly, computing was put into the hands of almost everyone, which led to extraordinary changes in the computing business as well as in almost all other businesses and, essentially, every aspect of life. The disruption arises from the *use* of the technology, which changed computing in a drastic way. Coupling personal computing with the internet is leading to a revolution in connectivity, with blogs, podcasts, wikis, and etc., changing how the world communicates. The combination of technology and use (CONOPS) form the basis of this study.

Disruptive innovation in warfare

Carl von Clausewitz, a Prussian general and military theorist, introduced the idea of the "friction of war" to describe how war in reality differs from that on paper – things that can go wrong often do go wrong. The friction of competition has led to many disruptive innovations in which new ways of using technology to advance CONOPS were developed and fielded. Just a few examples from American aviation are listed. However, this study chose to highlight two examples from the great Air Force innovators of the past as well some more modern examples.

After World War I ended, large battleships were believed to be invincible, and thus garnered a major part of Defense funds. General Billy Mitchell felt that no naval fleet could survive an attack by land-based air and, after an extensive and bitter controversy, forced an experiment with decommissioned U.S. capital ships and the "unsinkable" captured Ostfriedland as targets. Bombers sank them all, proving his ideas. This "experiment" made the Navy realize that a future force based solely on the battleship was too risky, so it shifted its focus from battleships to aircraft carriers, combining air and sea power in a way that changed naval warfare in a disruptive way.

In the 1930s, standard Air Corps doctrine assumed that pursuit planes would be ineffective against bombers; the war games of the day supported that view. Captain Claire Lee Chennault, however, felt the Air Corps rigged maneuvers in favor of bombers. To prove his point, Captain Chennault arranged for a test of his ideas by setting an early warning system in an

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exercise held in 1933. He placed spotters in the region of the test with telephone communication back to the fighter bases. When bombers were spotted, the fighters scrambled and intercepted the bombers. Despite protests by the bombers, who felt the exercise was “unfair,” Chennault’s experiment clearly showed that pursuit planes could intercept bombers. Unfortunately, the Air Corps largely ignored these results at that time. However, the victory of pursuit planes in the Battle of Britain verified his ideas, leading to a new age of air warfare.

There are a number of examples of disruptive innovations from more recent eras as well. While we describe them by their technology, the disruption arose from the change in doctrine enabled by the technologies; they changed how the Air Force did its job. Some examples are the combining of technologies to create the Intercontinental Ballistic Missile (ICBM), the development of precision-guided munitions, stealth technology, etc. An interesting example occurred in 2000, when the CSAF ordered a rapid study (90 days) to see if a UAV (the Predator) could be armed with Hellfire missiles. The CSAF asked the technologists and operators to assess feasibility and tactics. He allocated resources and gave them the right to fail. The disruptive innovation was not, however, the addition of a missile to an unmanned platform. The innovation came about when the system was put into the field (the “experiment”) and changed an observation platform into an offensive weapon. How disruptive this innovation will be is still unknown.

All of these examples show that disruptive innovation is much more than technology. It is the combination of technology and CONOPS, often developed through experimentation, that have led to fundamental shifts in how warfare is conducted. The study team notes that none of these examples resulted from the formal requirements process and, in fact, threatened to disrupt the plans that are pursued by the formal requirements and acquisition process.

The Air Force today

This quick look study could not research every Air Force organization nor could it examine all research and development activities. The study team did, however, interact with a wide range of organizations throughout the Air Force and thus feels comfortable with the assessment of the current state of Air Force practices. The team has the same position on the culture of the Army and Navy as well.

The Air Force is very good at sustaining innovation. The Air Force continues to advance technology throughout the service. However, it has often been a challenge to deploy those advances in a timely way due to the well-known issues with the acquisition process. Especially when faced with an innovative adversary (e.g., IEDs), the cumbersome processes limit the ability to respond in an effective way. We note, however, that recent acquisition improvements are targeting this issue by focusing on processes to more rapidly field technologies.

The Air Force lacks a focus on true discovery experiments. Since the development of stealth technology and accompanying operational procedures, the Air Force has not conducted major discovery experiments at the systems level. JEFX organizers have primarily devoted their exercises to evaluating “leave behind” capabilities and conducting limited demonstrations with a high probability for success. The original intent to explore alternative concepts of operation enabled by modern technology has acquiesced to concern over near-term needs and budgets. Indeed, the reliance on demonstrations rather than experiments seems pervasive throughout the

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Air Force. Organizers even constrain adversarial experiments to fit training scenarios, with red teams forced to follow scripts that prevent them from expressing creative, disruptive responses to situations. Indeed, the team even heard from one experimenter that a competition was set up so that the blue team would “win” so they would not “feel bad.”

The Air Force has innovative people, yet it fails to take full advantage of them and, indeed, sometimes hinders them. Over the course of the study the team met many creative Airmen (both military and civilian) predisposed to the types of disruptive thinking fundamental to this study. They uniformly expressed frustration at the lack of a forum to present their ideas and at the impediments for advancing those ideas as system solutions fielded for the war fighter. Both the Air Force’s bureaucratic acquisition process and risk-averse culture limit their effectiveness as innovators. A critical need, for example, in any innovative organization is the free flow of information. One of the most disappointing findings of the study was the identification of intentional efforts to stifle information exchange around the USAF. Borne of fears over cyber-security, the USAF communications systems managers implement an information lock-down that too often defies logic. No one questions the worth of readiness for cyber attacks and network warfare, but restrictive security practices frequently hamper reasonable, necessary information exchange. The Air Force needs policies and technologies that balance network security and the need to collaborate effectively to pursue innovation.

The Air Force has largely lost its ability to foster disruptive innovation. The future demands that the Air Force once again become a leader in disruptive innovation, and the rest of this report outlines our suggestions initiating this transition.

Lessons Learned from the Commercial Sector

Over the past few years there have been numerous studies on the status of innovation in industry [4,5,6]. From these studies, a common view of what it takes to be an innovative company is emerging.

1) *The CEO needs to be the “owner” of innovation.* In the private sector it is increasingly understood that the CEO is responsible for creating a culture of innovation. “Leading, setting direction, laying the cultural groundwork that stimulates innovation – it’s essential work for a CEO,” acknowledged one executive [4]. This does not mean that the CEO is the principal innovator. Rather, they are responsible for establishing the practices, organizations, and communication channels that create a culture in which innovation can flourish.

2) *Chief of Innovation.* Successful CEOs often appoint a single person who is responsible for innovation, the “Idea Tsar.” That chief innovator is not, in general, the General Manager of R&D. Rather it is someone who can balance emerging technology with the possibilities of the marketplace. This is a function that demands experience, someone who has experienced the effect of a disruptive innovation and who understands the difficulty in predicting how a given technology will be fully utilized.

3) *Organization.* Large organizations often become hierarchical, which tends to stifle the communication necessary for innovation. A successful way around this problem is to create small passion-driven teams to focus strictly on innovation (e.g., Whirlpool, Kodak, and etc.). These teams are separate from the main lines of the organization and are thus freed from at least

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some of the standard organization constraints. They also have the luxury of bringing together people that may have been separated due to organizational boundaries.

4) *Ideas*. Innovation cannot happen without ideas, and these ideas can come from any part of an organization as well as outside the organization. An organization successful at innovation must actively stimulate the generation of new ideas, seek out those ideas, explore competing ones, and ensure that communication flows freely so that “cross pollination” can occur. Creativity is a non-linear process; the total is often much more than the sum of its parts. The key is to listen to all voices in the search for game-changing ideas.

5) *People*. Not everyone is innovative. It is important to identify innovative people and to protect them from a system that rewards concrete results tied to a mission. Since ideas comprise an innovator’s primary “product” and a high percentage of ideas never reach fruition, management must not punish innovators for “bad” ideas; they should evaluate innovators on their idea-generation processes and reward them for sound decision making and thorough investigation of a topic. Often the good ideas and good people require a champion to shepherd them through the organization.

6) *Patience*. Innovation is a dynamic process and not without its fits and starts. It is a process that may not lead immediately to an improved product or strategy. It is important to experiment with new ideas and to fail early and often to find what ideas actually work. This is probably the most difficult element to deal with, since there is so much pressure for results now, but the reality is that patience can allow the creative process to play out and then to gain the insights that will be the basis for the revolutionary game-changing ideas.

A Framework for System-Level Experimentation

As previously noted, innovation often arises from the “friction of war.” To mimic that effect, SLEs must incorporate a challenge-competitive environment to maximize depth of innovation and exploration, with an *unfettered*, highly skilled adversary with no cultural limitations and with technical restrictions imposed only by physics. As suggested, the experiments should be staffed with carefully selected individuals who have attributes conducive to “out of the box” exploration. Experiments can be conducted in gaming environments ranging from simple “seminar explorations” to networked games or even exercises in the field. To achieve a full exploration of possible solution space requires a sustained campaign of game-based experiments, capturing, archiving, and mining the results to find patterns and insights that guide further system-level iterations and future experiments. The SLE process will result in a shared understanding of how technology and operations mesh together to form new capabilities for the future.

Through the analysis of the commercial lessons learned, we identified four essential components in the development of disruptive innovation by means of system-level experimentation: ideas, people, venue, and experiments. Before describing the components in detail, we can sum up the basic attributes for system-level experimentation as:

- *Ideas*: Innovation occurs throughout an organization and must be sought out. It is critical to identify ideas that challenge standard ways of doing things.

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- *People:* Not all people are innovative. Those that are must be identified, supported, protected, and valued. Bringing together the right mix of people is necessary to thoroughly explore a selected idea, and this team needs to include a champion.
- *Venue:* A venue is not a specific place or facility. It is an exploration space, which might be a virtual environment, a battlefield, or a war game.
- *Experiments:* The only way to explore the complexities of a system is through campaigns of experiments, based on the proper venue, people, and ideas. Combining these into a rigorous program of technology and CONOPS will create a deep understanding of what the future may be and how to best meet it.

Because these four components are central to the innovative process, we next explain them in further detail.

Ideas:

Increasingly, ideas are recognized as the most important resource of any organization whose business demands staying ahead of their competition. Innovative organizations actively seek ideas from the broadest possible base. Such organizations instill a cultural mindset that actively encourages their staff to challenge the basic assumptions on which the currently accepted ways of doing things are based. New voices in the organization must be sought out and listened to, regardless of their position in the organization. A bottom-up idea generation process is essential for an organization to innovate effectively.

This requires a system that permits all levels of the organization to actively engage in the idea-generation process, to participate in the debate over their merits, and to explore ways of combining the best aspects of widely differing ideas into potential innovations. Forced participation does not work; however, active encouragement to gain broad participation is essential. Approaches that simply allow ideas to be submitted are not sufficient. Blogs provide not only an electronic “suggestion box” but also serve as a debate space in which these ideas can be refined and allow true innovators in an organization to be identified. Wikis also provide a way for ideas to be easily transmitted. This is one area where the adage “if you build it they will come” is true. We want to create an environment that the most creative folks will thrive in.

Highly networked virtual reality games, such as America’s Army™, Counter-Strike™, and others, are approaching a level of realism that could provide an entirely new way of broadly generating and testing ideas for system-level innovations. Today, America’s Army™ – originally developed as an Army recruitment tool – has approximately 8 million users, of whom 4.2 million have reached the competency required for full participation in over 2.1 million games (“experiments”) being played each day on nearly 2,200 game servers spread around the globe. Over 100,000 new players join every month; they are predominantly young, creative, and bring with them perspectives and cultural insights to which access is otherwise limited. Counter-Strike™ is even more impressive: current statistics regularly show over 200,000 players simultaneously playing the three variants of Counter-Strike™ at any given time, accounting for almost 70 percent of the online first-person shooter playing audience, and amounting to over 4.5 billion minutes of playing time each month, making it the most popular online first-person shooter game in history.

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Today's games could be expanded to give players the unfettered ability to define their own new capabilities and CONOPS – limited only by the constraints of physics – and to experiment with them in the gaming environment. Software tools could automatically observe the resulting gameplay to discern successful patterns, and the worldwide network of discussion sites on which players collaborate to identify successful gaming ideas could be monitored to track evolving concepts. For example, it is imaginable that IEDs would have appeared in such a gaming environment long before they did in the “real” world, and their impact could have been appreciated on the basis of such monitored gameplay. The fidelity of reality games has reached a state that insights from such experiments are credible, and if even a tiny percentage of the millions of such “experiments” being played every day produce a useful insight, the effect on the pace of warfighting innovation could be enormous.

Regardless of where they come from, few ideas represent viable innovations on their own in the form in which they are proposed. However they may contain a key concept or insight that – when combined with other ideas – can lead to a clearer understanding of what might be possible, or provide a way of seeing a completely different approach for solving a problem. They may even lead to the solution of a completely different problem. Innovations result not so much from the original ideas themselves but from putting many ideas into a “mixing bowl” environment in which creative teams of technologists and operators can combine and evolve them to discover the hidden insights they may hold. A similar conclusion was reached by the 2000 SAB Battlelabs Study [7].

Consequently, ideas should not be constrained by current doctrines or requirements of current solution approaches. Nor should they be assessed by their performance in relation to metrics established for completely different solution approaches. Most new ideas will perform worse than accepted solution paths being explored from the current status quo. The idea behind an innovation becomes the preferred solution approach only when it is understood in terms of the new CONOPS in which it will operate and in the context of new metrics appropriate for that CONOPS.

People:

Innovation is the result of the insightful, collaborative interactions that can occur when small *ad hoc* teams of exceptional innovators are brought together in creative venues. These experimentation teams conduct campaigns of system-level discovery experiments that explore novel combinations of technology and CONOPS.

Few people are genuine innovators, and only genuine innovators should be assigned to these teams. True innovators can be recognized as people who work best in environments where risk, openness, and idea-sharing are the norm; where ideas outrank seniority; where being wrong is not a failure; where learning is recognized as a continual process; and where challenge is viewed as the highest form of respect. They have a sense of urgency, energy, and optimism. They challenge their own ideas and theories as much as those of others. They have broad interests, they often see things differently than the rest of an organization, and they continually push new ideas and approaches for doing things. They challenge everything – even processes that appear to be working well. As a result, they may be irritating to the organization's management, are often silenced by the mainstream of the organization, and are often found on

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the fringe of an organization. While being irritating does not make someone an innovator, true innovators are likely to be viewed as an irritant by many in their organization.

A process for discovering and cultivating such people is essential for an innovative organization. Those with true innovator personalities suited for such experimentation teams must be actively sought out and recruited. They should be made to understand that being selected to serve on one of these teams is a reflection of their abilities. Service on these teams must become seen throughout the organization as a prized assignment, and as part of building the “culture of innovation” it must be acknowledged as such by the highest levels of the organization. Those who prove to be successful as members of these *ad hoc* experimentation teams should be tapped again when appropriate for later teams. They should be given a continuing sense of association with the innovation process. They must be tracked through their careers to protect them from organizational pressures to sideline them, and their innovation talents should be actively developed over the course of their career. An organization that fails to cultivate them, or that fails to retain such people, loses what may be its most valuable asset.

Experimentation teams must consist of a mix of technologists and operators. System-level experiments require working at the interface between technology and CONOPS; the solution being sought will rarely be a purely technological one. Bringing technologists and operators together early in the process allows technologists to understand the operational context of the problem and gives operators an understanding of new CONOPS made possible by technology. Team integrity must be maintained throughout the experimentation campaign. Bringing new members onto the team in later stages of the process risks disrupting the deep, shared understanding of the problem and potential system-level solutions that have been gained by team members over the course of the experiment campaign. An important aspect of SLE is finding people, both technologists and operators, who are capable of collaborating about a future environment. Many people have a vision, but many are unwilling to change that idea. The notion here is that better understanding of future technologies should shape future operational concepts, and vice-versa.

A key member of the experimentation team is the “champion.” Every experimentation team needs a high-level champion to protect the experiment campaign from pressures to maintain the status quo. He or she is the driving force behind the experiment campaign, sustains the vision for innovation throughout the campaign, and often was the original advocate for the concept that led to the campaign. While the initial idea or concept will likely evolve – perhaps dramatically – over the course of the campaign, the champion’s original vision of a system-level innovation and the capabilities it could offer is what sustains the campaign. Historically, most innovations have had an identifiable champion behind them. The champion is typically the first member of the team and plays a key role in selecting and guiding the rest of the experimentation team. It is important to recognize, for example, that in a commercial organization the champion is not the CEO, but it is someone who clearly has the support of the CEO.

Another key member of the experimentation team is the facilitator. This is the person who understands how to form experiments such that they do not become biased by how we do business today. This is a very tricky process to figure out what elements of how we do business today to use, and which ones to shed.

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Venue:

Innovation teams do their work in a variety of venues; these are not necessarily physical spaces, but rather insight-promoting spaces where effective exploration of ideas and discovery of hidden insights can occur. Venues for system-level experimentation are different from the environments used for training exercises or for demonstrations. They are fundamentally based on challenge-competitive gaming environments in which the merits of ideas for the interplay between technology and CONOPS can be explored. The venues provide the “mixing bowl” within which operators and technologists interact to explore and evolve ideas.

The most productive venue must be used for each stage of an experiment campaign, and venues will differ at various stages of the campaign. In early stages of experimentation, simple “seminar games” allow for brainstorming to provide an understanding of broad concepts and allow rapid evolution of potential solution approaches. Subsequent stages may range from simple “maps on the floor” competitions to networked reality games that explore the effects – both intended and unintended – of proposed solutions in near-fully operational contexts. The venues for final stages of an experiment campaign may include field experimentation or even experimental operational implementation.

Networked reality games represent a rapidly emerging class of venues that could become a major enabling element for system-level experimentation. Experience with such games – from DARPA’s early SIMNET environment to today’s massively multiplayer online games (MMOGs) – shows that detailed realism in the venue itself is not needed to provide high fidelity in such games. More important are a rapid pace of operations, the almost limitless degrees of freedom and resulting fog-of-war created by interactions among large numbers of players, and the ability to work in a highly collaborative, competition-based environment. Today MMOGs, and especially team-based tactical first-person shooter games such as Counter-Strike™, provide venues in which highly complex, collaborative, and competition-based system-level experiments could be conducted. Adding the capability in such venues for participants – both friendlies and adversaries – to define their own capabilities, unfettered by doctrinal or cultural limitations and bounded only by the laws of physics, would enable a virtual environment for true system-level experimentation.

An important consideration with respect to venue is to make sure that the venue does not become the objective of the team. This is a common failure in many organizations. The venue is concrete and can easily become the focus of the resources and activity. SLE promotes the notion that the venue, while important, is simply a means to an end; the end being the successful exploration of a potential, disruptive innovation.

Experiment

A “campaign of experiments” is the process by which the *ad hoc* experimentation teams explore ideas for the interplay between technologies and CONOPS, develop the insights that produce a deep understanding of potential future environments, and discover combinations that provide innovative solutions to a problem. For any given problem, the campaign is a sequence of challenge-based discovery experiments that progresses from a typically simple initial venue to a final one in which the proposed solution can be understood in a near-fully operational context.

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Frequent experimentation with analysis and sharing of results are keys to achieving system-level innovations. Each experiment in the campaign is planned based on the experience and insights obtained from those preceding it. Results from early experiments exploring new solution approaches may compare poorly when measured by metrics established for currently accepted solution paths. Over the course of the campaign, the succession of experiments explores increasingly deeper aspects of the problem to develop a clearer understanding of potential solution approaches. A role of the “champion” is to protect the experiment campaign from pressures to revert to the status quo long enough for the SLE process to work.

Capturing and archiving results from the sequence of experiments is central to an effective experimentation campaign. This facilitates analysis and insight, which allows design of the next step in the campaign. Data mining of the experiment results permits hidden insights within them to be discerned. For experiments involving massively multiplayer online game venues such as Counter-Strike™, where 200,000 or more players worldwide may be involved in thousands of simultaneous games, the amounts of observational data collected by monitoring gameplay can be enormous. Data mining can then have potentially profound benefits; the range of innovations being conceived and explored in such games can far exceed what an *ad hoc* experimentation team could possibly do.

Contrasting the current system with the SLE approach

To better understand the SLE process, we can compare it to the Air Forces’s current practices and procedures.

The Air Force currently responds to defined requirements and key performance parameters (KPPs), limiting its ability to respond quickly to new challenges. It takes years to field new technologies in response to our adversaries’ innovations. By creating a shared understanding of possible future environments and by defining technology and tactics to respond to those environments, the SLE process should create a much more agile and responsive Air Force.

The Air Force tends to commit very early to defined concepts, often locking in place an approach that is not optimal. In an SLE, the concept evolves throughout the experimental campaign, yielding an iterated, and generally more optimized, result.

As in most hierarchical organizations, it is often difficult to form teams from different parts of the Air Force, which leads to “stove-piped” thinking. The SLE approach is focused on selecting teams from across the Air Force, emphasizing combined technologist/operator teams that generate synergies in knowledge and experience.

The Air Force currently performs demonstrations, not experiments, and fails to capitalize on lessons learned. SLE incorporates many small experiments to gain understanding, even when the experiments do not turn out as planned. Air Force demonstrations generally incorporate a constrained and predictable adversary; this does nothing to stimulate innovative responses. SLEs embrace the idea of an unfettered, technically-skilled adversary to “break the system.”

Finally, the demonstrations done by the Air Force are costly and inflexible, with disproportionately long preparation times with respect to execution times. This programmatic

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inertia makes it difficult for researchers to respond to unanticipated issues or challenges. The SLE process is inherently flexible with short approval times and iterative execution.

Organization for innovation

Building on the best industrial practices, we recommend that the Air Force create the position of Chief of Innovation (COI), selected by and reporting directly to the CSAF. The COI would lead a small, lightweight organization responsible for enhancing innovation in the Air Force. The COI must be predisposed to disruptive innovation, serving as the “Idea Tsar” and a provocateur of disruptive thought and a harvester of creativity of the Air Force. He or she must have authority derived from a direct connection to the CSAF. The COI must also have sufficient resources and the flexibility to directly fund experiments. Above all, the COI must have patience; innovation is not done on demand.

The Office of Innovation will build on the four principles of innovation suggested in this brief: ideas, people, venue, and experimentation. The role of this office will be to identify, mentor, and track AF innovators; search for, select, and define new SLEs; form Innovation Task Forces (ITFs) to execute SLEs; start, monitor, and stop SLEs; facilitate experiments and transition the results; and to maintain and evolve the SLE process. Perhaps most importantly, the Office of Innovation will be a magnet for innovators, attracting unsolicited ideas from throughout the Air Force.

The ITFs will execute experimental campaigns. Experience dictates that a champion lead each ITF to mentor and defend the team. The ITFs define and conduct the SLE campaign; observe, capture, and analyze the results; and iterate and evolve the system-level solution. The COI will monitor the ITFs and enhance or disband as appropriate. A key point is that these are to be real experiments, not demonstrations. Therefore, some experiments will not work as planned. The ITF will capture the lessons learned.

Potential SLEs

During this study a number of possible SLEs were considered that could be executed in the immediate future. These have not been vetted; it is beyond the scope of a quick look study to do more than suggest ideas for an experiment. The team had neither the time nor resources to plan an experiment campaign, and the team lacked the authority to set priorities for the Air Force.

1) *Find Once, Track Forever (Non-blinking Eye in the Sky)*: Recent technologies (e.g., Angel Fire) offer promise of continuous tracking, which continues to be a challenge for operators. Consider a campaign of experiments involving Battlefield Airmen (BA) and technologists to see how having such information would affect the CONOPS for, as an example, Air Force Special Operations Command (AFSOC). The experiments could examine the kind and quality of information available in the field, the interface between the operator and the information, and etc. The result would be the development of new CONOPS as well as a better definition of the necessary technology.

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2) *Cockpit Selectable Weapon Effects*: How would the ability of the operator to select weapons effects, yield, timing, etc., affect operations? A series of experiments, again involving operators and researchers, could define such a capability's employment benefits and the enabling technologies.

3) *Weight Reduction for AFSOC personnel – Battery Elimination*: AFSOC personnel currently carry heavy equipment, increasing their combined weight to well over 300 pounds. Batteries comprise much of that weight. To reduce the weight, either technological solutions will reduce the power needs (or provide lightweight means to generate power) or the BAs will change their operational needs. Experiments that assess new technologies as well as changes in the equipment the BAs carry could help define both new ways of doing their business as well as required technologies.

4) *Directed Energy (DE) Technology in the Joint Urban Fight*: The impact directed-energy technology will have in an urban environment is not yet clear, nor is it clear how such applications could be effectively employed. Experimentation involving researchers and operators are critically needed to work out new tactics and, as importantly, help delineate the kinds of DE technologies that could be most effective.

5) *Massively Multiplayer Online Games*: America's Army™ today has over 7.2 million users; with 4.2 million having the competency required for full participation in over 2.1 million games ("experiments") played each day on nearly 2,200 game servers spread around the globe. The Air Force should create a similar game to mine the world for new ways of thinking.

The Air Force should consider all of these possible scenarios as SLEs in the near future. The Air Force should stage a competition of ideas and then assemble Innovation Task Forces to execute the SLEs.

Recommendations

The study has two primary recommendations:

The Air Force should adopt system-level experimentation as a process by which it can provoke the development of disruptive innovations to meet its future challenges. The team recommends the adoption of the four components of the SLE process as described in this report and the encouragement and support of experimentation that combines technologists and operators. By exploring technologies and CONOPS for possible futures, the Air Force increases its ability to predict the future capabilities of adversaries (and to develop means to defeat them) and will more adeptly create new, disruptive capabilities for itself. The experimentation must be based on unfettered competition, to simulate the "fog and friction of war." The team urges pervasive adoption of the SLE process throughout the Air Force.

To facilitate and enhance the SLE process, the Air Force should create a Chief of Innovation position. This person, whether military or civilian, should be selected by and report to the CSAF. The COI must be someone predisposed to innovation. The CSAF should consider someone from industry with a proven track record. The COI must have authority to carry out his/her mission as well as the necessary resources to support SLEs. The COI will be responsible for coordinating with existing organizations to identify SLE opportunities and needs, organizing

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implementation of selected SLEs, evaluating SLE results, assessing and facilitating transition opportunities, and maintaining the knowledge database.

The SLE team suggests that one way to implement these recommendations is to designate the AU/CC as COI with execution coordinated by the Center for Strategy and Technology (CSAT) and with active involvement of AFRL. This is consistent with practices described in the report (e.g., report to CEO, disruptive innovation explored outside core processes). It is also consistent with the recent decision to form an Air Force Futures Group between AF/A8 and AU.

Summary

To recreate its ability to lead the development and application of disruptive innovation the Air Force must foster a culture that promotes innovation. Such a culture thrives on ideas that challenge conventional thought and doctrine harvested from all sources in and out of the Air Force. It is essential to find, recruit, develop, and protect true innovators from throughout the organization. Most importantly, however, the Air Force needs to embrace experimentation as a principle means of provoking disruptive innovation. They need to conduct campaigns of discovery experiments outside of the core process that involve both technologists and operators to co-evolve technology and CONOPS. They should include unconstrained adversaries to mimic the “friction of war” and to provoke creative tactics. They need patience and to recognize that in an experiment, failure only occurs when we do not learn something. Finally, leadership in innovation must start with the CSAF, who should appoint a Chief of Innovation to serve as the “Idea Tsar” and principle innovator.

References

A reading list on experimentation and innovation is included in Appendix F.

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Annotated Brief



Air Force Scientific Advisory Board

System-Level Experimentation
*discover, explore, and understand game-changing ways
... to fly and fight in Air, Space, and Cyberspace*

**SAB Summer Session
30 June 2006**

**Co-chairs
Steve Cross and Scott Fouse**

There are five key points in this study:

1. System-level experimentation (SLE) is an approach to unfettered exploration of alternative system concepts focused in future environments to aid in earlier discovery of game-changing ways to “fly and fight.”
2. Our adversaries innovate while we merely react – a more proactive approach would support system-level discovery experiments focused on disruptive ideas, thus increasing the likelihood of finding game-changing ways to “fly and fight” BEFORE the fight thereby forcing our adversaries to react to our innovations.
3. At one time the USAF aggressively searched for “game-changers,” arguably it has not for many years.
4. The USAF is not alone; this is also an important national issue for U.S. industry – but there has been impressive progress in the last year, and there are lessons learned the USAF can apply now.
5. Ad hoc groups (e.g., “innovation task forces”) drawn from Air Force organizations can be formed to do this – such needs to be supported by a small group of facilitators; they need to be resourced, protected, and visibly important to the Chief of Staff.

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National safety would be endangered by an air force whose doctrines and techniques are tied solely to the equipment and processes of the moment.

... any air force which does not keep its doctrines ahead of its equipment, and its vision far into the future, can only delude the nation into a false sense of security.

**Gen Henry “Hap” Arnold
November 1945**

This study is about provoking disruptive innovations through system-level experimentation

Even sixty-one years ago leaders recognized the importance of understanding technology and tactics required to dominate in future environments. In today’s parlance, General Arnold is talking about maintaining the USAF’s combat edge through innovation (e.g., pursuing revolutionary, game-changing systems). In the commercial world, innovation means staying competitive; in the military world it means being dominant. This is something the early Air Force leadership was concerned about just as the CSAF is today.

Air Marshall Mason makes some interesting observations about this famous quote in “Innovation and the Military Mind” (Mason 1986). He cautions that not focusing on innovation means becoming predictable and therefore vulnerable.

Even the most cursory survey of military history illustrates the critical importance of technological and tactical innovation. The stirrup, the longbow, barbed wire, the tank, blitzkrieg, radar, electronic countermeasures, AWACS, helicopter assault, and the astonishing aggregate of British innovation displayed during the Falklands War are random examples. Sometimes the vision of the innovators has outrun the capability of technology: the early submariners, the early aircraft carrier advocates, the first air power theorists, the proponents of surface-to-air missiles, and, just possibly, those enthusiasts who unreservedly espouse the cause of enhanced technology as the panacea for today's Western strategic dilemmas might be so categorized. Yet without such visionaries and without innovation, a nation's way of war becomes predictable; and predictable means vulnerable.

While most USAF experimentation today deals with demonstrations (e.g., JEFX, ATDs), the focus of this study is on discovering, exploring, and understanding “game-changing” ways to “fly and fight in air, space, and cyberspace.” What is suggested in this study is not new given the history of the Air Force; in fact, it is strikingly similar to how experimentation was pursued in the Air Corps Tactical School in the 1930s and in other case studies presented herein. The U.S. Air Force has gotten away from this kind of experimentation. It is time to reclaim our heritage!

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Our AF Heritage is Innovation



Common characteristics

- Led by *innovators* – *risk taking champions with a vision*
- Provoked a renaissance of ideas
- Created and used a *mixing bowl* (e.g., ops-tech teams)
- Conducted *discovery* experiments focused on *future* needs
- Enabled unfettered *exploration* in the right venue
- Rarely did the formal Requirements Process help; more often it impeded progress

Early experimentation played a key role

Innovation is not new to the Air Force; on the contrary, innovation is its heritage (i.e., a fundamental component of the “Air Force gene pool;” if you will the Air Force’s “organizational DNA”). This study highlights the innovators listed on the chart because they had a vision and they used experimental approaches to find ways to achieve that vision. Regardless of programmatic and cultural obstacles, to say nothing of the personal risks to their careers, they were determined to explore the operational benefits their tactical and technological ideas could bring to the Air Force. To test their theories, they pursued discovery experiments to understand the future and to develop system concepts that enabled the Air Force to dominate in that future. Case studies are presented in Appendix E of this report. An excellent description of innovation involving experimentation from the early days of the Air Corps is in Perry’s 1999 paper.

Outline



- Who we are and who we talked to
- System-level experimentation (SLE)
 - Definition
 - Provoking 'game changing' innovation
 - Approach
 - Example SLEs
- Summary of key points
- Recommendations

The briefing was designed to cover the objectives in the Terms of Reference (ToR) of this study. These objectives are listed below.

- An overview of current Air Force “state of practice” and published approaches for exploratory experiments involving technologists and operators.
- An overview of approaches practiced by others (e.g., other services, national laboratories, commercial industry, and adversaries).
- A description of an approach by which system-level experiments could be used to “stress test” technology, focus high payoff/high risk research, as well as envision and understand new operational and system concepts.
- A description of three system-level experiments in the domain of Air Force special operations.
- Recommendations for a potential follow-on study to address the scale-up of the approach and enhancements to technology transition processes to fully realize the benefits.

Note: The last objective was not addressed explicitly in this study. However, at the time of the study’s completion, there were several SAB studies proposed for consideration in FY07 that would include an SLE approach. This study builds on several recent SAB studies:

- USAF Battlelabs (2000)
- Air Force Operations in Urban Environments (2005)
- System-of-Systems Engineering for Air Force Capability Development (2005)



Contact List

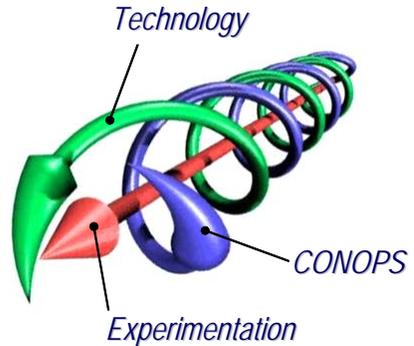
AIR FORCE	AIR FORCE SCHOOLS
SecAF	AU/CC
HQ USAF/A2/A8XC (Blue Horizons)	AWC/CC
SAF/AQR	- Center for Strategy & Technology
SAF/XCXX/XCOI	Air Command & Staff College (ACSC)
AMC/A58P	School for Advanced Airpower Studies
AFSOC/CC - A2-A6	USAFA
SMC/CV	OTHER GOV'T
AFRL/CC/CT	USMC
- Directorates: VA, PR, SN, HE, VS, DE, IF, MN	NWDC/CC, Chief Engineer
AFMC/A8	ONR, Chief Scientist
AFC2ISRC	MIISATCOM JPO
Battlelabs - C2, UAV, Air Warfare	JFCOM/J9 and JFIC
Rapid Capabilities Office (RCO)	TRADOC
Institute for Human & Machine Cognition	Los Alamos National Laboratory
Cisco	Sandia National Laboratories
IBM, VP Innovation & Technology	NASA
Council on Competitiveness	

Through a series of interviews, round table discussions, and competitive brainstorming sessions* occurring between December 2005 and June 2006, members of the study panel talked with representatives from each of the organizations listed above. This represented another key lesson in innovation best practice – “cast the net wide” throughout as wide a community as possible.

*Competitive brainstorming sessions were held during many of the meetings. Air Force attendees and SAB study teams were subdivided into subgroups and given the task to design an experiment related to the topic under discussion (e.g., high payoff applications when the team visited AFSOC and high payoff directed energy applications when the team visited the Directed Energy Director of AFRL). Groups presented their experiments in a contest where the best was chosen by a third party observer. Competition was fierce. Such competitions provoke good ideas; ideas that might not otherwise be envisioned through a more ‘group think’ venue. Such sessions were themselves another test of another best practice idea for innovation – create venues where it is permissible to think risky thoughts and to creatively explore ideas without fear of failure.

System-Level Experimentation (SLE) 

Campaigns of experiments to explore system alternatives through innovative combinations of technologies, CONOPS, and organizations in a future environment



Increases ability to discover game-changing ways to “fly and fight” BEFORE the fight

In this study, “system” is a combination of technology, processes (e.g., CONOPS), people, and an organizational construct to perform some set of functions. This short hand definition follows from one offered by INCOSE:

A system is a construct or collection of different elements that together produce results not obtainable by the elements alone. The elements, or parts, can include people, hardware, software, facilities, policies, and documents; that is, all things required to produce systems-level results. The results include system-level qualities, properties, characteristics, functions, behavior, and performance. The value added by the system as a whole, beyond that contributed independently by the parts, is primarily created by the relationship among the parts; that is, how they are interconnected.

SLE involves a campaign of discovery experiments (i.e., a series of experiments intended to explore and understand) that combine technology (both developed and envisioned) and CONOPS to develop new capabilities. SLEs can be used to explore a wide range of possible future environments and system alternatives in those environments. By exploring technologies and CONOPS for possible futures, the Air Force increases its ability to project the future capabilities of adversaries and to develop means to defeat them as well as being able to create new, disruptive capabilities for itself. SLEs are one type of experiment that compliment other forms used in the Air Force today.

Key words and phrases unique to SLE and discussed in more detail in the report include:

- Provoking ideas through competition; unfettered exploration of ideas
- An unconstrained adversary (e.g., red team)
- A series or campaign of discovery experiments
- Success includes, in fact starts with, understanding failure
- The outcome is a deep understanding of a future environment

SLE Is Not ...



- JEFX - *large bi-annual demonstration experiment*
 - *SLE involves frequent, smaller scale discovery experiments*
- Battlelab – *near-term focus (“Kenney initiatives”)*
 - *SLE is focused on system experiments in “Mitchell initiatives”*
- Big Safari, RCO* – *rapid fielding for high priority needs*
 - *SLE is focused on understanding the future - unknown needs*
- A8’s Future Game – *analysis of future environments*
 - *SLE is a campaign of system experiments in future environments*
- AFRL – *technology development to meet Air Force needs*
 - *SLE could be supported by AFRL to explore future systems*
- Air University – *education/training to meet Air Force needs*
 - *SLE could be supported by AU to explore future systems*

*Rapid Capabilities Office

SLEs can be compared and contrasted with ongoing forms of experimentation and other organizational pursuits. The focus is discovery (as opposed to demonstration) in the context of what were originally called “Mitchell initiatives” (i.e., revolutionary) when the Battlelabs were first formed. The products of SLEs may or may not be a prototype or working system, but rather a better understanding of a future environment (e.g., the discovery of unknown needs). As will be discussed, SLEs could be conducted within wargames, but they are not a wargame per se.

Alberts and Hayes (2005), in their book about campaign of experiments, define three types of experiments:

- Discovery experiments - designed to generate new ideas or ways of doing things
- Hypothesis testing experiments - the classic type used by scholars and researchers to advance knowledge (by seeking to falsify specific if / then statements) or to discover their limiting conditions
- Demonstration experiments - create a venue in which known truth is recreated; most Air Force experiments fall into this category
- In addition, they define a campaign of experiments as a “set of related activities that explore and mature knowledge about a concept of interest.”

Innovation Types	
Sustaining Innovation	Disruptive Innovation
“Play the Game Better”	“Change the Game”
Requirements focused	Experimentally derived
<u>Examples</u>	<u>Examples</u>
Latest PC	First PC
Latest Cell Phone	iPOD
Latest Automobile	Wikis
BAO* Toolkit	Southwest Airline’s Biz Model

*Battlefield Airman Operations

There are basically two types of innovation: sustaining and disruptive. Clayton Christensen, author of The Innovator’s Dilemma, The Innovator’s Solution, and many articles on innovation in recent years, used the concept of a disruptive technology to describe a new technological innovation, product, or service that eventually overturns the existing, dominant technology or product in the market. He broadened that concept to disruptive innovation when he recognized that few *technologies* are intrinsically disruptive; rather, their use creates disruptive impacts.

Sustaining innovation is the successive, incremental improvement to the performance of existing products. Examples of sustaining innovation are common – several examples are listed. Most Air Force technologies currently in development are sustaining in nature.

In contrast, disruptive innovation can originate from new technologies or processes to produce a radical new capability. Several examples are listed. Disruptive innovation is the formal name in the literature for “game-changer.”

Key insight: Game-changers are not the result of invention (e.g., a technological advance), but the use of that invention. Co-evolution and experimental assessment of system technology and its possible use in future environments are how game-changers are discovered.

Disruptive Innovation in Warfare



Throughout history, risk taking champions with a vision provoked a renaissance of ideas that led to game changing ways to dominate

Early Warning System – Chennault (1933)

Carrier Warfare – US Navy (1930s)

Blitzkrieg – Guderien (1940s)

ICBM – Schriever (1950s)

Space-based Surveillance – (1960s)

Precision Guided Weapons – (1970s)

Stealth – (1970s)

Armed Predator – (2002)



None of these resulted from the formal Requirements Process

Technology alone does not produce innovation

Military history contains many examples of disruptive innovation. Each of these disruptive innovations relied partially on technology and partially on the creative insights shared between operators and technologists on how best to use that technology. The military did not develop these solutions as products of a formal acquisition process; rather, innovators incorporated technologies and ideas then experimented with tactics and processes to change the conduct of war.

A recent example involves the armed UAV. The following quote from a speech by Air Force Chief of Staff General T. Michael Moseley to the American Enterprise Institute on 11 October 2005 should help motivate the need for SLE:

Having been the wing commander that got the Predator first and having had the Chief of Staff at the time, General Fogleman, say, “You’ve got these things,” and I said “Boss, what do you want me to do with them?” He said, “Go fly them and figure out how they work.” I said “I’m a little busy out here. If this is a hobby project let me know and I’ll give it some good thought, but you really want me to take these things and figure out how to fly them?” He said, “Yeah, just go figure it out.” I became a big fan, and I became a big fan of these things in combat, and I became a big fan especially when you can hook infrared imaging to a Hellfire missile or to a laser-guided 500-pounder off this thing. So not only can you go out and look for something, you can ID it and you can whack it.

This innovation described by General Moseley will be used later to illustrate how SLEs can facilitate disruptive innovation.

***AF Innovation:
What We Saw and Heard***



- Mostly demonstration experiments tied to requirements
- Institutionalized expertise in sustaining innovation
- Slow response to the enemy's rapid innovations
- Few discovery experiments focused on game changing
- Many Airmen predisposed to both types of innovation
- Culture and policies discourage disruptive innovation

**Air Force must again become a leader
in disruptive innovation...or we risk becoming irrelevant**

The Air Force is innovative, but its institutionalized expertise lies in sustaining innovation – a capability it should not lose. Well-known issues with the acquisition process often make the timely deployment of advances a challenge. Even when faced with an innovative adversary (e.g., improvised explosive devices), the cumbersome processes inhibit a quick, effective, and decisive response. Big Safari and RCO are current day “skunk work” approaches that accelerate the development and fielding of solutions to high priority needs. These solutions tend to be sustaining innovations.

The Air Force has struggled to develop or recognize disruptive innovation, partially due to a lack of focus on true discovery experiments and partially due to exercises being conducted to demonstrate and train. Red Force ROE are often constrained to achieve training and demonstration objectives. Allowing unfettered exploration, including unimpeded involvement of a red team (similar to a Red Flag Aggressor Squadron), is not typically allowed. Limiting the full exploration of a solution space, including what an intelligent adversary could do to inhibit operations, would dilute any attempt to develop a deep understanding of a future environment.

However, the Air Force has people in every organization the study team visited that are predisposed to both kinds of innovation. Those predisposed to disruptive innovation were constrained in that pursuit by culture and policy that inhibited the free exchange of ideas, displaying intolerance for risk, and the accompanying negative career and organizational budget impacts of real or perceived failure.

The Air Force is capable of disruptive innovation, but it has largely lost its ability to foster it. Expectations about future warfighting, however, strongly suggest that the Air Force must again be a leader in disruptive innovation. Some solace may be found in the fact that many large organizations in America today are facing a similar challenge.



Industry Renaissance in Innovation

National Innovation Initiative, Dec 2004

IBM Global Survey, Apr 2006



Business Week, Jun 2006

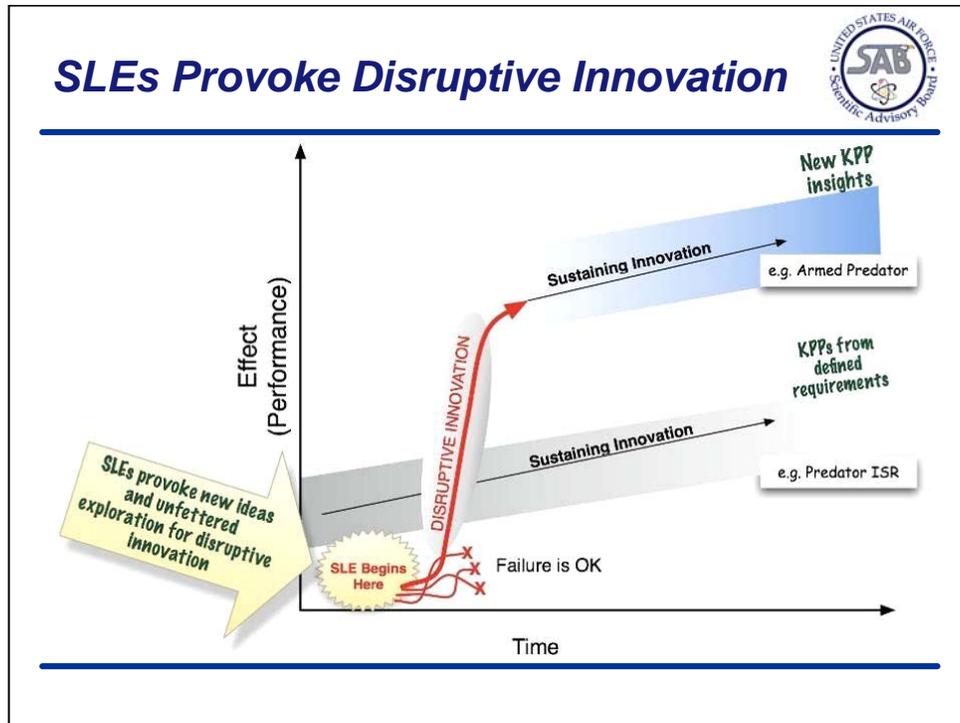
Industry Best Practices

- Search for ideas everywhere
- Assess ideas outside core processes
- Identify and protect people who are willing to challenge conventional wisdom
- Leadership in innovation must start with the CEO

“Making innovation work is the single most important business challenge in our era”

A national concern expressed two years ago and highlighted in the President’s 2006 State of the Union message dealt with the ability of U.S. industry to innovate. Several recent studies (see references) have been conducted on this topic, and within the time frame of this SAB study best practices have begun to be published.

Four key best practices for encouraging innovation within an organization are listed on the chart. The role of the CEO cannot be overstated. The CEO grants permission for trying “out of the box” ideas, for learning from failure, and for thinking risky thoughts. Another insight, also from Christianson in a recently published handbook on innovation, is a practice followed by many CEOs who create a small organization outside core processes with the task to pursue disruptive ideas. Christianson recommends that organizations do this when their culture and processes hinder disruptive thought.



The graphic is adapted from Clayton Christensen's, The Innovator's Dilemma. The graphic illustrates the potential impact of technology-based disruptive innovation by notionally plotting the performance of a product or a system (y axis) versus time (x axis). The key idea is that sustaining innovation facilitates a steady increase in product performance over time in pursuit of known requirements. Successful incumbents within the market place rarely recognize the next best thing. They are focused on incremental improvement to satisfy market needs (or in the military parlance, key performance parameters).

Disruptive innovation occurs when someone comes along with a new idea. Often the initial performance is below marketplace expectation. The innovation is pursued "under the radar" until it matures enough to leap over the existing system's capabilities and begin its own sustaining innovation path.

The Armed Predator mentioned a couple of charts back is a good example. The Predator was gaining an established position in the Air Force portfolio as a surveillance platform when General John P. Jumper, then Air Force Chief of Staff, tasked Lieutenant General Stephen Plummer, who was Principal Deputy to the Assistant Secretary of the Air Force for Acquisition, to talk to officials at Wright-Patterson AFB about adding a hellfire missile to the UAV. To introduce stress into the system, General Jumper gave the developers 90 days and \$3M. He believed that given the proper motivation, adequate resources, permission to fail, and their innovative culture, they could accomplish the task – and they did! They gave the Air Force a whole new capability.

The SLE approach is to integrate a series of discovery experiments with commercial best practices for innovation. It is suggested that by doing this the Air Force can institutionalize a capability to support and exploit disruptive innovation.



Ideas

- Cast the net wide; challenge all existing doctrinal limits
 - Don't constrain by known requirements
 - Listen to new voices – leave ego and rank at the door
 - Promote innovation as a cultural mindset, driven by insight
 - Challenge ideas, results, and theories – yours and others



Cybercraft

 **Use online simulations and internet software tools (e.g. wikis, blogs)**

Seek diversity of ideas and encourage open debate

Ideas are the JP8 of innovation. Ideas by themselves do not produce innovation. They must be captured, debated, and applied in an unconstrained, collaborative environment to have the desired disruptive impact. Ideas should be solicited from as wide a community as possible, and it should be encouraged that ideas be offered that challenge conventional thought.

The *Cybercraft* pictured above originated as a good idea from a young officer in AFRL. He asked what it would be like to ‘fly through cyberspace’ via a capability analogous to an aircraft. This has led to a whole new way of thinking about weaponization in cyberspace.

Companies are increasingly using new forms of internet software – such as blogs and wikis – to solicit ideas from throughout their organizations, their markets, and even from their competitors. Staging competitions to find the best ideas is one way to provoke new ideas that challenge the status quo. For a description of the use of such software in a way that provokes or encourages competition, see the recent book by Hagel and Brown (2005).

One promising new method of reaching a large number and wide variety of potential collaborators is through the use of online simulations and new forms of internet software. For example, the Army built a video game called America’s Army™ as a recruiting tool. There are a huge number of creative ideas generated by the online game community. Eight million users now play the game online. A few of the ideas have resulted in tangible benefits to the Army. The game is used in a variety of real training situations for Army recruits. The Army observes game play to discover innovative tactics. Picatinny Arsenal has even included a model of the Stryker fighting vehicle into the game that suggests a novel way to support OT&E.



People

- Stand up small ad hoc teams of exceptional innovators to conduct system-level discovery experiments
 - Recruit and mentor innovators
 - Assemble Innovation Task Forces (ITFs), mixes of operators and technologists
 - Collaborate freely – explore ideas as a team
 - Ensure existence of a champion



 **Identify, recruit, and protect the innovators!**

Small teams of innovators who challenge the status quo

Small teams of individuals predisposed to innovation will execute system-level experiments.

There are people that are predisposed to innovation. It is proposed that they brought together in ad hoc teams (i.e., innovation task forces) for short periods of times to support these experiments. Such teams operate for finite period of time. Protection of the team members is critical. They need the freedom to innovate, and this includes what might be thought of as failure in other venues.

How does one identify people predisposed to innovation? Some good ideas are in Coates (2004) and Synder and Duarte (2003). But as pointed out by Natalie Crawford (SAB Senior Mentor and Director of Rand Corporation’s Project Air Force), if appropriate venues are provided that allow such experimentation to take place, the innovators “will flock to this like bees to honey.” As observed previously, the Air Force has many people predisposed to innovation. The need is for the leadership to sanction and support disruptive innovation and to protect those few people selected to engage in such experiments.

Venues



- Conduct experiments in the right venues
 - Leverage the network of innovators in the Air Force
 - Provide an insight-sharing space for experimentation
 - Based on challenge-competitive gaming environments
 - Ranges from simple “seminar explorations” to networked reality games
 - Allow for multiple layers of realism and exploration



Not necessarily a physical space; an insight-sharing space for exploration and discovery

Experimentation venues are not necessarily physical spaces, but rather insight-promoting spaces where effective exploration of ideas and discovery of hidden insights occur. System-level experimentation venues are different from those used for training or demonstrations. They are fundamentally based on challenge-competitive gaming environments in which the merits of ideas for the interplay between technology and CONOPS can be explored. The venues provide the “mixing bowl” within which operators and technologists interact to explore and evolve ideas.

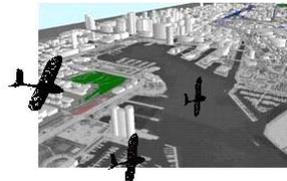
The most productive venue must be used for each stage of an experiment campaign, with venues differing at various stages of the campaign. Early stages of experimentation, like simple “seminar games,” allow for brainstorming to provide an understanding of broad concepts and allow rapid evolution of potential approaches. Following stages may range from “maps on the floor” competitions to networked reality games that explore the intended and unintended effects of proposed solutions in near-fully operational contexts. Final stages of the experiment campaign may include field experimentation or even experimental operational implementation.

Networked reality games represent an emerging class of venues that could become a major enabling element for SLE. Experience with such games – from DARPA’s early SIMNET environment to today’s MMOGs – shows that detailed realism in the venue itself is not needed to provide high fidelity in such games. More important are a rapid pace of operations, the almost limitless degrees of freedom, and the resulting “fog of war” created by interactions among large numbers of players, and the ability to work in a highly collaborative, competition-based environment. Today MMOGs, and especially team-based tactical first-person shooter games such as Counter-Strike™, provide venues in which highly complex, collaborative, competition-based, SLEs could be conducted. Adding the capability in such venues for participants – both friendlies and adversaries – to define their own capabilities, unfettered by doctrinal or cultural limitations and bound only by physics, would enable a virtual environment for true SLE.

Experiments



- Learn from campaigns of genuine discovery experiments
 - Explore interplay between technology and CONOPS
 - Campaigns of discovery experiments allow full exploration of ideas
 - Challenge-competition maximizes pace of discovery and depth of exploration
 - Unfettered and highly-skilled adversary; no cultural limitations; physics-only restrictions
 - Expect initial experiments to show lower performance relative to existing metrics
 - Capture, archive and mine experiment results to develop insights



Experiment with the system, not just the technology

A “campaign of experiments” is the process by which the ad hoc experimentation teams explore ideas for the interplay between technologies and CONOPS, develop the insights that produce a deep understanding of potential future environments, and discover combinations that provide innovative solutions to a problem. For any given problem, the campaign is a sequence of challenge-based discovery experiments that progresses from a typically simple initial venue to a final one in which the proposed solution can be understood in a near-fully operational context.

Frequent experimentation and analysis of results are keys to achieving system-level innovations. Each experiment in the campaign is planned based on the experience and insights obtained from those preceding it. Results from early experiments exploring new solution approaches may compare poorly when measured by metrics established for currently accepted solution paths. Over the course of the campaign, the succession of experiments explores increasingly deeper aspects of the problem to develop a clearer understanding of potential solution approaches. A role of the “champion” is to protect the experiment campaign from pressures to revert to the status quo long enough for the SLE process to work.

Capturing and archiving results from the sequence of experiments is central to an effective experimentation campaign. This facilitates analysis and insight and allows design of the next step in the campaign. Data mining of the experiment results permits hidden insights within them to be discerned. For experiments involving massively multiplayer online game venues such as Counter-Strike™, where 200,000 or more players worldwide may be involved in thousands of simultaneous games, the amounts of observational data collected by monitoring gameplay can be enormous. Data mining can then have potentially profound benefits; the range of innovations being conceived and explored in such games can far exceed what an ad hoc experimentation team could possibly do.

Example SLEs That Could Change the Game



- Find Once, Track Forever (Non-blinking Eye in the Sky)
- Cockpit Selectable Weapon Effects
- Eliminate Batteries
- Directed Energy Technology in the Joint Urban Fight
- Massively Multiplayer Online Games



Stage a competition of ideas and then assemble Innovation Task Forces (ITFs) to execute the SLEs

Several potential SLEs, the first four were discussed with the AFSOC Commander and his staff, are provided as examples. For each, one can ask the following questions. How would CONOPS change? What “fog and friction of war” issues would constrain this capability? What technical issues would have to be resolved? What series of discovery experiments should be conducted to explore these questions?

Find Once, Track Forever (Non-blinking Eye in the Sky). The picture on the chart is a mock up Iraqi town at Twenty-Nine Palms, California. Consider a new technical capability – browseable video – that allows an analyst or operator to pull desired information. Recent technical experiments conducted by AFRL and AFIT suggest this may be technically feasible.

Cockpit Selectable Weapon Effects. Ultra precision effects are desirable in urban environments. Suppose a “dial an effect’ munitions capability could be specified as late as near impact of the munition.

Eliminate Batteries. Suppose power were not an operational consideration for Battlefield Airmen? These combat controllers, pararescuemen, and combat weathermen often carry packs weighing several hundred pounds while executing dangerous and covert missions in austere locations around the world. Thirty percent of the weight is batteries.

Directed Energy Technology in the Joint Urban Fight. Another example might be directed energy technology in the joint urban fight. Despite power constraints, what if airborne DE capabilities were fielded?

Massively Multiplayer Online Games. America’s Army™ today has over 7.2 million users; with 4.2 million having the competency required for full participation in over 2.1 million games (“experiments”) played each day on nearly 2,200 game servers spread around the globe. The Air Force should create a similar game to mine the world for new ways of thinking.

In Summary, Key Points



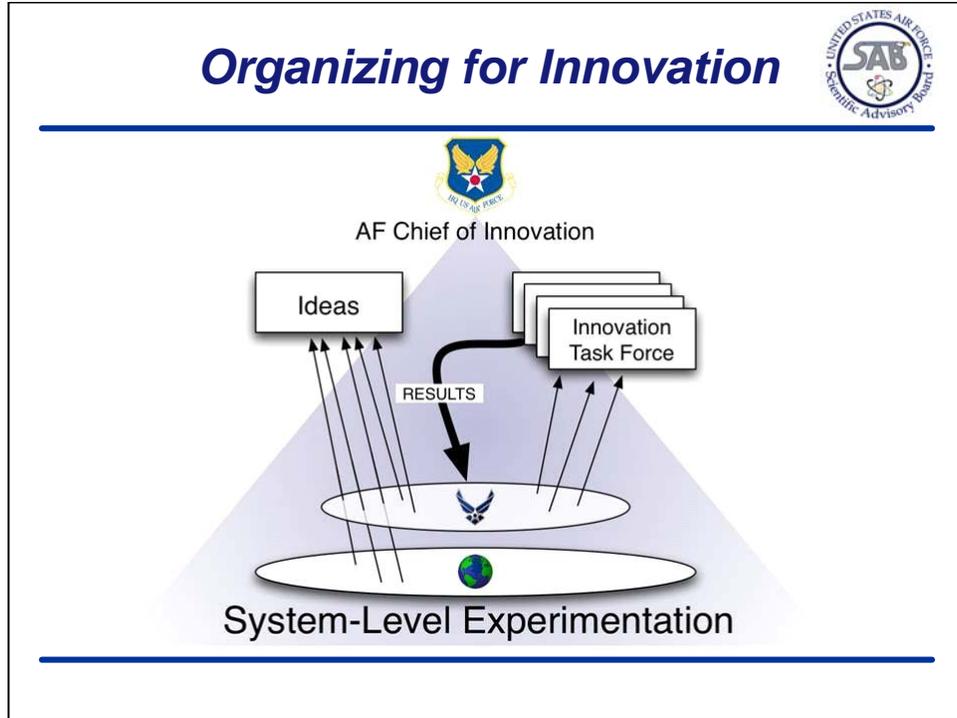
- Ideas – from everywhere, challenge conventional thought
- Protect innovators
- Experiment!
 - Conduct a campaign of discovery experiments
 - Do it outside core processes
 - Focus on co-evolution of technology and CONOPs
 - Stress via an unconstrained adversary
 - Failure is OK; Learning is the objective
- Leadership in innovation must start with the CEO

The Air Force must again become a leader in disruptive innovation

The four components of SLEs are listed below. They are a combination of recently codified industry best practices for disruptive innovation and the insight of this study with respect to the role of early discovery experimentation focused on system alternatives in a future environment.

- **Ideas** - cast the net wide; challenge all existing doctrinal limits
- **People** - exceptional innovators; driven to challenge convention
- **Venue** - a challenge-competitive exploration space
- **Experiments** - iterative campaigns of discovery experiments

These components are based on recently codified best practices for innovation in the commercial world and the historic role of experimentation in the Air Force.



The graphic suggest how to organize for SLEs. Ideas need to be solicited from throughout the Air Force and the external community. A coordinating office, headed by the Chief of Innovation, selects the best ideas for experimentation and selects innovators to serve on Innovation Task Forces (ITFs). The ITFs conduct the SLEs in an appropriate venue – either in an operational lab location (but not in facilities owned by the coordinating office). The coordinating office mentors, facilitates, and ensures the capture of lessons learned of the experiments. In addition, the coordinating office facilitates the transition of experimental outcomes to the appropriate Air Force functions (e.g., ACC/A8, inclusion in an out year JEFX, incorporation into an AFRL program, rapid fielding via RCO, etc.). It is critical that the Chief of Innovation and the coordinating office for SLEs operate outside core processes for requirements definition and acquisition. It is equally critical that the Chief of Innovation report to the CSAF and that he or she have sufficient resources and authority to conduct and pursue disruptive innovation.

Recommendations



- Identify Chief of Innovation
 - Selected by and reports to CSAF
 - Must be predisposed to disruptive innovation
 - Serves as idea provocateur and harvester
 - Must have authority and resources
- Support these functions
 - Coordinate across the Air Force to identify SLE opportunities
 - Assemble Innovation Task Forces (ITFs) to execute SLEs
 - Evaluate SLE results; ensure they are captured, shared and used
 - Assess and facilitate transition opportunities

Create a climate that encourages and rewards innovation

The recommendation follows from what is being quickly adopted in the commercial world – the designation of a Chief of Innovation with a direct reporting line to the CEO. Hence, it is recommended that the CSAF appoint someone with a direct reporting line to serve this function. The person must be tasked and predisposed to pursue disruptive innovation outside the core processes of requirements definitions and acquisition. This person needs to be provided sufficient resources and authority to solicit ideas widely throughout the Air Force and its external community and to pursue three to four SLEs per year.

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So when someone asks you what the Air Force will be doing in the future, tell them this. ... *We will innovate, and we will fly, we will fight, and we will win.*



General T. Michael Moseley, Sep 2005

This is a quote by Air Force Chief of Staff General T. Michael Moseley to the Air Force Association Air and Space Conference on 14 September 2005.

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Appendix A: Terms of Reference

USAF Scientific Advisory Board

Quick Look Study

FY 2006

System-Level Experimentation in Air Force S&T Programs

Terms of Reference

Background

An approach to experimentation in today's rapidly changing threat environment is needed to concurrently support the discovery and creation of new operational and system concepts and the technology needed to support those concepts. Such an approach would encourage creative exploration of the interplay among technology, system, and operational concepts and help establish a deep understanding of a future environment. While the focus would be on evolving S&T, the approach must include frequent technologist-operator interaction, accommodate the "fog and friction of war" (e.g., an adversarial component, system integration issues), involve higher risk than typically allowed in demonstration-based exercises (e.g., JEFX), and be implementable within technology transition processes.

Study Products

Briefing to SAF/OS & AF/CC in June 2006. Publish report in August 2006.

Charter

The "quick look" study will propose an approach to system-level experimentation in Air Force S&T programs by providing the following:

- An overview of current Air Force "state of practice" and published approaches for exploratory experiments involving technologists and operators.
- An overview of approaches practiced by others (e.g., other Services, national laboratories, commercial industry, adversaries).
- A description of an approach by which system-level experiments could be used to 'stress test technology,' focus high payoff/high risk research, and envision and understand new operational and system concepts.
- A description of three system-level experiments in the domain of Air Force special operations.
- Recommendations for a potential follow-on study to address the scale-up of the approach and enhancements to technology transition processes to fully realize the benefits.

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Appendix B: Study Members

Study Leadership

Dr. Stephen Cross,* Co-Chair Georgia Institute of Technology

Mr. Scott Fouse,* Co-Chair ISX Corporation

Study Members

Dr. Robert Byer* Stanford University

Prof. Werner Dahm* University of Michigan

Dr. Ken Ford* Institute for Human and Machine Cognition

Dr. Richard LeSar* Los Alamos National Laboratory

Maj Gen Eric Nelson, USAF (Ret) Independent Consultant

Dr. Brad Parkinson* Stanford University

Mr. Skip Saunders* Independent Consultant

Study Management and Support

Major Valerie Manning, USAFR AF/SB – Program Manager

Major Lee Chase, AFRL/PR – Executive Officer

Captain Justin Joffrion, USAFA – Executive Officer

Major Matt Keihl, AFRL/DE – Technical Writer

Mr. Justin Waters, AF/SB – Analyst

*Denotes current status as a member of the Air Force Scientific Advisory Board.

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Appendix C: Visits and Briefings

Air Force

Secretary of the Air Force

Assistant Secretary of the Air Force for Acquisition

- Deputy Assistant Secretary of the Air Force for Science, Technology, and Engineering
- Rapid Capabilities Office

Deputy Chief of Staff for Strategic Plans and Programs

- Future Concepts Development

Chief of Warfighting Integration and Chief Information Officer, Office of the Secretary of the Air Force

- Strategy and Plans
- Innovation and Technology

Air Mobility Command

- Strategic Plans and Programs

Air Force Special Operations Command

- Commander
- Intelligence
- Air, Space, and Information Operations
- Logistics
- Plans, Programs, Requirements, and Assessments
- Communications and Information

Air Force Materiel Command

- Strategic Plans and Programs

Air Force Space and Missile Center

- Vice Commander
- MILSATCOM Joint Program Office

Air Force Research Laboratory

- Commander
- Chief Technologist
- Air Vehicles Directorate
- Directed Energy Directorate
- Human Effectiveness Directorate
- Propulsion Directorate
- Sensors Directorate
- Space Vehicles Directorate

Air Force C2ISR Center

Air Warfare Battlelab

Command and Control Battlelab

Unmanned Aerial Vehicle Battlelab

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Air Force continued

Air University

- Air Command & Staff College
- Air War College
 - Center for Strategy & Technology
- School for Advanced Air and Space Studies

U.S. Air Force Academy

Other Government / FFRDCs

U.S. Joint Forces Command

- Joint Experimentation Directorate
- Joint Forces Intelligence Command

U.S. Army Training and Doctrine Command

U.S. Navy Warfare Development Command

- Commander
- Chief Engineer

Office of Naval Research

- Chief Scientist

U.S. Marine Corp

NASA

Los Alamos National Laboratory

Sandia National Laboratories

Industry

Cisco

Council on Competitiveness

IBM

Institute for Human & Machine Cognition

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Appendix D: Acronyms and Abbreviations

ACC/A8	Air Combat Command Director of Requirements
AF	Air Force
AF/A8	Deputy Chief of Staff, Strategic Plans and Programs
AFIT	Air Force Institute of Technology
AFRL	Air Force Research Laboratory
AFSOC	Air Force Special Operations Command
ARS	Advanced Reconnaissance System
ATD	Advanced Technology Demonstration
AU	Air University
AU/CC	Air University Commander
AWACS	Airborne Warning and Control System
BA	Battlefield Airman
BAO	Battlefield Airman Operations
CEO	Chief Executive Officer
COI	Chief of Innovation
CONOPs	Concept of Operations
CSAF	Air Force Chief of Staff
CSAT	Center for Strategy and Technology
DARPA	Defense Advanced Research Projects Agency
DDR&E	Director of Defense Research and Engineering
DE	Directed Energy
DMOC	Distributed Mission Operations Center
DMT	Distributed Mission Training
FBE	Fleet Battle Experiment
GPS	Global Positioning System
IADS	Integrated Air Defense System
ICBM	Intercontinental Ballistic Missile
ICE	Integrated Collaborative Environment
IED	Improvised Explosive Device

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IPA	Intergovernmental Personnel Act
IRBM	Intermediate-range Ballistic Missile
ITF	Innovation Task Force
JDAM	Joint Direct Attack Munition
JEFX	Joint Expeditionary Force Experiment
JSOW	Joint Stand-Off Weapon
KPP	Key Performance Parameter
MMOG	Massively Multiplayer Online Games
OT&E	Operational Test and Evaluation
PC	Personal Computer
R&D	Research and Development
RATSCAT	Radar Target Scatter
RCO	Rapid Capabilities Office
RCS	Radar Cross Section
ROE	Rules of Engagement
S&T	Science and Technology
SAB	Scientific Advisory Board
SAMOS	Satellite and Missile Observation Satellite
SIMNET	SIMulation NETwork
SLE	System-Level Experimentation
TOR	Terms of Reference
U.S.	United States
UAV	Unmanned Aerial Vehicle
USAF	United States Air Force
VLO	Very Low Observable
XST	Experimental Survivable Testbed

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Appendix E: Case Histories in Disruptive Innovation

Military history contains many examples of disruptive innovation. Each of these disruptive innovations relied partially on technology and partially on the creative insights shared between operators and technologists on how best to use that technology. The military did not develop these solutions as products of a formal acquisition process; rather, innovators incorporated technologies and ideas then experimented with tactics and processes to change the conduct of war. This study looked at a number of these historical examples and for each one has summarized the essential elements that enabled the disruptive innovation.

The following examples of disruptive innovation are included in this section:

- Sinking of the Ostfriedland – Mitchell (1921)
- Carrier Warfare – US Navy (1930s)
- Early Warning System – Chennault (1933)
- Blitzkrieg – Guderien (1940s)
- ICBM – Schriever (1950s)
- Space-based Surveillance – (1960s)
- Precision Guided Weapons – (1970s)
- Stealth – (1970s)
- Armed Predator – (2002)

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Sinking of the Ostfriedland

Gen Billy Mitchell is well known as one of the Air Force's great innovators. He achieved this acclaim in 1921 when he set out to prove that no naval fleet could survive an attack by land-based air.

...Mitchell stated that 1,000 bomber aircraft could be built and operated for the cost of one dreadnought and that his airplanes could sink a battleship. He volunteered to demonstrate this if the navy would provide him with some battleships, which were already due to be demolished. The navy reluctantly agreed to the demonstrations.

Once it was decided the tests would be performed under navy rules, it set strict guidelines that it felt would ensure failure for Mitchell. One was that the bombings be conducted slowly, stopping often to permit inspections of the damage by construction inspectors. This would allow a scientific appraisal of the capacity of different types of ships to withstand aerial attack. Also, the number and size of the bombs were to be limited.

The tests began in July off the coast of Virginia. The navy had provided Mitchell with three decommissioned U.S. battleships and three ships obtained from the Germans in the peace agreement--a destroyer, an armored light cruiser, and a dreadnought. All were successfully sunk. The climax of the demonstrations took place on July 21, when the navy brought out the German ship Ostfriedland, a great ship that had been the pride of the German fleet during the war. The vessel was considered unsinkable, and it probably would have been if Mitchell had adhered to the rules. But instead, he had personally overseen the design of a number of 2,000-pound (907-kilogram) bombs, knowing that smaller bombs would not be successful. Martin twin-engine MB-2 bombers dropped six of these bombs in rapid succession. Two scored direct hits and the others landed close enough for the ship's hull plates to rip open from the force of the explosion. Twenty-one minutes after the test began, the Ostfriedland plunged to the bottom of the ocean. The final plane dropped its bombs into the foam rising from the sinking ship.

The navy was horrified and declared the tests void since Mitchell had violated the guidelines. But it also began to focus more on aviation. The Bureau of Aeronautics, which had been established in 1921 as a defense against Mitchell's actions under the leadership of William Moffat, increased its development of the aircraft carriers that would eventually help win the Pacific campaign in World War II.

Mitchell's experiment is a prime example of an unfettered adversary. If Mitchell had adhered to the Navy's restrictions, then he would have not been able to fully demonstrate the supremacy of air power. Mitchell's experiment identified a major vulnerability in the Navy's fleet, and they eventually altered their strategic plans to develop aircraft carriers instead of the dreadnought.

Ref:

Feltus, P. "Billy Mitchell Sinks the Ships." *U.S. Centennial of Flight Commission*.
http://www.centennialofflight.gov/essay/Air_Power/mitchell_tests/AP14.htm.

Public Release

Carrier Warfare (The Early Development of Naval Aviation)

An overview of experimentation in the creation of the Navy's Aircraft Carrier capability is in a recent National Academy of Engineering report. A section is excerpted here.

The history of the Navy's use of experimentation to achieve new capabilities is illustrated by the role of experimentation in the introduction of aircraft and aircraft carriers. The motivation to undertake an experimentation campaign related to naval aviation was driven directly by a decision of Admiral of the Fleet George Dewey, who began to push the concept of naval aviation after viewing the use of dirigibles. The admiral is said to have commented, "If you can fly higher than the crow's nest, we will use you." To pursue the concept of naval aviation, Captain Washington Chambers was designated by Admiral Dewey as the Navy's lead aviation project officer. Chambers's jobs were to find funding for the project and to demonstrate that an aircraft could both take off from and land on a ship. George von L. Meyer, then Secretary of the Navy, refused to include funds in the budget for the demonstration. Not to be deterred, Chambers found a rich, politically well connected publisher and aviation enthusiast named John B. Ryan to help him. Ryan contacted President Taft, who persuaded Secretary Meyer to change his mind and designate the cruiser USS Birmingham to be used for the experiment. The experiment required the construction of a wooden ramp extending from bridge to bow. While the Navy provided the ship, the cost of the ramp (\$288) was paid for by Ryan. The first demonstration of an aircraft taking off from a ship took place near Norfolk, Virginia, in November 1910. Captain Chambers was then authorized to spend not more than \$500 to construct an aircraft recovery ramp on the stern of the cruiser USS Pennsylvania. On the basis of experiments ashore, Chambers and his pilot, Eugene Ely, determined that arresting cables would be needed to bring the aircraft to a stop. Accordingly, 15 cables were stretched across the deck, each fastened at either end to a 50-lb sandbag.

In 1913, Captain Chambers determined that all available aircraft and pilots should take part in the fleet's winter exercises of 1913 off Guantanamo Bay, Cuba. These annual exercises were the equivalent of the current Navy fleet battle experiments (FBEs). For these experiments, Chambers's officers rigged a wireless transmitter on one of the aircraft and a receiver on the flagship. An aircraft then flew over the horizon to scout out the position of the opposing forces. Although transmission took place on the plane, reception on the flagship did not occur. However, the concept of using an elevated platform to locate hostile forces had been established.

During the next 7 years, aircraft technology—driven by needs of the Allied and Central powers in World War I—accelerated rapidly, as did the number of qualified flyers and aircraft in the U.S. Navy. By the end of World War I, aircraft carried weapons (machine guns), could drop bombs, and could undertake primitive communications. Experiments had resulted in the development of moderately safe catapults that allowed pontoon aircraft to be launched from a ship's fantail. In 1917, the British Navy undertook experiments with arresting cables that could absorb the energy of a landing aircraft more efficiently than could Ely's arrangement of cables and sandbags. Thus, by the end of World War I, all of the technology required for an aircraft carrier was in place.

On March 20, 1922, the USS Langley, the Navy's first aircraft carrier, was commissioned. The ship had been converted from the former Jupiter, a collier. By the end of the decade, two more carriers, the Lexington and the Saratoga, were commissioned. The performance

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of carrier aviation in the war games (FBEs) of 1929 was a portent of the future. Opposing fleets were charged with the attack and defense of the Panama Canal. The Saratoga (attacking force), under cover of darkness and bad weather, launched 69 aircraft, which arrived over and theoretically destroyed the canal without incident. Thus, the role of the fast carrier was predicted 12 years before Pearl Harbor.

Ref:

Naval Studies Board. (2004). The Role of Experimentation in Building Future Naval Forces. Washington DC: The National Academies Press. ISBN: 0309088739.

www.nap.edu/books/0309088739/html/28.html

Public Release

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Early Warning System

The Air Corps Tactical School at Maxwell Field was the heart of early Air Force innovation in the 1930s. An excellent example of an early SLE is described in Perry's paper. The following illustrates one set of SLEs involving an early warning network to provide an unfair competitive advantage to technically less capable pursuit aircraft of the day over the bomber force.

Captain Chennault "talked so loud and long about the necessity for an aircraft warning net, and providing radio intelligence to the defending fighters in the air, that another air force maneuver was held in 1933 at Fort Knox, Kentucky." It tested his proposed air defense warning system. A line running between Indianapolis and Cincinnati divided the friendly forces based at Dayton and opposition forces located at Fort Knox. The former forces flew fast, modern bombers while the latter had slow, fabric-covered biplanes. Three regiments of antiaircraft artillery supplied guns, searchlights, and observers.

Chennault's warning system represented the heart of the exercise. It covered a 120 degree-wide sector centered on Fort Knox and radiating out towards Dayton with 69 observation posts at regular intervals. When planes were spotted, they telephoned fighter control at Fort Knox with the number, altitude, and course of the aircraft using a simple three-word code. This information was then plotted on a map. Opposition observation planes circled over the friendly base at Dayton, which had no defenses. These planes relayed their intelligence through a radio-equipped transport near Cincinnati. Prior experience had shown that fighter control must receive messages within four minutes or pursuit would not be able to intercept. In this exercise, however, almost 1,000 messages were sent in an average time of 2.7 minutes. The opposition pursuit group commander kept his planes on strip alert and issued the scramble order via a public address system. Information was updated by radio while the fighters were in the air. Clear, fast, precise reporting enabled the opposition to intercept friendly forces by day and night and at all altitudes. Most interceptions occurred between 25 and 50 miles from Fort Knox, and some bombers were intercepted more than once per mission.

The exercise illustrates the key points of SLE. Ideas were solicited from members of the Air Corps Tactical School. The champion for the ideas was Claire Chennault. Clearly he and his team were predisposed to disruptive innovation, even at the sake of their careers. The venue was a planned training exercise. The experiments explored innovative ideas both with existing technology and CONOPS. Chennault explored, in experiments, the utility of intelligence and (visual) early warning systems to demonstrate their effectiveness. The but lessons not assimilated prior to World War II.

Ref:

Perry, J. (1999). "Air Corps Experimentation in the Interwar years – A Case Study." Joint Force Quarterly. http://www.dtic.mil/doctrine/jel/jfq_pubs/0922.pdf.

Public Release

Blitzkrieg

Blitzkrieg, which means "lightening war," was first used by the Germans in World War II. It is a military tactic based on speed, surprise, and constant advance – using a force composed of light tank units supported by aircraft, motorized infantry, and engineers (to allow the vehicles to cross rivers and other difficult terrain quickly). The tactic was developed by a German officer named Hans Guderian, in whom Hitler placed great trust and authority, and who implemented it very effectively in 1939-1941 – rapidly defeating and occupying Poland and France, and making the initial deep incursions into the Soviet Union. The combination of speed, force, and technology resulted in a disruptive new way to advance the German occupation. The following excerpt describes some of the German's process to create and improve Blitzkrieg:

General Hans Von Seeckt clearly articulated that the goal of the German Army was a return to movement in hopes of avoiding the stagnant trench warfare of World War I. The model emphasized was: "offensive, combined arms maneuver, with independent action by officers, and intelligent, effective leadership at all levels." Information was gathered through the 57 committees and validated through numerous training exercises and leader development programs. Decisions were made using both a combination of experiments, for example, field testing new equipment of a select unit rather than the entire army, and using systems already in place. Effects were reviewed in an open forum, such as the Militär-Wochenblatt, that the military culture encouraged. The cycle was not as linear as this description might suggest. The process and goals were constantly adjusted as new information became available and, more importantly, as new technologies were introduced. A perfect example was the development of the panzer division. ... The panzer division was so effective that during and after World War II it became a model for many armies, including France, Britain, and the United States.

The Germans effectively utilized channels of communication in order to maximize the flow of information. This information was used throughout the experimentation campaign to make decisions and assess the effectiveness of the experimentation. They constantly adapted as new information and new technology came available.

In 1940, Britain and France still had a World War I mentality. What tanks they had were poor compared to the German Panzers. British and French tactics were outdated and Britain still had the mentality that as an island we were safe as our navy would protect us. Nazi Germany, if it was to fulfill Hitler's wishes, had to have a modern military tactic if it was to conquer Europe and give to Germany the "living space" that Hitler deemed was necessary for the Third Reich.

Ref:

Gukeisen, T. (2005). "The Operational Art of Blitzkrieg: Its Strengths and Weaknesses in Systems Perspective. *U.S. Army Command and General Staff College School of Advanced Military Studies*. DTIC Ascension # ADA435929

<http://www.dtic.mil/dodsrch/docView?c=5523EBCD2CDE5FFD&dk=http%3A%2F%2Fstinet.dtic.mil%2Fstinet%2FXSLTServlet%3Fad%3DADA435929&t=y>

"Blitzkrieg." <http://www.historylearningsite.co.uk/blitzkrieg.htm>

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ICBM

During and after World War II, Ballistic missile programs had a low priority within the Air Force, which instead concentrated its resources on manned bombers and jet fighters which were needed for the Korean conflict. Most people believed that a practical ICBM was far off, due to the weight of the warhead. That belief changed in 1953 when Princeton mathematician John von Neumann gave a presentation to the SAB that indicated a 1500 warhead capable of one megaton-yield could be developed by the end of that decade. This realization immediately raised the priority for ICBM to number one and then the challenge was how to quickly respond to this high priority challenge.

The ICBM development history, which is well documented in the book *The United States Air Force and the Culture of Innovation* by Stephen B. Johnson, is a very good example of the kind of innovation that can occur when you have the right mix of people and ideas.

In 1954 AF Secretary Harold E. Talbott formed the Strategic Missiles Evaluation Committee, or “Teapot Committee,” to investigate and recommend a course of action for strategic ballistic missiles. They recommended creating an organization that harkened back to the Manhattan Project and MIT’s Radiation Laboratory of World War II.

The nature of the task for this new agency requires that overall technical direction be in the hands of an unusually competent group of scientists and engineers capable of making systems analyses, supervising the research phases, and completely controlling the experimental and hardware phases of the program – the present ones as well as the subsequent ones that will have to be initiated.

Gen Shriever was the champion for this incredible effort, and he was able to enlist support from some of the greatest minds around, including John von Neumann, who was the head of the SAB’s Nuclear Weapons Panel and became the head of the Scientific Advisory Committee for the ICBM project. Gen Shriever successfully found new methods of operation, cut through red tape, and circumvented meddling. In addition, he was given broad authority to manage the program as he saw fit. Shriever’s team overcame several significant technical challenges dealing with propulsion, guidance, and re-entry among others.

Gen Schriever did what many considered impossible: He had led the development of four major missile systems – Atlas, Thor, Titan and Minuteman I – overseen the employment of roughly 300,000 people, administered a budget for these projects of nearly \$17 billion, and brought them to Initial Operational Capability in seven years. It transformed the USAF and the nation and helped usher in the nuclear deterrence capabilities which were the basis of national security throughout the remainder of the cold war.

Ref:

Johnson, S. (2002). *The United States Air Force and the Culture of Innovation*. Washington D.C.: Air Force History and Museums Program.

Public Release

Space-based Surveillance

March 16, 1955, the Air Force issued General Operational Requirement No. 80, officially establishing a high-level requirement for an advanced reconnaissance satellite. The document defined the Air Force objective to be the provision of continuous surveillance of “preselected areas of the earth” in order “to determine the status of a potential enemy's warmaking capability.”

Over the next five years the U.S. reconnaissance satellite program evolved in a variety of ways. The success of the Soviet Union's Sputnik I and II satellites in the fall of 1957 provided a spur to all U.S. space programs including, reconnaissance. The Air Force program was first designated the Advanced Reconnaissance System (ARS), then SENTRY, and finally SAMOS. The main objective of SAMOS was to develop a satellite that could scan its exposed film and return the imagery electronically.

In the early 1960s, CORONA replaced SAMOS as the primary USAF reconnaissance program. It took over a year, starting in 1959, and 14 launches before an operational CORONA spacecraft was placed in orbit. The thirteenth mission, a diagnostic flight without camera equipment, was the first success – then on the fourteenth mission (August 18, 1960), a camera-outfitted CORONA was placed into orbit for a day. This flight yielded more images of the Soviet Union in its single day of operation than did the entire U-2 program. The CORONA program allowed the U.S. to update the estimate of the Soviet ICBM force to between 25 and 50. CORONA imagery also allowed the U.S. to catalog Soviet air defense and anti-ballistic missile sites, nuclear weapons related facilities, submarine bases, IRBM sites, airbases - as well as Chinese, East European, and other nations' military facilities. It also allowed assessment of military conflicts - such as the 1967 Six-Day War - and monitoring of Soviet arms control compliance. Following the CORONA program, U.S. space-based surveillance capabilities continued to develop, leading to a full space imaging fleet employed today.

Ref:

Richelson, J. (1999). “US Satellite Imagery, 1960-1999.” National Security Archive Electronic Briefing Book No. 13. <http://www.gwu.edu/~nsarchiv/NSAEBB/NSAEBB13/>.

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Precision Guided Weapons or Precision Guided Munitions

Precision-guided munitions are self-guiding weapons intended to maximize damage to the target while minimizing “collateral damage.” The creation of precision-guided munitions resulted in the renaming of older bombs as “gravity bombs,” “dumb bombs,” or “iron bombs.” Through sustaining innovation, precision-guided weapons evolved through three primary types – laser guided, radio-controlled, and satellite guided. The use of these weapons has enabled disruptive innovations to occur, such as the CONOPS development leading to the use of B-52s for close air support during Operation Enduring Freedom in Afghanistan.



Radio-Controlled. The United States Army (Air Corps) began experimenting with radio-controlled remotely guided planes in World War I, but the program had few successes. The first successful experiments with guided bombs were conducted during World War II when camera-guided bombs, flare-sighted bombs, and other steerable munitions were developed. In the 1960s, the electro-optical bomb or camera bomb was introduced. They were equipped with television cameras and steerable flare sights, in which the bomb would be steered until the flare superimposed the target. The camera bombs transmitted a "bomb's eye view" of the target back to a controlling aircraft which then transmitted control signals to steerable fins fitted to the bomb. Such weapons were used increasingly by the USAF in the last few years of the Vietnam War.

Laser-Guided. By 1967 the USAF had conducted a competitive evaluation leading to full development of the world's first laser-guided bomb – the BOLT-117 in 1968. Laser-guided munitions rely on the target being illuminated by an encrypted laser "target designator" on the ground or on an aircraft.

Laser-guided weapons did not become commonplace until the advent of the microchip. The first large-scale use of smart weapons came in 1991 during Operation Desert Storm by coalition forces against Iraq. Laser-guided weapons have a disadvantage in that their effectiveness is impaired during poor weather conditions.

Satellite-Guided (GPS). Satellite-guided weapons, the most accurate of the precision weapons, use satellite navigation systems such as GPS (e.g., JDAM (Joint Direct Attack Munition) and JSOW (Joint Stand-Off Weapon). This offers improved accuracy compared to laser systems, and can operate in all weather conditions, without any need for ground support. The bomb reverts to inertial navigation in the event of losing the GPS signal.

Ref:

“Precision-guided Munition.” http://en.wikipedia.org/wiki/Precision-guided_munition.

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Stealth

By the mid-1970s, the Soviet-designed and widely distributed (radar-based) Integrated Air Defense System (IADS) had become a serious concern to the free world. In conflicts such as Rolling Thunder in North Vietnam and the 1973 Yom Kippur war, losses were at times unsustainable, and the forecast for losses in a major conflict involving NATO's forces was a grim one – owing in large measure to the IADS' effectiveness.

It had been shown through the years that the radar cross section (RCS) of aircraft could be reduced by shaping and other methods, but the fact that radar detection range for any particular aircraft varied as the fourth root of its RCS requires that many orders of magnitude reduction over extant values would be required to achieve operational utility. In 1974, Kent Kresa (later CEO of Northrop) and Ken Perko, both at DARPA, began a program to determine what levels were practically achievable—and to build actual aircraft if possible. They contracted with major aircraft companies (originally not Lockheed) for analyses and computer simulations. Ed Martin, Kelly Johnson (“Skunk Works” Director), and Ben Rich of Lockheed convinced DARPA that they should be included. Denys Overholser, Bill Scherrer, and Bill Schroeder at Lockheed came up with a “faceted” design approach, and computer programs which they believed predicted that a very low observable (VLO) with satisfactory performance could be achieved¹. In addition to analyses and computations, other venues were used to experimentally evaluate RCS, such as testing scale models in Lockheed's anechoic radar chamber.

DARPA awarded contracts to Lockheed and Northrop (the Experimental Survivable Testbed, or XST, program) in 1975 to actually build full scale RCS evaluation models, as phase I of an effort to achieve flying prototypes. The teams in the contractors' plants were expanded, and in March 1976 a “pole-off”² was accomplished at the Government's RCS evaluation facility (RATSCAT), with Lockheed selected to build the two flight demonstrators. The program name changed to Have Blue, and was taken under Air Force Leadership. Key to the subsequent success was Dr. Curry (DDR&E), Gen. Jones (CSAF), and Lt. Gen. Bond. Much of the program was now similar to a conventional fighter program:

Preparatory to and concurrent with aircraft construction, there were roughly 1,000 hours of high and low speed wind tunnel testing, 500 hours of propulsion wind tunnel testing, 88 test days at McDonnell Douglas' Gray Butte RCS range with a 1/3 scale model, and 40 days at RATSCAT with a full-scale RCS model. Other tests included structural testing, mockup, continued flight control development and simulation, and “iron bird” functional mockup testing.³

The Have Blue demonstrators flew from late 1977 through mid 1979, completing 88 sorties and, although both aircraft ultimately were lost, they accomplished all test objectives and demonstrated that tactically useful VLO aircraft were feasible. Ultimately 59 F-117A aircraft

¹ A major part of the mathematics to predict RCS was supplied by a paper written by (Soviet) Dr. P. I. Ufimtsev in 1962.

² RCS of models and full-size vehicles is measured on a range—with a radar illuminating and sensing the returns from the test article, mounted on a pylon (or pole), at varying aspects of azimuth and elevation.

³ Have Blue and the F-117A (Final Draft), Aronstein and Piccirillo, 12 March 1997 (later published by AIAA), p. 34.

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(essentially a scaled-up Have Blue), costing approximately \$6B were procured under the Senior Trend program and have been used with exceptional effect in conflicts around the world.

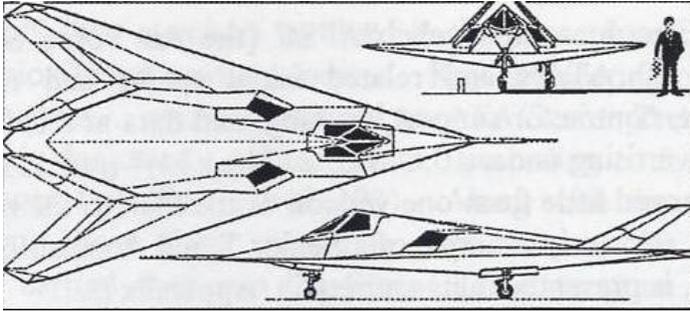


Figure 1: Have Blue

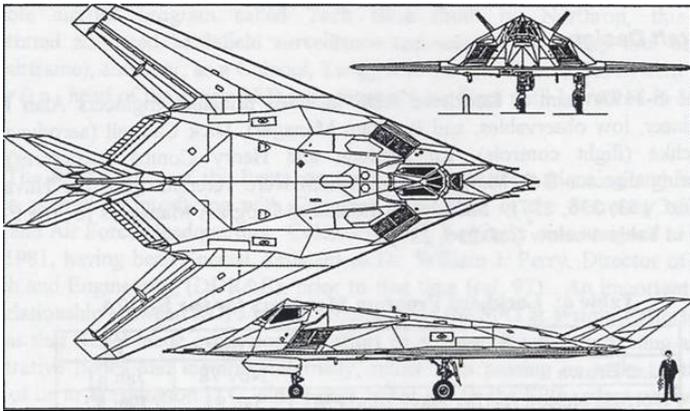


Figure 2: F-117A

Ref:

Aronstein, D. and Piccirillo, A. (1997). Have Blue and the F-117A: Evolution of the "Stealth Fighter." Reston VA: American Institute of Aeronautics and Astronautics, Inc. ISBN 1-56347-245-7.

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Armed Predator

The Armed Predator is another example of the great things that can be accomplished in a very short time when you marry up the right vision with the right team. The weaponized Predator was the brainchild of General John P. Jumper, who later became Air Force Chief of Staff, when he was commander of the Air Force Air Combat Command. He tasked Air Force Acquisition to “demonstrate a weaponized UAV” with the ability to “find a target, then eliminate it.” This was consistent with his vision for greatly reducing the sensor to shooter kill times.

The decision was made to use the Predator as the UAV and the Hellfire Missile as the Weapon, two systems that were designed and developed without the other in mind. The team that was tasked in July 2000 to make Gen Jumper’s vision a reality had to consider several risks inherent in integrating these two systems: could the Predator carry the missile, could the aircraft provide the necessary stability to launch the missile, and could the aircraft's onboard acquisition/designator system provide the stability to meet the missile's guidance requirements. All of this had to be done in a short timeframe.

A key to the success of this effort was the fact that the team did keep its focus on these three key technical issues while also exploring operational considerations, and it executed a campaign of experiments that led to a successful firing of a live Hellfire missile on Feb 21, 2001, just eight months after it got the tasking.

The Armed Predator project is another great example of the value of the key SLE Principles: A Champion with a vision (Gen Jumper), building the right team, and executing a campaign of system level experiments.

Ref:

“Predator Hellfire Missile Tests "Totally Successful"” May 12, 2001. Checkpoint.

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Appendix G: Initial Distribution

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Air Force Secretariat

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- Deputy Assistant Secretary of the Air Force for Science, Technology and Engineering
- Deputy Assistant Secretary of the Air Force for Acquisition Integration
- Director, Rapid Capabilities Office

Chief of Warfighting Integration and Chief Information Officer, Office of the Secretary of the Air Force

- Director, Strategy and Plans
- Director, Innovation and Technology

Air Staff

Assistant Vice Chief of Staff of the Air Force

Deputy Chief of Staff for Intelligence

Deputy Chief of Staff of the Air Force for Air, Space and Information Operations, Plans and Requirements

Deputy Chief of Staff of the Air Force for Strategic Plans and Programs

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Chief Scientist of the Air Force

Air Force Major Commands

Air Combat Command

- Eighth Air Force

Air Education and Training Command

Air Force Materiel Command

- Director, Strategic Plans and Programs

Air Force Reserve Command

Air Force Space Command

Air Force Special Operations Command

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- Director, Air, Space, and Information Operations
- Director, Logistics
- Director, Plans, Programs, Requirements, and Assessments
- Director, Communications and Information

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Air Force Major Commands continued

Air Mobility Command

- Director, Strategic Plans and Programs

Pacific Air Forces

U.S. Air Forces in Europe

Other Air Force Elements

Air Force Space and Missile Center

- Vice Commander
- MILSATCOM Joint Program Office

Air Force Research Laboratory

- Chief Technologist
- Air Vehicles Directorate
- Directed Energy Directorate
- Human Effectiveness Directorate
- Propulsion Directorate
- Sensors Directorate
- Space Vehicles Directorate

Air Force C2ISR Center

Air Warfare Battlelab

Command and Control Battlelab

Unmanned Aerial Vehicle Battlelab

Air University

- Air Command & Staff College
- Air War College
 - Center for Strategy & Technology
- School for Advanced Air and Space Studies

U.S. Air Force Academy

Office of the Secretary of Defense

Director of Defense Research and Engineering

Under Secretary of Defense for Acquisition, Technology and Logistics

Deputy Under Secretary of Defense for Advanced Systems and Concepts

Deputy Under Secretary of Defense for Science and Technology

Director, Defense Advanced Research Projects Agency

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U.S. Joint Forces Command

- Joint Experimentation Directorate
- Joint Forces Intelligence Command

U.S. Army Training and Doctrine Command

U.S. Navy Warfare Development Command

- Commander
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U.S. Marine Corp

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14. ABSTRACT This study is about system-level experimentation (SLE), campaigns of genuine discovery experiments, and how SLEs can be used to drive disruptive innovation. SLEs support the discovery, exploration, and understanding of new operational and system concepts and the technology needed to support those concepts in future environments. As such, SLEs are complimentary to, but different from ATDs or JEFX (focus on early discovery versus later demonstration), Battlelabs (focus on game changers versus near-term needs), or Big Safari or the Rapid Capabilities Office (focus on discovery in future environments versus fast fielding to meet high priority needs). Similarly, SLEs are not wargames, but SLEs could be conducted in the futuristic scenarios of such games. Disruptive innovations often arise from the "friction of war." To mimic that effect, SLEs must incorporate a challenge-competitive environment to maximize depth of innovation and exploration, with an unfettered, highly skilled adversary with no cultural limitations and with technical restrictions imposed only by physics. The experiments should be staffed with carefully selected individuals who have attributes conducive to "out of the box" exploration. Experiments can be conducted in gaming environments ranging from simple "seminar explorations" to networked gaming to being in the field. This SLE approach also integrates recently codified industry innovation practices (e.g., innovation starts with the CEO). The study identifies four essential components in the development of disruptive innovation by means of SLE: ideas, people, venue, and experiments.					
15. SUBJECT TERMS Air Force Scientific Advisory Board, Scientific Advisory Board, SAB, Experimentation, System-Level Experimentation, SLE, Experiment, Innovation, Disruptive Innovation, Sustaining Innovation, Chief of Innovation, Innovation Task Force					
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