Evaluating Future Trends in Support of the Air Force Strategic Environment Assessment

Discussion and Results from a Structured Workshop

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Preface

This report presents the results of a fiscal year 2016 RAND Project AIR FORCE add-on project. This project supported the Air Force Strategic Environment Assessment (AFSEA). The AFSEA is an examination of plausible futures for Air Force planning over a 30-year time frame. This report presents the results of analysis on nine future trends provided by the Air Force and the output of a structured workshop to consider interactions between the trends and to develop a set of future worlds.

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Summary

The Air Force Strategic Environment Assessment (AFSEA) is an examination of plausible futures over a 30-year time frame that serves as the basis upon which the U.S. Air Force (USAF) Strategy, Planning, and Programming Process (SP3) is executed. During the process of developing the 2016 AFSEA, USAF identified nine trends in three major categories:[1]

Geopolitical
- The Increasingly Multi-Polar World
- The Rise of Non-State Actors
- The Spread of Fragile & Failed States

Military & Warfare
- The Convergence of Warfighting Domains
- The Rapid Change of Threats & Weaponry
- The Growing Difficulty of Attribution & Targeting

Human & Workforce
- The Changing Culture & Capabilities of the Workforce
- The Augmentation of Humanity
- The Ubiquity of Information.

The USAF asked RAND for help in identifying plausible futures based on each of these trends. First, a RAND expert with expertise in each of the selected key trends did a brief assessment of that specific trend area. For each trend, we then developed a set of plausible alternate futures in an effort to bound the problem and explore the possibilities. Figure S.1 shows the identified plausible futures for each trend area.

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[1] USAF provided the descriptions of the three major categories and the nine trend areas presented in this report. We present this list verbatim.

Figure S.1. Plausible Futures Identified for Each Trend Area

Trends	Plausible Futures					
Increasingly Multipolar World	Persistent US Hegemony	Back to Bipolarity	First Among Equals	The Asian Century	Twilight of the Great Powers	
Non-State Actors and Fragile & Failing States	Regional Instability	Rise of Regional Dictators	Large Regional Power Brokers	Western Powers Intervene		
Growing Difficulty of Attribution & Targeting	Non-Attribution Warfare as an Instrument of National Power	Highly Amorphous Irregular Warfare	Conventional Warfare with Peer Hiding in Plain Sight	Easier Attribution and Targeting		
Convergence of Warfighting Domains	Super State	Mad Max	Super Chaos	Heterogeneous Convergence		
Rapid Change of Threats & Weaponry	Bots, Bots, Bots	The Light Fantastic	A Can of Worms - Attacking Operators	The New Look Redux	Rejection of Fully Autonomous "Thinking Machines" and Enhanced Humans	Incremental Weapons Development
Augmentation of Humanity	Fully Bionic Human	Greatly Enhanced Humans	Moderately Enhanced Humans	Incrementally Evolved Human		
Ubiquity of Information	Ubiquity of Information					
Changing Culture & Workforce Capabilities	Changing Culture & Workforce Capabilities					

Based on this initial set of work for each of the trend areas, we then convened a structured exercise to evaluate those trends in the development of plausible futures and developed future worlds that combine the different key trend futures to provide a variety of plausible futures that USAF can use to inform scenario development. The research focused on likely direction and plausible progress during the 30-year time frame in an effort to bound plausible futures.

The workshop was a two-day event during which the RAND trend experts (1) presented their trend assessments and plausible futures; (2) conducted a cross-consistency analysis to look for any combinations of futures that they felt would be inconsistent with each other; (3) identified "interesting pairings" of futures; and (4) developed future worlds using different combinations of trend futures. The purpose of the workshop was to create a set of future worlds that represented diverse contexts and potential challenges for USAF to consider. The outputs from the workshop included plausible futures for each trend and descriptions of the different future worlds.

During the development of each world, we began with the degree of multipolarity trend, because it is the highest order and basic characteristics of the international order. We chose this trend area as the launching point for each world because it informed how the other trend areas would potentially play out. We then built a variety of worlds by choosing different futures from each of the other trend areas. After we completed development of a world, we gave it a shorthand name to describe it.

Based on the discussions in the workshop, we identified seven future worlds that capture the different aspects of the alternate trend futures. These seven future worlds were organized by

degree of multipolarity. These worlds range from a continuation of the current situation out through the next 30 years ("Status Quo"), through a variety of more multi-polar worlds, to a situation where China has surpassed the United States and has achieved a state of more global influence than the United States. Figure S.2 shows that we have three major groupings with regard to degree of multipolarity: (1) persistent U.S. hegemony, (2) persistent multipolarity, and (3) changing hegemonic power.

Figure S.2. Future Worlds Organized by Degree of Multipolarity
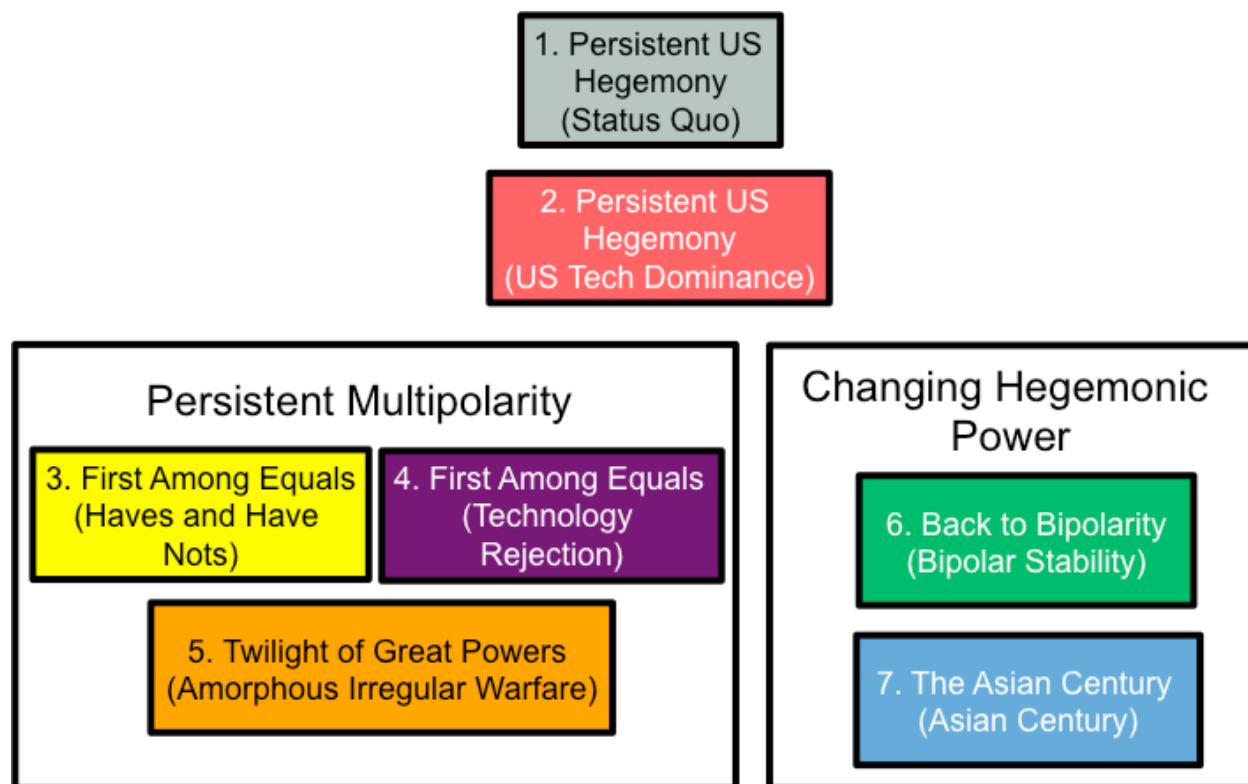
Based on this work, a range of plausible futures can be envisioned for the next 30 years. The futures identified are diverse, illustrate the complex ways in which different trends might play out in the future, and show how different contexts could have significantly different effects on future USAF operations. Figure S.3 provides a visual summary of the analytic structure underneath this particular set of worlds, as well as a means of visually comparing the futures that the different worlds covered.

Figure S.3. Visual Comparison of Future Worlds

<u>Trends</u>   <u>Plausible Futures</u>

Increasingly Multi-Polar World	Persistent U.S. Hegemony	Back to Bipolarity	First Among Equals	The Asian Century	Twilight of the Great Powers
Non-State Actors and Fragile & Failing States	Regional Instability	Rise of Regional Dictators	Large Regional Power Brokers	Western Powers Intervene	
Growing Difficulty of Attribution & Targeting	Non-Attribution Warfare as an Instrument of National Power	Highly Amorphous Irregular Warfare	Conventional Warfare with Peer Hiding in Plain Sight	Easier Attribution and Targeting	
Convergence of Warfighting Domains	Super State	Mad Max	Super Chaos	Heterogeneous Convergence	
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Ubiquity of Information	Ubiquity of Information				
Changing Culture & Workforce Capabilities	Changing Culture & Workforce Capabilities				

Orange World	Yellow World	Green World	Blue World	Purple World	Red World	Status Quo World
Amorphous Irregular Warfare	Haves and Have Nots	Bipolar Stability	The Asian Century	Technology Rejection	U.S. Technological Dominance	Status Quo

RAND *RR1701*

Each of these futures encapsulates the various potential trends to create vastly different plausible worlds. The future worlds identified in this report are a diverse set that could have significant effects on how USAF operates. This is, of course, not a complete set, but one intended to provide a diverse backdrop for planning purposes. It is also an effort to provide USAF with ideas on how these different trends could evolve and could interact with one another, resulting in diverse situations for USAF.

In this project, we used an adapted General Morphological Analysis (GMA) approach for the workshop that was able to produce a range of possible futures in a condensed period. On the issue of how to improve the workshop product, there are several factors we can identify. First, we feel that a slightly smaller set of trends, with less overlap between them in some cases, could

have led to a more-efficient process without any loss in the quality of the worlds created. Second, we could have spent more time exploring whether certain trends, such as the Ubiquity of Information or Changing Culture & Capabilities of the Workforce, could have been expressed in terms of discrete futures. Third, we could have run this exercise with different groups to see whether we could get broadly different futures depending on the group. Furthermore, after several iterations, we could have explicitly explored different parts of the scenario space by asking the participants specific questions to explore. All of this would have required more time and resources than were available for this project.

There are also other potential ways that this method might be useful to USAF for structuring the thinking about other complex and challenging problems. GMA and its different adaptations are extremely useful as scenario generation methods that seek to identify the key factors that will drive the future. On this front, GMA may be the most comprehensive scenario generation method in existence. It is also useful for structuring highly technical questions, where the cross-consistency analysis can be useful in ruling out certain combinations on technical grounds.

Acknowledgments

Abbreviations

A2AD	anti-access/area denial
A5SG	Strategic Studies Group
AFSEA	Air Force Strategic Environment Assessment
AI	artificial intelligence
AR	augmented reality
CCD	camouflage, concealment, and deception
CFR	counterfactual reasoning
DARPA	Defense Advanced Research Project Agency
EMP	electromagnetic pulse
EU	European Union
F2T2EA	find, fix, track, target, engage, and assess
FOD	foreign object damage
GDP	gross domestic product
GMA	General Morphological Analysis
IoT	Internet of Things
ISR	intelligence, surveillance, and reconnaissance
IT	information technology
IW	irregular warfare
LO	low observable
MNC	multinational corporation
NATO	North Atlantic Treaty Organization
NGO	non-governmental organization
OODA	observe, orient, decide, and act
R&D	research and development
SAM	surface-to-air missile
SDA	Scenario Diversity Analysis

SFOR	Stabilization Force in Bosnia and Herzegovina
SIM	subscriber identification module
SP3	Strategy, Planning, and Programming Process
TBM	theater ballistic missile
USAF	U.S. Air Force
WWII	World War II

1. Introduction

The Air Force Strategic Environment Assessment (AFSEA) is an examination of plausible futures over a 30-year time frame, which serves as the basis upon which the U.S. Air Force (USAF) Strategy, Planning, and Programming Process (SP3) is executed. The USAF is developing the 2016 AFSEA to provide a set of environmental drivers that could greatly affect the future of the USAF and USAF operations. In late 2015, USAF conducted a survey of various USAF organizations to identify a set of the most important key trends for further analysis. Nine trends were identified in three major categories: Geopolitical, Military & Warfare, and Human & Workforce. The nine trend areas provided by USAF are[1]

Geopolitical
- The Increasingly Multi-Polar World
- The Rise of Non-State Actors
- The Spread of Fragile & Failed States

Military & Warfare
- The Convergence of Warfighting Domains
- The Rapid Change of Threats & Weaponry
- The Growing Difficulty of Attribution & Targeting

Human & Workforce
- The Changing Culture & Capabilities of the Workforce
- The Augmentation of Humanity
- The Ubiquity of Information.

The USAF asked RAND for help in identifying plausible futures based on these trends. First, a RAND analyst with expertise in each of the USAF-selected key trends conducted a brief assessment of a specific trend area and identified plausible directions and impacts the trend could have over the next 30 years. Two of the trends—(1) the Rise of Non-State Actors and (2) the Spread of Fragile & Failed States—were highly related to each other, so we assigned these two to a single RAND researcher. For each trend, we developed a set of plausible alternate futures in an effort to bound the problem and explore the possibilities. Based on this initial work in each of the trend areas, the RAND team then convened a structured exercise to consider those trends in the development of plausible futures and developed future worlds that combine the different trend futures to provide a variety of overall plausible futures that USAF can use to inform scenario development. Figure 1.1 shows the identified plausible futures for each trend area.

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[1] See Appendix A for descriptions of each trend provided by USAF. We present them here verbatim.

Although we focused on likely direction and potential progress during the 30-year time frame in an effort to ensure a plausible and logically thought-out process, we do not intend these futures to be any sort of projection. Our object here was to take the USAF-provided trends and assemble them in a way to give USAF a set of plausible and diverse alternatives that could be used to develop non-standard vignettes and scenarios to highlight assumptions and explore capabilities.

Figure 1.1. Plausible Futures Identified for Each Trend Area

Trends	Plausible Futures					
Increasingly Multipolar World	Persistent US Hegemony	Back to Bipolarity	First Among Equals	The Asian Century	Twilight of the Great Powers	
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The objective of this project was to generate a range of future projections to assist USAF strategic planning in developing the AFSEA. Our goal was to identify plausible but diverse future alternatives that could be used to enhance scenario development. The focus of this work was development of the different futures based on a collaborative workshop. This document presents the results of that workshop.

Chapter 2 presents a discussion of the Trend areas and a short description of the futures developed for each. Chapter 3 describes the methodology of the project and the conduct of the workshop. Chapter 4 presents the future worlds developed. Chapter 5 provides some concluding observations. The nine trend areas, along with a brief description of each provided by USAF, are presented verbatim in Appendix A, while Appendix B shows the cross-consistency of each future in each trend area.

2. Discussion of Trend Areas

This chapter provides a synopsis of the discussion that took place during the structured exercise for each trend area. As discussed in Chapter 1, we had a RAND expert assigned to each trend area. During the first half-day of the workshop, each RAND researcher presented his or her work on a specific trend. Each presentation covered some background information on the topic and then speculated on how this trend could evolve over the next 30 years. The objective of this exercise was not to predict the future, but to provide a range of plausible and different futures to help the Air Force expand planning scenarios. This chapter presents the discussions during the structured workshop covering both the RAND researchers' presentations and resulting dialogues.

This chapter highlights a few combinations that produce interesting challenges. It is not definitive, by any means, but more of a speculative tool to investigate how different threats and weapons could significantly affect warfighting over the next 30 years.

Increasing Multipolarity (Presenter: Karl Mueller)

Summary of Presentation

Presenter Karl Mueller discussed this trend area as shorthand for thinking about shifts in distribution of power between major powers. He noted that there are two different dimensions to consider when discussing multipolarity: static and dynamic. The static dimension indicates the way in which relative power is distributed among the members in the international system, while the dynamic dimension identifies how power is shifting between countries, that is, which countries are rising and which are falling in terms of relative power.

Mueller discussed several arguments associated with the degree of stability related to the static distribution of power and identified three major theoretical schools of thought:

- First is the traditional notion that a multi-polar system is most stable. This is the Congress of Vienna image that a group of powers can form alliances as needed to maintain stability and join forces to defeat states that aspire to dominate the system.
- The second notion arose during the Cold War when the idea emerged that a bipolar configuration is more stable because it is simpler.[1] In this case, each superpower knows that the other is the enemy. Shifting alliances with other countries matter, but are of only secondary importance.
- The third perspective is that hegemony or unipolarity, in which a single power plays a dominant role in the international system, is most conducive to stability. Recent U.S.

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[1] See Kenneth N. Waltz, *Theory of International Politics*, Long Grove, Ill.: Waveland Press Inc., 1979.

foreign policy discourse focuses implicitly on this idea in emphasizing the desirability of American global leadership and of "near-peer" rivals not becoming actual peers.[2]

Mueller continued by presenting the idea that depending on the context, the expression *increasing multipolarity* could mean several different (although potentially overlapping) things:

- First is the potential that power is shifting from the leading state or states to a larger number of potential challengers. This can be less about losing power in absolute terms than a flattening of the world in terms of relative power differences. In this case, the presenter noted that we could postulate that the differences between major and non-major powers are diminishing because of increased information flows and other factors.
- Second is a shift in the way alliances and partnerships work. Polarity usually refers not only to countries having power but also to the alliances built around them. If every conflict is fought by an ad hoc coalition because countries cannot count on the same states choosing to be part of the alliance all of the time, leading states must attend to a larger number of consequential national preferences.
- Third is the idea that there is a shift in power away from states to entities that are not states (non-governmental organizations [NGOs], multinational corporations [MNCs], non-state actors, and others). This is addressed to some degree in the following section.

With this as the backdrop, the presenter noted that the question becomes how power should be measured. Gross domestic product (GDP), industrial production, and other factors could be considered, but these factors can be fairly unpredictable over the long term. Technological change can be an important determinant of relative power, and can create the potential for sudden disruptions. At the other end of the spectrum, demography is relatively predictable over a range of some decades. There are some clear trends in demographics such as that the populations of African states are projected to continue to grow well into the mid-21st century, while the populations of Europe and Japan are expected to fall relative to other countries. The United States remains high on the list of national population size in spite of being an advanced industrialized country primarily because of strong immigration flows.

Finally, the presenter noted that there are many uncertainties that will drive the degree of multipolarity over the next 30 years. A few of the most conspicuous are:

- How much do major states, such as India, Russia, and Iran, reform dysfunctional aspects of their economic and governmental systems?
- How common are success stories in Africa, Asia, and Latin America, and what do they look like?
- How united does Europe become and how pro-American is it?
- Is there a new ideological organizing principle to fight about?
- How much does war go out of style?
- How much does modernity undermine fundamentalist religion?

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[2] Robert Gilpin, *War and Change in World Politics*, Cambridge, UK: Cambridge University Press, 1981.

These and other factors can greatly affect the degree of multipolarity. As a result, one can envision a wide range of plausible alternatives regarding the degree of multipolarity in the future and how that multipolarity might manifest itself as we think through potential scenarios USAF might confront.

Futures Identified

The presenter next moved to a discussion of the range of plausible future worlds that could be envisioned as a result of the multipolarity trend area. He identified five different futures to explore this trend area. For each of the following five futures, we identified a tag line and the major characteristics of that plausible future.

Future A.1, "Persistent U.S. Hegemony":

- The United States remains the leader of the international system in spite of relative decline in its power.
- China's growth plateaus and the European Union (EU) does not unify to become a superpower.
- This system looks very much like the current system.

Future A.2, "Back to Bipolarity":

- China rises to be a genuine superpower alongside the United States and the two countries dominate the international landscape.
- This future assumes that China wants to be a superpower rather than an economically immense but unassertive member of the system.

Future A.3, "First Among Equals":

- The United States is one of the leading powers but no longer dominant.
- China, India, and maybe Brazil could become great powers in this future.
- There is a more-widespread tendency for states to rely on their weapons as the arbiter of their own national security.
- The United States will wage wars in coalitions because unilateral actions would be increasingly difficult.

Future A.4, "The Asian Century":

- China replaces the United States as the dominant global power.
- The United States loses its relative advantage in education, technology, research and development (R&D), and others, so that being smaller than China translates into being correspondingly less powerful.
- This would be reminiscent of periods during the Cold War when the Soviet Union appeared (mostly incorrectly) to be ascendant, but far more pronounced.

Future A.5, "Twilight of the Great Powers":

- In this future, major power conflict is a thing of the past—all countries decide there is nothing worth fighting major power wars over, so the distribution of military power among them is relatively unimportant.
- Residual conflicts are about failing state instability, humanitarian issues, and others.
- Maintaining stability on the periphery tends to be a shared interest among the major powers.
- This future has more powerful intergovernmental organizations.
- Although conflict with Russia or China is a real possibility, this future may resemble present day.

In closing, Mueller noted that these futures focused on global distribution of power at the static level. In practice the national security environment is dependent on changes at the regional level as well. For example, it is possible to have a multi-polar world, but a hegemonic power in a specific region (e.g., the Middle East). He further noted that the dynamic relationships also matter. Moreover, rapidly rising or declining powers can lead to conflict as states seek to forestall unfavorable shifts in the distribution of power or as newly powerful states impatiently seek to realign the system, and these dynamics can be far more consequential than the static distribution of power per se.

Non-State Actors and Fragile & Failed States[3] (Presenter: William Young)

Summary of Presentation

As noted earlier, two of the trends heavily overlap and were therefore considered together in this section. Presenter William Young began by noting that both of these areas are currently increasing. He stated that the growth of non-state actors includes terrorist and criminal groups and the countertrends currently do not appear sufficient to limit the growth of these groups. The presenter stated that countering these trends is very difficult, and he pointed to the United States' inability to stabilize Afghanistan, Iraq, and Syria to demonstrate the difficulty. Although it is possible that the United States might have been able to identify more effective approaches, creating stability in conflict zones is a notoriously difficult task.

Looking to the future, the presenter noted that these trends are likely to continue to grow. Terrorism and insurgency in various regions of the world will increase, particularly in the Middle East, South Asia, and Africa, but also in Western Turkestan, the Caucasus, and Central Asia. As urbanization increases, conflicts will be more urban in nature and will lead to further state fragmentation and instability in these regions. The presenter pointed out that there is a reason that terrorists and insurgents choose unstable regions as safe havens. These ungoverned areas allow them to hide, acquire support, plan, and operate with impunity.

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[3] The term *failed state* was included in the USAF list of key trends. It is fairly widely accepted that there have been very few actual failed states in the modern era. We keep the term *failed state* in the title of this section, but we use the phrase *failing state* throughout the text and subsequent chapters to describe the concept more precisely.

He stated that increases in ethnic conflict and "spillover" to other regions in the future are possible. External military assistance to the conflict zones and refugee flows might promote spillover and result in an increased spread of violence to neighboring states. He postulated that the consequent increased radicalization of youth would be a huge problem in such regions as the Middle East for years to come and that civil war and religious sectarianism have the potential to harden attitudes for the indefinite future. The Middle East has always had an underlying foundational conflict between the different factions of Islam, namely the Sunni and Shia. However, this conflict is now very much on the surface and is playing out in proxy wars between Saudi Arabia and Iran. Refugee flows are one way to spread radicalization.

The presenter discussed how different forces at work could spread unrest. As refugees flee from conflict zones, they have the potential to bring with them anger and radical ideologies or religious beliefs and practices. The Internet and virtual reality technologies are other ways to spread religious extremism and otherwise radicalize neighboring populations within a given region.

Another point the presenter stressed is that increased diffusion of commercial technology can drive the impact of this trend.[4] Drones and other widely used commercial technologies could allow non-state actors to be similarly disruptive, enabling them to do the unexpected and to have impact at greater distances.

As discussed earlier, these trends are difficult to counter. Before moving to a discussion of plausible futures, the presenter identified several possible countertrends to the rise in non-state actors and fragile and failing states. He identified the emergence of strong, authoritarian leaders as a potential countertrend, but this runs counter to current U.S. foreign policy objectives. Another potential way to slow this trend is a more-active U.S. foreign policy. The Marshall Plan after World War II (WWII) and the efforts to build the Bosnian state in the 1990s are examples of how U.S. foreign policy can be proactive and have a positive effect on reducing these disruptive trends.

A final issue the presenter discussed is the potential effect of non-state actors. He contended that during this time frame of 30 years we do not anticipate multinational corporations, private companies, or wealthy individuals playing a larger role than they have typically played in the past. However, we might see formal state actors like China and other countries playing a larger role globally and have an effect especially in places like Africa and Asia.

Futures Identified

Next, the presenter moved to a discussion of the range of plausible future worlds that could be envisioned as a result of these trend areas. He identified four different futures. For each of the following four futures, we identified a tag line and the major characteristics of that plausible future.

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[4] See Eric von Hippel, *Democratizing Innovation*, Cambridge, Mass.: The MIT Press, 2005.

Future B.1, "Regional Instability":

- There is continued growth in both non-state actors and fragile and failing states.
- This future is characterized by rising numbers of non-state actors and failing, fragile, and fragmented states experiencing conflict.
- This is a product of a U.S. foreign policy that has become increasingly non-interventionist and focused on quick transition to democracy.
- Any efforts by Western powers to stabilize regions were unsuccessful.
- This future is an extension of current trends.

Future B.2, "Rise of Regional Dictators":

- Dictators counter the instability of failing and fragmenting states.
- Failing states existing in 2016 could not be reformed without a strong, authoritarian leader.
- Characterized by the failure of U.S. policy to promote peaceful transition to democracy in the Middle East, Africa, and other unstable regions and conflict zones.
- In this future there is less insurgency and terrorism but more human rights violations and localized wars over territory.

Future B.3, "Large Regional Power Brokers":

- Large regional power brokers take a greater role and provide more stability in their regions.
- This future offers some stability to regions that would otherwise be fragmented and in conflict.
- Characterized by large regional, competitive blocs created by such states as Saudi Arabia and Iran.
- The competition between these blocs could lead to numerous proxy wars on the region's periphery, such as in Yemen and Africa.

Future B.4, "Western Powers Intervene":

- Western or other powers intervene to promote stability.
- This future offers partial, temporary stability to areas otherwise fragmented and in conflict.
- This future is characterized by a highly proactive U.S. role in foreign conflicts.
- This future is characterized by on-the-ground diplomacy and the military intervention of a large Western and Allied stabilization force along the lines of the Stabilization Force in Bosnia and Herzegovina (SFOR) in the 1990s.
- Intervention includes no-fly zones and safe areas for delivering humanitarian aid.
- Refugees are kept inside the boundaries of their countries while peace negotiations are conducted, thereby reducing the spillover of violence into neighboring states.

Growing Difficulty of Attribution & Targeting (Presenter: Brien Alkire)

Summary of Presentation

Presenter Brien Alkire began by noting that attribution is the association of an actor to an action. The actor can be either a state or non-state entity. Targeting and attribution can take place in a single domain or in multiple domains. Both the value and the costs of attribution are important. The ability to attribute actions can have several positive effects, including enhancing deterrence, mitigating effects, or allowing for retribution. The potential costs must also be considered. Increased capability for attribution could infringe on privacy rights. The ability to specifically attribute certain actions to individuals could be used by our adversaries. This could better enable censorship and crackdowns on antigovernment groups by adversary nations. This lack of anonymity could also hinder U.S. covert operations.

Next, the presenter discussed how attribution could be especially difficult for attacks in cyberspace and space. In cyberspace, the key challenge is that there is no direct link between packet source and application user. Links can be made to a particular computer, but not necessarily the person. Furthermore, packet source addresses can be forged if they only require one-way delivery of packets. Many actors use multistage actions in which they log into one machine that hacks into another and another, making it difficult to trace actions. Actions might also cross jurisdictional lines, making information gathering and enforcement difficult. Applications, such as Tor, facilitate two-way anonymous delivery of packets. One way to improve attribution would be through the use of "license plates" that link specific packets of information to specific users, as opposed to linking that information to machines. This would require global adoption and consensus on a "new Internet" and would imply that our policies favor security over privacy. Telecommunication networks are similar to Internet communications in that the telecommunication packets of information are linked to a particular device by a specific subscriber identification module (SIM) card, but not necessarily to a specific user.

The presenter then discussed the issues of attribution in space. Currently, attribution in space attacks requires a method to maintain chain of custody from launch by a specific state actor to a potential weapon identified in space. The challenge is that maintaining the chain of custody is technically difficult. Covert payloads may deliver effects that are difficult to detect. Furthermore, some forms of attack could also give an adversary plausible deniability. Additional investments in sensors, on orbit detection, and tracking capabilities are required to improve attribution methods for space attacks.

Next, the presenter moved to a discussion of terrestrial targets. Prosecuting a mobile target prior to action might enhance deterrence, while doing it afterward might prevent a target from acting again and also enhance the deterrent effect on others. However, he noted that there are some specific difficulties in targeting mobile targets, insurgent strongholds, and insurgent infrastructure. One can envision several methods an adversary could use to harden targets. These include reducing spatial temporal presence by having fleeting targets in time and space. Highly

mobile weapons systems and insurgents coalescing for short periods to create an impact and then blending back into population are examples of this approach. Target hardening can also be accomplished by reducing signatures with the use of camouflage, concealment, and deception.

Actors will often try to blend into the population or use decoys or feints to create false targets and other approaches to conceal actions. From a find, fix, track, target, engage, and assess (F2T2EA) perspective, reducing spatial temporal presence, such as using highly mobile tactical ballistic missiles (TBMs) spread over a large area, creates challenges for finding and fixing targets. To overcome this issue, the United States could proliferate the area with large numbers of sensors and shooters. Multimode sensors could be used to find camouflaged targets. Hyperspectral imaging (HSI) that samples many bands over a wide range of frequencies could provide significant capability at defeating camouflage, concealment, and deception (CCD) efforts and locating targets, but there is a significant challenge in terms of processing time. Processing of HSI images requires an enormous amount of time. Figure 2.1 shows an example of the time required for both onboard and off-board (i.e., supercomputer) processing of an HSI image. The presenter noted that, even looking out 30 years, processing of these images on board the aircraft is likely to take an unreasonable amount of time. It is possible to process the images off board using supercomputers. Projections indicate that the timelines could be reduced to minutes, which might be operationally useful depending on the number of images required to successfully engage the target. Finally, the presenter noted that one potential risk of using off-board processing is that the adversary could disrupt or change the data stream. Another potential issue with HSI images is the poor resolution. Figure 2.2 shows the ground resolution as a function of slant range for different wavelengths. Visible light provides good resolution while the resolution at longer wavelengths is considerably worse. As a result, HIS does provide a potential capability to enhance targeting ability, but the data processing requirement and reduced resolution capability present challenges.

Figure 2.1. Expected Time to Process HSI Image
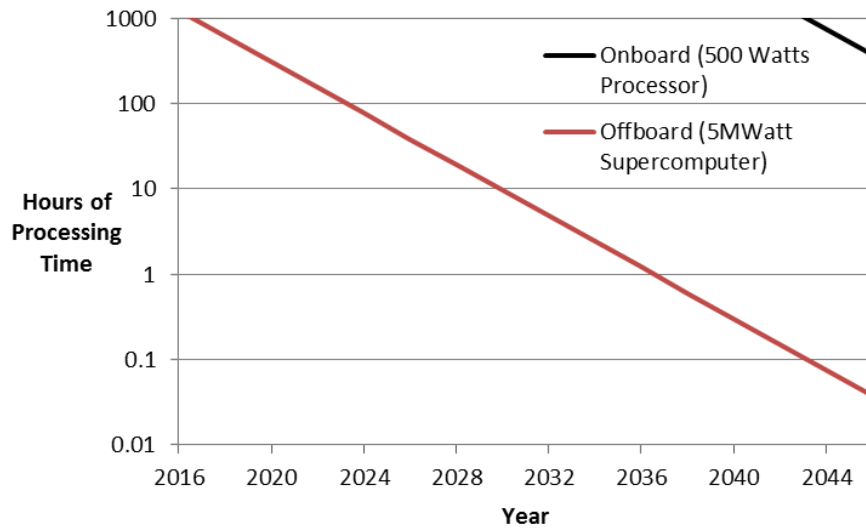
NOTE: The assumptions are HSI sensor with 100 bands, 16 megapixels per band, 16 bits per pixel, 7.2 GFLOPS/watt performance in 2016 (HPCWire, "Riken's Shoubu Supercomputer Captures Top Spot on Green500 List," Green500, August 8, 2016); processing times double every two years (Moore's Law); 25 percent of pixels require processing with O(n^3) algorithm; 500-watt onboard processor; and 5 megawatts off-board (supercomputer) processor.

Figure 2.2. Target Resolution for Different Wavelengths
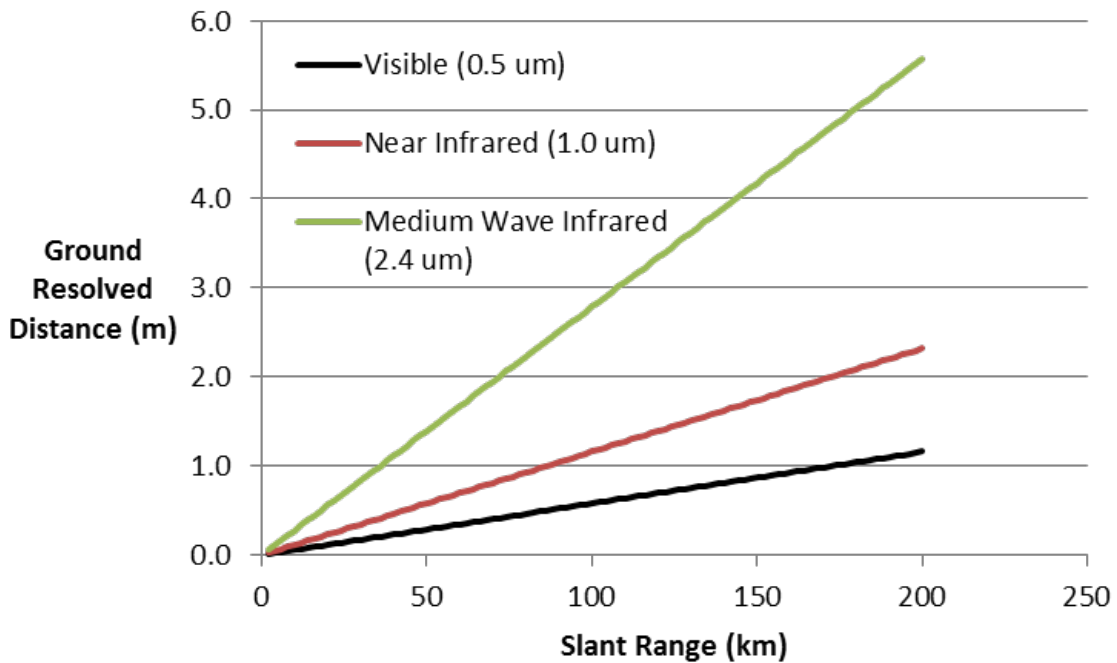
NOTE: The assumptions are 0.25-meter aperture, diffraction limited performance, and 45-degree grazing angle.

Futures Identified

Next, the presenter moved to a discussion of the range of plausible future worlds that could be envisioned as a result of these trend areas. He identified four different futures. For each of these futures, we identified a tag line and the major characteristics of that plausible future. At the end of the first three futures, a discussion of things that would need to occur for each future to take place is presented. Although we could have done this for the other trend areas, we thought it was most important for this topic due to technical aspects that would not have otherwise been clear. These four futures are presented below:

Future C.1, "Non-Attribution Warfare as an Instrument of National Power":

- The primary tenant of this future is that the adversary engages in actions that are not expected to provoke a response—cyber is a major component for that reason.
- This is the "little green men" scenario.[5]
- Direct actions against target government are undertaken by third-party actors.
- Actions remain below the threshold of war (e.g., North Atlantic Treaty Organization [NATO] Article V) due to the difficulty of attribution.
- Non-attributable actions include operations in cyberspace, EW, kinetic attacks using weaponized commercial drones.
- Related enablers: commercial encryption; commercial communications infrastructure, including commercial space.

For this future to occur, the tension between privacy and security would need to be resolved toward a greater value on privacy. Furthermore, international treaties and law would not be a major factor and would not adapt in this world. Progress in optical and quantum computing (encryption) would need to occur, and expansion of commercial markets for space and drones would also be required. Finally, the trend toward integration of weapon systems into civil and commercial communications infrastructure would complicate targeting.

Future C.2, "Highly Amorphous Irregular Warfare":

- There is further evolution of irregular warfare (IW) where actors do not hold territory as in regular warfare.
- Model is an ideological movement that is highly dispersed in space and time.
- Political power is wielded by coalescing in space and time to conduct operations and then blending back in, much like IW today.
- There truly are no distinct borders and many of the actors live among us.
- Their reach, power, and defensive mechanisms are enhanced through the difficulty of attribution and targeting.

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[5] "Little green men" is the shorthand name given to troops in Crimea who were equipped as Russian soldiers but in nondescript green uniforms. The Russian government denied that these forces were associated with the Russian military and said they were instead local militia.

- Financing is enhanced through emerging concepts, including cyberransom.

For this future to occur, the following would be necessary:

- Tension between privacy and security would have to be resolved toward placing greater value on privacy.
- Optical and quantum computing and encryption technology would need to develop and proliferate.
- The trend of Internet of Things (IoT) would have to continue.
- Markets would need to expand for commercial space and drones.
- Military weapon systems would have to rely more on commercial and civil computing and communication infrastructure, as opposed to dedicated military computing and communication infrastructure.
- Treaties and international law would not adequately adapt to evolving treaties.
- Social media and other sources of information would need continued growth to facilitate recruiting and propaganda.

Future C.3, "Conventional Warfare with Peer Hiding in Plain Sight":

- Model is Russia in the Crimea or potentially how China is currently approaching the South China Sea.
- Peer's ability to rapidly seize the initiative is enhanced by hiding its military buildup through mobility, decoys, and deception.
- Target hardening is a problem.
- For attribution in cyberspace, the problem is policy, not technical.

For this future to occur, the following would be necessary:

- Standoff range would need to increase.
- High mobility and multispectral camouflage would need to continue to erode the USAF observe, orient, decide, and act (OODA) loop speed.
- Weapon system integration into commercial infrastructure would have to reduce the military fingerprint of adversary weapon systems and complicate U.S. targeting.
- Optical and quantum computing and encryption technology would need to see advances.
- Trends toward IoT would have to continue.
- Social media and alternative sources of information would need to provide additional opportunities for the adversary to control the message.

Future C.4, "Easier Attribution and Targeting":

- Both attribution and targeting become easier.
- Privacy versus security policies trend toward security.
- Consensus among major powers that the Internet should be redesigned to make attribution easier.

- Technology advancements in advanced sensor technologies, such as hyperspectral imaging, outpace technology advancements in concealment, camouflage, and deception and the associated tactics, techniques, and procedures.
- The United States increases investments in space situational awareness technology.

Convergence of Warfighting Domains (Presenter: Forrest Morgan)

Summary of Presentation

Presenter Forrest Morgan began by noting that warfare has historically been thought of as taking place in one or more discrete physical domains. Until the 20th century, they were land and sea. Later, air and space were added. Most recently, cyberspace became a warfighting domain. These domains are converging, as are different levels of conflict. The presenter discussed levels of conflict as different types or intensities of operations in the same domain. Examples of the convergence of levels of conflict include terrorism and guerilla warfare supporting or supported by conventional operations, and a blurring of the distinction between limited and unlimited conventional war. He went on to discuss a further theoretical possibility that he described as the potential "slippery slope" from tactical nuclear to strategic nuclear war.

The presenter continued by discussing the idea that technological development has historically been the main driver increasing the number of physical domains. For example, the development of aircraft added the air domain and putting systems into orbit added the space domain. As computer technology evolved, cyberspace was added to the potential domains of warfighting. The presenter further discussed how strategic necessity, opportunity, or both have driven the convergence of these domains. For example, land and sea are naturally separate, but strategic necessity caused a degree of convergence (amphibious operations and others). Conversely, air and space naturally converge with other domains because they overlap with the Earth's surface and with each other, creating opportunities to integrate operations across domains in ways that amplify their warfighting effects.

The presenter then turned to levels of conflict and noted that the levels have also converged over time. The proverbial "spectrum of conflict" now has few clear boundaries and is not purely linear. He rhetorically asked, for example, where does one draw the line between limited and unlimited conventional war? Even WWII, which is often described as "total war," had limits in terms of the use of chemical weapons on battlefields. Hybrid warfare has been a big focus lately and is often discussed as a new concept, but some amount of IW has always occurred in parallel with conventional operations. Recent developments do not signal the emergence of hybrid warfare as a new phenomenon; rather, these developments simply reflect a noticeable acceleration in the pace of convergence.

The presenter continued by noting that for more than half a century, geopolitical developments and technology have driven greater convergence in the levels of conflict, but this has not always been the case. The rise of the nation state and the industrial revolution resulted in

several centuries of increasing divergence, as compared with previous eras when the levels of conflict were more convergent. Most early armies were not professional; kings and noblemen made their peasants exchange plowshares for swords as needs arose. But the industrial revolution allowed nation states to raise, equip, and pay large armies, making war a specialized function separate from civil society. This divergence in the levels of conflict peaked during WWII. The Cold War era saw the reemergence of civil war, terrorism, and IW (although they never fully disappeared, even during WWII) and their growing convergence with conventional warfare. State failures during the post-Cold War period have accelerated this convergence. Now regional hegemons are deliberately using IW to destabilize the states around them and conventional forces to quell the resulting disorder on their terms. For example, Russia used these tactics in South Ossetia, Abkhazia, Crimea, Transnistria, and eastern Ukraine, while Russia has accused the United States of using them to destabilize and overthrow Ukraine's previous pro-Moscow government.

The presenter concluded by noting that as cyber and nuclear capabilities proliferate in the emerging geopolitical environment, the interaction of these two dimensions of convergence—physical domains and levels of conflict—could create any one of various troubling futures.

Futures Identified

Next, the presenter moved to a discussion of the range of plausible future worlds that could be envisioned as a result of the Convergence of Warfighting Domains trend. He identified five different archetypal futures, four of which are discussed here as plausible alternatives.[6] For each of the four we developed, we provided a tag line and the major characteristics. The futures identified here are built along two dimensions: (1) varying degrees of interaction between military domains and (2) varying degrees of convergence in levels of conflict. Although these dimensions are a continuum, for the analysis, we identified three of the four futures at their theoretical extremes. The fourth "Heterogeneous Convergence," lies in the middle ground of both dimensions. Figure 2.3 shows where the futures are along the two dimensions.

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[6] Although we identify "Industrial Revolution Redux" as a theoretically possible archetypal future, we do not develop it for further exploration because we consider it unlikely that the world would return to that geopolitical and technological configuration.

Figure 2.3. Convergence of Military Domains and Levels of Conflict
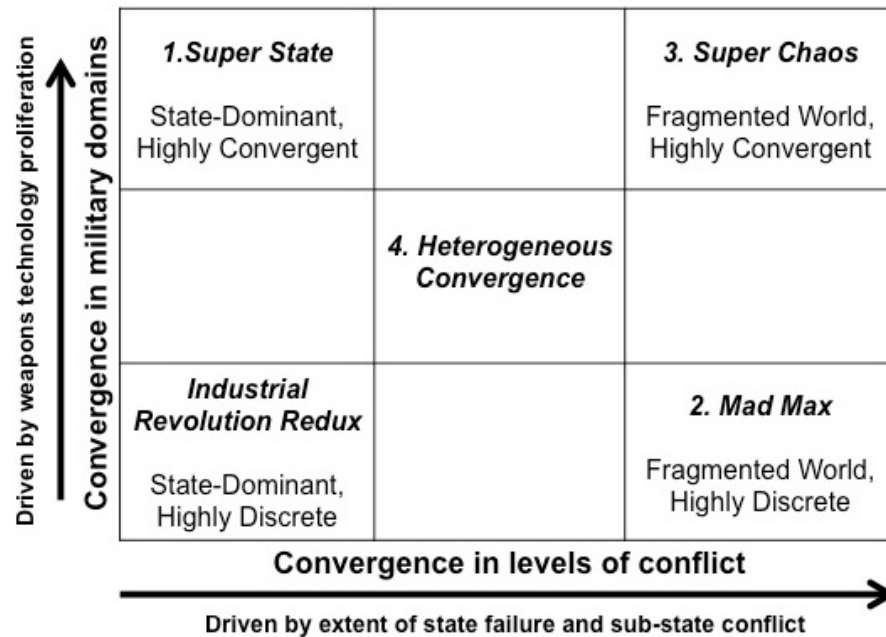
Future D.1, "Super State":

- The convergence of military domains is upper bound, and the convergence of levels of conflict is lower bound.
- State-dominant, physical domains of war are highly convergent.
- There is a preponderance of stable states with very capable, integrated terrestrial, space, and cyberforces.
- There are high levels of proliferation of nuclear and high-technology conventional weapons among states.
- Fear of nuclear escalation causes states to avoid war most of the time.
- Warfare, when it does occur, is very robotic.
- War itself is short and violent.
- Limited wars for limited objectives.

For this future to emerge, we would need to see relatively little state failure in an environment in which weapons-related technologies are more easily obtained, controlled, and used by the states than by internal and external non-state actors. This might occur were the most powerful states to decide that maintaining order and stability is a higher priority than propagating their values and ideologies. The technologies might then trickle down to other less-powerful and less-stable states, allowing them to repress internal dissent and stabilize their own countries.

Future D.2, "Super Chaos":

- The convergence of military domains is upper bound, and the convergence of levels of conflict is upper bound.
- The world is fragmented, but highly convergent in both military domains and levels of conflict.
- Many substate groups have very high levels of technology and dangerous weapons.
- Different groups would have different capabilities—very heterogeneous with some having armor or mechanized forces, others air power, some with nuclear weapons, and others.
- This future could see multiple eruptions of major regional conflict or even genocide before the international order evolves to a different configuration.

For this world to emerge, we would need to see high levels of weapons proliferation to states with a lot of ethnic or sectarian strife. Then states fail, leaving substate groups in control of the weapons. Conflicts erupt, leading to more state failures and regional chain reactions.

Future D.3, "Mad Max":

- The convergence of military domains is lower bound, and the convergence of levels of conflict is upper bound.
- The world is politically fragmented with pressures for convergence in the levels of conflict, but highly discrete in terms of weapons technology proliferation.
- Vast failing-state regions plagued by conventional and IW and barbarism between multiple criminal, sectarian, or tribal groups, and paramilitary forces (i.e., ISIL).

For this world to emerge, there would need to be high levels of state failure and low levels of weapons technology proliferation. There could be chain reactions of state failures in the lesser-developed world that would create larger areas of failing states, to the point that other countries stop trying to stabilize them or render humanitarian assistance and, instead, focus their efforts on internal security.

Future D.4, "Heterogeneous Convergence":

- There is middle ground on both dimensions of convergence.
- There is heterogeneity in the convergence of military domains for different actors.
- There are varying degrees of convergence in levels of conflict.
- Most accurately reflects the situation today.

Rapid Change of Threats & Weaponry (Presenter: David Frelinger)

Summary of Presentation

Presenter David Frelinger began by noting that there are many technologies that could dramatically change the interaction between military forces. These technologies include robotics,

micro-machines, advanced computing, cyberwarfare, directed energy weapons, man-machine combinations, and high-speed systems (e.g., hypersonics). These technologies will significantly impact legacy systems. However, it is unclear which technologies will actually make the impact, especially looking 30 years into the future. One of the main drivers of where things will go and which technologies will emerge is the degree to which different technologies are funded. In other cases, the presenter noted, the technology could be available, but it might take time for people to put the technological components together. New capabilities sometimes emerge spontaneously from new technologies, and old equipment is sometimes used for new purposes.

The presenter specifically noted that this discussion highlights a few combinations that produce interesting challenges. It is not definitive, by any means, but more of a speculative tool to investigate how different threats and weapons could significantly impact warfighting over the next 30 years.

The presenter concluded his introductory remarks by discussing the important point that potential changes will impact both Blue and Red Worlds in our analysis. These technological advancements are likely to be in the areas of intelligence, surveillance, and reconnaissance (ISR) and targeting, sortie generation, inflight survivability, and effects on targets.

Futures Identified

The lion's share of this presentation was a discussion of the plausible futures. The presenter discussed a set of plausible future worlds that highlighted different types of technologies and weapons that could result in significantly different future worlds. The presenter identified five different futures. For each of these futures, he provided a tag line and the major characteristics of that plausible future. In addition to these five, he provided an incremental development version based on evolutionary changes from today. All of these futures are presented below:

Future 0, "Incremental Weapons Development":

- Assumes we continue on the same path.
- Incremental weapons development has led to continual improvement in sensors, networking, and more.
- There is discomfort with letting swarms of things make lethal force decisions—no willingness to expand autonomy of weapons.
- Unique advantages are eroded in the process, but the United States stays in an advantageous situation:

  – Expect that the development of sensor and shooter mixes to attack USAF operations will continue.
  – Increasingly long-range surface-to-air missiles (SAMs) and fractioning payloads start looking more like unmanned interceptors.
  – The United States will still have a scale of force that very few adversaries can beat.
  – Even a very competent small adversary cannot play the numbers game against the United States.

– This might lead to an adversary seeking to hold the United States at arm's length and focus on attacking their neighbors.

Future E.1, "Bots, Bots, Bots":

- Assumes that the ability to easily produce and direct macro-scale robots is improved.
- There will be improved energy efficiency and storage.
- Robots will be able to operate in all environments and have limited autonomy.
- Air power becomes a mix of capabilities.
- May retain conventional forces, but they are more about deterring the other side's conventional forces.
- Builds a different mix of forces where robots are purpose built and tailored to a specific mission or task. These are small, cheap robotics that cause problems for larger, more expensive machines.

  – Examples of build-to-function design approaches:
    - "FOD-bot" with a (perhaps) tungsten core that is designed to be ingested by aircraft engines[7]
    - "Fuzz-bot" with sticky dipoles and hard corners to damage low observable (LO) aircraft
    - "Pyro-bot," which is a short-range flyer that goes after fuel systems and has a small igniter.

Future E.2, "The Light Fantastic":

- This future postulates advanced lasers and directed energy weapons.
- Efficiency has improved so that megawatt class lasers are practical on tactical platforms, making direct overflight difficult, because these weapons can target the aircraft or the pilot:

  – Mobile ground systems take snap shots at aircraft when cloud free line of site is available.
  – Shaping, spinning, ablative coatings, and shorter exposure make weapons less vulnerable.

Future E.3, "A Can of Worms—Attacking Operators":

- Advances in weapon-system capabilities has resulted in more difficulty destroying the weapon systems themselves, so adversaries focus on attacking the pilots or people that maintain the systems.
- Use small machines and a clandestine system to lay in wait to be activated against operators in less well-defended areas (their homes, off-base activities, and others).
- These can be used as a system in waiting against high-value targets or against less well-protected adversaries.

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[7] FOD refers to "foreign object damage" that can cause damage to an aircraft during ground operations.

Future E.4, "The New Look Redux":

- Other countries no longer play by U.S. rules.
- Might decide to reembrace nuclear weapons with low collateral damage potential as viable in extreme situations.
- Nuclear protection will have to be built into systems.
- Nuclear flash protection becomes an issue in large areas.
- There is a possibility of surgical nuclear attack on bases.

Future E.5, "Rejection of Fully Autonomous 'Thinking Machines' and Enhanced Humans":

- This future is marked by loss of confidence in our electronic systems and concern about lack of predictability for autonomous weapons (e.g., if 10 percent of swarms do not achieve what they are supposed to do, it could be a major problem).
- There are concerns about embedded applications in humans.
- This future ends up returning to combat largely within augmented visual range operations.
- There is a focus on enhanced sensing, increased spectral ranges.
- One or two errors in a machine could lead to a total cancellation, even if the machine is valuable.

The Augmentation of Humanity (Presenter: Richard Silberglitt)

Summary of Presentation

Presenter Richard Silberglitt began by noting that there are four principal, but not entirely disparate, areas in which human enhancement is advancing. These are in the areas of strength and mobility, non-contact control of externals, computation and intelligence, and endurance and survival. These areas of advancement could be possible through a range of possible future developments, including soft exoskeletons, thought control of external devices, neural implants, brain implanted processing, artificial intelligence (AI)–empowered augmented reality (AR) devices, molecular-scale drug delivery, pharmacogenomics development leading to genetically tailored drugs, breathable fabric skin, and energy harvesting and control. Each of these areas is at some stage of development and requires various degrees of technical development. The presenter noted that the Defense Advanced Research Project Agency (DARPA), among others, is working on these technologies and the commercial sector has made big advances in such areas as prosthetics and genetics.

The presenter discussed each of the four areas and described the technology involved and current state of the developments. One of the areas receiving considerable attention and research is in the enhancement of strength and mobility (prosthetic limbs, exoskeleton). This includes commercial exoskeletons for lift-assist and systems to increase speed and mobility of an individual. There is a new trend for soft exoskeletons, which are primarily composed of

backpacks with attached leg bands that can enable the wearer to walk or run, allowing for faster movement. The second area discussed was non-contact control of externals (direct brain interface), which allow the user to control devices without manual control. One can envision many uses for this technology, including remote control of sensing devices and remote control of other types of machines.

The third area discussed was computation and intelligence enhancement (brain implanted processors). This is a highly advanced and speculative technology that envisions brain implants that would provide a vast amount of information to the user and perhaps greatly enhance processing power.

Finally, the presenter discussed potential endurance and survival enhancement (chemical/physiological stimulation) technologies. To some extent, this is being done now with chemical enhancement. However, this could be greatly extended to include specific chemicals that are tailored to each individual to achieve the desired effect.

Development in all of these areas has begun, and there is a wide range of where these technologies might lead. Figure 2.4 shows the presenter's assessment of where these technologies might lead and the relative difficulty of achieving specific areas.

Figure 2.4. Degree of Difficulty of Plausible Future Augmentations
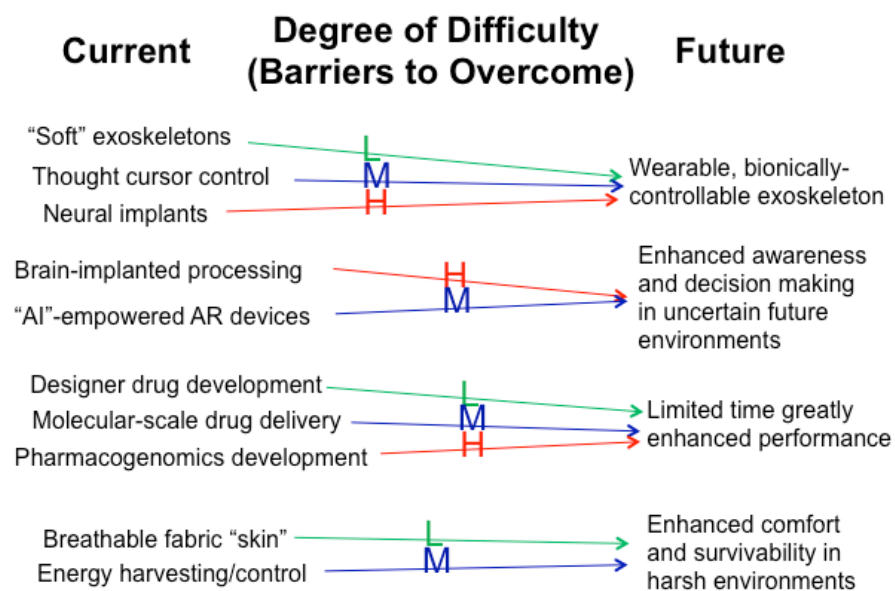
NOTE: L = low; H = high; M = medium.

The presenter went on to explain that these human augmentation technologies could have applications to control autonomous systems to achieve highly agile and flexible performance; more efficient use of assets and better integration with other domains; enhanced understanding of network capabilities; and a capacity for faster response to the rapidly changing battle space,

allowing humans to analyze large amounts of diverse data and achieve better command and control of forces.

He concluded his initial presentation with a short discussion of the how these types of human augmentation technologies might manifest themselves in various warfighting domains. He discussed how different levels of these technologies could impact warfighting in the future.

Futures Identified

Next, the presenter moved to a discussion of the range of plausible future worlds that could be envisioned as a result of advances in human augmentation. He identified four different futures. For each of these futures, we identified a tag line and the major characteristics of that plausible future. We note that Futures 2 and 3 are illustrative points on a continuum between Futures 1 and 4. Many other alternatives could be envisioned with different levels of development and implementation in the four principal areas of enhancement. These four futures are presented next:

Future F.1, "Fully Bionic Human":[8]

- This future has a fully working and seamlessly integrated exoskeleton.
- It has control of external devices through the brain.
- It has a cognitive brain implant.
- It has personally tailored performance-enhancing drugs.
- Major technical advances take place, including:

    − Weight and size constraints have to be overcome.
    − Connection to nervous system has to become seamless.
    − Significant advances in brain science and engineering required.
    − Pharmacogenomics has to develop.
- DARPA did significant work, and so did the Russians.
- Commercial sector has made big advances in prosthetics and genetics.

Future F.2, "Greatly Enhanced Human":

- This future features progress to a mostly effective exoskeleton.
- There is no seamless brain interface to externals.
- There are range limitations on brain control of external devices.
- There is limited capability of cognitive brain implant.

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[8] *Fully* refers to the four principal areas considered, for example, it does not include optical and audio bionics.

Future F.3, "Moderately Enhanced Human":

- This future has incremental growth of exoskeleton technology—mechanical limbs have good progression but the working interfaces only have to work under very specific conditions.
- Exoskeleton is not well integrated with mental function.
- Brain interface to externals is strongly limited.
- There is no cognitive brain implant.
- Pharmacology developments are incremental.

Future F.4, "Incrementally Evolved Human":

- This future features mechanical enhancement with partially enhanced body parts.
- There is no cognitive brain implant.
- There is some control of external devices through brain wave communication, but extremely limited.
- This future would need incremental technological advances and implementation of applications.
- Funding, social, or ethical issues keep developments in check.

The Ubiquity of Information (Presenter: Steven Berner)

Summary of Presentation

Presenter Steven Berner began by identifying a number of different drivers coming together that seem to be resulting in nearly ubiquitous information. He further noted that this is very likely to continue in the future. There are several important factors. The world is becoming more urbanized and more people will be technologically literate. The number of information devices will continue to expand, resulting in the collection of massive amounts of information. It is reasonable to assume that we will see a world in which virtually everything has a capability for gathering information, computing, and communicating. Smart and adaptive sensor networks will emerge. However, the presenter cautioned that there is a difference between massive amounts of information and successfully using the information to achieve a much-higher level of understanding. There will be a huge mix of data from various sources, with different quality and types complicating the analysis task. Having the computing capability needed to analyze these data and make sense of the information is a major issue. In addition, there will be privacy, legal, and ethical barriers to fully using the level of information available.

The presenter then moved to a discussion of the implications to the USAF and offered two primary implications from this trend. First, he noted that because the United States has a major comparative advantage in information dominance, ubiquity of information could erode this position. If information becomes a commodity available to anyone in the future, information dominance may no longer be a meaningful concept for military operations. A second implication

is the ability to turn information into knowledge. There will be a very rich environment for intelligence collection. Countries that can most effectively collect and process information in this new environment will achieve an advantage.

Futures Identified

Next, the presenter moved to a discussion of the range of plausible future worlds that could be envisioned as a result of this trend. He started his discussion of plausible futures by noting that he considered this trend a continuum as a result of the huge availability of data, but there was uncertainty regarding the ability to turn these data into knowledge because of computational, data, and legal and ethical barriers. One could have developed different points along that continuum to treat as the future worlds, identifying the characteristics that such a world would have as a result of the relative dominance of different characteristics (such as privacy concerns). This was done to some extent during the development of overall future worlds and is presented in the next chapter of this report, but these different futures are not presented here.

One issue is credibility of the information available. The degree to which the information is correct is a significant driver in this area and a major concern. In order to make the most of the huge amount of information available, the user must have a very high level of confidence in accuracy and completeness of the available information.

The presenter focused his futures discussion on factors that drive toward ubiquity and barriers that impede achieving ubiquity of information. Figure 2.5 shows the multiple trends converging and driving toward the ubiquity of information, while Figure 2.6 shows the barriers that could constrain this trend. However, ubiquity of information is here. Where it goes over the next 30 years is a matter of degree. The future worlds in this case go from a low (current) level of information ubiquity to a very high level.

Figure 2.5. Multiple Converging Trends Driving Toward Ubiquitous Information
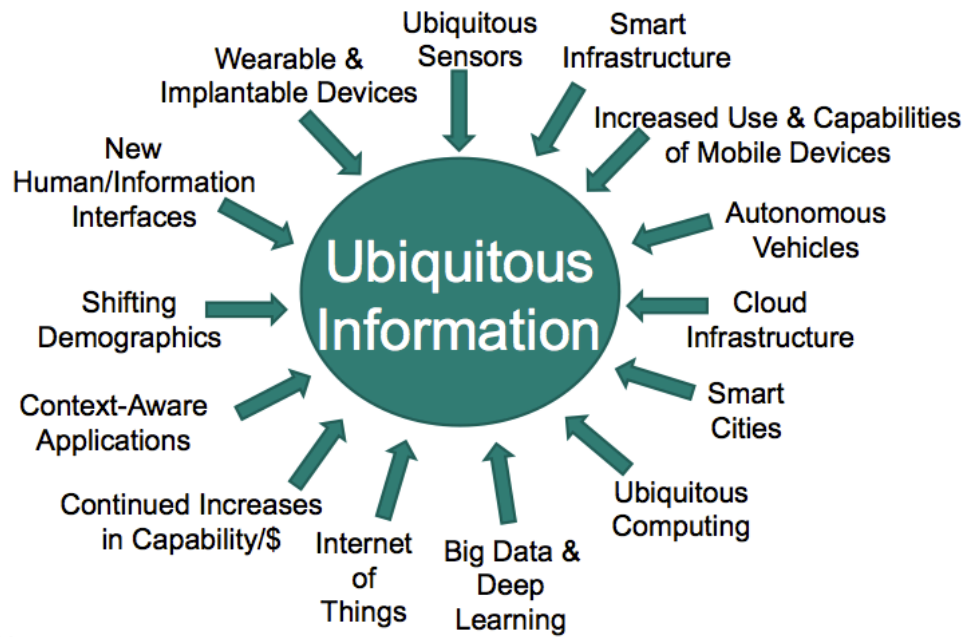
SOURCE: Compiled by authors.

Figure 2.6. Barriers That Could Constrain Ubiquitous Information
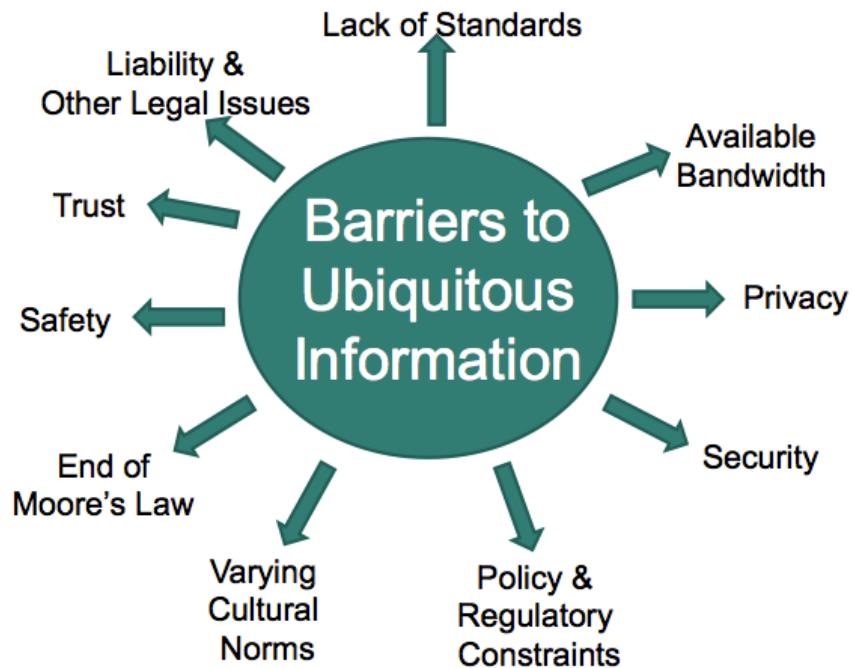
SOURCE: Compiled by authors.

These drivers and constraints were discussed at length and considered during the discussion of the overall future worlds and their potential effects on the other trends.

Changing Culture & Capabilities of the Workforce (Presenter: Marek Posard)

Summary of Presentation

Presenter Marek Posard began his discussion with some thoughts on generational aspects of the workforce in 30 years. Although there is no widely accepted definition of the term *millennials*, this generation is typically discussed in terms of those born from the early-1980s to 2000. According to the U.S. Census Bureau, the baby boomer generation is the only explicitly defined generation.[9] As part of his preoperational work for this exercise, the presenter identified five emerging subtrends that are likely to continue and impact the USAF workforce.

First, competition for USAF personnel is likely to increase. With a technology-focused mission, USAF personnel have in-demand skills (e.g., commercial aviators, remotely piloted aircraft [RPA] pilots, air traffic controllers, and information technology [IT] professionals). The presenter noted that USAF would find that many of these skill sets are receiving high salaries in the civilian labor market.

The second subtrend is that the U.S. population is becoming more diverse. Figure 2.7 shows the projected change over the next 45 years. Greater attention will be given to the demographic makeup of USAF, including race/ethnicity, sex, sexual orientation, and gender identities. New questions about personnel policies that affect transgender, physical fitness and ability, mental health, and others are likely to emerge as social policy in civilian society attends to the needs of these groups. There is evidence, for example, that some U.S. military personnel hold more conservative views on social issues than their civilian counterparts.[10] These differences could persist for some time within the military.

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[9] In recent years, the U.S. Census Bureau has become more relaxed with using the term *millennial*. Some reports now refer to millennials as those born from 1982 to 2000 (see U.S. Census Bureau, "Millennials Outnumber Baby Boomers and Are Far More Diverse, Census Bureau Reports," Release No. CB15-113, June 25, 2015); Philip Bump, "Your Generational Identity Is a Lie," *The Washington Post*, April 1, 2015.

[10] Thomas S. Szayna, Kevin F. McCarthy, Jerry M. Sollinger, Linda J. Demaine, Jefferson P. Marquis, and Brett Steele, *The Civil-Military Gap in the United States: Does It Exist, Why, and Does It Matter?* Santa Monica, Calif.: RAND Corporation, MG-379-A, 2007.

Figure 2.7. U.S. Population by Race/Ethnicity: 2014 and 2060

■ 2014   ■ 2060
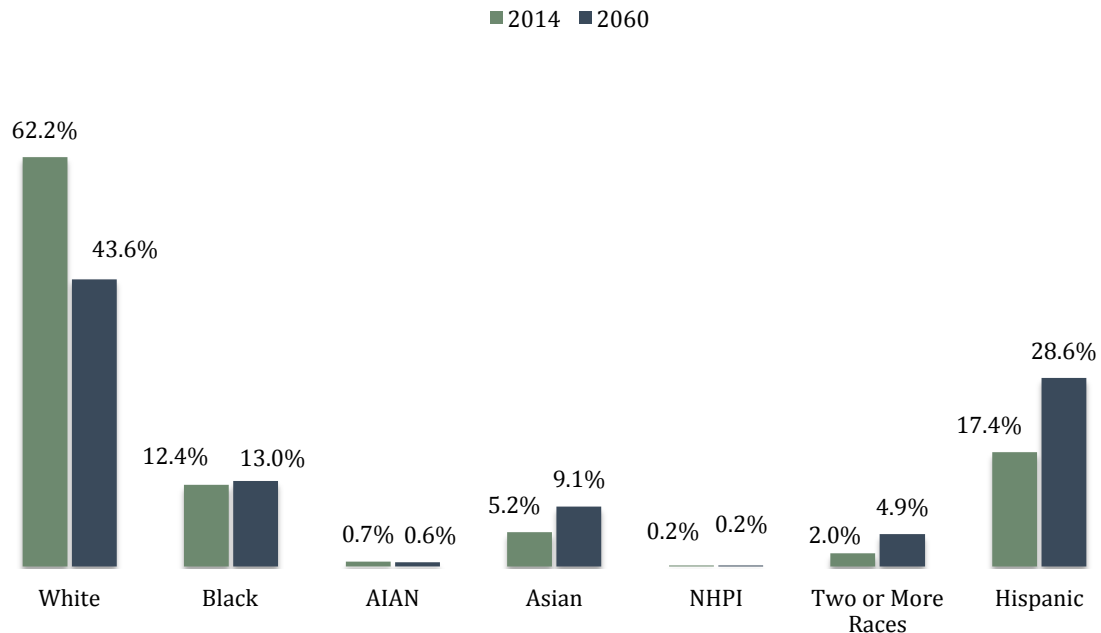
NOTE: AIAN = American Indian and Alaska Native; NHPI = Native Hawaiian and Pacific Islander.

The third subtrend the presenter discussed is that military families will continue to matter. Junior enlisted personnel tend to marry earlier than comparable civilians (see Figure 2.8), and marriages between younger people are more likely to experience problems. In addition, many older households have no retirement savings. As a result, aging parents are expected to have a higher percentage of dependency in the future, potentially resulting in an increase in secondary dependents for military personnel. Figure 2.9 presents the expected rise in older dependents through 2050. This may result in new and added work stressors that affect the family lives of personnel.

Figure 2.8. Percentage of Junior Enlisted Men and Women Married Compared with Comparable Civilians, 2002

■ Junior enlisted (E1-E4)

■ Civilian high school graduates (ages 18-24)

25%   13%   31%   24%

Men   Women
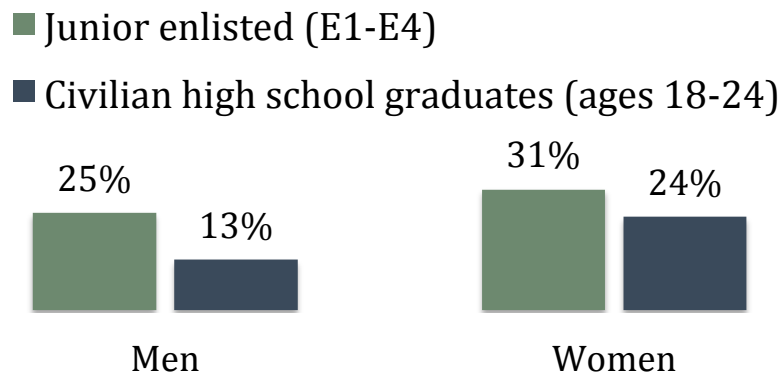
Figure 2.9. Dependency Ratios for the United States: 2010 to 2050

■ Old Age Dependency

■ Youth Dependency

| | 2010 | 2020 | 2030 | 2040 | 2050 |
Old Age: 22% 28% 35% 37% 37%
Youth: 45% 46% 48% 48% 48%

2010   2020   2030   2040   2050
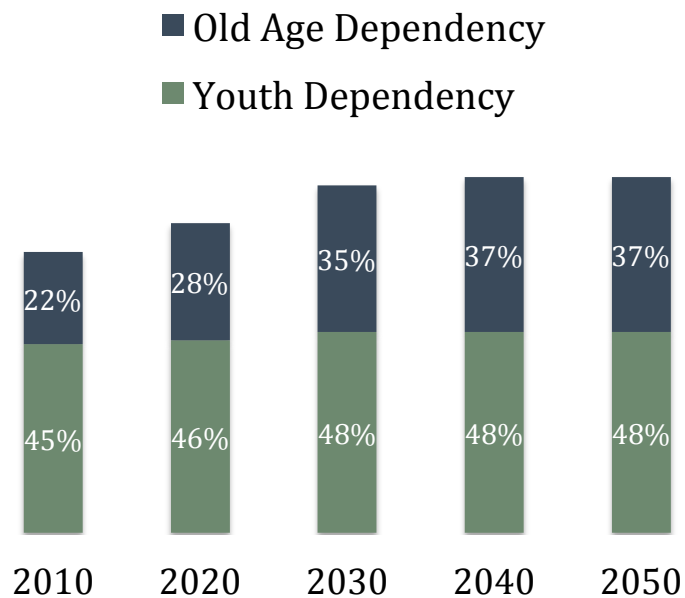
The fourth subtrend is the continued merging of work and family lives. How personnel balance their warfighting and domestic roles will be a major issue. The presenter discussed how this is now becoming a potential issue with RPA pilots participating in wartime operations during the day and then going home at night.[11]

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[11] Wayne Chappelle, Kent McDonald, Billy Thompson, and Julie Swearengen, *Prevalence of High Emotional Distress and Symptoms of Post-Traumatic Stress Disorder in U.S. Air Force Active Duty Remotely Piloted Aircraft*

The fifth subtrend is increasing use of social media by young adults. Younger adults are comfortable sharing personal information online. As a result, there are challenges with oversharing in such areas as combat videos, disclosing sensitive information, online criticism of leaders, and online bullying and harassment. Furthermore, adversaries could use this information to target families and hack personal information.

Futures Identified

Similar to the Ubiquity of Information trend, many of the attributes discussed earlier are currently being experienced. As a result, this trend area is considered a continuum. How it develops over the next 30 years is a matter of degree. As with the previous topic, one could have developed different points along that continuum and this was done to some extent during the development of overall future worlds, but these different futures are not presented here.

In terms of manpower implications, the presenter noted that it may be useful to consider how the changing workforce for USAF will affect the career fields of personnel (whether the AFSCs require a higher versus lower level of specialized skills) and what type of work airmen would do within these fields (humans operating machines versus humans supporting the work of intelligent machines). Figure 2.10 shows a way to potentially characterize the context for future AFSCs.

Figure 2.10. Sample Table to Evaluate Requirements for Future AFSCs

		Specialized Skills	
		High	Lower
Job Focus	Humans operating machines		
	Humans supporting machines		

Operators, (2010 USAFSAM Survey Results), Wright-Patterson Air Force Base, Ohio: U.S. Air Force School of Aerospace Medicine, 2010.

3. Workshop Methodology

Methodological Foundations for the Workshop

General Morphological Analysis

The workshop used General Morphological Analysis (GMA) as its primary organizing principle and the backbone of its methodological approach. GMA is a problem-structuring method for the non-quantitative modeling of multidimensional and highly complex problems.[1] Developed initially by Fritz Zwicky to examine problems in astrophysics, GMA is now used for a variety of topics.

GMA involves defining the *parameters* of a problem, and then identifying the individual *parameter values* that each parameter can take on. These parameters and parameter values are organized into what is known as a Zwicky morphological field (or morphological box); each unique combination of parameter values across the morphological box is known as a *scenario* or a *configuration*. The second step in GMA is a cross-consistency analysis that identifies which combinations of parameter values are inconsistent with one another. An additional potential step in GMA is to then take the morphological box and cross-consistency analysis to create a computer-assisted *inference model*. With such an inference model, a user could highlight certain parameter values, and see what remaining values are consistent with the user's choices.[2]

In its group method form, GMA is typically used with six to seven experts who have diverse perspectives on a problem. Participants usually have a one- to two-hour overview of the method, and two days to develop the morphological box and conduct the cross-consistency analysis.[3]

Adaptations to GMA for This Workshop

We made adaptations to the typical, group-run GMA process in a number of ways. First, we used it less for its problem-structuring properties than for its configuration management abilities. Although GMA is highly valuable in helping a group identify the most important aspects (the parameters) in a complex problem, USAF had already provided RAND with a set of previously identified trends that could be used as parameters within the method. Therefore, the RAND experts did not need to go through a divergent thinking process in which they identified the

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[1] Tom Ritchey, "General Morphological Analysis: A General Method for Non-Quantified Modelling," Swedish Morphological Society, 1998 (revised 2013); and Jonathan Rosenhead, "Past, Present and Future of Problem Structuring Methods," *Journal of the Operational Research Society*, Vol. 57, No. 7, 2006, pp. 759–765.

[2] Ritchey, 1998.

[3] Tom Ritchey, *Wicked Problems—Social Messes: Decision Support Modeling with Morphological Analysis*, Heidelberg, Germany: Springer, 2011, pp. 65–67.

primary parameters affecting futures for USAF, and then a convergent thinking phase in which they agreed on a common set of parameters and parameter values. Group GMA might have produced parameters that were more distinct from one another than the set already identified by USAF, but the organizational legitimacy of the USAF's process to arrive at the trend areas is important. The Chief of Staff of the Air Force Strategic Studies Group (A5SG) runs the AFSEA process. For the 2016 AFSEA future trend projections used in this workshop, A5SG sent out a survey to various USAF organizations in late 2015 to solicit input on the trends that Air Force stakeholders felt were the most important drivers for future USAF operations over the next 30 years.

Additionally, GMA typically has the group arrive at the parameters and parameter values by consensus; GMA facilitators also help arrive at a consensus answer for the cross-consistency analysis. However, because the setup of the project assigned individual experts to each trend area, we were able to ask them to individually come up with the parameter values (plausible futures) for their "own" parameter (trend area). While the creation of the individual futures could have benefited from group feedback, time constraints did not permit this. Additionally, having each individual "own" a trend area made the round-robin format for the cross-consistency analysis possible, greatly reducing the amount of time required.

Other Methodological Influences

We also incorporated elements of other methodological approaches within the workshop. One method that influenced the approach to creating the individual future within each trend area was counterfactual reasoning (CFR) as developed for intelligence analysts projecting events into the future. In asking the trend experts to consider what would have to happen for their individual futures to emerge, we borrowed the portion of the method that asks intelligence analysts for the *antecedent scenario*, or backstory of an event. This is one of the steps within CFR for projecting forward into the future.[4]

Another method that influenced our workshop was the Scenario Diversity Analysis (SDA). SDA is a quantitative method that seeks to ensure diversity when selecting among many scenarios by scoring diversity at the scenario set level. The purpose of SDA is to help decisionmakers by selecting scenarios from a range of possibilities while trying to (1) avoid clustering around "business as usual" cases and (2) provide a balanced set that covers a wide scenario space.[5] A balanced scenario set is one that maximizes diversity across a space of possible scenarios, rather than "arbitrarily mixing some conservative and some extreme

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[4] Noel Hendrickson, *Counterfactual Reasoning: A Basic Guide for Analysts, Strategists, and Decision Makers*, Proteus Monograph Series, Vol. 2, Issue 5, October 2008, p. 23.

[5] Henrik Carlsen, E. Anders Eriksson, Karl Henrik Dreborg, Bengt Johansson, and Orjan Bodin, "Scenario Diversity Analysis for Systematic Exploration of Scenario Spaces," *Foresight*, Vol. 18, No. 1, 2016, pp. 59–75.

scenarios."[6] Although we did not apply the quantitative scoring approach advocated by SDA, we did use the GMA cross-consistency matrix as a visual aid to assist in avoiding clustering status quo cases, and to ensure that a variety of plausible futures combinations were considered.

Finally, we also drew from the literature on small group psychology that has been applied to group outcomes in analytic teams for the intelligence community. Specifically, we examined the lesson of *productivity loss* and *production blocking* that can arise when brainstorming sessions and other group methods are not structured to account for such potential negative outcomes.[7] Increasing the amount of time spent on individual work or work in pairs was done in part to address some of these issues.

Workshop Process

We ran a two-day workshop that took the plausible futures for each of the trend areas and combined them into seven different future worlds for USAF to consider. The goal was to create a diverse set of worlds from the interplay of different combinations of trend futures. The inputs for the workshop were the individual trend area research and plausible futures in each trend. The outputs of the workshop were a set of seven worlds that combined different trend futures.

Workshop Overview

The primary workshop participants were the eight trend area experts whose works were presented in Chapter 2 and Appendix B of this report. Table 3.1 presents an overview of the workshop process.

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[6] Carlsen et al., 2016.

[7] Susan G. Straus, Andrew M. Parker, James B. Bruce and Jacob W. Dembosky, *The Group Matters: A Review of the Effects of Group Interaction on Processes and Outcomes in Analytic Teams*, Santa Monica, Calif.: RAND Corporation, WR-580-USG, 2009, pp. viii and 7.

Table 3.1. Workshop Overview

Step	Timing	Description	Output
1	Before Workshop	Background research on trend areas	Individual briefing slides by trend experts
2	Before Workshop	Identification of plausible futures in each trend	Slides on plausible, named "futures" within each trend
3	Before Workshop	Compilation of the Zwicky morphological box	Initial morphological box of 3,600 potential configurations
4	Day 1	Individual briefings on trends and plausible futures	Explanation of the individual morphological box elements
5	Day 1	Cross-consistency analysis of the morphological box	Futures combinations that are inconsistent with one another
6	Day 1	Nomination and voting on "interesting pairings"	Selection of "interesting pairings" of different futures
7	Day 1	Futures selections around first two "interesting pairings"	Complete morphological box configurations for two worlds
8	Day 2	World building – sequential, layered narrative by trend experts for each world	Narrative about each world from six morphological box configurations
9	Day 2	Diversity check using cross-consistency matrix	Visual display of what worlds paired which futures
10	Day 2	Status quo world	Configuration and narrative for a status quo world; final morphological box

As shown in Table 3.1, several steps took place prior to the workshop. Experts were asked to compile information on their trend areas ahead of the workshop (Step 1), and to identify and name different plausible futures in their trend (Step 2). This information was summarized in Chapter 2. The nine trend areas, along with a brief description of each provided by USAF, are presented verbatim in Appendix A, while Appendix B shows the cross-consistency of each future in each trend area.

Building the Zwicky Morphological Box

We then took the plausible futures identified for each trend and compiled an initial Zwicky morphological box, shown in Figure 3.1. This was Step 3 in our overall process and was completed before the workshop.

Figure 3.1. Initial Zwicky Morphological Box of Trend Futures

Trends	Plausible Futures				
Increasingly Multipolar World	Persistent US Hegemony	Back to Bipolarity	First Among Equals	The Asian Century	Twilight of the Great Powers
Non-State Actors and Fragile & Failing States	Regional Instability	Rise of Regional Dictators	Large Regional Power Brokers	Western Powers Intervene	
Growing Difficulty of Attribution & Targeting	Non-Attribution Warfare as an Instrument of National Power	Highly Amorphous Irregular Warfare	Conventional Warfare with Peer Hiding in Plain Sight		
Convergence of Warfighting Domains	Super State	Mad Max	Super Chaos		
Rapid Change of Threats & Weaponry	Bots, Bots, Bots	The Light Fantastic	A Can of Worms - Attacking Operators	The New Look Redux	Rejection of Fully Autonomous "Thinking Machines" and Enhanced Humans
Augmentation of Humanity	Fully Bionic Human	Greatly Enhanced Humans	Moderately Enhanced Humans	Incrementally Evolved Human	
Ubiquity of Information	Ubiquity of Information				
Changing Culture & Workforce Capabilities	Changing Culture & Workforce Capabilities				

This figure displays all the futures trends considered in Chapter 2 in the left-most column under "Trends." Along the row for each trend are the plausible futures identified for each. For example, next to the trend on increasing multipolarity, there are the five identified futures discussed in Chapter 2:

1. Persistent U.S. Hegemony
2. Back to Bipolarity
3. First Among Equals
4. The Asian Century
5. Twilight of the Great Powers

Taking the first six trends and multiplying the number of futures for each, the initial morphological box represented $5 \times 4 \times 3 \times 3 \times 5 \times 4 = 3,600$ potential configurations or worlds. For the two trends on the Ubiquity of Information and Changing Culture & Capabilities of the Workforce, the plausible futures were seen as continuous rather than discrete. The extent to which they developed was seen as a matter of degree, and highly

dependent on the context created by the other combinations of futures.

Cross-Consistency Analysis

Workshop participants presented each of their trend areas and plausible futures during the morning of the first workshop day (Step 4). During the afternoon, they then conducted Step 5, the cross-consistency of their futures. Given the time constraints, and a workshop design philosophy aimed at reducing individual idle time, participants were engaged in a round-robin process of checking for futures that would be inconsistent when paired. This would allow for us to drop any overall configuration with this inconsistent pairing from consideration during subsequent steps for developing future worlds.

For example, the expert on increasing multipolarity met with the expert on Non-State Actors and Fragile & Failed States in the first round. The two experts reviewed their sets of futures and identified one combination as inconsistent: The "Asian Century" future for increasing multipolarity and the "Western Powers Intervene" future for Non-State Actors and Fragile & Failed States were deemed to be inconsistent with one another. Figure 3.2 shows the cross-consistency matrix between the futures for these two trend areas. The black box in Figure 3.2 shows the single inconsistent pairing in a matrix with 20 total pairwise comparisons.

Figure 3.2. Initial Cross-Consistency Matrix for Increasingly Multi-Polar World Versus Non-State Actors and Fragile & Failed States

		Non-States Actors and Fragile & Failing States			
		Growth of Instability and Non-State Actors	Rise of Regional Dictators	Regional Power Brokers	Western Powers Intervene
Multipolar World	Persistent US Hegemony				
	Back to Bipolarity				
	First Among Equals				
	The Asian Century				■
	Twilight of the Great Powers				

Overall, there were five rounds of this cross-consistency round robin in which the experts in the first six trend areas paired off into three groups working in parallel to examine futures. The two experts without discrete futures (Ubiquity of Information, and Changing Culture & Capabilities of the Workforce) also joined in different discussions, and they were assigned to groups to ensure exposure to every other expert present. Each round took 20 minutes: Ten minutes for people to do the cross-consistency and identify an interesting pairing, and ten minutes for all three groups to report out to all participants. In this way, the workshop was able to conduct a cross-consistency analysis for the entire morphological box (238 pairwise

comparisons) in approximately one hour. The full cross-consistency matrix across all trends is available in Appendix B.

Interesting Pairings

Step 6, nominating interesting pairings, was also accomplished during this round-robin process. While reporting out any inconsistent future pairs between two trend areas, groups were also asked to nominate a plausible pairing of futures that they found particularly interesting. One such interesting pairing was a future world of "Bots, Bots, Bots," in the Rapid Change of Threats & Weaponry trend, and "Growth of Instability and Non-State Actors" under the Rise of Non-State Actors and the Spread of Fragile & Failed States trends. Another pairing nominated by the round-robin groups was "Highly Amorphous Irregular Warfare" under the Growing Difficulty of Attribution & Targeting trend, and "Twilight of the Great Powers" under the Increasingly Multi-Polar World trend. These were the two interesting pairings with the most votes among the group, and formed the kernel of the first two worlds built during the workshop. Other interesting pairings were recorded and incorporated into the building of other worlds.

Building Worlds

The first workshop day ended with Step 7: choosing two complete configurations for the first two worlds. Building on an initial interesting pairing, trend experts selected futures in their areas until there was one complete configuration. Colors were initially used to keep track of the worlds because the name and characteristics of the worlds would not become evident until they were developed. Hence, the day ended after the group had identified the configurations for what were initially called the "Orange World" and the "Yellow World."

Much of the second workshop day involved building worlds and choosing configurations. Workshop participants began by fleshing out the Orange and Yellow Worlds. The discussion began with the initial interesting pairing at the heart of the future. The experts then weighed in by level of analysis and created context and details: The expert on increasing multipolarity gave the geopolitical background, the expert on Non-State Actors and Fragile & Failed States then layered on the next portion of the narrative in his area. These two were followed by what the world looked like in terms of the Growing Difficulty of Attribution & Targeting, and then the Convergence of Warfighting Domains. A discussion on what threats and weaponry looked like in the world built so far was followed by added narrative on human augmentation. The expert on the ubiquity of information explained how this area had played out, and the expert on the changing workforce ended the discussion with specific effects and challenges for USAF in the world built by the rest of the team. Participants were specifically asked to use the past tense in their language to further immerse themselves in the world.

For the next four worlds (Green, Blue, Purple, Red), we again began with interesting

pairings or combinations of pairings. The trend area experts had the latitude to choose which future to select during their turns, unless explicitly identified in the initial pairings. The final, seventh world created in the workshop was the Status Quo World, where each expert identified the status quo future for their area. The group also suggested a name for each world once it was discussed. With roughly ten minutes for the discussion for each of the eight experts, it took about an hour and a half to build each world. During the process of building worlds, we used the cross-consistency matrix to keep track of which worlds contained which combination of futures. This was done to check that we had included interesting pairings identified by the group, to see which futures had not yet been incorporated into any world, and to visually check that we were touching areas throughout the solution space.

Using the Cross-Consistency Matrix to Cover the Space of Possibilities

Figure 3.3 shows one part of the cross-consistency matrix: Augmentation of Humanity against Rapid Change of Threats & Weaponry. The black squares represent combinations that would be inconsistent. Here, the two trend experts decided that anything but an incrementally evolved human would be inconsistent with a future where people had rejected enhanced humans. The other colors note the world where that combination of futures had come up between the two trends. Therefore, we can see from Figure 3.3 that the workshop participants considered a future with incrementally evolved humans in the Purple and Status Quo worlds; while the specter of the fully bionic human appeared in both the Red and Blue worlds. The full cross-consistency matrix appears in Appendix B.

Figure 3.3. Cross-Consistency Matrix for Augmentation of Humanity Versus Rapid Change of Threats & Weaponry (Used to Track Worlds)

		Rapid Change of Threats & Weaponry					
		Bots, Bots, Bots	The Light Fantastic	A Can of Worms - Attacking Operators	The New Look Redux	Rejection of Fully Auto "Thinking Machines" and Enhanced Humans	Incremental Weapons Development
Augmentation of Humanity	Fully Bionic Human		Red	Blue		(black)	
	Greatly Enhanced Human	Orange		Blue		(black)	
	Moderately Enhanced Human	Yellow		Green & Blue	Green	(black)	
	Incrementally Evolved Human					Purple	Status Quo

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Figure 3.3 also shows an extra future for the Rapid Change of Threats & Weaponry trend, "Incremental Weapons Development," that did not appear in the cross-consistency matrixes (Appendix B) or the initial morphological box in Figure 3.1. This is because it was added during the course of the workshop. As the workshop progressed, experts realized in a few instances that another future within their trend was both plausible and fitting for the world being developed. The two other added futures were: "Easier Attribution and Targeting" in the Growing Difficulty of Attribution & Targeting trend; and "Heterogeneous Convergence" in the Convergence of Warfighting Domains trend. Figure 3.4 shows the final morphological box with these additions from the workshop. The final Zwicky morphological box that came out of the workshop had 7,680 possible configurations, not excluding those that would drop out because of inconsistent pairings.

Figure 3.4. Final Zwicky Morphological Box

Trends	Plausible Futures				
Increasingly Multipolar World	Persistent US Hegemony	Back to Bipolarity	First Among Equals	The Asian Century	Twilight of the Great Powers
Non-State Actors and Fragile & Failing States	Regional Instability	Rise of Regional Dictators	Large Regional Power Brokers	Western Powers Intervene	
Growing Difficulty of Attribution & Targeting	Non-Attribution Warfare as an Instrument of National Power	Highly Amorphous Irregular Warfare	Conventional Warfare with Peer Hiding in Plain Sight	Easier Attribution and Targeting	
Convergence of Warfighting Domains	Super State	Mad Max	Super Chaos	Heterogeneous Convergence	
Rapid Change of Threats & Weaponry	Bots, Bots, Bots	The Light Fantastic	A Can of Worms - Attacking Operators	The New Look Redux	Rejection of Fully Autonomous "Thinking Machines" and Enhanced Humans / Incremental Weapons Development
Augmentation of Humanity	Fully Bionic Human	Greatly Enhanced Humans	Moderately Enhanced Humans	Incrementally Evolved Human	
Ubiquity of Information	Ubiquity of Information				
Changing Culture & Workforce Capabilities	Changing Culture & Workforce Capabilities				

4. Seven Worlds

In this chapter, we present the different worlds produced by the workshop. Combining the individual futures for each of the nine trend areas developed these worlds. The objective here is to develop a set of worlds that are internally consistent with respect to the trend futures and are combined in ways to present a variety of interesting plausible future worlds to explore the potential possibilities looking out 30 years. This is by nature very speculative. We developed these scenarios to help expand planning horizons.

During the development of each world, we started with the overarching geopolitical situation and built a variety of worlds by choosing different futures from each of the other trend areas. We began at the highest level of analysis, the basic characteristics of the international order, and the degree to which it was multi-polar. We chose this trend area as the launching point for each world because it informed how the other trend areas would potentially play out. After we completed development of a world, we gave it a shorthand name to describe it. The worlds we developed range from a continuation of the current situation out through the next 30 years ("Status Quo"), through a variety of more multi-polar worlds, to a situation where China has surpassed the United States in education and technology in the 2020s and 2030s and has achieved more global influence than the United States.

In this chapter, we organized discussion of the worlds by degree of multipolarity. Figure 4.1 shows how the worlds are organized relative to multipolarity and the order in which we will discuss them in this chapter. This figure first shows that we have three major groupings with regard to degree of multipolarity: (1) persistent U.S. hegemony, (2) persistent multipolarity, and (3) changing hegemonic power.

Figure 4.1. Future Worlds Organized by Degree of Multipolarity
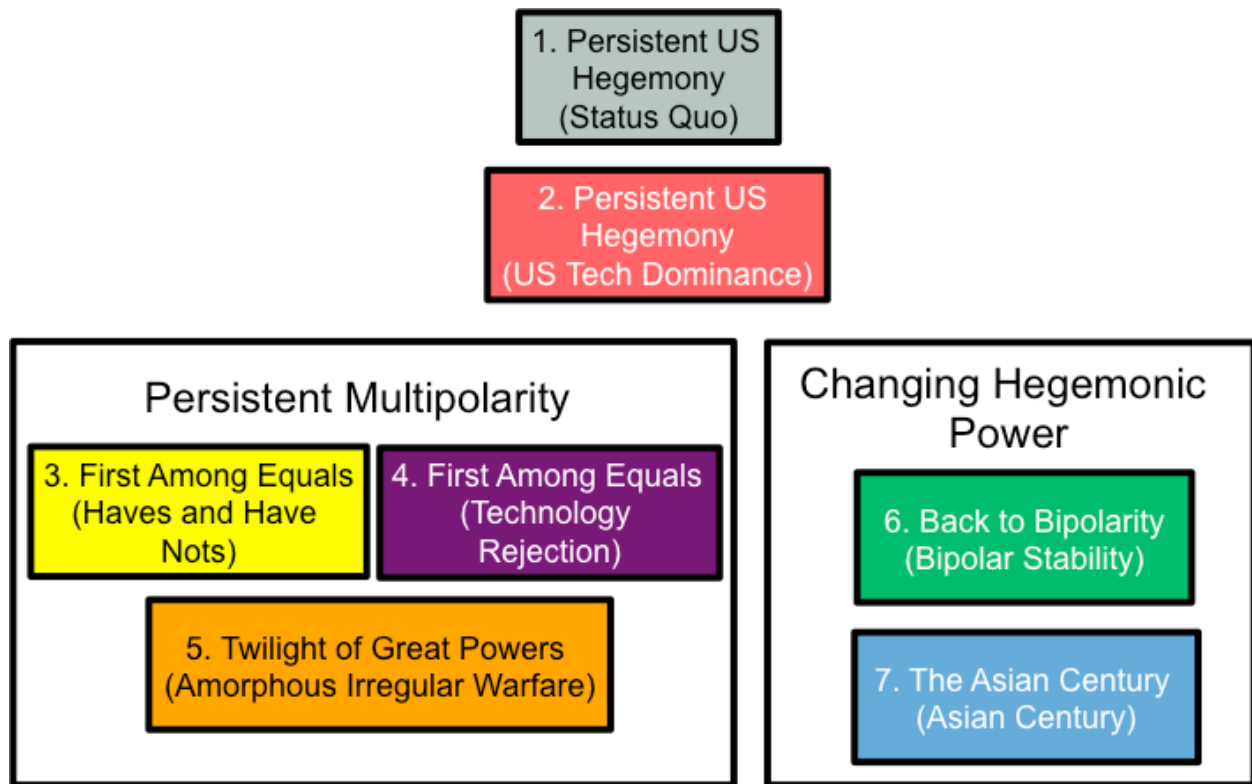
"Status Quo" World

The United States has remained the global leader because no other nation has stepped up to claim the job. China continued to advance through the 2040s, but it experienced drags on its development and ultimately had limited geopolitical ambitions. India continued to lag China and did not emerge as an economic or military power relative to China despite its large population. The status quo trend of increasing regional instability also continued for the three previous decades. Radicalized youth continued to be drawn to warzones during much of this period, MNCs did not increase their role, and NGOs continued to have a hard time operating in many environments. Different countries have mastered warfighting in air, land, sea, space, and cyber to varying degrees. Players who were dominant 30 years ago remain the dominant players: There has been no radical change to the relative dominance that countries have held in the different domains for many years. Attribution and targeting continued to be difficult in the decades leading up to this world. Despite hope for technological advancement in such areas as robotics, directed energy, human augmentation, and others, specific advanced applications did not emerge. Most U.S. military programs started in the early part of the century are now in midlife. Advances in communications and antijamming have led to more bots and drones, and the United States has sixth generation aircraft. Unmanned sensors are common. Everyone has "stayed in their lanes" for a generation and shown only incremental improvements. Despite early excitement over the

possibilities of human augmentation, there have been none of the breakthroughs that societies hoped or feared. Instead, the humans of the mid-2040s are only incrementally evolved from where they were 30 years ago. This is despite personalized medicine, designer drugs, stimulant use by the military, and significant advances in prosthetics. For the military workforce, management trends continued moving away from authoritarian type management to cohesive management. Military workforce specialization has continued, and the military system of talent management is making marginal improvements to the system, rather than changing fundamental approaches. Figure 4.2 shows which futures are associated with this world.

Figure 4.2. Trend Futures That Comprise the "Status Quo" World

Trends	Plausible Futures				
Increasingly Multipolar World	Persistent US Hegemony	Back to Bipolarity	First Among Equals	The Asian Century	Twilight of the Great Powers
Non-State Actors and Fragile & Failing States	Regional Instability	Rise of Regional Dictators	Large Regional Power Brokers	Western Powers Intervene	
Growing Difficulty of Attribution & Targeting	Non-Attribution Warfare as an Instrument of National Power	Highly Amorphous Irregular Warfare	Conventional Warfare with Peer Hiding in Plain Sight	Easier Attribution and Targeting	
Convergence of Warfighting Domains	Super State	Mad Max	Super Chaos	Heterogeneous Convergence	
Rapid Change of Threats & Weaponry	Bots, Bots, Bots	The Light Fantastic	A Can of Worms - Attacking Operators	The New Look Redux	Rejection of Fully Autonomous "Thinking Machines" and Enhanced Humans / Incremental Weapons Development
Augmentation of Humanity	Fully Bionic Human	Greatly Enhanced Humans	Moderately Enhanced Humans	Incrementally Evolved Human	
Ubiquity of Information	Ubiquity of Information				
Changing Culture & Workforce Capabilities	Changing Culture & Workforce Capabilities				

"U.S. Technological Dominance"

The United States has remained the preeminent global superpower for a century. It has continued to have a burgeoning technology sector and benefited from the brain drain from other countries to the United States. Western powers are more interventionist globally in the 2040s. The United States is in charge, has lots of allies, and is spending a lot of money.

The United States embraced the third and fourth offsets and continues to believe it is the global leader.[1] But at this point, it holds significant technological advantages in such areas as

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[1] An *offset* is a DoD term of art referring to a means of asymmetric advantage in military capabilities. The first offset was U.S. nuclear capability to avoid the requirement of a massive conventional capability to confront the Soviet Union, while the second offset was weapon system technological superiority to confront much larger

fully bionic humans and directed energy. The United States has very sophisticated bots. U.S. investments have paid off and mitigate anti-access/area denial (A2AD) technology.

Advanced sensors allow for attribution, including on the Internet. Ground based lasers and passive sensor networks make getting munitions on target more difficult. Directed energy defenses make it difficult to use SAMs, airplanes, and other air-based systems. Space is also greatly affected. The United States has a smaller and more professionalized force. This also means fewer bases and issues over base realignment. Many technology industry companies rely on USAF for training and heavily recruit the superhumans they produce, making retention more of a problem.

Full bionics allows people to download vast amounts of information, for example, giving them immediate access to the full operational plan. This also allows for humans to be uploaded and achieve a type of immortal consciousness. This technology could enable the next Osama bin Laden to continue to inspire followers even after death. Figure 4.3 shows which futures are associated with this world.

Figure 4.3. Trend Futures That Comprise the "U.S. Technological Dominance" World

Trends	Plausible Futures					
Increasingly Multipolar World	Persistent US Hegemony	Back to Bipolarity	First Among Equals	The Asian Century	Twilight of the Great Powers	
Non-State Actors and Fragile & Failing States	Regional Instability	Rise of Regional Dictators	Large Regional Power Brokers	Western Powers Intervene		
Growing Difficulty of Attribution & Targeting	Non-Attribution Warfare as an Instrument of National Power	Highly Amorphous Irregular Warfare	Conventional Warfare with Peer Hiding in Plain Sight	Easier Attribution and Targeting		
Convergence of Warfighting Domains	Super State	Mad Max	Super Chaos	Heterogeneous Convergence		
Rapid Change of Threats & Weaponry	Bots, Bots, Bots	The Light Fantastic	A Can of Worms - Attacking Operators	The New Look Redux	Rejection of Fully Autonomous "Thinking Machines" and Enhanced Humans	Incremental Weapons Development
Augmentation of Humanity	Fully Bionic Human	Greatly Enhanced Humans	Moderately Enhanced Humans	Incrementally Evolved Human		
Ubiquity of Information	Ubiquity of Information					
Changing Culture & Workforce Capabilities	Changing Culture & Workforce Capabilities					

numbers of less advanced systems. The third offset is generally identified as the U.S. military taking advantage of technological advances in such areas as "robotics, autonomous systems, miniaturization, big data, and advanced manufacturing, including 3-D printing" (see Sydney J. Freedberg Jr., "Hagel Lists Key Technologies for U.S. Military; Launches 'Offset Strategy,'" Breaking Defense, November 16, 2014). The fourth offset would be a similar asymmetric technological advantage some number of decades from now.

"Haves and Have Nots"

This is a multi-polar world that is less orderly than either of the first two hegemonic worlds discussed earlier. The United States is one of many former great powers. A number of actors have developed power projection in the past few decades: Greater Europe, India, China, and others. The United States is reluctantly interventionist and its defense posture relies on more closely allied operations, but coalitions are typically weak. Climate change has driven widespread urban insurgency in multiple cities in fragile states. Apocalyptic anarchists have taken over MNCs, which do not have their own mercenaries. This is a bifurcated world where there is first among equals, but also chaos at the lower end. There has been development and proliferation of massive communication technologies. A2AD technology has advanced but so have sensors. Attribution is difficult but finding targets is not. This has empowered non-state actors and MNCs, who use new forms of cyberwarfare and cyberransom. There has been the rise of "constabulary bots" trying to respond to complex challenges. The need to hit low-cost points to meet the needs of security forces and MNCs has driven the development of the constabulary bots, which are networked sensor bots that talk to each other. States have used the ubiquity of information to gain more control of their territory than they had in the early 21st century. In this world, U.S. forces face enemies with high levels of technology and dangerous weapons, while limited attribution makes preemption and retaliatory strikes difficult. Figure 4.4 shows which futures are associated with this world.

Figure 4.4. Trend Futures That Comprise the "Haves and Have Nots" World

Trends	Plausible Futures				
Increasingly Multipolar World	Persistent US Hegemony	Back to Bipolarity	First Among Equals	The Asian Century	Twilight of the Great Powers
Non-State Actors and Fragile & Failing States	Regional Instability	Rise of Regional Dictators	Large Regional Power Brokers	Western Powers Intervene	
Growing Difficulty of Attribution & Targeting	Non-Attribution Warfare as an Instrument of National Power	Highly Amorphous Irregular Warfare	Conventional Warfare with Peer Hiding in Plain Sight	Easier Attribution and Targeting	
Convergence of Warfighting Domains	Super State	Mad Max	Super Chaos	Heterogeneous Convergence	
Rapid Change of Threats & Weaponry	Bots, Bots, Bots	The Light Fantastic	A Can of Worms - Attacking Operators	The New Look Redux	Rejection of Fully Autonomous "Thinking Machines" and Enhanced Humans / Incremental Weapons Development
Augmentation of Humanity	Fully Bionic Human	Great Enhanced Humans	Moderately Enhanced Humans	Incrementally Evolved Human	
Ubiquity of Information	Ubiquity of Information				
Changing Culture & Workforce Capabilities	Changing Culture & Workforce Capabilities				

"Technology Rejection"

A confluence of societal factors (mishap, distrust, and social pushback against technology) and the failure of technology to meet expectations brought the rejection of many advances in machine autonomy and human enhancement more than a generation ago. One partial reaction has been information systems that are highly secure, including the creation of a new highly secure Internet. Another reaction has been wider social rejection of technology, particularly against certain types of military autonomy and enhancement. Certain people object to greater enhancement of humans for religious reasons or because of other belief systems (i.e., those against genetically modified organisms [GMOs]), and certain ideas about the human body have become sacrosanct. This reversal against networked autonomy and human-machine interfaces meant a return to more standalone and independent systems compared with moves toward autonomous and interconnected systems in the early part of the century. This has driven the need for military personnel to be highly trained and skilled because they are not able to rely on semiautonomous, autonomous, or intelligent systems whose development might have made human knowledge and skill less relevant. The countries that were the best at training 30 years ago are still considered so in this world. This kept up continued demand for USAF pilots. The United States was unlikely to walk away from potential advantages in machine autonomy and human enhancement if it had faced significant geopolitical competition. Therefore, the "First Among Equals" future was thought consistent with this set of developments. Figure 4.5 shows which futures are associated with this world.

Figure 4.5. Trend Futures That Comprise the "Technology Rejection" World

Trends	Plausible Futures				
Increasingly Multipolar World	Persistent US Hegemony	Back to Bipolarity	First Among Equals	The Asian Century	Twilight of the Great Powers
Non-State Actors and Fragile & Failing States	Regional Instability	Rise of Regional Dictators	Large Regional Power Brokers	Western Powers Intervene	
Growing Difficulty of Attribution & Targeting	Non-Attribution Warfare as an Instrument of National Power	Highly Amorphous Irregular Warfare	Conventional Warfare with Peer Hiding in Plain Sight	Easier Attribution and Targeting	
Convergence of Warfighting Domains	Super State	Mad Max	Super Chaos	Heterogeneous Convergence	
Rapid Change of Threats & Weaponry	Bots, Bots, Bots	The Light Fantastic	A Can of Worms - Attacking Operators	The New Look Redux	Rejection of Fully Autonomous "Thinking Machines" and Enhanced Humans / Incremental Weapons Development
Augmentation of Humanity	Fully Bionic Human	Greatly Enhanced Humans	Moderately Enhanced Humans	Incrementally Evolved Human	
Ubiquity of Information	Ubiquity of Information				
Changing Culture & Workforce Capabilities	Changing Culture & Workforce Capabilities				

"Highly Amorphous Irregular Warfare"

This world represents a continuation of trends since the end of the Cold War: Major powers have shied away from conflict and there have been no major wars for several decades. There is a new concert in Europe, and the United States and China have managed to avoid conflict. Large wars have disappeared and major powers continue to deconflict their actions. Stability has pushed conflict into the shadows. IW continues to be a challenge, but it is highly amorphous rather than geographically based, and actors blend into the population and come together via virtual means.

Technology has advanced in the past 30 years but the greater powers hoard more of it. Lack of conflict has meant lots of money to develop humans. There are greatly enhanced humans in special forces and police. There are greater autonomous machines. Humans interact with bots, which are adapted autonomous sensors. There is conflict between privacy and a premium on finding things out before they happen. Liberal states have leaned toward privacy, but illiberal regimes have been collecting massive data on their populations and some have even tagged them. Pressures to cut military budgets have resulted in the outsourcing of many military career fields to contractors. Greater automation has also meant the "de-skilling" of jobs. There has been a loss of the warrior culture, as the USAF became just another job. Personnel have become more diverse over time, but airmen join for postservice opportunities from clearances and neural implants. Figure 4.6 shows which futures are associated with this world.

Figure 4.6. Trend Futures That Comprise the "Highly Amorphous Irregular Warfare" World

Trends	Plausible Futures				
Increasingly Multipolar World	Persistent US Hegemony	Back to Bipolarity	First Among Equals	The Asian Century	Twilight of the Great Powers
Non-State Actors and Fragile & Failing States	Regional Instability	Rise of Regional Dictators	Large Regional Power Brokers	Western Powers Intervene	
Growing Difficulty of Attribution & Targeting	Non-Attribution Warfare as an Instrument of National Power	Highly Amorphous Irregular Warfare	Conventional Warfare with Peer Hiding in Plain Sight	Easier Attribution and Targeting	
Convergence of Warfighting Domains	Super State	Mad Max	Super Chaos	Heterogeneous Convergence	
Rapid Change of Threats & Weaponry	Bots, Bots, Bots	The Light Fantastic	A Can of Worms - Attacking Operators	The New Look Redux	Rejection of Fully Autonomous "Thinking Machines" and Enhanced Humans / Incremental Weapons Development
Augmentation of Humanity	Fully Bionic Human	Greatly Enhanced Humans	Moderately Enhanced Humans	Incrementally Evolved Human	
Ubiquity of Information	Ubiquity of Information				
Changing Culture & Workforce Capabilities	Changing Culture & Workforce Capabilities				

"Bipolar Stability"

China continued to rise and became more global and interventionist from the early 21st century onwards. The United States and China continued to jockey for power and regional allies during this time. Russia is now in third place, resisting this new bipolarity and refusing to take a position on the bipolar powers. New methods of wielding power remain below the threshold of war. Because the United States, China, and Russia want to avoid direct confrontation, they continue to use non-attribution warfare. Russia uses cyber and electromagnetic pulse (EMP) attacks, but it also emphasizes their nuclear arsenal. Large regional power brokers have stabilized regions and also jockeyed for power. There are numerous religious insurgencies and a hardened Sunni-Shia divide. These regional powers also use new means to stay below the threshold of conventional conflict. In addition to facing nuclear, conventional, and non-attribution warfare, operators face attacks directed at them to disrupt all phases of operations. These attacks have been on focused on pilots, maintenance personnel, and other system operators. The attacks have taken place in less defended areas using systems that can wait for high-value targets. The technology focus has been on sensors, and exoskeleton and drugs for lower-level conflicts. A return to bipolarity has brought massive U.S. military expansion and stable career paths that are competitive with the private sector. Individuals in the military have continued to specialize and personnel receive more focus even where autonomy is cheap. Figure 4.7 shows which futures are associated with this world.

Figure 4.7. Trend Futures That Comprise the "Bipolar Stability" World

Trends	Plausible Futures				
Increasingly Multipolar World	Persistent US Hegemony	Back to Bipolarity	First Among Equals	The Asian Century	Twilight of the Great Powers
Non-State Actors and Fragile & Failing States	Regional Instability	Rise of Regional Dictators	Large Regional Power Brokers	Western Powers Intervene	
Growing Difficulty of Attribution & Targeting	Non-Attribution Warfare as an Instrument of National Power	Highly Amorphous Irregular Warfare	Conventional Warfare with Peer Hiding in Plain Sight	Easier Attribution and Targeting	
Convergence of Warfighting Domains	Super State	Mad Max	Super Chaos	Heterogeneous Convergence	
Rapid Change of Threats & Weaponry	Bots, Bots, Bots	The Light Fantastic	A Can of Worms - Attacking Operators	The New Look Redux	Rejection of Fully Autonomous "Thinking Machines" and Enhanced Humans / Incremental Weapons Development
Augmentation of Humanity	Fully Bionic Human	Greatly Enhanced Humans	Moderately Enhanced Humans	Incrementally Evolved Human	
Ubiquity of Information	Ubiquity of Information				
Changing Culture & Workforce Capabilities	Changing Culture & Workforce Capabilities				

"The Asian Century"

China surpasses the United States in education and technology in the 2020s and 2030s, and leads the economic world order in the 2040s. The United States is recovering from a costly intervention in North Korea in the previous decade, and it is also confronting the failure of its foreign policies on human rights. Rising dictators have suppressed terrorists, and there are fewer failing states than there were 30 years ago. Top actors have been able to advance warfighting abilities in multiple domains, with China dominating in this area. Advances in hardening targets have outpaced countermeasures. Advances in technology now mean more hiding in plain sight because the infrastructure is not visible. China can amass highly mobile forces without detection and achieve objectives quickly. There have been fewer deaths, as conflicts have ended more quickly. The United States has responded to its loss of conventional advantage over time by developing ways to attack operators and maintenance. As in the previous world ("Bipolar Stability"), these attacks have taken place in less-defended areas using systems that wait for high value targets. The United States no longer focuses on broad-spectrum warfare but only has to be good at a couple of things to counter China. China has greatly enhanced or fully bionic humans. The United States has physical and mechanical improvements in human augmentation, but it has not risen to the level of brain implants as China has. The United States has experienced brain drain, as China has offered leading private sector opportunities in the previous 20 years. The Central Intelligence Agency (CIA) has money, and USAF has been able to develop a small number of superpilots. However, overall cuts to USAF spending means that the greater proportion of airmen are "deskilled" compared with previous generations of airmen. Contemporary personnel now mostly monitor sensors and are not competitive for private sector jobs. Figure 4.8 shows which futures are associated with this world.

Figure 4.8. Trend Futures That Comprise the "The Asian Century" World

Increasingly Multipolar World	Persistent US Hegemony	Back to Bipolarity	First Among Equals	The Asian Century	Twilight of the Great Powers	
Non-State Actors and Fragile & Failing States	Regional Instability	Rise of Regional Dictators	Large Regional Power Brokers	Western Powers Intervene		
Growing Difficulty of Attribution & Targeting	Non-Attribution Warfare as an Instrument of National Power	Highly Amorphous Irregular Warfare	Conventional Warfare with Peer Hiding in Plain Sight	Easier Attribution and Targeting		
Convergence of Warfighting Domains	Super State	Mad Max	Super Chaos	Heterogeneous Convergence		
Rapid Change of Threats & Weaponry	Bots, Bots, Bots	The Light Fantastic	A Can of Worms - Attacking Operators	The New Look Redux	Rejection of Fully Autonomous "Thinking Machines" and Enhanced Humans	Incremental Weapons Development
Augmentation of Humanity	Fully Bionic Human	Greatly Enhanced Humans	Moderately Enhanced Humans	Incrementally Evolved Human		
Ubiquity of Information	Ubiquity of Information					
Changing Culture & Workforce Capabilities	Changing Culture & Workforce Capabilities					

5. Concluding Thoughts

Based on this work, a range of plausible futures can be envisioned for the next 30 years. The futures identified in this report are diverse, illustrate the complex ways in which different trends may play out in the future, and show how different contexts could have significantly different impacts on how USAF will operate in the future. The seven futures presented in this report are far from a complete set, but were constructed to provide a diverse set of backdrops for planning purposes. They represent an effort to provide USAF with ideas on how these different trends could evolve and could interact with one another in ways that might result in vastly different situations for USAF. Figure 5.1 offers a visual summary of the analytic structure underneath this particular set of worlds, as well as a means of visually comparing the futures that the different worlds covered.

Reflections on the Workshop Method

We used an adapted GMA approach for the workshop that was able to produce a range of possible futures in a condensed period. We were gratified by our sponsor's feedback that the workshop went smoothly. But because no approach is ever perfect in its conceptualization or perfect in its execution, it is always appropriate to ask how a method might have worked better and how it might be improved. It is also useful to ask about the other potential applications of a method to other USAF problems.

Potential Improvements to the Workshop

On the issue of how to improve the workshop, there are several factors we can identify. First, we feel that a slightly smaller set of trends, with less overlap between them in some cases, might have led to a more-efficient process without any loss in the quality of the worlds created. For example, we combined two initial trends (Non-State Actors and Fragile & Failed States) into one and did not feel that this compromised the workshop output. The same might have been possible for other trends that were heavily interdependent, such as Rapid Change of Threats & Weaponry and the Convergence of Warfighting Domains. The original GMA method seeks to keep "parameters" on as distinct (or orthogonal) axes as possible, and is consistent with this idea.

Second, in retrospect, we might have spent more time exploring whether certain trends such as the Ubiquity of Information or Changing Culture & Capabilities of the Workforce could have been expressed in terms of discrete futures. Although these areas can in fact be extremely context-dependent and it might not have been possible, a good list of discrete futures for either had the possibility of better defining a morphological field that would have been slightly more transparent.

Figure 5.1. Visual Comparison of Future Worlds

Figure 5.1. Visual Comparison of Future Worlds
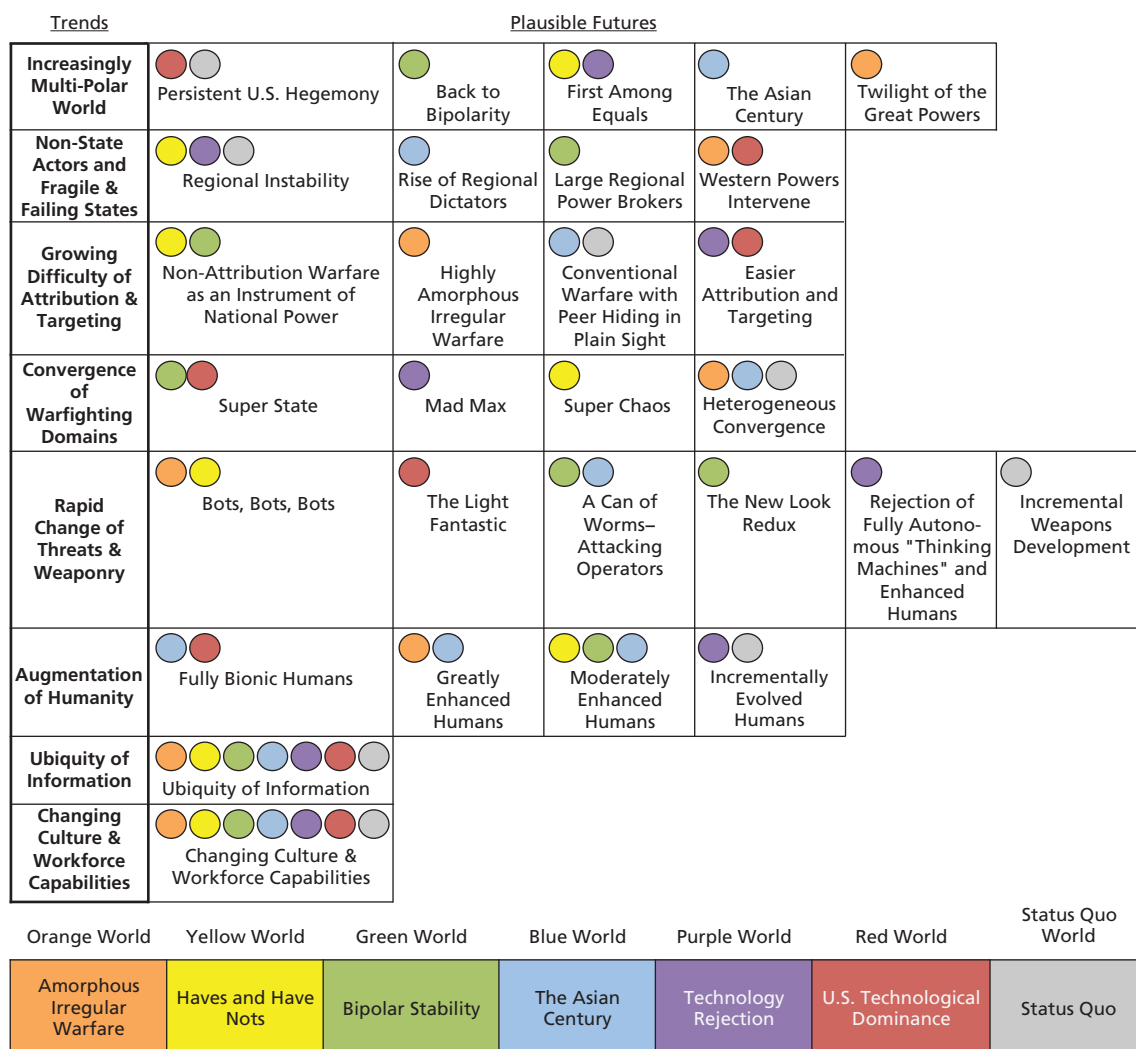
Another way the workshop could have been improved would have been to spend more time in advance with each trend expert reviewing whether each list of discrete futures (1) included status quo futures and (2) was as complete as possible. In a few instances, the trend experts added a future to their lists during their workshop, and so the workshop might have benefited from greater feedback from organizers ahead of time.

However, this leads to the final factor that could have improved workshop results: time. The constraints of time and resources for the workshop meant that trend experts only had a very brief period to collect their thoughts on each trend. Time for additional research into each trend area would have been beneficial. Additional time might also have permitted more interaction between USAF stakeholders (who initially identified trend areas) and the RAND experts tackling each

area, improving the integration of this effort with the time and resource investment USAF had already put into the AFSEA process.

Additional Applications for the Air Force

There are also other potential ways that this method might be useful to USAF for structuring the thinking about other complex and challenging problems. GMA and its different adaptations are extremely useful as scenario generation methods that seek to identify the key factors that will drive the future. On this front, GMA may be the most comprehensive scenario generation method in existence.

It is also useful for structuring highly technical questions, where the cross-consistency analysis can be useful in ruling out certain combinations on technical grounds. The exercise of a group of stakeholders or experts within an organization coming together to participate in such an exercise is also valuable for building cross-domain awareness, cross-cutting insights, and a collective understanding of problems.

What is done with the results of a GMA can also be valuable. For example, each of the worlds generated in this workshop might drive different solutions to such problems as ISR or deterrence. The ability to look across a diverse scenario space for robust or hedging solutions can also be valuable. This approach allows USAF to test different force structures and CONOPs across a range of plausible and diverse future scenarios to identify insights into what shortfalls might exist under specific circumstances. This approach allows development of a wide range of diverse scenarios.

This process could also be used to achieve even broader futures than the ones identified in this report. Due to the funding and time constraints available to execute the project, we were only able to run the exercise once. As a result, the participants of the exercise had certain shared assumptions and biases. It is possible, that a different running of the exercise would have led to a vastly different set of worlds—especially had we set out to explore different parts of the spectrum by asking participants different sets of questions. It would be valuable to incorporate other participants into the group and run the exercise multiple times with different groups to see whether a broader set of worlds emerges and the results of various runs of the exercise.

Appendix A: Trends and Descriptions Provided by the Air Force

Nine trends were identified in three major categories: Geopolitical, Military & Warfare, and Human & Workforce. The nine trend areas provided by USAF, along with brief descriptions, are in the following sections. The USAF provided these descriptions. We present them verbatim in this appendix.

Geopolitical

- **The Increasingly Multi-Polar World:** A dispersal of economic, political, and military power is already underway. How far will multipolarity go? Will states arise which can challenge the U.S. on equal terms on regional or even global scales? Or will the rising states find themselves unable to manage the transition, leaving the U.S. as the undisputed global hegemon?
- **The Rise of Non-State Actors:** The democratization of information and technology is empowering non-state groups and individuals with tools that were once limited to the domain of states. How important will they be in the future world, and just how much power will they be able to wield? Includes extremists, criminals, non-government organizations, private companies, and individual actors.
- **The Spread of Fragile & Failed States:** A variety of demographic trends (population growth, migration, urbanization) and environmental trends (climate change, resource scarcity) will be felt most harshly in the states whose governments are the least-prepared to deal with the fallout. Will the international community be able to contain the problem, or will an epidemic of failed states rage out of control?

Military & Warfare

- **The Convergence of Warfighting Domains:** The Air Force's warfighting domains are air, space, and cyberspace. Military personnel and systems operating in these three domains are increasingly dependent on those operating in the other two. Meanwhile, the proliferation of advanced technology is lowering the barriers to entry for state and non-state actors alike, making these domains increasingly congested and contested. How does this play out across the thirty-year timeframe?
- **The Rapid Change of Threats & Weaponry:** As computers and information access fuel unprecedented levels of innovation around the world, new technologies and combinations of technologies are cropping up more and more frequently, accelerating the overall rate of

change. When combined with next-generation manufacturing technology, the possibility for new threats to emerge overnight becomes a distinct possibility. Well-resourced states may be able to flexibly adopt and field new technology in comparatively short times. To what extent could this becoming reality, and how will it change the battlefield of the future?

- **The Growing Difficulty of Attribution & Targeting:** As sensors, information fusion, and precision weaponry has improved, the adversaries operating against these reconnaissance-strike complexes have been forced to become hard targets. Basic techniques include high mobility, hiding in difficult terrain or urban areas, limiting communications, and blending with civilian populations. More advanced actors may employ multi-spectral camouflage, hyper-realistic decoys, passive sensors, and cyber deception. Some emerging forms of non-kinetic warfare, such as cyber warfare, legal warfare, or economic warfare, do not necessarily even cross the threshold of "conflict" in any traditional sense. What challenges will this pose in the future?

Human & Workforce

- **The Changing Culture & Capabilities of the Workforce:** Much has been made of how to integrate the Millennials into the military, but by the time the Millennials are in charge, they will have to learn how to integrate their children's generation. What will these generations be like? What will their motivations be? What skills might they have? Will they be better or less prepared to fight the wars of the future?

- **The Augmentation of Humanity:** We find ourselves more and more reliant on our technology every day, but humanity is on the verge of much more significant changes. Whether it be teaming with autonomous systems, nanotech implants, performance-enhancing drugs, or genetic engineering, humans may soon become something much more than they are now. Are these trends plausible or simply over-hyped popular science?

- **The Ubiquity of Information:** The volume of data in our world is expanding at an incredible rate, and the world of 2045 may look back at the technology of 2015 with the same quaint fondness we have for Apple II computers and brick-sized car phones. How will a world raised on constant, pervasive information and 24/7 surveillance be different from that today? What will this mean for the next generation of recruits? What about our adversaries?

Appendix B: Cross-Consistency Matrixes

This appendix contains the cross-consistency matrixes generated by the morphological box (Figures B.1–B.16). It was used to (1) identify individual futures that were inconsistent with each other, thus revealing possible combinations that should be ruled out; and (2) visually depict the pairing of futures that were being considered in the worlds built by the workshop to help keep world development spread out over a diverse solution space. The color-coding for the matrix in Figure B.1 shows the color scheme for the different worlds and the color-coding to denote inconsistent pairs of futures and "soft" inconsistencies. Soft inconsistencies were where a pair of futures might be unlikely or unusual together but not inconceivable.

Figure B.1. Color Coding for Cross-Consistency Matrix
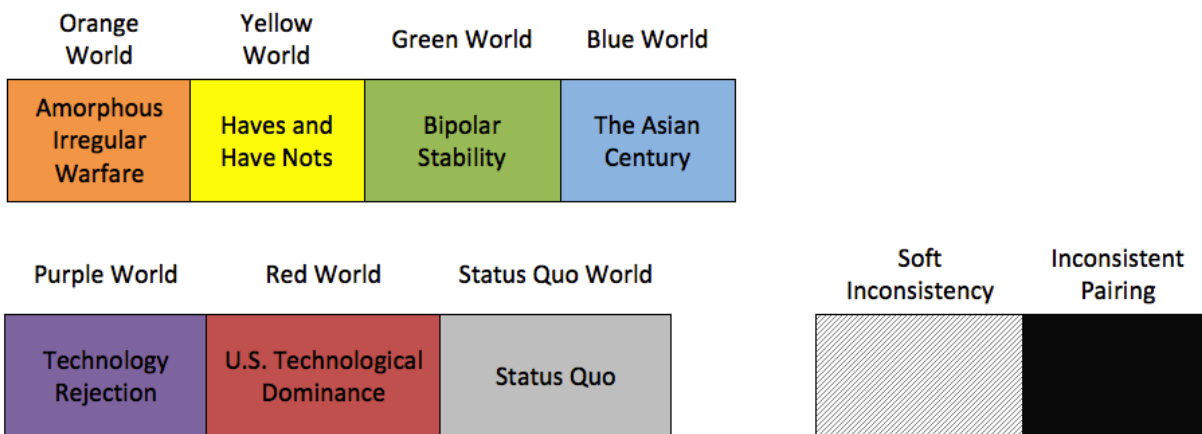
Figure B.2. Cross-Consistency Matrix for Increasingly Multi-Polar World Versus Non-State Actors and Fragile & Failed States

Mutipolar World	Non-States Actors and Failed & Fragile States			
	Regional Instability	Rise of Regional Dictators	Large Regional Power Brokers	Western Powers Intervene
Persistent US Hegemony	Status Quo			Red
Back to Bipolarity			Green	
First Among Equals	Yellow & Purple			
The Asian Century		Blue		
Twilight of the Great Powers				Orange

Figure B.3. Cross-Consistency Matrix for Increasingly Multi-Polar World Versus Growing Difficulty of Attribution & Targeting

Mutipolar World	Growing Difficulty of Attribution & Targeting			
	Non-Attribution Warfare as an Instrument of National Power	Highly Amorphous Irregular Warfare	Conventional Warfare with Peer Hiding in Plain Sight	Easier Attribution and Targeting
Persistent US Hegemony			Status Quo	Red
Back to Bipolarity	Green			
First Among Equals	Yellow			Purple
The Asian Century			Blue	
Twilight of the Great Powers		Orange		

Figure B.4. Cross-Consistency Matrix for Increasingly Multi-Polar World Versus Convergence of Warfighting Domains

| | Convergence of Warfighting Domains | | | |
Mutipolar World	Super State	Mad Max	Super Chaos	Heterogeneous Convergence
Persistent US Hegemony	Red			Status Quo
Back to Bipolarity	Green			
First Among Equals		Purple	Yellow	
The Asian Century				Blue
Twilight of the Great Powers				Orange

Figure B.5. Cross-Consistency Matrix for Increasingly Multi-Polar World Versus Rapid Change of Threats & Weaponry

| | Rapid Change of Threats & Weaponry | | | | | |
Mutipolar World	Bots, Bots, Bots	The Light Fantastic	A Can of Worms - Attacking Operators	The New Look Redux	Rejection of Fully Auto "Thinking Machines" and Enhanced Humans	Incremental Weapons Develop-ment
Persistent US Hegemony		Red				Status Quo
Back to Bipolarity			Green	Green		
First Among Equals	Yellow				Purple	
The Asian Century			Blue			
Twilight of the Great Powers	Orange					

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Figure B.6. Cross-Consistency Matrix for Increasingly Multi-Polar World Versus Augmentation of Humanity

	Augmentation of Humanity			
Mutipolar World	**Fully Bionic Human**	**Greatly Enhanced Human**	**Moderately Enhanced Human**	**Incrementally Evolved Human**
Persistent US Hegemony	Red			Status Quo
Back to Bipolarity			Green	
First Among Equals			Yellow	Purple
The Asian Century	Blue	Blue	Blue	
Twilight of the Great Powers		Orange		

Figure B.7. Cross-Consistency Matrix for Augmentation of Humanity Versus Non-State Actors and Fragile & Failed States

	Non-States Actors and Fragile & Failing States			
Augmentation of Humanity	**Regional Instability**	**Rise of Regional Dictators**	**Large Regional Power Brokers**	**Western Powers Intervene**
Fully Bionic Human		Blue		Red
Greatly Enhanced Human		Blue		Orange
Moderately Enhanced Human	Yellow	Blue	Green	
Incrementally Evolved Human	Purple & Status Quo			

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Figure B.8. Cross-Consistency Matrix for Augmentation of Humanity Versus Growing Difficulty of Attribution & Targeting

Augmentation of Humanity	Growing Difficulty of Attribution & Targeting			
	Non-Attribution Warfare as an Instrument of National Power	Highly Amorphous Irregular Warfare	Conventional Warfare with Peer Hiding in Plain Sight	Easier Attribution and Targeting
Fully Bionic Human			Blue	Red
Greatly Enhanced Human		Orange	Blue	
Moderately Enhanced Human	Yellow & Green		Blue	
Incrementally Evolved Human			Status Quo	Purple

Figure B.9. Cross-Consistency Matrix for Augmentation of Humanity Versus Convergence of Warfighting Domains

Augmentation of Humanity	Convergence of Warfighting Domains			
	Super State	Mad Max	Super Chaos	Heterogeneous Convergence
Fully Bionic Human	Red			Blue
Greatly Enhanced Human				Orange & Blue
Moderately Enhanced Human	Green		Yellow	Blue
Incrementally Evolved Human		Purple		Status Quo

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Figure B.10. Cross-Consistency Matrix for Augmentation of Humanity Versus Rapid Change of Threats & Weaponry

Rapid Change of Threats & Weaponry

Augmentation of Humanity	Bots, Bots, Bots	The Light Fantastic	A Can of Worms - Attacking Operators	The New Look Redux	Rejection of Fully Auto "Thinking Machines" and Enhanced Humans	Incremental Weapons Development
Fully Bionic Human		Red	Blue		(black)	
Greatly Enhanced Human	Orange		Blue		(black)	
Moderately Enhanced Human	Yellow		Green & Blue	Green	(black)	
Incrementally Evolved Human					Purple	Status Quo

Figure B.11. Cross-Consistency Matrix for Rapid Change of Threats & Weaponry Versus Non-State Actors and Fragile & Failed States

Non-States Actors and Fragile & Failing States

Rapid Change of Threats & Weaponry	Regional Instability	Rise of Regional Dictators	Large Regional Power Brokers	Western Powers Intervene
Bots, Bots, Bots	Yellow			Orange
The Light Fantastic				Red
A Can of Worms - Attacking Operators		Blue	Green	
The New Look Redux			Green	
Rejection of Fully Auto Machines and Enhanced Humans	Purple			
Incremental Weapons Development	Status Quo			

Figure B.12. Cross-Consistency Matrix for Rapid Change of Threats & Weaponry Versus Growing Difficulty of Attribution & Targeting

	Growing Difficulty of Attribution & Targeting			
Rapid Change of Threats & Weaponry	Non-Attribution Warfare as an Instrument of National Power	Highly Amorphous Irregular Warfare	Conventional Warfare with Peer Hiding in Plain Sight	Easier Attribution and Targeting
Bots, Bots, Bots	Yellow	Orange		
The Light Fantasic				Red
A Can of Worms - Attacking Operators	Green		Blue	
The New Look Redux	Green	(black)		
Rejection of Fully Auto Machines and Enhanced Humans				Purple
Incremental Weapons Development			Status Quo	

Figure B.13. Cross-Consistency Matrix for Rapid Change of Threats & Weaponry Versus Convergence of Warfighting Domains

	Convergence of Warfighting Domains			
Rapid Change of Threats & Weaponry	Super State	Mad Max	Super Chaos	Heterogeneous Convergence
Bots, Bots, Bots			Yellow	Orange
The Light Fantasic	Red			
A Can of Worms - Attacking Operators	Green			Blue
The New Look Redux	Green			
Rejection of Fully Auto Machines and Enhanced Humans		Purple		
Incremental Weapons Development				Status Quo

Figure B.14. Cross-Consistency Matrix for Convergence of Warfighting Domains Versus Non-State Actors and Fragile & Failed States

Non-States Actors and Fragile & Failing States

Convergence of Warfighting Domains	Regional Instability	Rise of Regional Dictators	Large Regional Power Brokers	Western Powers Intervene
Super State			Green	Red
Mad Max	Purple			
Super Chaos	Yellow			
Heterogeneous Convergence	Status Quo	Blue		Orange

Figure B.15. Cross-Consistency Matrix for Convergence of Warfighting Domains Versus Growing Difficulty of Attribution & Targeting

Growing Difficulty of Attribution & Targeting

Convergence of Warfighting Domains	Non-Attribution Warfare as an Instrument of National Power	Highly Amorphous Irregular Warfare	Conventional Warfare with Peer Hiding in Plain Sight	Easier Attribution and Targeting
Super State	Green			Red
Mad Max				Purple
Super Chaos	Yellow			
Heterogeneous Convergence		Orange	Blue & Status Quo	

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Figure B.16. Cross-Consistency Matrix for Growing Difficulty of Attribution & Targeting Versus Non-State Actors and Fragile & Failed States

	Non-State Actors and Failed & Fragile States			
Growing Difficulty of Attribution & Targeting	Regional Instability	Rise of Regional Dictators	Large Regional Power Brokers	Western Powers Intervene
Non-Att. Warfare as Instrument of National Power	Yellow		Green	
Highly Amorphous Irregular Warfare	(black)			Orange
Conventional War with Peer Hiding in Plain Sight	Status Quo	Blue		
Easier Attribution and Targeting	Purple			Red

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201507-Zhao.pdf?token=1bRg5htzQ%2BVLSDBbCaJP2j0f5u8%3D

Every few years, the Air Force develops the Strategic Environment Assessment (AFSEA). The 2016 AFSEA is a 30-year look into the future for Air Force planning. As part of this process, Air Force asked RAND researchers to identify plausible futures based on nine trends in the categories of Geopolitical, Military & Warfare, and Human & Workforce to assist Air Force strategic planning in developing the AFSEA. The RAND team generated a range of future projections based on each of these trends and then convened a collaborative structured workshop to identify important interactions between these trends and to develop a set of future worlds during a 30-year time frame to assist the Air Force during the AFSEA.

The workshop was a two-day event during which the RAND trend experts (1) presented their trend assessments and plausible futures; (2) conducted a cross-consistency analysis to look for any combinations of futures that they felt would be inconsistent with each other; (3) identified "interesting pairings" of futures; and (4) developed future worlds using different combinations of trend futures. The purpose of the workshop was to create a set of future worlds that represented diverse contexts and potential challenges for the Air Force to consider. This report presents the results of that workshop.