Report of the

Defense Science Board Advisory Group on Defense Intelligence

Operations Research Applications for Intelligence, Surveillance and Reconnaissance (ISR)

January 2009

Office of the Under Secretary of Defense
for Acquisition, Technology, and Logistics
Washington, D.C. 20301-3140

This report is a product of the Defense Science Board (DSB). The DSB is a Federal Advisory Committee established to provide independent advice to the Secretary of Defense. Statements, opinions, conclusions, and recommendations in this report do not necessarily represent the official position of the Department of Defense.

The DSB Advisory Board Group on Defense Intelligence Task Force on Operations Research for ISR completed its information gathering in September 2008.

This report is UNCLASSIFIED and releasable to the public.

OFFICE OF THE SECRETARY OF DEFENSE
3140 DEFENSE PENTAGON
WASHINGTON, DC 20301-3140

DEFENSE SCIENCE
BOARD

January 13, 2009

MEMORANDUM FOR UNDER SECRETARY OF DEFENSE FOR INTELLIGENCE
UNDER SECRETARY OF DEFENSE FOR ACQUISITION,
TECHNOLOGY & LOGISTICS

SUBJECT: Final Report of the Defense Science Board (DSB) Advisory Group on Defense Intelligence Task Force on Operations Research Applications for Intelligence, Surveillance and Reconnaissance (ISR)

I am pleased to forward the final report of the DSB Advisory Group on Defense Intelligence Task Force on Operations Research Applications for ISR co-chaired by Dr. Robert Lucky and Major General Richard O'Lear, USAF (Ret). This Task Force was sponsored by the Under Secretary of Defense for Intelligence (USD(I)).

As requested in the Terms of Reference (TOR) the Task Force was asked to assess the use of operations research (OR) methods within the DoD, determine how OR supports DoD decision making for ISR programs and recommend needed improvements.

The final report addresses the taskings in the TOR and provides two test cases for using OR methodologies. The report provides recommendations for the USD(I) which include establishing an organic ISR OR oversight function within USD(I) as well as a capability to conduct OR for strategic investment decisions. Further recommendations address the details of the OUSD(I) OR function.

I endorse the Task Force's findings and recommendations and encourage you to review the report.

William Schneider, Jr.

Dr. William Schneider, Jr.
DSB Chairman

This page is intentionally blank.

OFFICE OF THE SECRETARY OF DEFENSE
3140 Defense Pentagon
Washington, DC 20301-3140

DEFENSE SCIENCE
BOARD

December 9, 2008

MEMORANDUM FOR THE CHAIRMAN, DEFENSE SCIENCE BOARD

SUBJECT: Final Report of the Defense Science Board (DSB) Advisory Group on Defense Intelligence Task Force on Operations Research Applications for Intelligence, Surveillance and Reconnaissance (ISR)

Attached is the final report of the DSB Advisory Group on Intelligence Task Force on Operations Research Applications for ISR. The Task Force was asked to examine the use of operations research (OR) methods to support ISR decision making within the Department of Defense (DoD).

The Terms of Reference asked the Task Force to survey the departments and agencies to determine how much OR is being performed; assess how the results of OR are being used in decision making; recommend a test case(s) for using OR methodologies; and recommend steps the Department can take to institutionalize the use of OR in future DoD decision making.

The Task Force reviewed the application of OR – which it views as decision support analysis based on information collected and analyzed using the scientific method – throughout the DoD and the Services focusing primarily on the resources available to conduct OR, as opposed to reviewing specific programs. The Task Force examined the commitment of decision makers to the use of OR and the extent to which these resources reflected the application of standard OR processes and practices and the manner in which the results appeared to be employed. The Task Force also looked at several private-sector OR application models and at recent and historical uses of OR in support of national security requirements.

Based on its inquiry the Task Force arrived at the following observations:

- Operations Research represents a powerful tool to help improve the quality of investment decision making by illuminating key issues, assumptions, and sources of information.
- Operations Research is applied inconsistently throughout the Defense and ISR communities and each lacks standard OR processes and practices, and consistent organizational models or commitments.

- OR and the use of it can be strengthened in the Defense and ISR communities through effective institutionalization.
- The utility of OR can be more firmly established through appropriate test cases.

Based on its findings, the Task Force recommends establishing an organic OR oversight function and investment decision capability within the USD(I). In response to the TOR, the Task Force recommends two test cases, one related to the balance in the intelligence cycle and the other related to investment decision making in biometrics technologies.

The attached report provides the rationale for the Task Force's findings and recommendations, reflects on the historical use of OR, details current OR practices, specifies attributes required for the test cases, and offers potential institutionalization models.

We appreciate the contributions made by the Department of Defense, Intelligence Community, and private sector professionals who took the time to provide us with their knowledge and expertise; the members of this study; the Executive Secretary; and the DSB Secretariat and its military assistant.

Dr. Robert Lucky
Co-Chairman

Maj Gen Richard O'Lear, USAF (Ret)
Co-Chairman

TABLE OF CONTENTS

Executive Summary 3
Chapter 1: Introduction and Tasking 7
Chapter 2: The Task Force's Understanding of Operations Research 9
2.1 Desired Attributes of Operations Research 9
2.2 Advantages of Operations Research 10
2.3 ISR Decisions to which Operations Research is Applicable 10
2.4 Conditions under which Operations Research can be Institutionalized 10
Chapter 3: Operations Research – Historical Context 13
3.1 General Lessons Learned from Historical Experience 18
Chapter 4: Relevance of Operations Research to Intelligence, Surveillance, and Reconnaissance 21
4.1 Current ISR Issues that can Benefit from the Application of OR 21
4.2 Past ISR Investment Issues that have Benefited from the Application of OR 22
4.3 Complications in Applying OR to ISR Investment Issues 22
4.4 Challenges in Applying OR to ISR Issues 23
Chapter 5: Current Operations Research Practices (TOR Tasks 1 and 2) 25
Chapter 6: ISR Test Case(s) Attributes (TOR Task 3) 29
6.1 Importance 29
6.2 Leadership Commitment 29
6.3 OR Process Credibility 30
6.4 Test Case Scope 30
6.5 Test Case Timing and Duration 32
6.6 A Note on ISR Test Case Challenges 32
Chapter 7: Institutionalizing Operations Research (TOR Task 4) 33
Chapter 8: Findings and Recommendations 37
Appendix A: Terms of Reference 39
Appendix B: Task Force Membership 43
Appendix C: Briefings Received 45
Appendix D: Test Cases 47
D.1 Biometrics 47
D.2 Investing in a Balanced Intelligence Cycle and Imagery UASs - a Value Proposition ... 49
Appendix E: Glossary 53

This page is intentionally blank.

EXECUTIVE SUMMARY

The Advisory Group on Defense Intelligence (the Task Force) of the Defense Science Board (DSB) was tasked by the Under Secretary of Defense for Intelligence (USD(I)) to examine the manner and extent to which Operations Research (OR) is employed by the Department of Defense; how OR can be used to support Intelligence, Surveillance, and Reconnaissance (ISR) decision making; and the manner in which OR can be institutionalized in the Department of Defense (DoD).

The Task Force reviewed the application of OR[1] – which it views as decision support analysis based on information collected and analyzed using the scientific method – throughout the DoD and the Services. The review was done on a selective basis, focusing principally on the resources available to conduct OR as opposed to specific programs. The Task Force looked at decision makers' commitment to the use of OR, the extent to which resources reflected the application of standard processes and practices, and the manner in which the results of resources appeared to be employed by the organizations of which they are a part. The Task Force also looked at several private-sector OR application models (notably FedEx), and at recent and historical use of OR in support of national security requirements.

Four aspects of our inquiry stand out:

1. Operations Research represents a powerful tool to help improve the quality of investment decision making by illuminating key issues, assumptions, and sources of information.
2. Operations Research is applied inconsistently throughout the Defense and ISR communities. These communities do not possess standard OR processes and practices, a consistent organizational model, or a consistent commitment to the use of OR.
3. OR – and its use – can be strengthened in the Defense and ISR communities through effective institutionalization. The Task Force commends to the USD(I) for further consideration models employed by the private sector (of which FedEx appears to be a strong examples) and the Army (TRAC and CAA). The Military Operations Research Society (MORS) is a domain expert resource that should be used in building a plan for institutionalization.
4. The utility of OR can be more firmly established through appropriate test cases. The Task Force points to two cases for USD(I) consideration: Biometrics and Investment in a Balanced Intelligence Cycle, with specific emphasis on Unmanned Aerial Systems (UASs).

[1] The analytical study of military problems undertaken to provide responsible commanders and staff agencies with a scientific basis for decision on action to improve military operations. Also called operational research; operations analysis." (JCS Pub 1-02)

The Task Force believes Operations Research can strengthen the quality of ISR decision making in terms of the ability of investment decisions to more clearly reflect requirements, alternatives, resources, and technologies. However, OR is currently employed throughout DoD and the Services on an inconsistent basis, reflecting varying levels of leadership commitment and support, a lack of standards regarding OR training and methodologies, and uncertain career recognition and prospects for OR practitioners. Although the Federal Acquisition Regulations (FAR) require the use of OR in support of Major Acquisition Programs, OR is used inconsistently in ISR investment decision making, even on major systems, and the resources employed do not reflect standard practice. In general, OR is used to configure existing resources or to support (or refute the need for) additional "buys" of existing systems. OR is also used to support complex mission management decisions regarding operational systems. Overall, however, the use of Operations Research is diminished by a seeming lack of leadership support for its application in support of program investment, career investment, and sufficient resource investment to create sustained excellence in its practice throughout the ISR and larger DoD communities. In contrast, OR (and science method-based analysis) *were* disciplines prized for their ability to help decision makers meet significant challenges, particularly in support of U.S. military operations during World War II, in determining force mix and sufficiency after WWII, and in rationally mobilizing the U.S. industrial base in support of national security requirements. While there exist islands of OR practice today – some of them quite competent – in DoD and the Services, institutional capacity to apply science-based analysis to complex decisions is far less than it has been in the past, and less than it should be.

Institutionalization of OR for ISR investment decision making requires a sound management model and the sustained support of DoD leaders, both in its application and sustainment of the resources necessary to keep OR a robust discipline throughout the Department and the Services. Such commitment will be required to reach a level of competent OR practice throughout the ISR community. At present, competent OR cells exist, but are poorly connected as a professional community and inconsistently utilized by decision makers. The Task Force believes OR should be institutionalized, practiced consistently (from a standards and methodology perspective), and used routinely to support high value decisions involving complex requirements and significant resources. The Task Force understands clearly that OR does not "make" decisions; rather OR can and should make visible the sources of data and information used to make decisions, help drive the development of consistent assumptions and requirements, and give an objective basis against which decisions can be weighed. The Task Force recognizes that complex decisions exist within a wider context of policy and changing requirements; OR provides an objective "anchor" that decision makers should consider.

The Task Force recommends that the Federal Express (FedEx) management model be given strong USD(I) consideration as a sound example of the use of OR in the private sector. In addition, the work being done by the Army's Training and Doctrine Command's (TRADOC) Analyses Center (TRAC) and the Center for Army Analysis (CAA)

provide good examples of utilizing OR within the government. The private sector model used by FedEx employs OR at a corporate level to decide which lines of business are competitive and at what level; employs OR at the line-of-business level for investment decision making and configuration of operational resources; and provides corporate oversight to ensure the presence of consistent OR standards methodology throughout the company's family of businesses. FedEx does not "require" the use of OR instead the FedEx leadership commitment to OR-based decision making creates a culture which gives its practitioners substantial influence during high value decision making. At the same time, the Task Force believes that TRAC may represent a strong example of an embedded, "line-of-business" capability, analogous to the OR capabilities in FedEx's various lines-of-business. Overall, the Task Force recommends the USD(I) establish an organic[2] ISR OR oversight function that requires, sustains, and reviews OR standard processes and practices in DoD ISR investment decisions.

In response to the TOR, the Task Force recommends two ISR test cases. The first related to investment decision making in biometrics technologies in support of ISR requirements; and the second to investment decision making for balance in the overall intelligence cycle, and specifically in regard to UASs. These test cases should be structured to illuminate challenges and opportunities to strengthen OR decision making in the ISR investment domain. The biometrics test case provides an opportunity to help biometrics meet its ISR potential through stronger investment strategy decision making, creation of a real biometrics information architecture, and development of a biometrics information sharing environment useful to both intelligence analysts and warfighters.

Building a more effective OR capability to support ISR is a difficult but meaningful challenge. The Task Force believes that the Military Operations Research Society (MORS) is a resource the USD(I) can use to help implement this study's recommendations.

In summary, the decision maker must commit to using the OR results in support of decisions to be made. While it is not realistic to believe that an important ISR investment decision will be driven solely by OR analytical results, it should be clear to stake-holders that the results were carefully considered in the decision-making process.

The Task Force looks forward to discussing with the USD(I) and the ISR community its recommendations and is grateful for this opportunity to serve the larger national security community.

[2] An in-house OR function.

This page is intentionally blank.

CHAPTER 1: INTRODUCTION AND TASKING

As a result of the recent High Value Targets (HVT) Study performed by Edge Consulting, Inc. to examine the application of ISR assets in support of operations in the U.S. Central Command's Area of Responsibility (USCENTCOM AOR), senior leaders in the Office of the Under Secretary of Defense for Intelligence (OUSD(I)), Program Analysis and Evaluation (PA&E), and the Joint Staff engaged in a discussion about the merits of operations research in support of planning, programming, and operations.[3] This discussion led to a request by the USD(I) to the Defense Science Board (DSB) to perform a study on the use of Operations Research methods to support decision making within the Department, with a focus on Intelligence, Surveillance, and Reconnaissance (ISR) investment choices. The DSB assigned this task to its Advisory Group on Defense Intelligence (the Task Force). The Terms of Reference (TOR) directed the Task Force to examine the manner and extent to which OR is employed by the Department of Defense (DoD), how OR can be used to support ISR decision making, and the manner in which OR can be institutionalized in the DoD. The TOR included the following four tasks:

1. Survey the departments and agencies to determine how much OR is being performed;
2. Assess how the results of that OR are being used in decision making;
3. Based on these findings, recommend a test case for using OR methodologies to improve DoD ISR investment decisions; and
4. Recommend steps the Department can take to "institutionalize" the use of OR in DoD decision making in the future.

The Task Force discussed the scope of the OR inquiry that would best serve the USD(I)'s needs and considered limiting the inquiry to an examination of OR as a component of technology and acquisition strategy. The Task Force also considered extending the inquiry to ways in which OR can be used to strengthen operational planning. In the end, the Task Force concluded that a broad inquiry was appropriate to the TOR tasks provided by the USD(I). Such an inquiry included examination and discussion of OR as a component of operational planning, as an element in resource allocation in support of operations, and as an element of acquisition and technology strategy pertinent to supporting resource allocation and operational planning. The Task Force believes this broad-based approach is particularly relevant to the ISR challenges facing the Department now and in the foreseeable future. Secretary of Defense Robert Gates

[3] The Office of the Undersecretary of Defense (Intelligence), Program Analysis and Evaluation, and the Joint Staff co-sponsored Edge Consulting, Inc. to deliver a series of quantitative ISR performance analyses. The Department's objective was to enrich the standard methods - interviews, surveys, war games - with quantitative analysis of empirical operations and intelligence performance data. As one example, the Department tasked Edge with quantifying the contribution of a dozen Intelligence Surveillance and Reconnaissance (ISR) systems to the special operations campaign against High Value Targets (HVT). Working in close cooperation with the Department, U.S. Central Command, and Special Operations Forces, Edge gathered over one million empirical records associated with thousands of HVT operations. Operations Research techniques were adapted and applied to quantify the contribution of ISR systems to successful operations. Causal factor analysis was applied to understand root causes of poor performance. The Department and special operations forces applied these results to adjust both acquisition and operational decisions.

described some of these challenges – related to requirements of ever increasing complexity and constrained resources – in a speech on September 29, 2008 at the National Defense University.[4] His speech highlighted the challenges associated with employing complex platforms and capabilities against an ever-changing set of missions and requirements. These challenges apply clearly to current and prospective ISR investments.

Given this complex environment, the Task Force believes that OR can strengthen end-to-end analysis associated with coupling long-term investment strategies, requirements, operational concepts, and operational plans. The Task Force received 22 briefings and questioned representatives of the Services, various operational agencies, planning and evaluation specialists from PA&E, and program management cadres within the DoD and Office of the Director of National Intelligence (ODNI). The Task Force also spoke with industry representatives who provided useful insights regarding ways in which OR can be used for strategic investment planning and in support of missions associated with specific lines of business. Appendix C lists the organizations that briefed Task Force.

The Task Force believes its broad approach to the TOR tasking provides the USD(I) with insights pertinent to a full range of ISR investment needs, ranging from long-range technology strategy to the efficient use of existing ISR resources. In regard to methodology, the Task Force focused principally on the resources available to conduct OR, instead of reviewing specific programs, a task beyond the means and time available for this effort. The Task Force looked at the extent to which these resources reflected the application of standards and the manner in which the results appeared to be employed by the respective organizations. This approach allowed the Task Force to infer a lack of OR use and standard processes and practices in ISR investment decision making. Inquiries into specific programs and investments could more precisely establish the manner and competence with which OR has been or is being employed.

[4] As delivered by Secretary of Defense Robert M. Gates, Washington, D.C., Monday, September 29, 2008. See: http://www.defenselink.mil/speeches/speech.aspx?speechid=1279

CHAPTER 2: THE TASK FORCE'S UNDERSTANDING OF OPERATIONS RESEARCH

Joint Chiefs of Staff Publication 1-02 (JCS Pub 1-02), *Department of Defense Dictionary of Military and Associated Terms*, defines Operations Research as "The analytical study of military problems undertaken to provide responsible commanders and staff agencies with a scientific basis for decision on action to improve military operations." Operations Research may also be referred to as Operational Research or Operations Analysis.

The Task Force received numerous briefings from Operations Research (OR) practitioners from a variety of organizations. Information gleaned from these briefings convinced the Task Force that the application of structured decision making tools and processes can provide significant assistance to the decision maker in the analysis of complex operational and investment decisions. OR can increase significantly the decision maker's insight and also improve the quality of the debate around the key decision issues.

OR CAN SIGNIFICANTLY INCREASE THE DECISION MAKER'S INSIGHT AND IMPROVE THE QUALITY OF DEBATE AROUND KEY DECISION ISSUES.

As noted in Chapter 1, the Task Force's understanding of OR – decision support analysis based on information collected and analyzed using the scientific method – broadly encompasses analysis of operations as well as strategic technology, investment, and acquisition planning in support of operations. OR practitioners have a variety of tools at their disposal. These tools consist of applied mathematical techniques such as statistical and data analysis, linear and non-linear regression, queuing theory, stochastics, as well as linear and non-linear programming. Additionally, practitioners have access to a variety of off-the-shelf models and simulations, as well as commercial software packages. For those problems where off-the-shelf tools are not practicable, OR practitioners can develop models and simulations using the techniques listed above.

It is the Task Force's opinion that OR should be used as an important component of an analytical approach to decision making. Information provided to the Task Force by briefers also assisted in formulating a picture of what good OR practices should entail.

2.1 Desired Attributes of Operations Research

The Task Force viewed OR as a scientific method; a method based on gathering empirical and measurable evidence or data and subjecting it to repeatable principles of reasoning. These principles of reasoning often involve the formulation and testing of hypotheses. This process requires a thorough identification of the problem to be solved, which includes advance agreement by decision makers on the objective function,[5] metrics, data provenance, and the study assumptions and boundary

[5] The Task Force considered at length the manner in which valid objective functions could be employed in the OR analysis of ISR investments. We considered established "attrition models" by which the effectiveness of a system is assessed as a function of the extent to which it contributes to the attrition of adversary forces, as well as the extent to which an ISR system can reduce the level of uncertainty

conditions – all of which are keys to solid analysis. The best use of OR occurs when employed by a team composed of operators and analysts capable of investigating the entire problem and conducting analyses without bias. In so doing, a good OR team will seek agreement on assumptions and objective functions, and advocacy from all key stakeholders up-front, and continue to cultivate that advocacy throughout the analytic process.

2.2 Advantages of Operations Research

Good analysis involves all decision makers and stakeholders from the very beginning. This involvement includes, but is not limited to, agreement on the actual questions to be answered by the analysis as well as all assumptions and constraints pertinent to the decision to be made. Such involvement by senior leadership facilitates periodic reviews and assessments of progress, and provides the opportunity to redirect or refine guidance to the study team if needed. A repeatable process based on the scientific method enhances the likelihood that the analysis will be objective and the results will provide the organizational leadership with the analytic underpinnings to make sound, informed decisions. Structured analyses will provide decision makers with clear traceability from study requirements to final results. In addition, analyses can often illuminate problems previously unidentified or unknown to senior leadership.

2.3 ISR Decisions to which Operations Research is Applicable

OR readily lends itself to assisting organizational leadership in making high-value decisions in which significant consequences and resources are at stake. Such decisions involve risk and uncertainty, and are often driven by complex requirements involving multiple stakeholders with competing objectives. These analytic processes can be used across all ISR disciplines focused on a prioritized list of current and future threats and missions. Tailored approaches can be applied to the entire intelligence cycle including system requirements analysis, asset tasking, data collection, processing and exploitation, as well as intelligence analysis.

2.4 Conditions under which Operations Research can be Institutionalized

OR cannot be institutionalized without strong commitment, support, and advocacy from senior leadership, which is assumed to have the authority to implement decisions influenced by the OR process. The senior leadership to which the Task Force is referring includes those individuals responsible for the outcome of the decision process, that is, those that will make the decision based upon various inputs.

This approach requires senior leadership to assemble and sustain a critical mass of OR resources to include a well-trained and adequately-funded staff. OR professionals need career development and prospects. The Task Force found noteworthy the approach

---

regarding a question of intelligence interest. The Task Force recognizes that establishing objective functions will continue to challenge decision makers, although we believe good work has been done to establish Key Performance Parameters (KPPs) for many ISR systems.

employed by the Army (TRAC) in building and sustaining a cadre of competent OR professionals.

The essential requirement for effective OR in support of decision making is the support, confidence, and early participation of the decision maker. The decision maker must ensure that the question asked, the assumptions made, the objective function defined, and the metrics chosen all meet the needs of the decision process.

A decision maker who demands good analytical support for decisions will get it.

This page is intentionally blank.

CHAPTER 3: OPERATIONS RESEARCH – HISTORICAL CONTEXT

The Task Force examined, at a high level, OR from a historical perspective. The Task Force looked at OR in the context of its development and use principally in the U.S., with an understanding that the OR discipline is not confined to the U.S. This review of OR's historical context (from World War I to present day requirements and acquisition processes) provided the Task Force with useful insights regarding the need for standards, involvement of operators alongside analysts, and senior leadership commitment.

World War I

During World War I civilian scientists on both sides of the Atlantic joined together to apply scientific methods to defeating the forces of the Triple Alliance, specifically the submarine threat. In 1915, after reading one of Thomas Edison's speeches on military preparedness published in *The New York Times*, Secretary of the Navy Josephus Daniels came upon the idea of the Naval Consulting Board. After discussions with Edison, it was determined that a board consisting of the brightest scientific and industrial minds in the country would be convened under Edison's chairmanship. Its primary purpose was to advise the Navy on systems acquisition. Edison, fully aware of the threat the U-boat posed to merchant shipping and Britain's survival, focused his talents on developing systems and tactics to be used in the fledgling anti-submarine warfare (ASW) effort. He employed many applied mathematics techniques, such as time-motion analysis to understand the effects of zigzagging in disrupting fire control solutions; graphical and statistical data analysis to understand U-boat operations; threat system assessments; and military wargaming.[6] That same year the British Admiralty instituted the Board of Invention and Research to encourage the naval service to solicit expert technical assistance in solving tactical problems. Chaired by Sir Jackie Fisher, former First Sea Lord, it was comprised of numerous scientists and divided into six science and technology sections. Of these, Section II: Submarines and Wireless Telegraphy, was the most important. In the two years of the Board's existence, its members evaluated over 41,000 submitted inventions.[7]

British use of OR during World War II

Operations Research (Operational Research in the United Kingdom and Canada) was formally established in the late 1930's at a time when Adolf Hitler announced his intentions to create a Luftwaffe equal to the combined air forces of Britain and France. To defend Britain against an attack from Germany, the British government established radar installations along the coast to provide the Royal Air Force (RAF) with early warning of incoming German strikes. However, in 1938, tactical exercises demonstrated that the system fell short of its operational requirements. A.P. Rowe, Superintendent of

[6] Scott, Lloyd N., *Naval Consulting Board of the United States*, Government Printing Office, Washington, D.C., 1920.

[7] Hackmann, Willem, *Seek & Strike: Sonar, Anti-Submarine Warfare and the Royal Navy 1914-54*, Her Majesty's Stationary Office (HMSO), London, 1984.

the Bawdsey Research Station, proposed that research into operational aspects rather than technical aspects of the system should be conducted – thus coining the phrase "operational research."[8, 9] These studies led to the establishment of formal techniques of command and control of fighter versus bomber operations in the Battle of Britain.

Operational Research spread to other organizations throughout the British military establishment. Operational Research sections in the Coastal Command and the Admiralty were responsible for developing convoy procedures to keep Britain's lifeline to North America open, perfecting the use of airborne radar in detecting U-boats, and shutting down the U-boat transit lanes from bases along the Bay of Biscay to open ocean operating areas.[10, 11, 12] Other sections were established to support the Army (primarily the Antiaircraft Command), as well as RAF Bomber Command where studies in navigation accuracy, radar performance, and the employment of chaff contributed to improved bombing accuracy and aircraft survivability during the area bombing of German cities.[13] Recent studies in the United Kingdom indicate that the area bombing campaign undertaken by Bomber Command in 1942, and espoused by the Commander-in-Chief, Sir Arthur Harris, may have been validated by the misapplication of operations research and was of less impact on the German war economy and civilian morale then was believed at the time.[14]

U.S. use of OR during World War II

American scientists became involved in the war effort in June 1940 with the formation of the National Defense Research Committee (NDRC) and the subsequent formation of the Office of Scientific Research and Development (OSRD) under Dr. Vannevar Bush.[15, 16] Like the Naval Consulting Board of World War I, both the NDRC and OSRD were comprised of some of the brightest minds from academia and industry. Upon the entry of the United States into the war, the Navy took the lead in establishing operations research organizations. In March 1942 the Mine Warfare Operations Research Group (MWORG) was established at the Naval Ordnance Laboratory. MWORG went through numerous reorganizations throughout the war, and ultimately supported the Army Air Forces XXI Bomber Command in planning Operation Starvation in the Far East – the

[8] Cunningham, W. Peyton, et al, "Of Radar and Operations Research: An Appreciation of A.P. Rowe (1898-1976)," *Operations Research*, Volume 32, Number 4 (July-August 1984), pp. 958-967.

[9] Larnder, Harold, "The Origin of Operational Research," *Operations Research*, Volume 32, Number 2 (March – April 1984), pp. 465-475.

[10] Falconer, N., "On the Size of Convoys: An Example of the Methodology of Leading Wartime OR Scientists," *Operational Research Quarterly (1970-1977)*, Volume 27, Number 2, Part 1 (1976), pp. 315-327.

[11] McCue, Brian, *U-boats in the Bay of Biscay: An Essay in Operations Analysis*, National Defense University Press, Washington, DC, 1990.

[12] McCloskey, Joseph F., "British Operational Research in World War II," *Operations Research*, Volume 35, Number 3 (May – June 1987), pp. 453-470.

[13] Ibid.

[14] Kirby, M. and R. Capey, "The Area Bombing of Germany in World War II: An Operational Research Perspective," *The Journal of the Operational Research Society*, Volume 48, Number 7 (July 1997), pp. 661-677.

[15] Meigs, Montgomery C., *Slide Rules and Submarines: American Scientists and Subsurface Warfare in World War II*, National Defense University Press, Washington, DC, 1990.

[16] Fortun, M and S.S. Schweber, "Scientists and the Legacy of World War II: The Case of Operations Research (OR)," *Social Studies of Science*, Volume 23, Number 4 (November 1993), pp. 595-642.

mining of Japan's Inland Sea. During the campaign, more than 1,000 ships were damaged or sunk, including over 100 naval vessels, greatly reducing Japanese shipping in this area.[17, 18]

When the U.S. entered WWII, the loss of shipping to U-boats in the Atlantic rapidly reached catastrophic proportions. In March 1942, Captain Wilder D. Baker, Commander of Destroyer Squadron 31 formed the Anti-Submarine Warfare Unit in Boston. It did not take the Unit long to conclude that the major cause of America's poor ASW campaign was inadequate tactical doctrine. By the end of March, Baker approached Professor Philip M. Morse of MIT and asked him to undertake the role of lead analyst in what would be called the ASW Operations Research Group (ASWORG). One of the first issues ASWORG tackled was the problem of search, by ship or plane, for submarines and warships. Its first memorandum, published 1 May 1942, was titled "Preliminary Report on the Submarine Search Problem." The recommendations in this report were immediately put into effect and improved the tactics of convoy protection and the search for U-boats. As successes grew, ASWORG gradually undertook studies in the Pacific, first on submarine operations, then naval air activities, and finally on all aspects of operations.[19, 20] During this time Operations Research was successfully employed in both the Army and Army Air Forces as well.[21]

OR and the Cold War

After World War II, acceptance of Operations Research techniques became widespread throughout industry leading to the establishment of professional societies in the United States, United Kingdom, and Canada. OR's utility to military operations continued with the introduction of Federally Funded Research and Development Centers (FFRDCs), first with the Center for Naval Analyses, then Project Air Force, and then followed quickly by Lincoln Laboratories.[22] At the outset of the Cold War, Operations Research found new missions, most notably in the development of the Single Integrated Operational Plan (SIOP), a plan and planning process to determine the use of U.S. nuclear weapons in the event of nuclear war. The first such plan was submitted in 1960. Operations Research tools are still employed to study blast, thermal, and radiation effects, as well as mission-asset allocation.[23] However, since 1983 this capability has diminished significantly.[24]

---

[17] Shortley, George, "Operations Research in Wartime Naval Mining," *Operations Research*, Volume 15, Number 1 (January-February 1967), pp. 1-10.

[18] McCloskey, Joseph F., "U.S. Operations Research in World War II," *Operations Research*, Volume 35, Number 6 (November – December 1987), pp. 910-925.

[19] Tidman, Keith R., *The Operations Evaluation Group: A History of Naval Operations Analysis,* Naval Institute Press, Annapolis, MD, 1984.

[20] Morse, Philip M., "The Beginnings of Operations Research in the United States," *Operations Research*, Volume 34, Number 1 (January – February 1986), pp. 10-17.

[21] Shrader, Charles R., *History of Operations Research in the United States Army, Volume I: 1942-1962*, United States Army, Washington, DC, 2006.

[22] U.S. Congress, Office of Technology Assessment, *A History of the Department of Defense Federally Funded Research and Development Centers*, OTA-BP-ISS-157, U.S. Government Printing Office, Washington, DC, 1995.

[23] Pringle, Peter and William Arkin, *SIOP, the Secret U.S. Plan for Nuclear War*, Norton Publishing, New York, New York, 1983.

Also in the early 1960s, Secretary of Defense Robert McNamara, convinced that the Secretary of Defense should control the evaluation of military needs, established the Systems Analysis discipline as an administrative tool to estimate the required quantity and performance of forces and weapons in relation to their mission and costs known as the Planning, Programming and Budgeting System (PPBS).[25] The effort was not entirely successful – "McNamara's systems analysis instilled structure and discipline, too, but in the Pentagon, it was applied in an atmosphere of competition and distrust. He introduced systems analysis explicitly to obtain control over Service programs. The mutual trust and regard in the fleet were impossible in Washington. Decision making by analysis took on a hostile, jaded, and onerous cast."[26]

Goldwater-Nichols Act

In 1986, the Goldwater-Nichols Department of Defense Reorganization Act called on the Joint Chiefs of Staff to advocate the effectiveness of joint operations. In so doing, it tasked the Vice Chairman to chair a special council on military requirements known as the Joint Requirements Oversight Council (JROC) to provide programmatic recommendations to the Chairman of the Joint Chiefs for consideration and submission to the Secretary of Defense.[27] This Act positioned the Joint Staff to be the only military body to address force integration and to resolve inter-service conflict with a total organizational perspective. It assigned the Chairman of the Joint Chiefs of Staff (CJCS) with determining strategy, military requirements, programmatic prioritization, and budget recommendations. The fact that the Joint Staff is comprised of military personnel avoided the problems encountered with the McNamara PPBS.[28] In 1994, Admiral William Owens, Vice Chairman of the JCS established the Joint Warfighting Capability Assessment (JWCA) process to provide better advice to the CJCS by increasing the involvement of the Combatant Commanders and the Services in the JROC process. The JWCA process "examines relationships and interactions among warfighting capabilities and identifies opportunities for improving joint effectiveness."[29] Each team is comprised of representatives from the Unified Commands, OSD, and the Services and is chartered with assessing areas where capabilities gaps or duplication may exist, as well as determining where technologies may be brought to bear. The JWCA findings are then presented to the JROC for consideration. The process has been instrumental in providing a deeper analytic underpinning to the recommendations from the CJCS to the Secretary.

---

24 Technology Strategies & Alliances, Prepared for the Office of Net Assessment, Maintaining Advantage in a Multi-polar Nuclear World: Declining Resources Final Report, December 2007.

[25] Enthoven, Alain and K. Wayne Smith, *How Much is Enough?: Shaping the Defense Program 1961-1969*, RAND Corporation, Santa Monica, CA.

[26] Hughes, Wayne P., "Navy Operations Research," *Operations Research*, Volume 50, Number 1 (January – February 2002), pp. 103-111.

[27] Owens, William A., "JROC: Harnessing the Revolution in Military Affairs," *Joint Forces Quarterly*, Summer 1994, pp. 55-57.

[28] Turcotte, Dr. William E., "Service Rivalry Overshadowed," *Airpower Journal*, Fall 1996, pp. 28-33.

[29] Statement of General Joseph W. Ralston, The Vice Chairman of the Joint Chiefs of Staff, to the Senate Armed Services Committee, 10 March 1999.

To bring the historical context up to date, there are two Major Acquisition Program examples in which OR tools were used effectively. These examples may be instructive for ISR investment decision making.

Joint Direct Attack Munition Program

Operations Research techniques were the key element in the process that led to the definition of the requirements and optimization of the trade space for the Joint Direct Attack Munition (JDAM).

Following Desert Storm, a review of lessons learned identified the fact that adverse weather or limited visibility of the ground caused by blowing sand, smoke from ground fires, fog and cloud cover limited the employment of precision guided weapons. These same conditions also limited the delivery accuracy of unguided weapons when delivered from medium and high altitudes.

Data from Desert Storm was analyzed by a team of operators and requirements officers from the Tactical Air Command and the Strategic Air Command (later combined into Air Combat Command). This process was facilitated by Glenn Kent of the RAND Corporation. The team used optimization techniques to identify the needed key characteristics of the new weapon and sensitivity analysis to identify the available trade space during acquisition.

The key characteristics included reduced sensitivity to weather, reduced crew workload (laser weapons required human-in-the-loop through most of the flight time), launch and leave, and reduced cost over existing precision weapons. Air Force Research Laboratory personnel then joined the process and various guidance schemes were traded-off against the key characteristics before arriving at a guidance scheme which featured GPS-aided inertial guidance.

The end-game set of requirements and technology trades defined an Adverse Weather Precision-Guided Weapon which became the JDAM following industry competition.

Joint Strike Fighter

Operations Research methodologies were critical to the Joint Strike Fighter (JSF) Requirements Process, Technology Development Activity and affordability trades. The JSF program was initiated when OSD was forced to cancel three separate fighter development activities with very diverse characteristics. During the first phase of the program, called the Joint Advanced Strike Technology Program (JASTP), a joint process involving service war-fighters and technologists was employed which identified the key characteristics of a next-generation strike system for the USAF, USN, USMC and Royal Navy.

Structured analysis of the needs against scenarios defined by the Joint Staff led to a set of key characteristics, associated sensitivity analysis, and a Concept of Operations.

Industry primes then entered the process and began identifying design space around the key characteristics. System design attributes were then analyzed against the key characteristics and cost and displayed in carpet plots which allowed senior Service and OSD decision makers to understand cost as an independent variable.

This process resulted in the Services coalescing around a set of requirements that allowed satisfaction through a "Family of Airplanes" concept that allowed for a high degree of commonality and program affordability.

As the industry prime contractors refined their design concepts, they were evaluated by service warfighters and maintainers in simulation activities conducted by the Program Office. This simulation used several core tools provided by and maintained by the Program Office. This provided configuration control and increased confidence in the simulation results.

As the program entered the System Design and Development (SDD) phase, this simulation activity and the carpet plots provided decision makers the tools to continue to make system trades for program affordability.

3.1 General Lessons Learned from Historical Experience

There are two important lessons to be learned from the historical examples cited above. The first lesson is that, for Operations Research to have a positive impact, the analyst should be imbedded in or closely connected to the decision maker's organization. In 1941, in a note prepared by Professor P.M.S. Blackett entitled "Scientists at the Operational Level," he stated, "The object of having scientists in close touch with operations is to enable operational staffs to obtain scientific advice on those matters which are not handled by the Service technical establishments." In addition, "Operational staffs provide the scientists with the operational outlook and data. The scientists apply scientific methods of analysis to these data, and are thus able to give useful advice."[30]

While outstanding work was done by organizations on both sides of the Atlantic during World War I, they were never accepted by the Services they were established to assist. In the case of the Naval Consulting Board, they failed to have any great effect on the conduct of naval operations because they were a civilian organization that reported directly to the Secretary of the Navy. Not once throughout the course of the War did the Board establish contact with the operational commanders in the field.[31]

The widespread success of operations research in World War II can be attributed to the close relationship the analyst had with the warfighter. In most cases, the analyst was deployed to support a specific command in a specific theater of operations. Data were readily available at the source, and interactions with staff personnel enabled the analyst

[30] Air Ministry, *The Origins and Development of Operational Research in the Royal Air Force*, Her Majesty's Stationary Office, London, 1963.

[31] Whitmore, W.F., "Edison and Operations Research," *Operations Research*, Volume 1, Issue 2 (February 1953), pp. 83-85.

to personally demonstrate the utility of operations analysis through near-immediate results.

During the 1960s, McNamara's "Whiz Kids" failed to take notice of the successes enjoyed by Operations Research groups during World War II as a result of their close alignment with the decision maker – an alignment not present with operators – thereby alienating the Services. The result was Service "stiff-arming" of the PPBS process and its ultimate failure. With the JROC and JWCA processes, control of the analytic process, regardless of its rigor, has been returned to the DoD.

The second lesson to be learned is that Operations Research can be misused if the analysis team is not free from bias. The case in point is the deliberate use of analysis to support "Bomber" Harris' position to continue area bombing of German cities during World War II rather than redirecting the forces at his disposal to conduct precision bombing of military targets (airfields, shipyards, U-boat pens, etc.). As early as the autumn of 1944, Strategic Bombing Surveys were initiated by both the United States and Britain. These surveys revealed that neither civilian morale nor the German economy were as severely impacted as the Bomber Command Operational Research Section (ORS) claimed. In fact, it is interesting to note that British analysts stated that the effects of the London Blitz were not long-lasting. Analyses conducted by the ORS were biased because the analysts were influenced by Harris' strong personality and the refusal to depart from pre-war concepts derived from the Japanese attack on Shanghai in 1931 and the obliteration of Guernica during the Spanish Civil War by the German Condor Legion.

This page is intentionally blank.

CHAPTER 4: RELEVANCE OF OPERATIONS RESEARCH TO INTELLIGENCE, SURVEILLANCE, AND RECONNAISSANCE

The Task Force was tasked by the USD(I) to examine how OR can be used to support ISR decision making. Although OR may have wider applicability in broader investment decision making, the focus on ISR is driven by several factors that make it both relevant and challenging.

A more consistent scientific and quantitative approach to evaluation could assist the USD(I) and the Director of National Intelligence (DNI) with many key investment issues. Below are a few examples of past and current issues that illustrate the trade-offs that can be illuminated by the proper application of OR.

4.1 Current ISR Issues that can Benefit from the Application of OR

In the current conflicts, full motion video (FMV) collection has proven to be a very valuable intelligence input. However, studies suggest that a large number of UASs, bandwidth and exploitation resources would be required to meet all the anticipated requirements for FMV. A program known as the Wide-Area Airborne Sensors is designed to collect a wider field persistent view of the battle space as a way of capturing information. Understanding the cost/benefit of these programs and their optimum mix would be very valuable at this juncture.

With the focus on current operations, resources allocated to science and technology (S&T) collection and exploitation have been reduced. S&T data is essential for identifying new adversary capabilities and determining approaches to collect against them. The lack of S&T data creates vulnerabilities in the United States' ability to counter new threats and collect information against adversaries when they are using new technologies. The key to making acquisition decisions is understanding the appropriate balance between S&T and current collection capabilities to ensure a continued ability to adapt and understand new threats. Acquisition delays and failing national systems programs require key investment decisions. These decisions weigh trading lower risk and lower capability short term solutions against higher risk and higher capability longer term solutions. Prudent investment decisions should be based on the optimization of factors such as how UASs and manned aircraft can work with national systems to provide support to national and military needs over the next 10 years.

In the Global War on Terror, information about individuals can be more important than information on military equipment. This has given rise to the desire to collect and use biometric data on the battlefield. However, assessing the value of this information and how it will be used versus the value of other kinds of collection will be important. In addition, as investments in biometrics increase, OR should prove helpful in ensuring that investments are made in a balanced fashion across the entire intelligence cycle (i.e., requirements, tasking, collection, processing, exploitation, dissemination).

4.2 Past ISR Investment Issues that have Benefited from the Application of OR

THE SUCCESSFUL USE OF OPERATIONS RESEARCH REQUIRES SOUND ASSUMPTIONS

The requirements process for the Future Imagery Architecture (FIA), the Integrated Overhead SIGINT Architecture (IOSA), the recent U-2 / Global Hawk trade-off decision, and the aforementioned HVT Study employed OR in a significant manner. In all of these cases, there was a clear mandate from decision makers for the use of OR, general consensus in advance on the objective function, a broad base of community involvement, and sound methodology. The Task Force notes, however, that the use of OR cannot guarantee successful program implementation, particularly if technical capabilities for implementation assumed to exist during analysis are not present during design and development. As always, the successful use of OR requires sound assumptions.

4.3 Complications in Applying OR to ISR Investment Issues

ISR programs are complicated by several factors that make investment decision making difficult.

To add value for a decision maker, information has to be collected, processed, exploited and disseminated. Typically the programs that operate in each of these stages are controlled by different organizations. Thus, in evaluating an investment decision and its impacts, the OR analyst must be careful to look across program elements and across organizations. In many cases, the funding streams to support a program may include both Military Intelligence Program funding and National Intelligence Program funding. The first is controlled by the Secretary of Defense under Title 10 authority, the latter by the DNI under Title 50 authority.

Most ISR systems are used to support a broad variety of missions. For example, the same UAS may be tasked to support force protection, battlespace awareness, and targeting. National systems are often used to support decisions ranging from national strategy and policy to striking individual tactical targets. Evaluating the value of a system requires looking at its impact on all of the missions it might support.

Most major ISR systems are complex and expensive, which generally results in both a long development time and a long design life. These factors often result in an ISR system operating for more than 20 years after the requirements for the system were initially developed. During that time period, threats may change substantially and the types of uses for which the system was initially designed may become less relevant. To make effective investment decisions throughout the life cycle of ISR assets requires a broad view of what the future may hold so that the system can be evaluated against all potential future uses.

4.4 Challenges in Applying OR to ISR Issues

The proper use of OR to examine ISR investment decisions objectively can address many of the complications identified above. However, applying OR to ISR issues has several key challenges. The primary challenge is to answer the question: "What is a pound of ISR worth?"[32] That is, what is an objective measure of the value of ISR information? Unlike lethal weapon systems, ISR does not directly destroy enemy targets. Instead, it produces knowledge that informs decision makers as they make a broad range of decisions. This issue makes it difficult to agree on the objective function against which OR is performed. To evaluate what this knowledge is worth requires some understanding of how decisions are made and what contribution ISR provides to those decisions. Although there are no universally-accepted measures that have been developed to address this issue, there are some approaches that have been used to measure the impact of a specific ISR contribution in specific circumstances.

The most common ISR metric used for national systems evaluation is "User Satisfaction." User Satisfaction allows analysts to quantify the impact of an ISR system by measuring the fraction of collection requirements it is able to meet. Using this metric, trade-off decisions can be made between architectures or systems by assessing the amount of "User Satisfaction" they produce versus the cost of the system. Unfortunately, this approach is heavily dependent on the validity of the requirements provided, and it assesses only the relative value – not the absolute value – of the systems being traded. That is, it does not identify how much is enough or the direct impact of this information on outcomes. It is also hard to evaluate systems from different collection disciplines, since user requirements are generally specified by discipline.

Other OR approaches attempt to characterize the effect of ISR on outcomes by trying to quantify the effect of ISR on attrition of enemy forces, a traditional measure of effectiveness. There have been many different ways of addressing this challenge, with most suffering from strong limitations. Typically the tactical effect of finding, classifying, and locating a target can be related to the rate and probability of killing the target. These "sensor-to-shooter" models capture some of the tactical impacts of ISR, but do not capture the value of situational awareness or the value of ISR in non-combat situations.

Attempts to capture the wider value of ISR are often stymied by the view held by many practitioners that ISR is a craft that is too complex to be characterized. This view makes it difficult to address quantitative measures for system performance. As a result, the community will have to continue to study the impact of ISR on decision making and outcomes to better characterize its value. The development of community accepted metrics and the agreement by decision makers on objective functions in advance of an OR effort is essential to the successful application of OR.

[32] As quoted by the Honorable James R. Clapper, Jr., Under Secretary of Defense for Intelligence.

This page is intentionally blank.

CHAPTER 5: CURRENT OPERATIONS RESEARCH PRACTICES (TOR TASKS 1 AND 2)

Given the Task Force's understanding of OR, its attributes, the conditions under which it can be employed successfully, and in response to TOR Tasks 1 and 2, the Task Force looked at several specific examples of OR from a broad array of organizations across the Department of Defense, the Intelligence Community (IC), and industry. Given the time available to the Task Force, it was not possible to explore the entirety of OR and OR-related activities in the Department and the IC. However, the representative sampling, while not exhaustive, provided the Task Force with a good opportunity to assess the extent to which OR is institutionalized, how it is being employed, and how its employment might be improved. This approach should allow the USD(I) to infer the extent to which OR is being used to support ISR investment decisions. A list of organizations that made presentations is located in Appendix C.

The Task Force received presentations from entities from each of the Services, from the National Geospatial-Intelligence Agency (NGA), the National Security Agency (NSA), the National Reconnaissance Office (NRO), ODNI, OSD PA&E, and others, including industry. Edge Consulting, Inc. provided a briefing on their ongoing work regarding ISR in support of the search for High Value Targets. The Navy has pockets of excellence where OR is conducted, and most importantly has a strong curriculum for OR at the Naval Postgraduate School (NPS). The Army, which has made the most consistent commitment to institutionalizing OR, uses the NPS to great advantage to educate their OR workforce. The Air Force also maintains an OR degree program at the Air Force Institute of Technology (AFIT). The most robust OR at the OSD level is performed by PA&E. Of note, it is now almost exclusively outsourced with little internal capability. The Intelligence Community brought multiple examples to the Task Force of the ongoing decline in OR capability in support of planning, programming, and materiel acquisition. FedEx presented a compelling example of a model used in the private sector for OR institutionalization and application. Finally, the expertise embodied in the MORS, a professional organization dedicated to defense-related OR, represents a unique resource for the Department.

…THE APPLICATION OF OR IS GENERALLY UNCOORDINATED, SOMETIMES ORGANIZATIONALLY BIASED, INCONSISTENTLY RESOURCED, AND NOT WELL INTEGRATED…

From an overarching perspective, there are some findings that became clear to the Task Force. While OR is used widely across the Services, especially in support of operations, the application of OR is generally uncoordinated, sometimes organizationally biased, inconsistently resourced, and not well integrated into processes and programs. There is no strong central champion for OR at the Department level, and therefore there is no clear ability to identify and support best practice transfer, or to capture, document, or share OR lessons learned. Consequently there is not a jointly accepted OR review or accrediting organization. While Federal Acquisition Regulations require OR for Major

Acquisition Programs, the application of OR in response to this requirement is inconsistent in level of effort and quality, and often requires rework when submitted for OSD review.

Efforts to support and resource OR have generally been in decline in the Department, but this trend is even more stark in the Intelligence Community. In the cases of the NGA, NSA, and the NRO, it was clear that OR capabilities for programming and acquisition decision making are atrophying rapidly. The Task Force did note that in contrast, these same agencies use significant and effective OR in support of current operations. Notably, there is a nascent analytic capability in the Defense Intelligence Operations Coordination Center (DIOCC), and while its parent organization, the National Intelligence Coordination Center (NIC-C) was originally intended to have a strong OR capability, that effort has not been resourced. Finally, there is no evidence of OR leadership or direction from the staff of the Director of National Intelligence, nor any significant OR capability noted on that staff. The recent decision to terminate the Integrated Concepts Development Office (ICDO) is further evidence of the apparent decline of interest in OR at the ODNI.

Of the many presentations given to the Task Force, two stood out in a positive manner. First, the Army has continued to support a historically strong OR program. The Army has developed and sustained an officer career field for OR which includes opportunities for advanced degrees and promotion. The Army has continued to support institutions that promulgate OR best practices, including the Army Training and Doctrine Command (TRADOC) Analyses Center (TRAC). The Army has traditionally maintained a strong champion on the Army Staff with direct access to the most senior leadership. The Army uses OR both in support to current operations, (with deployed OR specialists embedded with units in theater) as well as to support strategic planning, programming, materiel acquisition, and the generation of requirements.

Second, a model which may have direct applicability to the Department is the application of OR in the private sector, as evidenced by FedEx. FedEx has a strong and consistent commitment to OR, and uses OR extensively in its decision making, both for daily operations and long-term strategic planning. The FedEx corporate model is a very small (approximately 200 people) headquarters overseeing multiple robust independent operating units. FedEx has a hybrid model for OR which is both centralized and distributed. A small OR group of approximately eight to ten people provides corporate-level OR support, and each of the line operations maintains their own OR entities. OR is valued as part of the culture at all levels of the organization, but also seen through a pragmatic lens. While OR is often used to great advantage, OR entities within FedEx have no line authority. The leader of the corporate-level OR organization made it clear that in no case would OR be utilized if there was not clear leadership support, and articulated that even the most well-executed OR would be of no value if the decision maker did not support it.

FedEx uses OR at the corporate level to determine which lines of business are appropriate, how much capability is required to support each line of business, and what FedEx should be prepared to invest in support of those lines of business. The FedEx corporate OR organization does not provide decision support at the operational level within the separate lines of business, but does directly support decision making for the C-level (CEO, CFO, CIO, etc.) corporate leadership, and can assist the C-level leaders with OR-related expertise as they review the analytics submitted by the operating units. The corporate OR entity also provides some measure of oversight to the practice of OR in the operating units to ensure quality and consistency. Within the line operating units, OR is used to optimize efficiency, to test alternative operating concepts, to guide investment priorities, and to support other decisions as management deems necessary.

THERE IS NO CHAMPION ADVOCATE IN THE DEPARTMENT, NO COHERNT STRATEGY, AND NO ORGANIZATION OR STAFF ELEMENT IDENTIFIED TO PROVIDE LEADERSHIP IN THIS DOMAIN.

It was clear to the Task Force that OR is used, in some form or another, in every Service and the intelligence Combat Support Agencies. It was also clear that save for a few "points of light," OR is in decline and not universally valued in decision making, especially at the strategic level, and with respect to investment decisions and systems acquisition. There is no champion advocate in the Department, no coherent strategy, and no organization or staff element identified to provide leadership in this domain. Moreover, while the IC conducts truly world class OR in determining the daily allocation of scarce collection resources against myriad increasing requirements, there has been an astounding decay in the ability of these same agencies to conduct OR in support of planning, programming, and acquisition. In the case of both the Army and FedEx, however, the Task Force identified some significant best practices that may have immediate use as models for a way ahead in OR to support ISR investment decisions.

This page is intentionally blank.

CHAPTER 6: ISR TEST CASE(S) ATTRIBUTES (TOR TASK 3)

In approaching TOR Task 3, which is to recommend an ISR test case in which OR might be used to reach a better decision, the Task Force found it useful to examine the attributes that possible test cases should possess. It is unlikely that every possible test case will be characterized by every attribute discussed herein, but the Task Force is persuaded that successful cases should be characterized by all or most elements described in the sections below.

The Task Force considered several test cases and believes two cases in particular would serve the USD(I) in establishing ways to employ OR effectively in support of ISR. These cases are:

- Biometrics technology investment and architecture
- Balance intelligence cycle investment

These test cases are discussed in more detail in Appendix D.

6.1 Importance

The Task Force considers it critical that potential test cases be viewed by ISR decision makers as involving issues of great importance – certainly to the ISR community and especially to USD(I) and DNI leadership. If the issue(s) chosen to examine with OR do not meet the common sense test of importance, they are unlikely to receive the kind of leadership "buy-in" and resource support that will be required for success. While it is true that the Task Force believes that OR could significantly contribute to ISR decisions for a multitude of operational, architectural, and investment or acquisition issues, we believe that it is the latter area (investment/acquisition of significant resources) that will provide the most unique benefit to the USD(I) and DNI missions.

6.2 Leadership Commitment

Closely related to, and even driven by, the *importance* attribute described above, is the issue of leadership commitment. If any selected test case is to successfully demonstrate the value of OR in ISR decision making, USD(I) (and probably DNI) leadership must be fully committed to the case and the process. The following elements of leadership commitment to the test case must be present and evident:

1. Leadership must ensure that stakeholders agree to the terms of reference and assumptions for the test case. It is critical that the questions to be answered and assumptions to be used are clear and properly framed.
2. The test case sponsor must commit to providing the resources necessary to seeing the test case through to completion, and should provide a "time-certain" date when the project is to be completed if it is to have value in decision making.

3. The test case sponsor must commit to using the OR results in support of the decision. While it is not realistic to believe that an important ISR investment decision will be driven solely by the OR analytical results, it should be clear to stake-holders that the results were carefully considered in the decision-making process. This is particularly true if, for some reason, the ultimate decision diverges significantly from the direction suggested by the OR analysis, and it would be helpful if the decision maker provided feedback as to how the OR analysis was used and the degree to which it was helpful and/or could have been more useful.

6.3 OR Process Credibility

All decision makers and stake-holders involved with the chosen test case must be convinced of the credibility and integrity of the OR process, even if they ultimately might disagree with the results. This means that everything used in the test case OR process must be credible and transparent – terms of reference, questions to be answered, data to be used, OR tools to be applied, OR practitioners to be utilized, and the decision(s) intended to be supported by the process. In addition, decision makers and stake-holders must agree in advance on the objective functions against which the analysis is conducted. If the initial test case(s) conducted do not "ooze" credibility, the prospects for the institutionalization of OR for making ISR investment decisions are slim.

6.4 Test Case Scope

The issue of test case scope is a challenge. The Task Force has already highlighted the attribute of importance, but to be important, the test case does not have to be "huge" – especially in terms of scope. The broader the scope the more difficult it will be to achieve stakeholder "buy-in" on the credibility of the process and its contribution to good decision making. In this regard, an optimal test case may be one that employs OR to examine the potential impacts of decisions that are already being contemplated or nearing "finality," which by definition are likely to meet the "importance" test already described. Generic examples of these kinds of "impact" examinations are provided below:

1. **Examining the impact of a contemplated ISR investment decision on its applicability against a range of threats, current and future.** For example, assume that a costly investment in additional high altitude/long endurance UASs equipped for imagery and full motion video is contemplated primarily for GWOT, and specifically for OIF and OEF, and that the coverage factor and output of those UASs is credibly quantified and modeled. An OR examination of the contemplated investment could be conducted in other scenarios – for example a "defense of Taiwan" or "conflict with Iran." In this example, the need for the UASs for GWOT may be the overriding requirement, but one could definitively analyze and understand in a credible OR process whether the same UASs equipped with the same sensors will be applicable to the

other scenarios and consider future alternate utility (either positive or negative) into the investment decision.

2. **Examining a contemplated ISR investment decision in a specific new discipline for its potential impact (specifically cost and capability) on other parts of the relevant intelligence cycle.** For example, consider the impact of a costly investment in biometric data collection capability. OR techniques could be used to analyze the capability of the entire ISR system to effectively use the contemplated new collection capability and/or understand what additional costs would have to be incurred. An obvious case in point would be whether or not appropriate investment has been made in the analytical resources (specific skills, recruitment and training) and dissemination capability needed to handle the volume of new product that would be produced by a UAS investment. Additionally, in an area like biometrics, are there legal or privacy impediments that make the collection capability more difficult or more expensive to direct, task, and use, and have the costs of these factors been credibly analyzed and considered?

3. **Examining the impact of new war-fighting capabilities on the ability of the ISR system to support them.** A notable historic instance of this was the impact on the ISR system of fielding large numbers of precision munitions since Desert Storm and the continuing impact of fielding "extreme precision" systems today. For example, GPS-guided weapons are only as precise as the quality of the Digital Terrain Elevation Data (DTED) that is collected and analyzed to provide exact target coordinates. The demand for extraordinarily detailed and high-quality imagery to support precision application of military capability (strike or SOF) continues to grow significantly. Can OR be used to understand and plan for new weapons or strike capabilities on the horizon that will produce new quality or volume demands on the ISR system? One possible example of this opportunity would be the extension of precision strike into ground and naval force artillery. The dramatic increase in precision strike potential brought on by such an exponential increase in precision weapons would potentially bring about a similar exponential increase in the need for highly accurate target geographic coordinates and/or high quality target imagery. OR techniques seem ideally suited to examine this critical question.

4. **Examining different intelligence disciplines/portions of the intelligence cycle to determine where - for a given problem - investment of limited resources can provide the most effective and efficient prospects for mission satisfaction.** Since this type of examination is often hindered by the fact that resource sponsors or political proponents are aligned parochially by intelligence discipline, organizational interests, budget authorities, or constituent concerns versus mission optimization; unbiased OR using good quality data and credible analytical techniques could make a significant contribution. Even if the challenges were such that OR did not "drive the

decision," it is still possible that applying good OR techniques could improve the quality of the debate and create the environment for a more favorable outcome. Examples of the kind of problems are numerous: HUMINT vs. SIGINT as the route toward discovering enemy intentions, faster/broader dissemination vs. more imagery collection, and/or the value of more investment in analysis vs. just adding collection capability.

6.5 Test Case Timing and Duration

While not as critical as the other attributes, the Task Force considers it optimal if the first test case(s) could begin soon, address a near term issue, and be completed relatively quickly. It will obviously create more IC interest if the OR process dealt with issue(s) that are currently important and relevant to ongoing resource or operational deliberations. Similarly, if the first test case(s) were suitable for a credible OR analysis that could be completed in three to six months it would be helpful in getting an early determination of the value of the OR process for ISR decision support.

6.6 A Note on ISR Test Case Challenges

While the Task Force believes that the ISR test case attributes cited above are valid, it is under no illusion about the difficulties of applying OR in the ISR community. OR is hard for ISR and challenges abound:

1. Typically, models exist primarily for collection systems, making the "SR" (surveillance and reconnaissance) part of the ISR acronym much easier to model and measure than the "I" (Intelligence). In fact, probably the single biggest challenge for using OR for ISR investment decision support is the fact that we have never been able to successfully measure or model the value of the product of the intelligence process – knowledge about an enemy's capabilities and intent. In short, the impact of intelligence on decision making is not easily measured or understood.
2. ISR platforms are often multi-purpose, making their total output and relative value difficult to measure, model, and compare.
3. The ISR community lacks analytic models that reflect the utility of ISR product assessment.
4. Funding and control streams are in different organizations, and often in different departments of government.
5. The same ISR platforms and agencies often serve many different customers whose requirements range from tactical through strategic, and whose missions can range from combat to operational planning or national level policy.

CHAPTER 7: INSTITUTIONALIZING OPERATIONS RESEARCH (TOR TASK 4)

The Task Force looked at a number of current OR and decision-support institutions in use by the Services, DoD, the IC, and industry. The Task Force found that OR, systems analysis, and other decision-support disciplines (including modeling and simulation) are used widely in the Services and DoD, as well as the IC. However, the application of OR (and related disciplines) is uneven in these organizations, as is the extent to which OR is recognized as a distinct discipline and career field. Some organizations (e.g., the NRO) use OR to optimize the use of current ISR resources to support specific mission requirements, while others (e.g., the NSA) employ modeling and simulation to support architecture analysis. The former example represents robust and sustained use of OR, albeit without strong coupling of the resources of OR analysis to strategic investment decision making. The latter example typifies a situation in which structured decision making has fallen into disuse and in which its practitioners struggle to find opportunities to apply their discipline. Of note, the Army has done the most to sustain an institutionalized OR capability, one that is well instantiated at the TRAC. TRAC's Website states:

> *"TRAC conducts operations research (OR) on a wide range of military topics, some contemporary but most often set 5 to 15 years in the future. How should Army units be organized? What new systems should be procured? How should soldiers and commanders be trained? What are the costs and benefits of competing options? What are the potential risks and rewards of a planned military course of action? TRAC directly supports the mission of the Army's major command, the Training and Doctrine Command (TRADOC), to develop future concepts and requirements while also serving the decision needs of many military clients. TRAC analysis enables change."*[33]

While the Task Force did not assess in detail the extent to which TRAC is performing successfully in all of the roles described above, our discussions allowed us to conclude that TRAC is comprised of dedicated professionals who enjoy leadership commitment and support and whose work is visible and highly regarded in the Army planning and operational communities.

As described in Chapter 5, the FedEx example also represents a seemingly robust approach to institutionalizing OR and structured decision making. This model employs OR at a corporate level to help decide on the lines of business in which the company should compete, and at what level. FedEx also employs OR at the line-of-business level to support investment decision making and to configure operational resources; it provides corporate oversight to ensure the presence of consistent OR standard processes and methodology throughout the FedEx family of businesses. The company

[33] http://www.trac.army.mil/

does not "require" the use of OR so much as the leadership commitment of the company to OR-based decision making gives its practitioners substantial influence as high value decisions are made. That leadership extends to empowering the company's corporate OR organizational to ensure that appropriate professional standards, processes, and practices are employed in the conduct of OR throughout the company's various lines-of-business.

Four common elements unite the Army and FedEx cases.

- The OR professionals in both organizations enjoy leadership commitment and support. In both organizations, senior leaders employ the results of OR in a visible fashion to support key strategic decisions. In the FedEx case, discussions regarding important business decisions are expected to be supported by corporate or line-of-business specific OR analyses. Recommendations not supported risk being dismissed.
- In both the Army and FedEx, OR is regarded as a discreet career field. OR professionals are recruited, and in the case of the Army, developed. OR professionals in both organizations enjoy respect; career prospects; and the opportunity to develop, refine, and demonstrate their capabilities. In the other Services, the Task Force found that a career in Operations Research can lead to careers removed from the mainstream resulting in diminished career prospects.
- The Army and FedEx use OR broadly. The TRAC mission unites investment decision making with operational concepts. While many companies employ OR in decision making, the Task Force found the FedEx model very relevant to the functioning of DoD. FedEx uses OR to help decide in which businesses to compete and how to allocate resources within specific lines of business in support of current operations. In the FedEx process model, OR proves its value constantly.
- The Army and FedEx appear to have aligned closely their respective OR cadres, decision makers, and operators. Analyses employing OR appear to reflect current operational experience. The Task Force notes that this factor is also demonstrated in the historical context in which OR has been used.

In the past DoD tried to institutionalize structured ISR decision support. In the mid-1990's it established a Joint C4ISR Decision Support Center (the Center). In particular, the FY97 Defense Planning Guidance (DPG) directed that the Office of the Assistant Secretary of Defense for Command, Control, Communications and Intelligence (OASD (C3I)) lead an effort in coordination with the USD(AT&L), Joint Staff, CINCS, Services and Agencies to develop a DoD Joint C4ISR Conceptual Architecture which would identify opportunities to invest in Joint and integrated C4ISR Systems. The purpose of this directive was to increase efficiency in the performance of C4ISR systems in Joint operations and to reduce the apparent duplicative expenditures in C4ISR systems across

the Department of Defense. $10M per year was made available for FY97-2001 in support of this effort. The Center's challenge was specific; it was expected to provide analysis results to the Joint C4ISR DSC Senior Steering Group, Joint Requirements Oversight Council (JROC) and the Defense Acquisition Board (DAB) to assist senior decision makers in making Joint C4ISR investment decisions.

The Center was used actively in support of a number of studies including Sensor-to-Shooter, Precision Force C4I Operational Architecture, and other efforts. The Center's efforts, however, were not generally coupled to acquisition strategies. Over time, the Center's resources diminished and, while it still exists, the Center conducts fewer studies and enjoys limited visibility. Overall, the Center lacked sustained leadership support, resources, and the mandate to conduct meaningful analyses coupled to acquisition and investment decisions.

The Task Force recognizes that several organizational models are available to the USD(I) to institutionalize Operations Research (and scientific method-based decision-support) that can address these problems. The Task Force urges the USD(I) and the Department to look closely at the private sector and the FedEx model, one in which there exists "corporate" governance regarding the necessity to employ OR for key decisions, enforcement of OR standards processes and practices, oversight of line-of-business-specific OR capabilities, and evaluation of the quality of OR products. The company's approach encompasses a compact, but influential corporate organization (for governance, oversight, and OR analysis in support of corporate strategy decisions), and more fully elaborated OR organizations embedded in the lines of business. The Army's TRAC organization may represent a sound example of such an embedded organization, performing a wide range of decision-support analyses. However the USD(I) proceeds, the MORS represents a powerful domain expert resource that can help build a plan to institutionalize OR.

This page is intentionally blank.

CHAPTER 8: FINDINGS AND RECOMMENDATIONS

The USD(I) should recognize explicitly that the value, quality, and use of OR in support of a given decision is dependent on the decision maker's perception of its value and relevance; that the quality of ISR decisions can be improved by increased use of high quality OR in decision making; and that the state of OR is advancing.

OR often gets attention on an ad hoc basis, but when immediate demand subsides, interest in sustaining its use tends to wane. Institutionalization of OR is missing in the overall decision-making process. It is important to develop a set of required standard processes and practices, milestones, methodologies, and thresholds for objective application of OR to high-value decisions. The Task Force recommends the USD(I) closely examine the FedEx and TRAC models. Buttressing these views are four important observations:

1. Operations Research represents a powerful tool to help improve the quality of investment decision making by illuminating key issues, assumptions, and sources of information.
2. Operations Research is applied inconsistently throughout the Defense and ISR communities. These communities do not possess standard processes and practices relating to OR practice, a consistent organizational model, or a consistent commitment to the use of OR.
3. OR – and its use – can be strengthened in the Defense and ISR communities through effective institutionalization.
4. The utility of OR can be more firmly established through appropriate test cases.

The USD(I) should employ OR to support ISR investment decisions relating to the dynamic set of capabilities found throughout the intelligence cycle that need to be maintained, upgraded, developed, or acquired to satisfy the changing requirements that the intelligence cycle must support. This OR capability should be organic to the Office of the USD(I), enjoy the full confidence and support of the USD(I), and be comprised of OR professionals who can provide objective OR-based recommendations to guide ISR investment decisions.

The Task Force offers the following recommendations:

1. As Battlespace Awareness portfolio manager, USD(I) should:

   1.1. Establish an organic ISR OR oversight function that requires, sustains, and reviews OR standard processes and practices in DoD ISR investment decisions.

   - Consider the approach employed by FedEx as an institutional OR model, i.e., decentralized OR-based decision support performed in lines of

business; a compact corporate OR organization provides standard processes and practices, and oversight of OR use, and conducts OR on strategic corporate issues.

- Consider MORS as a domain expert resource to assist in ISR OR institutionalization.

1.2. Establish a USD(I) capability to conduct OR for strategic investment decisions (includes delegation of specific OR analyses to subordinate ISR organizations).

- Create a professional OR community of interest and practice across DoD and the IC.
- Coordinate development and application of OR models for specific ISR investment decisions.

1.3. Define requirements for broad based studies for decision making milestones and a joint capability for accrediting the studies, models, and data used and develop best practices/models for ISR effects.

1.4. Ensure OR requirements for MAPs and programs below Milestone Decision Authority are understood and met.

2. This OUSD(I) OR function should:

2.1. Serve as the implementation mechanism for the institutionalization of ISR OR within the DoD.

2.2. Advocate OR as a required input to ISR decision-making processes.

2.3. Oversee the application of OR to run test cases and scenarios.

2.4. Apply OR to validate assumptions.

2.5. Use OR to test investment decisions for proper balance.

2.6. Track the state of OR and improve OR tools supporting ISR decisions and employ them in the decision-making process.

3. Test Cases:

3.1. In response to the TOR, the Task Force recommends two test cases: one related to investment decision making in biometrics technologies, and one related to the balance in the intelligence cycle. These test cases should be structured to illuminate challenges and opportunities to strengthen OR decision making in the ISR investment domain.

APPENDIX A: TERMS OF REFERENCE

THE UNDER SECRETARY OF DEFENSE
3010 DEFENSE PENTAGON
WASHINGTON, DC 20301-3010

ACQUISITION,
TECHNOLOGY
AND LOGISTICS

JUL 05 2007

MEMORANDUM FOR CHAIRMAN, DEFENSE SCIENCE BOARD

SUBJECT: Terms of Reference – Defense Science Board (DSB) Advisory Group on Defense Intelligence

You are directed to form a permanent DSB Advisory Group to provide study support and independent advice to the Under Secretary of Defense for Intelligence on a broad range of defense intelligence matters. The initial review area will be on Improving Intelligence Systems Acquisitions. Additional study areas will be formulated over time to support the evolving needs of the defense intelligence enterprise.

The Advisory Group will report via the full DSB to the interested Federal Official. Acquisition related matters will be reported to both USD(AT&L) and USD(I), and intelligence related matters to USD(I).

At least one member of the DSB must be a member of the Advisory Group and any sub groups formed under the Advisory Group.

The Task Force shall have access to all classified information, including special access programs, relevant to the performance of its tasks.

Major General Richard O'Lear, USAF (ret.) will serve as the Chairman of this Task Force. Ms. Betty Sapp, OUSD(I), will function as the primary Designated Federal Official. USD(I) will coordinate on all proposed Task Force members.

The Task Force will operate in accordance with the provisions of Public Law 92-463, the "Federal Advisory Committee Act" and DoD Directive 5105.4, the "DoD Federal Advisory Committee Management Program". We do not anticipate that this Task Force will need to go into any 'particular matters' within the meaning of Title 18, United States Code, section 208, nor will it cause any member to be placed in the position as a procurement official.

This Task Force will be renewed annually or upon change of the Task Force Chairman or Designated Federal Official.

for Kenneth J. Krieg

OFFICE OF THE UNDER SECRETARY OF DEFENSE
5000 DEFENSE PENTAGON
WASHINGTON, DC 20301-5000

JAN 29 2008

INTELLIGENCE

MEMORANDUM FOR CHAIRMAN, DEFENSE SCIENCE BOARD ADVISORY GROUP ON DEFENSE INTELLIGENCE

SUBJECT: Terms of Reference –Operations Research Applications for Intelligence, Surveillance and Reconnaissance (ISR)

You are requested to perform a DSB Advisory Group on Defense Intelligence study to examine the use of operations research (OR) methods to support decision-making within the Department, with a focus on ISR investment choices.

The principal objective is to assess the use of OR methods within the Department, determine how OR supports Department decision-making for ISR programs and to recommend improvements, if needed.

DoD ISR is a large, complex enterprise managed by the Under Secretary of Defense for Intelligence (USD(I)). While primary stakeholders for DoD ISR are the Combatant Commands, global ISR requirements come from many sources and the low volume, high demand DoD ISR assets are continually budget-constrained. Recent use of OR analysis to inform the High Value Target study has received positive feedback, and there is a wealth of operational data that could be used to expand this analysis across the ISR spectrum of requirements.

The "OR Methods ISR Study" should proceed in four stages:

(1) Survey the departments and agencies to determine how much OR is being performed;
(2) Assess how the results of that OR are being used in decision making;
(3) Based on the findings of "(1)" and "(2)", recommend a test case for using OR methodologies to improve DoD ISR investment decisions;
(4) Recommend steps the Department can take to "institutionalize" the use of OR in DoD decision making in the future.

The study will be sponsored by the Under Secretary of Defense for Intelligence. USD(I) is authorized to act upon the advice and recommendations of the Board.

CAPT Keith May, OUSD(I), will serve as the Executive Secretary.

The Task Force will operate in accordance with the provisions of P.L. 92-463, the "Federal Advisory Committee Act," and DoD Directive 5105.4, the "DoD Federal Advisory Committee Management program." It is not anticipated that this Task Force will need to go into any "particular matters" within the meaning of Section 208 of Title 18, United States Code, nor will it cause any member to be placed in the position of action as a procurement official.

Betty J. Sapp
Deputy Under Secretary of Defense
(Acquisition, Resources & Technology)

This page is intentionally blank.

APPENDIX B: TASK FORCE MEMBERSHIP

CO-CHAIRMEN

Dr. Robert Lucky	*Telcordia Technologies*
Maj Gen Richard O'Lear, USAF (Ret.)	*Lockheed Martin*

MEMBERS

Mr. Dennis Fitzgerald	*Private Consultant*
Mr. Sid Fuchs	*OAO Technology Solutions*
Mr. Keith Masback	*U.S. Geospatial Intelligence Foundation*
Mr. Ken McGruther	*Northrop Grumman*
Lt Gen George Muellner, USAF (Ret.)	*Private Consultant*
Lt Gen Gene Santarelli, USAF (Ret.)	*S'relli Consulting, LLC*
Mr. Howard Schue	*Technology Strategies & Alliances*
Mr. Bill Thoet	*Booz Allen*
Mr. Samuel S Visner	*CSC*
VADM Tom Wilson, USN (Ret.)	*Alliant Techsystems, Inc. (ATK)*

OBSERVERS

Mr. Jack Keane	*MORS*

EXECUTIVE SECRETARY

Capt Keith May, USN	*OUSDI(PPR/ISRP)*

DSB SECRETARIAT

Mr. Brian Hughes	*Defense Science Board*
LTC Karen Walter, USA	*Defense Science Board*

SUPPORT

Ms. Michelle Ashley	*SAIC*
Mr. Jimmy Hyatt	*DUSD(PPR/ISRP) (Scitor)*
Ms. Amely Moore	*SAIC*
Ms. Lauren York	*SAIC*

This page is intentionally blank.

APPENDIX C: BRIEFINGS RECEIVED

April 2-3, 2008

Col Del Delapena, OUSD(I)	HVT

May 14-15, 2008

Mr. Kevin Meiners, OUSD(I)	BA Portfolio Management
COL Michael Wilmer, Army Capabilities Integration Center	Army OR
Dr. Chris Morey, TRADOC Analysis Center	
CDR Eric Law, Navy N81	Navy OR
Mr. Martin Steele, NASA Kennedy Space Center	NASA/KSC Overview
Mr. Jack Keane, Military Operations Research Society	MORS Overview
Dr. Jacqueline Henningsen, Air Force A9	Air Force OR
Dr. George Akst, Marine Corps Combat Development Command	USMC OR

June 11-12, 2008

Lt Col Michael Fredley, NRO	OR at NRO
Mr. Jack Stewart, NSA	OR at NSA
Mr. Tim Grayson, ODNI	OR at ODNI
Mr. Will Payson, FedEx	FedEx Use of OR for Decision Support
Dr. George Stone, Alion Science & Technology	The Nexus of Operations Research and Modeling & Simulation in DoD Decision Making
Mr. Winston Beauchamp, NGA	OR at NGA
Mr. Brian Peters, NSA	RT-RG

July 9-10, 2008

Mr. Dave Terry, NIC-C	DIOCC Brief
Mr. Eric Benn and Mr. Keith Barber, NGA	Hi-Res Utilization & Hi-Res Characterization

July 30-31, 2008

Dr. Scott Comes, PA&E	OR at PA&E

August 27-28, 2008

Mr. Josh Kerbel, ODNI Lessons Learned Center	ODNI Perspectives on Lessons Learned
COL Thomas Cioppa, TRADOC	OIF Strategic Communications Analysis and Assessment

September 17-18, 2008

Mr. Scott Thayer, NSA	Cyber Discussion

APPENDIX D: TEST CASES

D.1 Biometrics

The Secretary of Defense (SecDef) has recently taken steps to organize DoD biometrics activities. Department of Defense Directive (DoDD) 8521.01E of February 21, 2008 "…designates the Director, Defense Research & Engineering (DDR&E) as the Principal Staff Assistant (PSA) responsible for oversight of DoD biometrics programs and policy…" 8521.01E also "…designates the Secretary of the Army as the DoD Executive Agent (EA) for DoD biometrics..." Section 5.3 of the Directive assigns to the Under Secretary of Defense for Intelligence (USD(I)) a broad range of responsibilities to ensure biometrics are used effectively to meet intelligence and counter-intelligence challenges.[34]

Although the Directive clarifies DoD Biometrics responsibilities, questions remain regarding the application of biometrics to military operations in general, and to the ISR domain in particular. Although the Administration has requested funding from Congress for biometrics applications and the Army has established a Biometrics Fusion Center (BFC), no clear path exists yet for investment in biometrics. Concepts of operations (CONOPS) for application of biometrics attributes are lacking, as are the requirements important to making biometrics investment decisions. As a result, the DSB Advisory Group on Defense Intelligence regards biometrics as an appropriate test case for the use of Operations Research in ISR investment decision making.

In the Task Force's view, OR can be used in three ways pertinent to biometrics investment decision making, each of which would help the Department understand OR's potential as a decision-support discipline and lead to concrete results in the short term relevant to biometrics.

First, the Department can employ OR to <u>establish and refine concepts of operations for the application of biometrics, end-to-end, in support of military operations in general and to meet ISR requirements in particular</u>. OR has been used traditionally by the Services to model operational requirements, desired effects, and the application of resources to meet those requirements and achieve those effects. OR can be used to help refine the understanding of the ways in which the insertion of specific biometrics data can support and improve the effectiveness of specific military operations. In this regard, OR can also help improve the architecture of military operations that employ biometrics.

Second, the USD(I) can work with the Office of the Director of National Intelligence (ODNI) to <u>strengthen the information architecture associated with biometrics</u> databases, information sharing, as well as biometrics collection, analysis, and dissemination. While laudable work has already been done at the National Counterterrorism Center (NCTC), Federal Bureau of Investigation (FBI), and elsewhere in

[34] Department of Defense Directive (DoDD) 8521.01E, dated February 21, 2008.

the Intelligence Community to employ biometrics information, a unified information architecture for the application of biometric attributes (i.e., biometrics) by the Intelligence Community does not exist. Work remains to be done to build capabilities to query a wide variety of biometrics databases on a federal basis. Indeed, information sharing schemes remain rudimentary, dependent on security restrictions, and hampered by a lack of data standards. Nonetheless, investment continues in a wide variety of programs associated with counter-terrorism and war-fighter support, many of them dependent on the availability and use of biometrics data. In addition, the IC needs, but does not possess, a sound analytical concept for the use of biometric attributes, a fact that can also impair the ability of the IC to define biometrics ISR requirements and an effective information architecture that encompasses the use of biometrics. Indeed, the Task Force is aware of broad concerns that biometrics collection capabilities have outpaced the ability of the Intelligence and Defense Communities to share and employ biometrics data, both for analysis and for tactical military operations. As a result, the "promise" of biometrics has yet to be fulfilled, even through biometrics collection capabilities (e.g., retinal, facial, and voice recognition) and tools to "enroll" and compare an individual with biometrics data (e.g., the Biometrics Automated Toolset) have continued to develop.

OR should be assessed as a mechanism for defining intelligence operations including tasking, collection, and analysis pertinent to biometrics data, and dissemination of intelligence products encompassing a biometrics component. Such an application of OR could have several distinct benefits:

- It can lead to better, Community-wide biometrics information architecture.
- It can help the Community achieve true biometrics information sharing.
- It can help the USD(I) and others understand how OR might be employed to build information-centric inter-agency and Community-wide ISR capabilities.

Third, the Secretary of the Army and the BFC can use OR to conduct trade studies on a variety of specific biometrics technologies and acquisition strategies, consistent with DoD acquisition program management requirements. OR can be used to compare Technology Readiness Levels, expected investment levels, and likely operational capabilities associated with competing technologies, acquisition and investment strategies, and funding arrangements. In this instance, OR would employ biometrics as a technology development and acquisition strategy test-bed. Such an approach is particularly appropriate, given recent moves to strengthen DoD biometrics oversight, enhance the financial resources associated with biometrics investment, and upcoming acquisition activities on the part of the Biometrics Fusion Center. In this instance, the Department should choose an upcoming procurement activity related to biometrics collection or enrollment and employ OR to help define and frame a set of investment decisions related to two or more specific technologies and two or more specific acquisition strategies.

Overall, the three elements described above could help the USD(I) understand how OR could improve warfighter operations through the use of biometrics as a component of ISR, lead to a stronger analytic concept for the use of biometrics, contribute to the development of a biometric information architecture, and strengthen biometrics technology and program investment decision making.

D.2 Investing in a Balanced Intelligence Cycle and Imagery UASs - a Value Proposition

The Intelligence Community has a history of investing in new, discipline-specific capabilities without proper consideration of the impact of decisions on the entire intelligence cycle. In the past this resulted in large outlays of resources that, because of this imbalance, were either not very useful or were marginalized because of an inability to realize full value from the investment. For purposes of this discussion, the Task Force defines the "Intelligence Cycle" as follows: Planning and Direction, Collection, Exploitation, Analysis, Dissemination, and Feedback (Note: The Task Force recognizes that, depending upon the collection system being considered, dissemination may occur at multiple places in this cycle, for example between collection and exploitation, again between exploitation and all-source analysis, and finally to the end-user). Some historic examples of where cycle imbalance caused significant problems or challenges include the following:

1. **Inability to adequately disseminate national imagery to tactical units during Desert Shield/Desert Storm.** This is perhaps the most notable example of where a lack of balance in the intelligence cycle made a magnificent collection product not available in a timely fashion to warfighters in the volume or time-frame needed. In this case an enormous investment in imagery collection capability was not matched by the investment needed in dissemination capability or technology. The result was air strike target imagery or amphibious landing zone imagery was available at national and/or combatant command levels, but not to those with the mission of striking the targets or landing on the beaches. In addition, even if dissemination had been much more capable, imagery analysts were not available in the numbers needed for exploitation of the imagery product. The reasons for this imbalance are multiple (failure to consider dissemination or analysis requirements by a collection system acquirer, failure to properly invest in dissemination capability or technology by military Service users) so the purpose here is not to try to establish blame, but to point out that an OR approach to examining the dissemination and exploitation issues at the time of collection system investment decision would have been helpful.
2. **Inability to adequately provide timely feedback to collection system planning and direction, especially when the feedback to planning and direction reaches across collection disciplines.** This challenge is often referred to as "cross-cueing," and it is one that is rarely provided for in the design and procurement of a collection system. U.S. war-fighting history is replete with examples of where adequate and timely feedback from one collection discipline to another (notably

among and between SIGINT, ELINT, and IMINT) might have resulted in high-value target location or important intelligence discovery.

3. **Inability to adequately provide specialized analysis to support new collection capabilities.** Measurement and Signature Intelligence (MASINT) is an area where new technical collection capability and capacity may be significantly outpacing the ability to realize the full value of new kinds of technical collection. Many MASINT products require specialized exploitation and specifically trained and experienced analysts to make good use of products. It is a problem for intelligence cycle effectiveness and utility if investment in exploitation and analysis for MASINT does not match the developing collection capacity and it is probably better to re-balance the investment than continue to pour more MASINT data into the system. An historical example of where an effective MASINT intelligence cycle was achieved through balanced investment in planning and direction, collection, exploitation, analysis, dissemination and feedback was the U.S. Navy's use of Acoustic Intelligence (ACINT) during the Cold War. Over several decades, very large investment by the Navy – in both operations and intelligence – resulted in strong technical and tactical ACINT collection matched by exploitation of the data and use in all-source intelligence analysis to provide cueing information to operational forces and technical information to weapons systems developers. Coincidentally, this same highly developed (and expensive) system (SOSUS, ASWOCS, FOSICS, and FOSIFS) made very good use of cross-cueing techniques between ACINT and IMINT/SIGINT/ELINT. U.S. Navy anti-submarine warfare is strongly rooted in a history of Operations Research, and the degree to which OR played a part in developing the ASW/ACINT system might be a useful case study in its own right.

Significant discussion is underway in the Intelligence Community regarding the appropriate balance of resource investment in the Tasking, Processing, Exploitation, and Dissemination (TPED) segments of ISR systems. The Task Force suggests that to look only at TPED may be "shooting short of the mark." Instead, a test case using OR techniques, tools, and practitioners analyze an ISR resource decision with the goal of optimizing allocation of resources in a balanced way across the entire intelligence cycle as described in paragraph 1 above**. A potential test case would be to look at a planned investment in imagery UASs, whose collection potential can surely be examined in detail using valid coverage factors and collection capability. However, all the additional parts of the intelligence cycle should be analyzed similarly with a view toward answering the following questions about other parts of the intelligence cycle relevant to the potential UAS collection system investment**.

1. <u>Planning and direction</u>: What is the command and control apparatus and are there the right number of sufficiently trained personnel in that system to do mission planning relevant to the type of missions envisioned? If not, how many are needed and what is the cost associated with recruiting, training, and retaining them? Are the planned UASs fully compatible with existing ground

station infrastructure and is there sufficient capacity in them to handle the envisioned new system? If ground station additions/modifications and additional ground station personnel are required, have the costs been fully analyzed and included in the planned investment?

2. Collection: Even assuming that the collection capability of the planned UAS system has been correctly measured and modeled, have the costs of future potential upgrades and/or alternative collection capabilities been estimated?

3. Dissemination: Is the contemplated new UAS collection capability fully compatible with existing dissemination networks and is there sufficient communications capacity to handle the increased volume of collection? Additionally, once exploitation has been conducted, is there sufficient secondary dissemination capacity to get exploited data into the hands of users? The bottom line is to ensure that there is sufficient, credible analysis to answer the questions relative to primary and secondary dissemination requirements, and that associated cost data are included in the investment planning.

4. Exploitation: An historic problem associated with imagery collection systems is a failure to plan and pay for sufficient imagery exploitation personnel to handle the increased data quantity. An OR analysis approach could help answer this question, as well as provide cost estimates of what the additional personnel and their training would cost so that these costs could be included in the cost of the overall procurement plan.

5. Analysis: There is a difference between exploitation and analysis, and if the planned new collection capability is to fully contribute to actual knowledge development, the capacity must exist to disseminate and incorporate the exploited information into the all-source analysis system. While all-source analysis is not a part of the collection system per se, pre-decisional OR analysis should be conducted to ensure that the envisioned system is fully compatible with all source analysis requirements in all parts of the ISR system that could benefit from the information.

6. Feedback: Often the most overlooked part of the intelligence cycle, any new system acquisition should include plans for providing feedback – to the entire ISR system if required. Perhaps the most sophisticated form of feedback is "cross-cueing," where exploited data from one collection system can immediately cue (or be cued by) other collection systems. This type of feedback is critical to an effective and efficient ISR system and has rarely been incorporated in system acquisition decisions, but should be analyzed and accounted for during investment decision deliberations.

This page is intentionally blank.

APPENDIX E: GLOSSARY

ACINT	Acoustic Intelligence
AFIT	Air Force Institute of Technology
AOR	Area of Responsibility
ARCIC	Army Capabilities Integration Center
A/S	Assistant Secretary
ASD	Assistant Secretary of Defense
ASW	Anti-Submarine Warfare
ASWORG	Anti-Submarine Warfare Operations Research Group
BA	Battlespace Awareness
BAT	Biometrics Automated Toolkit
BDC	Biometrics Fusion Center
BFC	Biometrics Fusion Center
C3I	Command, Control, Communications, and Intelligence
C4ISR	Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance
CAA	Center for Army Analysis
CIA	Central Intelligence Agency
CINCs	Commanders in Chief
CJCS	Chairman of the Joint Chiefs of Staff
COCOM	Combatant Command
CONOPS	Concept of Operations
DAB	Defense Acquisition Board
DARPA	Defense Advanced Research Projects Agency
DDRE	Director of Defense Research and Engineering
DEPSECDEF	Deputy Secretary of Defense
DFAR	Defense Federal Acquisition Regulation
DIA	Defense Intelligence Agency
DIOCC	Defense Intelligence Operations Coordination Center
DNI	Director of National Intelligence

DoD	Department of Defense
DoDD	DoD Directive
DPG	Defense Planning Guidance
DSB	Defense Science Board
DTED	Digital Terrain Elevation Data
DTRA	Defense Threat Reduction Agency
EA	Executive Agent
ELINT	Electromagnetic Intelligence
FAR	Federal Acquisition Regulations
FBI	Federal Bureau of Investigation
FedEx	Federal Express
FFRDC	Federally Funded Research and Development Center
FIA	Future Imagery Architecture
FMV	Full Motion Video
FYDP	Future Year Defense Plan
GWOT	Global War on Terror
HUMINT	Human Intelligence
HVT	High Value Target
IC	Intelligence Community
ICDO	Integrated Concepts Development Office
IOSA	Integrated Overhead SIGINT Architecture
ISR	Intelligence, Surveillance, and Reconnaissance
JASTP	Joint Advanced Strike Technology Program
JCS	Joint Chiefs of Staff
JDAM	Joint Direct Attack Munition
JROC	Joint Requirements Oversight Council
JSF	Joint Strike Fighter
JWCA	Joint Warfighting Capability Assessment
MAP	Major Acquisition Program
MASINT	Measurement and Signature Intelligence
MIT	Massachusetts Institute of Technology

MOA	Memorandum of Agreement
MORS	Military Operations Research Society
MOU	Memorandum of Understanding
MWORG	Mine Warfare Operations Research Group
NCTC	National Counterterrorism Center
NDRC	National Defense Research Committee
NGA	National Geospatial-Intelligence Agency
NIC-C	National Intelligence Coordination Center
NPS	Naval Postgraduate School
NSA	National Security Agency
NRO	National Reconnaissance Office
OASD	Office of the Assistant Secretary of Defense
ODNI	Office of the Director of National Intelligence
OIF	Operation Iraqi Freedom
OR	Operations Research
ORS	Operational Research Section
OSD	Office of the Secretary of Defense
OSRD	Office of Scientific Research and Development
OUSD(AT&L)	Office of the Under Secretary of Defense for Acquisition, Technology and Logistics
OUSD(I)	Office of the Under Secretary of Defense for Intelligence
PA&E	Program Analysis and Evaluation
PPBS	Planning, Programming and Budgeting System
PSA	Principal Staff Assistant
R&D	Research and Development
RAF	Royal Air Force
RDT&E	Research, Development, Test and Evaluation
S&T	Science and Technology
SA	Systems Analysis
SDD	System Design and Development
SecDef	Secretary of Defense

SIGINT	Signals Intelligence
SIOP	Single Integrated Operational Plan
SOF	Special Operations Forces
SOSUS	Sound Surveillance System
TOR	Terms of Reference
TPED	Tasking, Processing, Exploitation, Dissemination
TRAC	TRADOC Analyses Center
TRADOC	U.S. Army Training and Doctrine Command
TSWG	Technical Support Working Group
UAS	Unmanned Aerial System
USA	United States Army
USAF	United States Air Force
USD(AT&L)	Under Secretary of Defense for Acquisition, Technology, and Logistics
USD(I)	Under Secretary of Defense for Intelligence
USMC	United States Marine Corps
USN	United States Navy
U.S.	United States
VCJCS	Vice Chairman of the Joint Chiefs of Staff