World-Class Research and Development: Characteristics for an Army Research, Development, and Engineering Organization

Standing Committee on Program and Technical Review of the U.S. Army Natick Research, Development and Engineering Center, National Research Council

ISBN: 0-309-56201-5, 82 pages, 6 x 9, (1996)

WORLD-CLASS RESEARCH AND DEVELOPMENT

Characteristics for an Army Research, Development, and Engineering Organization

Standing Committee on Program and Technical Review of the
U.S. Army Natick Research, Development and Engineering Center
Board on Army Science and Technology
Commission on Engineering and Technical Systems
National Research Council

NATIONAL ACADEMY PRESS
Washington, D.C. 1996

NOTICE: The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The members of the committee responsible for the report were chosen for their special competencies and with regard for appropriate balance.

This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

The National Academy of Sciences is a private, nonprofit, self-perpetuating society of distinguished scholars engaged in scientific and engineering research, dedicated to the furtherance of science and technology and to their use for the general welfare. Upon the authority of the charter granted to it by the Congress in 1863, the Academy has a mandate that requires it to advise the federal government on scientific and technical matters. Dr. Bruce M. Alberts is president of the National Academy of Sciences.

The National Academy of Engineering was established in 1964, under the charter of the National Academy of Sciences, as a parallel organization of outstanding engineers. It is autonomous in its administration and in the selection of its members, sharing with the National Academy of Sciences the responsibility for advising the federal government. The National Academy of Engineering also sponsors engineering programs aimed at meeting national needs, encourages education and research, and recognizes the superior achievements of engineers. Dr. William A. Wulf is interim president of the National Academy of Engineering.

The Institute of Medicine was established in 1970 by the National Academy of Sciences to secure the services of eminent members of appropriate professions in the examination of policy matters pertaining to the health of the public. The Institute acts under the responsibility given to the National Academy of Sciences by its congressional charter to be an adviser to the federal government and, upon its own initiative, to identify issues of medical care, research, and education. Dr. Kenneth I. Shine is president of the Institute of Medicine.

The National Research Council was organized by the National Academy of Sciences in 1916 to associate the broad community of science and technology with the Academy's purposes of furthering knowledge and advising the federal government. Functioning in accordance with general policies determined by the Academy, the Council has become the principal operating agency of both the National Academy of Sciences and the National Academy of Engineering in providing services to the government, the public, and the scientific and engineering communities. The council is administered jointly by both Academies and the Institute of Medicine. Dr. Bruce M. Alberts and Dr. William A. Wulf are chairman and interim vice chairman, respectively, of the National Research Council.

This is a report of work supported by Contract DAAK60-95-C-2069 between the U.S. Army Soldier Systems Command, Acquisition Directorate, and the National Academy of Sciences.

Limited copies are available from:
Board on Army Science and Technology
National Research Council
2101 Constitution Avenue, N.W.
Washington, D.C. 20418

Additional copies are available for sale from: National Academy Press Box 285 2101 Constitution Ave., N.W. Washington, D.C. 20055 800-624-6242 202-334-3313 (in the Washington Metropolitan Area)

Printed in the United States of America.

Standing Committee on Program and Technical Review of the U.S. Army Natick Research, Development and Engineering Center

JOSEPH F. SOUKUP (chair), Science Applications International Corporation, McLean, Virginia
DONALD L. ZINK (vice chair), Nestle USA, Glendale, California
BISHNU S. ATAL, AT&T Bell Laboratories, Murray Hill, New Jersey
HAROLD R. BOOHER, Senior Executive Service (retired), Baltimore, Maryland
PHILIP EBERT, DuPont Company (retired), Wilmington, Delaware
CHRISTINE HAILEY, Utah State University, Logan
DENNIS R. HELDMAN, University of Missouri, Columbia
RICHARD M. HODGETTS, Florida International University, Miami
FRANK K. KO, Drexel University, Philadelphia, Pennsylvania
PARRY M. NORLING, DuPont Central Research & Development, Wilmington, Delaware
ALAN B. PERKINS, MITRE Corporation, Huntsville, Alabama
JANICE A. PHILLIPS, Lehigh University, Bethlehem, Pennsylvania

Board on Army Science and Technology Liaison

JOYCE L. SHIELDS, Hay Management Consultants, Arlington, Virginia

Staff

BRUCE A. BRAUN, Director, Division of Military Science and Technology and Study Director
E. VINCENT HOLAHAN, Study Director (to May, 1996)
NORMAN M. HALLER, Consultant
JACQUELINE A. CAMPBELL-JOHNSON, Senior Program Assistant

Army Liaison

ROBERT W. LEWIS, U.S. Army Soldier Systems Command, Natick, Massachusetts
PHILIP BRANDLER, U.S. Army Natick Research, Development and Engineering Center, Natick, Massachusetts
PETER F. DeCOSTA, U.S. Army Natick Research, Development and Engineering Center, Natick, Massachusetts

BOARD ON ARMY SCIENCE AND TECHNOLOGY

Staff

Preface

This report is the first of a two-phase response to a request that the National Research Council (NRC) assess the U.S. Army Natick Research, Development and Engineering Center (RDEC). This report defines the characteristics of a world-class research, development, and engineering (RD&E) organization and the associated metrics, which will then be used to assess the RDEC. The results of that assessment will appear in a later report, which will complete the second phase of the NRC response.

We are fortunate to have as members of this committee experts in the assessment of RD&E organizations as well as in the products and technologies at the Natick RDEC. The merits of this mix were evident in our exploration of the meaning of world-class performance, especially in a military organization.

Given the captive nature of Army RD&E organizations, we first confronted the question of whether or not the characteristics and metrics for world-class performance were relevant. Unlike athletes who compete in the Olympics, it is difficult to compare military RD&E organizations with one another. Some military RD&E organizations are unique, or nearly so. Also, military secrecy is an obstacle to open competition. Ultimately, the outcome of a battle or a war may furnish a convenient, albeit imperfect, measure of the excellence of military RD&E.

Despite these difficulties, we decided that characteristics and metrics for world-class performance of military RD&E organizations are relevant. We took the view that attributes associated with world-class civilian organizations—especially organizations with strong programs in research and development—can provide a valid guide for defining and characterizing world-class performance in organizations like Army RDECs.

Our thinking about world-class performance was supported and broadened by the contributions of many experts from industry, academia, and government (see the appendix and reference sections). Their input was invaluable. After considering the various characteristics that can be used for assessing excellence, we recognized that a substantial degree of judgment is involved. For example, the number of characteristics and their level of specificity are matters of judgment. We have yet to find a standard that fits all situations. After becoming familiar with the large body of opinion on this subject, the final judgments concerning the characteristics and metrics used in this report were made solely by the committee.

Joseph Soukup, chairman

Standing Committee on Program and Technical Review of the U.S. Army Natick Research, Development and Engineering Center

Contents

Tables and Figures

TABLES

FIGURES

Executive Summary

The U.S. Army intends to conduct "world-class" research and pursue advances in technology to maintain superiority in land warfare. This report, which was prepared for an Army sponsor, defines the characteristics of a world-class research, development, and engineering (RD&E) organization.

BACKGROUND AND APPROACH

The Natick Research, Development and Engineering Center (RDEC) is a major element of the U.S. Army Soldier Systems Command, which, in turn, is a major subordinate command of the U.S. Army Materiel Command. The Natick RDEC vision is to be a world-class RD&E team that provides global customers with the essentials of life. The RDEC is organized into the following five directorates, which reflect the essential elements of its mission: (1) survivability, (2) sustainability, (3) mobility, (4) science and technology, and (5) advanced systems concepts.

The technical director of the Natick RDEC requested the assistance of the National Research Council in shaping the RDEC's future role and direction. A committee of the National Research Council (known as the Natick Standing Committee) was asked to (1) define world-class research, development, and engineering; (2) identify the major components of world-class research, development, and engineering; and (3) identify measurable qualitative and quantitative characteristics (and associated metrics) that must be met in order for an Army RDEC

to declare itself world-class. The characteristics and metrics will be used later by the committee for an assessment of the Natick RDEC.

The committee recognized that the phrase world-class is widely used and has different meanings to different people. Although providing a general definition of world-class is relatively easy, defining the term for a research and development organization, particularly an Army RDEC, is more difficult. The committee attempted to develop a definition that takes into account the Army's mission and the RDEC's role in fulfilling that mission. Although an Army RD&E organization has unique features (e.g., it exists principally to serve the Army) that distinguish it from academic and industry research and development centers, the committee found that research and development centers that are considered world-class share similar, measurable characteristics.

WORLD-CLASS RESEARCH AND DEVELOPMENT

To define world-class research and development (R&D), the committee drew on material from general discussions with representatives of industry, academia, and government. The committee also examined relevant literature and four examples of widely respected organizations (i.e., Motorola, Milliken & Company, Intel, and FedEx). The committee determined that a world-class R&D organization is one that is recognized by peers and competitors as among the best in the field on an international scale, at least in several key attributes.

The committee observed that world-class R&D organizations maintain performance by creating and sustaining certain critical competitive advantages (e.g., a strategic focus on unique competencies of the organization). These competitive advantages result from excellence in five key attributes, which are often called “pillars.” The pillars are (1) customer focus, (2) resources and capabilities, (3) strategic vision, (4) value creation, and (5) quality focus. These pillars are founded, in turn, on a demonstrated commitment to achieving world-class performance.

The major components of a world-class R&D organization are, therefore, demonstrated commitment, the five pillars, and the competitive advantages. Of these, the committee believes that the base—a demonstrated commitment—is the most important. Without it, aspirations to achieve world-class performance will be doomed.

WORLD-CLASS ARMY RESEARCH, DEVELOPMENT, AND ENGINEERING

The uniqueness of an Army RD&E organization makes it difficult to find similar peer and competitive organizations on which to base performance comparisons. Therefore, a definition of a world-class Army RD&E organization must also recognize the unique aspects of the organization's vision, mission, and strategy. For example, the Natick RDEC mission, which flows from its vision of becoming a world-class organization, is to (1) maximize the soldier's survivability, sustainability, mobility, combat effectiveness, and quality of life through the research, development, and engineering of items such as rations, clothing, shelters, and airdrop systems; (2) provide the necessary research, development, and engineering to integrate several combat-essential elements (e.g., survivability, sustainability, and mobility) into the soldier system; and (3) perform similar, related functions for other Department of Defense services and federal agencies (e.g., be the center of excellence for food science and technology). The strategy includes developing highly skilled personnel, acquiring quality equipment and facilities, and establishing consistent and stable funding. However, this strategy—and ultimately the vision—are necessarily influenced by the current environment, which includes shrinking budgets and levels of personnel.

Taking the factors listed above into account, the committee determined that a world-class Army RD&E organization is one that excels in several key attributes by matching core competencies to its mission, thereby fulfilling the needs of soldiers as well as, or better than, similar organizations anywhere in the world. To achieve and maintain world-class performance, an organization must identify and develop the necessary core competencies. For an Army RD&E organization, these include the ability to move quickly from developing to fielding new, applied technologies. The technological capability must encourage continued development of new, superior products.

The committee believes that the pillars of a world-class R&D organization provide the most convenient means of articulating the prominent aspects of world-class performance. The five pillars are also applicable to Army RD&E organizations. The pillars are described below.

- *Customer focus* is the ability to identify, anticipate, and respond to customer needs both now and in the future. The focus is on internal customers as well as external customers.

- *Resources and capabilities* are the assets and talents with which the organization creates value for the customer.
- *Strategic vision* is a mental view of the type of organization that senior-level management would like the enterprise to become. This vision must be communicated indelibly to all personnel and translated into key elements that will make the vision a reality.
- *Value creation* is the ability to produce or increase benefits perceived by customers so they feel they are getting more value than they expected or previously received.
- *Quality focus* is the ability to continue striving for higher quality. The commitment to quality often results in breakthroughs.

CHARACTERISTICS AND METRICS

The characteristics of a world-class RD&E organization are derived from the five pillars. The committee judged that 25 characteristics are most relevant to an Army RD&E organization. These characteristics are discussed below according to the pillar under which they fall.

Customer Focus Pillar

The characteristics of this pillar are customer satisfaction, customer involvement, and market diversification. Both types of customers (e.g., internal product development teams and soldiers external to the RD&E organization) can be surveyed to ascertain how satisfied they are with the technological solutions and products delivered. Customer involvement in setting program objectives and following progress can also be evaluated. Although an Army RDEC must focus on the primary markets it serves, the committee believes that some market diversification is proper for any RD&E organization. Indeed, in the private sector world-class RD&E organizations seek to exploit fully the results of their research and product development. The extent of market diversification by Army RDECs can be determined; but diversification must also be considered carefully because Army RDECs exist primarily to support their Army missions and rely on government funding, which is usually authorized only to satisfy specific needs. Satisfaction, involvement, and the nature of market diversification indicate how well an RDEC is connected with and focused on the long-term and short-term needs of customers.

Resources and Capabilities Pillar

The characteristics of this pillar are the quality of personnel; facilities and infrastructure; budget; RD&E capabilities, skills, and talents; use of external resources; important technologies; information technology; and organizational climate. Internal and external reviews (e.g., by management of the RD&E organization or by higher headquarters) can be conducted to assess the organization's resources and capabilities. These reviews may include analyses of the core technical programs, evaluations of employee morale and the research climate, and assessments of the ability to reach "make versus buy" decisions. The quality and quantity of the human, physical, and financial resources and core capabilities of the RD&E organization indicate the ability and power to achieve world-class results. A positive organizational climate usually correlates with high productivity.

Strategic Vision Pillar

The characteristics of this pillar are alignment of vision and mission, anticipatory strategic planning, stakeholder buy-in, and leadership. Internal and external (e.g., peer) reviews can determine if the strategic vision of the RD&E organization and the mission are aligned and whether anticipatory strategic planning is sufficient to develop future Army and joint service products rapidly. To assess stakeholder buy-in, the stakeholders must first be identified. Assessments of strategic vision should include the organizational leadership to ensure that the organization's vision is understood by staff and stakeholders alike. The quality of the strategic vision will give a reading of the enduring capability of the organization to plan and achieve world-class results.

Value Creation Pillar

The characteristics of this pillar are a proper portfolio, product performance, cycle time and responsiveness, and the value of work in progress. Value creation is often a perception based on a comparison of previous products (or lack thereof) with current products. Reviews of the breadth of effort (i.e., the portfolio) and other characteristics are important for making a meaningful assessment.

Reviews can be conducted using both internal and external evaluations. The extent to which the RD&E organization produces outstanding, meaningful results reflects the impact of the organization.

Quality Focus Pillar

The characteristics of this pillar are the capacity for breakthroughs, continuous improvement, commitment to quality, structured processes, a learning environment, and the quality of research. The capacity for scientific and engineering breakthroughs can be assessed, in part, by reviewing past performance (e.g., how many breakthroughs have already occurred). Continuous improvement and structured processes (i.e., the ability to work in a disciplined and organized fashion) can be assessed by reviewing processes and results. The commitment to quality must be assessed at all levels, from topmost management down. Reviews can determine the ability of the staff and the organization as a whole to learn and use knowledge to achieve outstanding results. Finally, research quality can be assessed by expert review. Measurements of all these characteristics can give an overall assessment of the focus on quality in an Army RD&E organization.

Measuring the Characteristics

Metrics can be developed to measure various aspects of input, processes, output, and outcomes in the past, present, and future. Using the wrong metrics may limit performance or lead to inappropriate results. For an RD&E organization, the metrics should foster improvement and be related to the vision and mission. With these factors in mind, the committee developed a set of metrics that can be used as part of an assessment of the Natick RDEC. Beyond measuring the extent to which the RDEC exhibits world-class performance, the metrics can also be helpful for self-evaluation or for evaluations of other RD&E organizations by higher-level Army commands.

To describe adequately the many facets of RD&E performance, the committee chose metrics with qualitative descriptors for four levels of performance. These levels are poor, adequate, good, and excellent. The committee believes that a predominance of excellent performance is necessary for an organization to be deemed world-class. The

committee also considered the concept of best-in-class, which is the level of performance beyond excellent. This level is not included in the metrics because descriptors would apply to unique situations.

The 100 metrics (i.e., 25 characteristics, with four metrics each) are tabulated in the body of the report according to the characteristics to which they belong. They are sorted by pillar (e.g., there are 12 metrics for the customer focus pillar, four for each of the three characteristics). Assessment results can be summarized in tables or figures, which include overall assessments for each pillar.

It should be noted that the committee has implicitly given equal weight to all five pillars. Under some circumstances, it may be appropriate to assign greater weight to one pillar or another. Other adaptations (e.g., for self-assessment) could also be considered.

CONCLUSIONS AND RECOMMENDATIONS

Conclusion 1. The phrase "world-class" is widely used to describe products and services. This phrase, however, can reasonably mean different things to different people. Therefore, if the phrase "world-class" is to be useful as a vision, it must be defined, tailored, and characterized in detail.

Conclusion 2. A world-class R&D organization is one that is recognized by peers and competitors as among the best in the field on an international scale, at least in several key attributes.

Conclusion 3. A world-class Army RD&E organization is one that excels in several key attributes by matching core competencies to its mission, thereby fulfilling the needs of soldiers as well as, or better than, similar organizations anywhere in the world.

Conclusion 4. Efforts to reach or maintain world-class performance require the demonstrated commitment of the full chain of command, from topmost management to the lowest level.

Conclusion 5. World-class R&D organizations are likely to excel in certain fundamental attributes, which are based on demonstrated commitment. These attributes, often called pillars, are customer focus, resources and capabilities, strategic focus, value creation, and quality focus.

Conclusion 6. The five pillars are the basis of 25 characteristics that the committee believes are most relevant to an Army RD&E organization.

Conclusion 7. Metrics with qualitative descriptors for four levels of performance (i.e., poor, adequate, good, and excellent) of the 25 characteristics are the preferred means of determining the extent to which an RD&E organization has achieved world-class performance.

Conclusion 8. Good or excellent performance for each characteristic, and excellent overall performance for all five pillars, are believed to be necessary for an organization to be judged world-class.

Recommendation 1. The concepts, characteristics, and metrics developed in this study should be used to assist the committee to assess the Natick RDEC.

Recommendation 2. These concepts, characteristics, and metrics should be considered by the Army or outside reviewers for use in assessing other Army RD&E organizations.

Recommendation 3. Army RD&E organizations should consider using these concepts, characteristics, and metrics for self-evaluation.

Recommendation 4. The concepts developed in this study should be considered by RD&E organizations in general for making assessments and self-evaluations. Some tailoring of the characteristics and metrics will probably be needed to suit specific organizations, be they inside or outside the Department of Defense.

Recommendation 5. The concept of a world-class organization should be used principally as an internal focusing mechanism for achieving excellence rather than as an external mechanism for advertising the virtues of an organization.

1

Introduction

The report begins with a description of the circumstances that led to this study and the statement of task. This description is followed by an explanation of how the committee carried out its task.

BACKGROUND

The Department of Defense (DoD) develops and applies superior technology to provide affordable, decisive military capability and to enhance the economic security of the United States (AS&TMP, 1994). The corresponding Army strategy is to provide affordable and timely technology, training, and support that meets the needs of soldiers so they can achieve swift, decisive, low-casualty victories in a wide spectrum of conflicts (AS&TMP, 1994).

The Army has a multibillion dollar network of research, development, test, and evaluation facilities at approximately 100 sites worldwide. Using these facilities and a network of other government and private science and technology capabilities, the Army intends to conduct “world-class” research and pursue advances in technology, thereby maintaining superiority in land warfare (Milton, 1995). The Army will foster a science and technology system that employs the best practices from any source to ensure, among other things, continuous improvements in quality, reduced costs, and managed risks (AS&TMP, 1994).

The U.S. Army Natick Research, Development and Engineering Center (RDEC) is a major component of the U.S. Army Soldier Systems Command. The Soldier Systems Command, in turn, is a major subordinate command of the U.S. Army Materiel Command. The mission of the Natick RDEC is to develop products that “maximize the soldier's survivability, sustainability, mobility, combat effectiveness, and quality

of life" (Business Plan, 1995). The mission also includes integration of several "combat essential elements" (e.g., survivability, sustainability, and mobility) into the "soldier system." Key elements of this mission are explicit in the five directorates of the Natick RDEC organization (1) survivability, (2) sustainability, (3) mobility, (4) science and technology, and (5) advanced systems concepts. The responsibilities of these directorates include such items as rations, food-service equipment, clothing, shelters, and airdrop systems. (See the beginning of Chapter 3 for a more complete discussion of the mission and responsibilities.)

Senior managers at the Natick RDEC share the Army Materiel Command's vision "to be recognized leaders in acquiring superior technology which will provide a decisive materiel edge and sustain the force" (Business Plan, 1995). The Natick RDEC vision is "to be DoD's world-class research, development, and engineering team that provides global customers with the essentials of life" (Business Plan, 1995). The Natick RDEC must operate effectively and efficiently in an environment that includes constrained defense budgets and reductions in funding and personnel for research and development.

In response to these challenges, and in recognition of the Natick RDEC vision, the technical director of the Natick RDEC requested the National Research Council's assistance in shaping the RDEC's future role and direction. This study, which responds to the director's request, is the first phase of a two-phase assessment of the Natick RDEC by a standing committee of the National Research Council known as the Natick Standing Committee. The purpose of this study is to define the characteristics of a world-class research, development, and engineering organization. Those characteristics, and the associated metrics, will then be used during the second phase, which is to assess the Natick RDEC directorates.

STATEMENT OF TASK

The Natick Standing Committee will carry out the investigations necessary to prepare a report on the characteristics of a world-class research, development, and engineering[1] organization. The resulting

[1]The original statement of task omitted the word "engineering." However, because that function is integral to the RDEC mission, it was explicitly included in the committee's interpretation.

report will (1) define world-class research, development, and engineering; (2) identify the major components that comprise world-class research, development, and engineering; and (3) identify the measurable qualitative and quantitative characteristics (metrics) that apply to or are appropriate for an Army RDEC to be identified as a world-class research, development, and engineering organization. The characteristics and metrics derived from this definition will be used by the committee during the second-phase assessment of the Natick RDEC.

STUDY APPROACH

The committee recognizes that the phrase world-class is widely used and means different things to different people. Although providing a general definition of world-class is relatively easy, defining the term for a research and development organization, particularly for an Army RDEC, is more difficult. If world-class is defined with too little regard for the Army context, then the phrase may have little relevance in terms of the Army's paramount goal of winning wars. Therefore, the committee has attempted to develop a definition that takes into account the Army's mission and the RDEC's role in fulfilling that mission.

To define world-class objectively, the committee began by surveying various dictionaries for formal definitions, explanations of usage, and origins of the phrase. The committee then conducted a search of the literature dealing with the concept of world-class as applied to different types of organizations. The committee also reviewed aspects of quality management programs (e.g., the Malcolm Baldrige and the President's Quality Award programs). Finally, the committee consulted representatives of industry, academia, and government to ascertain their views regarding world-class research, development, and engineering.[2] Although an Army research, development, and engineering (RD&E) organization has unique features[3] that distinguish it from academic and industrial research and development centers, the

[2]The review of the literature led, in large part, to the selection of representatives from industry and academia; representatives of government were selected based either on their contributions to the literature or their familiarity with DoD research, development, and engineering.

[3]For example, as discussed in Chapter 3, the Natick RDEC exists principally to serve the Army. It is funded for the most part by the Army and is managed and operated by Army employees.

committee found that entities commonly considered world-class share certain measurable characteristics.

ROAD MAP

Chapter 2 contains a description of the general concept of world-class. The committee also defines a world-class research and development organization, identifies the major components of the definition, and lists five attributes (also called pillars) that are likely to be shared by world-class organizations. In Chapter 3, the committee recognizes the uniqueness of an Army RD&E organization like the Natick RDEC and establishes a definition of world-class that is appropriate for an Army RD&E organization. The committee also discusses the major components of a world-class organization as they apply to an Army RD&E organization, with emphasis on the pillars. In Chapter 4, working from the five pillars discussed in Chapter 3, the committee develops a set of characteristics and associated metrics that apply to the definition of world-class for an Army RD&E organization. Chapter 5 contains the conclusions and recommendations resulting from this study.

REFERENCES

AS&TMP. 1994. Army Science and Technology Master Plan. Volume 1. Department of the Army. December. Pp. I-11, I-14.

Business Plan. 1995. U.S. Army Soldier Systems Command Business Plan. FY96-01. Volume 2. Appendix F. September.

Milton, A. Fenner. 1995. America's Army into the 21st Century. Presentation to the National Research Council Board on Army Science and Technology, Washington, D.C. November 29.

2

General Description of "World-Class"

In this chapter the committee describes the concept of world-class in general terms, drawing on examples from industry, academia, and government. The committee also defines the phrase world-class as it applies to research and development (R&D) organizations and identifies the major components of the definition, including a list of attributes likely to be shared by world-class R&D organizations.

USE AND MEANING OF THE TERM WORLD-CLASS

Webster's Collegiate Dictionary defines the phrase world-class as "being of the highest caliber in the world" (Webster's, 1995). The *American Heritage Dictionary of the English Language* (American Heritage, 1992) defines world-class as follows:

> **world-class** adj. **1.** Ranking among the foremost in the world; of an international standard of excellence; of the highest order; *a world class figure skater.* **2.** *Usage Problem* [This label warns of possible difficulties involving grammar, diction, and writing style.]. Great as in importance, concern, or notoriety. **USAGE NOTE:** The adjective *world-class* became current as a result of its original use to describe athletes capable of performing at an international level of competition…In recent years it has been extended to mean "of an international standard of excellence" and has been applied to a wide variety of categories. When used of things that naturally admit such comparison, the extended use of the word is generally acceptable to the Usage Panel [a group

> of 173 well-known writers, critics, and scholars]. In the most recent survey 65 percent accepted the description *world-classrestaurant,* and 53 percent accepted *world-class sports car.* But the expression is not generally accepted as a vague way of emphasizing magnitude or degree. The sentence *Johann Sebastian Bach's 300th birthday will rank as a world-class anniversary* was acceptable to only 7 percent, and only 4 percent accepted a description of AIDS as *a world-class tragedy.*

These dictionary definitions do not fully satisfy the purpose of this study, which is to define world-class with respect to an Army RDEC. Therefore, to develop the concept of world-class further, the committee (1) consulted with representatives of industry, academia, and government; and (2) reviewed a large amount of written material on the subject. Highlights of these consultations and reviews are described below.

A senior industry representative characterized a world-class company as one that is customer focused and dedicated to continuous improvement (Stempel, 1995). He explained that world-class is not to be confused with "best-in-class." World-class is a balanced approach to excellence,[1] whereas best-in-class refers to a superlative performance in a single category or attribute. A representative from academia characterized a world-class organization as one that can make "strategy, process, and structure all work together" (Gobeli, 1995). Another representative from academia highlighted the importance of human resources. He stated that "human resources are the distinctive core competencies" that characterize world-class organizations (Luthans, 1995). A representative from the Sandia National Laboratories with experience in the federal government highlighted the importance of value in R&D performance. He stated that R&D laboratories "need to focus more on R&D outcomes" rather than "outputs" (Gover, 1995a). By this he meant that the true measure of success for R&D is delivering a product or service of value to the customer.

[1]A balanced approach is one that focuses on meeting a wide range of customer requirements, thus achieving a high level of overall performance. For example, General Motors Cadillac Division, a 1990 Baldrige Award winner, used this concept in designing the Cadillac Eldorado (Stempel, 1995). Consumer research defined a group of requirements for the car (e.g., concerning economy, acceleration, road handling, and human factors). Although this model did not have the acceleration of a "best-in-class" sports car or the economy of a "best-in-class" compact car, it was a world-class car because it met all the requirements of the target consumer.

When referring to companies and research laboratories, many of the experts and sources available to the committee emphasized the link between an organization being customer focused and being world-class. In his recent book, *World-Class Customer Satisfaction,* Jonathan Barsky writes: "World-class companies understand what satisfies their clientele the most and utilize this information in customer programs and employee training to promote customer loyalty" (Barsky, 1995, p.6). For understanding the phrase world-class, the committee also found it helpful to review descriptions of several leading organizations and their paths to success. The following four examples were selected to illustrate a range of approaches to excellence.

In 1981, Motorola Incorporated dedicated itself to a tenfold improvement in quality within five years (Main, 1994). After discovering that its competitors were capable of matching this level of quality, the goal was extended to a hundredfold improvement in 10 years. Motorola is a 1988 recipient of the Malcolm Baldrige National Quality Award. Today, Motorola is widely recognized as a leader in product quality and the use of benchmarking programs that analyze all aspects of a product (manufacturability, reliability, cost, and performance) to encourage continuous improvement. Also, Motorola is identified with what is perhaps the United States' most famous quality goal, the "six-sigma quality" standard. Six sigma, a statistical measure of deviation from a desired result, translates into a manufacturing target of no more than 3.4 defects per million products, customer services included. The company's goal is simple —"zero defects in everything we do" (World Wide Web, 1996a).

Milliken & Company committed itself in 1981 to value creation through continuous improvement (Main, 1994). The company set goals for reducing defects, improving on-time delivery, shortening development times, and improving other internal processes. Today, Milliken & Company, a 1989 Malcolm Baldrige National Quality Award winner, is recognized as a world leader in the textile industry, both in product quality and technology. The Massachusetts Institute of Technology Commission on Industrial Productivity recognized Milliken & Company as "a front runner in research on performance fabrics" (MIT, 1989).

FedEx Corporation, a 1990 Malcolm Baldrige National Quality Award winner, was founded in 1973 with a management philosophy that emphasized people, service, and profit (World Wide Web, 1996b). The FedEx quality-improvement process focuses on 12 service quality indicators linked to customer expectations. FedEx has invested heavily

in advanced technology to handle the demands of its expanding business and to ensure customer satisfaction. The on-time delivery of more than 1.5 million packages each day is managed by scanning bar codes every time shipments change hands between pick-up and delivery. These data are incorporated into a daily service-quality-indicator report, which is transmitted to workers at all FedEx sites.

In 1992, Intel Corporation became the world's largest manufacturer of semiconductors, the first time in a decade that an American company held that position. Intel took the lead by adopting and focusing on six guiding principles: (1) results orientation, (2) risk-taking, (3) discipline, (4) customer orientation, (5) product quality, and (6) recognition of employees as a fundamental strength (Main, 1994). Intel's effective management of R&D and manufacturing processes has allowed it to deliver new products to the marketplace consistently faster than its competitors.

OBSERVATIONS

The phrase world-class is widely used to describe products and services. However, world-class can reasonably mean different things to different people. To athletes, it means being competitive with the best athletes in the world. To General Motors, it means a balanced approach to excellence. To others, it means having and implementing a winning strategy, being able to anticipate customer needs, and meet those needs faster and with higher quality products than competitors can.

The committee believes that world-class organizations generally have a balanced approach in that they perform very well in the areas of operation they choose to focus on, and exceptionally well in some of these areas. In addition, most world-class organizations do not try to cover all areas of operation. Finally, the committee believes that world-class organizations generally use the concept of world-class as a method of internal focusing to achieve excellence rather than as an external mechanism to advertise organizational virtues. Excellence is advertising enough.

In the R&D field, it is important that strategy be compatible with the business objective (Deschamps and Nayak, 1995). In markets driven by product and process improvement, R&D strategies based on breakthrough research will probably not be successful. However, breakthrough research may be vital to technology-driven businesses.

Also, it is especially important to distinguish between breakthrough research and commercialization. For example, many U.S. R&D organizations have conducted breakthrough research, but they have not done as well as others in terms of commercializing the results (Gover, 1995b). To grasp this point, one need only look at the U.S. experience with television sets and videocassette recorders vis-à-vis the Japanese.

Based on a review of information from many sources, the committee developed the following definition of the phrase world-class as it applies to R&D organizations:

> A world-class R&D organization is one that is recognized by peers and competitors as among the best in the field on an international scale, at least in several key attributes.[2,3]

World-class R&D organizations maintain their performance by creating and sustaining certain critical competitive advantages. The committee identified the following competitive advantages:[4]

- *Strategic focus* concentrates energy on unique competencies that can be used by the organization for an extended period of time (perhaps in multiple applications), thus providing a source of information and knowledge for generating productive output for the indefinite future.
- *Technological leadership* supports the strategic focus and ensures that the organization is able to generate new, state-of-the-art products and services with a continuous influx of new ideas.
- *Identification of output* is the ability to identify and define what will be needed over the next decade to accomplish certain outcomes and thus provide direction for all R&D activities.

[2]This definition has some similarities to another definition, which indicated that the phrase world-class refers to an organization described as "the best in its class or better than its competitors around the world, at least in several strategically important areas" (Luthans et al., 1994).

[3]The committee also notes that this definition should not be interpreted as a condition that can generally be satisfied by a simple voting process without analysis. If that were the case, there would be no need for components, characteristics, and metrics to define world-class. On the other hand, voting by peers and competitors who are well informed about a particular R&D organization and who know what it takes to be world-class could lead to the same results as an analysis (e.g., the peers and competitors may implicitly rely on similar metrics).

[4]Readers interested in learning more about competitive advantages can refer to Porter, 1985.

- *Staying the course* means persistence, staying with the agreed agenda, maintaining the strategic focus, and not being distracted from the central mission of the R&D organization.
- *A highly stable work force* ensures that the same personnel will be working together for an extended period of time and can learn from and draw on each other's talents.
- *Continuous improvement* is an imperative for becoming a leader and maintaining leadership indefinitely by (1) continuously improving current activities, and (2) expanding the scope of activities to include new areas of inquiry that result in radically new products or services.

The committee concluded that world-class R&D organizations are likely to excel in five key attributes: (1) customer focus, (2) resources and capabilities, (3) strategic vision, (4) value creation, and (5) quality focus. These attributes are the pillars that support a world-class R&D organization. The competitive advantages result from excellence in these pillars (the five pillars are discussed in Chapter 3).

The committee strongly believes that the pillars must rest on a foundation of demonstrated, strong, and steadfast commitment. This commitment is characterized by openness at all levels to exchanging information, facilitating interaction, and bringing all individuals in the organization into the process of analyzing goals, defining methods, and implementing procedures. This commitment usually mandates a shift in the operating paradigm of the organization and must be communicated throughout the organization, sending the message that the entire organization, individually and collectively, from the highest management to the lowest staff levels, recognizes the benefits of striving to be world-class. It dictates an allocation of time and resources—principally, people and dollars—to the systematic implementation of details required of a world-class organization. Without this commitment, only lip service can be paid to the concept and goal of world-class performance. Lip service is obvious in an organization that claims to be world-class but makes no deliberate, focused efforts to achieve it.

Figure 2-1 shows the relationship between the major components of a world-class R&D organization. These components, starting at the base, are a demonstrated commitment, the five pillars, and the competitive advantages. The committee believes that the base—a demonstrated commitment—is the most important component. Without a demonstrated commitment, reaching or maintaining world-class performance will be doomed.

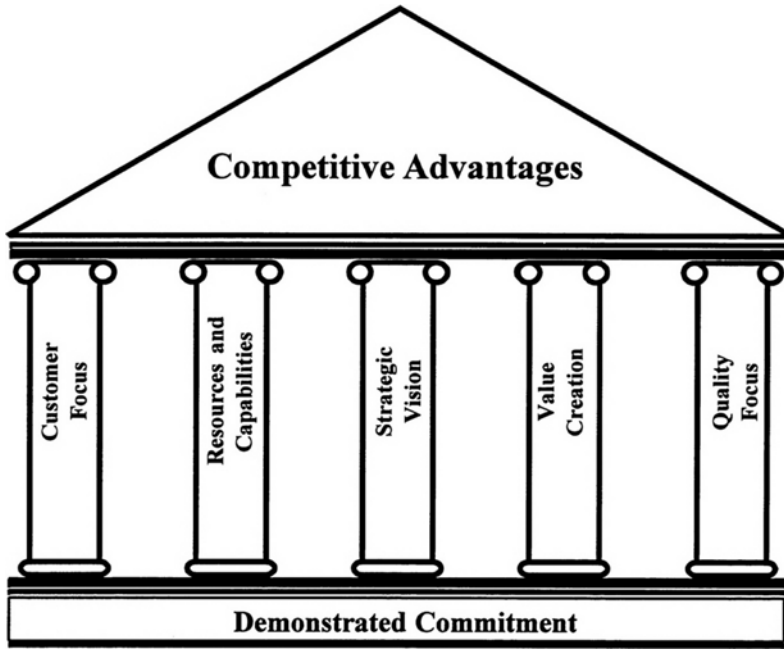

FIGURE 2-1 Relationship of the components of world-class R&D organizations.

Note: Figure 2-1 is intended to describe the relationship of the components that the committee judged to be mandatory considerations for a world-class R&D organization; the figure is not meant to convey organizational structure. The central components were considered by the committee to be absolute, rigid supports for world-class performance and, therefore, were deliberately portrayed as pillars. Portrayal of these components as pillars clearly does not preclude their implementation through a flexible, open, productive, and supportive organizational structure. In fact, the metrics proposed in Chapter 4 for assessing the strength of each pillar reflect the committee's understanding and validation of an organizational structure that achieves the world-class objective.

REFERENCES

American Heritage. 1992. *American Heritage Dictionary of the English Language.* Third Edition. Boston and New York: Houghton Mifflin.

Barsky, Jonathan. 1995. *World Class Customer Satisfaction.* Burr Ridge, Ill. and New York: Irwin Professional Publishing.

Deschamps, Jean-Philippe and P. Ranganth Nayak. 1995. *Product Juggernauts: How Companies Mobilize to Generate a Stream of Market Winners.* Boston, Mass.: Harvard Business School Press.

Gobeli, David. 1995. World Class R&D at Natick RDEC. Presentation to the World-Class Panel of the National Research Council Standing Committee on the Program and Technical Review of the U.S. Army Natick Research, Development and Engineering Center. Washington, D.C. December.

Gover, James. 1995a. World-Class R&D Performance: A synthesis of relevant research, opinions, and ideas. Presentation to the World-Class Panel of the National Research Council Standing Committee on the Program and Technical Review of the U.S. Army Natick Research, Development and Engineering Center. Washington, D.C. December.

Gover, James. 1995b. Corporate Management of R&D—Lessons for the U. S. Government. Research-Technology Management. 38 (2): 27–36.

Luthans, Fred. 1995. Summary Outline of World-Class Management. Presentation to the World-Class Panel of the National Research Council Standing Committee on the Program and Technical Review of the U.S. Army Natick Research, Development and Engineering Center. Washington, D.C. December.

Luthans, Fred, Richard Hodgetts, and Sang Lee. 1994. New Paradigm Organizations: From Total Quality to Learning to World-Class. Organizational Dynamics. 22 (3): 5–19.

Main, Jeremy. 1994. *Quality Wars: The Triumphs and Defeats of American Business.* New York: Free Press.

MIT. 1989. The MIT Commission on industrial Productivity.*Working Papers.* Volume 2. Cambridge, Mass.: MIT Press.

Porter, Michael. 1985. *Competitive Advantage.*New York: Free Press.

Stempel, Robert. 1995. Highlights of Total Quality Management: Philosophies and Applications. Presentation to the World-Class Panel of the National Research Council Standing Committee on the Program and Technical Review of the U.S. Army Natick Research, Development and Engineering Center. Washington, D.C. December.

Webster's. 1995. *Merriam Webster's Collegiate Dictionary.* Tenth Edition. Springfield, Mass.: Merriam Webster, Inc.

World Wide Web. 1996a. http://www.nist.gov/quality_program/doc/Win/ Motorola_Inc.html

World Wide Web. 1996b. http://www.nist.gov/quality_program/doc/Win/ Federal_Express_Corporation.html.

3

World-Class Army Research, Development, and Engineering

In this chapter the committee establishes a definition of the phrase world-class appropriate for an Army RD&E organization. The major components of a world-class R&D organization, as they apply to an Army RD&E organization, are also discussed, with emphasis on the pillars.[1]

WORLD-CLASS DEFINED FOR AN ARMY RESEARCH, DEVELOPMENT, AND ENGINEERING ORGANIZATION

The phrase world-class as applied to an Army RD&E organization must encompass the basic ideas discussed in Chapter 2. The definition must also recognize the uniqueness of an Army RD&E organization, which is reflected in its vision, mission (including DoD-wide responsibilities), strategy, as well as in other ways. Therefore the phrase world-class must be tailored to incorporate the organization's philosophy and *raison d'être.* In the following discussion, the committee uses the Natick RDEC as an example.

The Natick RDEC vision is to be the world-class research, development, and engineering team for DoD (see Chapter 1). This vision is to be fulfilled through (1) the development and integration of leading edge technologies and soldier-system capabilities; and (2) a customer-focused, empowered, innovative work force operating in an open, productive, and supportive environment (Business Plan, 1995).

[1]General references for this chapter are: Brown and Gobeli, 1992; Dimancescu, 1991; Hodgetts, 1993; Luthans, 1993; Luthans et al., 1995; Matheson et al., 1994; McArthur, 1994; McGill et al., 1992; Ransely and Rogers, 1994; and Senge, 1990. See complete citations in the references listed at the end of this chapter.

The Natick RDEC mission statement, which flows from the essentials of its vision, is threefold: (1) to maximize the individual soldier's survivability, sustainability, mobility, combat effectiveness, and quality of life through research, development, and engineering of rations, food-service equipment, clothing, individual equipment, shelters, airdrop systems, and organizational equipment; (2) to provide the necessary research, development, and engineering to integrate the combat-essential elements of command and control, survivability, lethality, sustainability, and mobility into the soldier system; and (3) to perform similar and related functions for other DoD services and federal agencies (Business Plan, 1995).

The Natick RDEC's DoD-wide responsibilities extend into four major areas: (1) commodities (e.g., rations, food-service equipment, and airdrop systems); (2) food and nutrition research, development, testing, and evaluation; (3) the development of tactical shelters; and (4) being the DoD center of excellence for clothing, textiles, and food science and technology (Business Plan, 1995).

The Natick RDEC strategy for fulfilling its mission and meeting its responsibilities has five objectives: (1) the development of highly skilled, resolute, innovative personnel; (2) the acquisition of quality equipment and facilities to support a leadership role in technology; (3) the development of integrated management information and communication systems; (4) establishing consistent, stable funding; and (5) the exploration and pursuit of DoD-wide responsibilities[2] (Business Plan, 1995).

Finally, a definition of world-class appropriate to an Army RD&E organization must take into account the nature of the current DoD environment, which includes shrinking budgets and levels of personnel and increasing numbers of joint ventures and external alliances. The environment can influence the strategy, and ultimately, even the vision of an Army RD&E organization. Although all organizations seeking to compete on a world-class level must concentrate on core competencies and must maintain a strong focus on customer needs, the current environment reinforces these imperatives for organizations like the Natick RDEC.

[2]Although the pursuit of DoD-wide responsibilities is a major objective of the Natick RDEC, the committee observes that this objective should not be pursued to a degree that results in a loss of focus on the central mission (i.e., maximizing survivability, sustainability, and mobility and integrating them into the soldier system).

The committee believes the preceding discussion applies to Army RD&E organizations in general, as does the following definition:

> A world-class Army RD&E organization is one that excels in several key attributes by matching core competencies to its mission, thereby fulfilling the needs of soldiers as well as, or better than, similar organizations anywhere in the world.

To achieve and maintain world-class performance, an organization must identify and develop the necessary core competencies. The "core" must be a "bundle" and not just one or two discrete items (Hamel and Prahalad, 1994). In the case of an Army RD&E organization, the bundle includes the ability to move quickly from developing to fielding new, applied technologies. The technological capability must encourage continued development of new generations of products superior to the current products. The required competence comprises a broad range of underlying skills important to designing products, preplanning production, and testing and evaluating prototypes. The organization must be able to identify and use the best outside provider of technologies and competencies that are not available in-house.

When identifying and developing core competencies, an RD&E organization must focus on three "test points." First, each area of competence must make a disproportionate contribution to soldier-perceived value (i.e., the recipients or customers must feel they are getting superior value). Second, the area of competence must make possible the production of unique goods and services judged to be superior, thus helping to set a particular RD&E organization apart from other organizations that produce more generic or less technologically advanced goods and services. Third, the area of competence must be a vehicle for promoting newer, more useful goods and services in the future (e.g., the capability should not be limited to a food-science breakthrough that will be generic within two years).

COMPONENTS

In Chapter 2, the committee concluded that the major components of a world-class R&D organization are a demonstrated commitment, the five pillars, and the competitive advantages (see Figure 2-1). As discussed in Chapter 2, the committee believes that a demonstrated

commitment is the most important component. The pillars, which rest on the demonstrated commitment, support the organization. The competitive advantages result from excellence in the pillars. The committee believes this analogy is applicable to Army RD&E organizations.

In the analogy, the pillars stand between the competitive advantages and a demonstrated commitment. As such, the pillars are critical links that shape the entire structure and hold it together. The pillars reflect the properties of both the demonstrated commitment and the competitive advantages. For example, strategic vision (a pillar) yields strategic focus (an advantage) but requires a demonstrated commitment (the base) to be realized. As another example, elements of a demonstrated commitment have to be present in the pillars to create advantages, such as staying the course, a highly stable work force, and continuous improvement.[3,4] Accordingly, the committee believes that the pillars provide the most convenient means of articulating the prominent aspects of world-class performance. The next section concentrates on the pillars.[5]

PILLARS

The number of pillars may vary depending on the nature of the organization. However, the committee believes that the five pillars associated with a world-class R&D organization in Chapter 2 are

[3]Commitment can be, and will be, measured in a very practical sense by the methods that appear later in this report. Achievement of world-class performance will necessitate an organizational focus on many concrete elements (e.g., obtaining and keeping high-quality personnel, satisfying customers, providing superior leadership, monitoring outside endeavors for solutions to problems, and stressing organizational learning). Such elements require a genuine commitment of resources. Specifically, if an organization is charged with identifying and fully satisfying customer needs, people and dollars must be allocated intensely and visibly for this purpose. Examination of an organization's operation can clearly show whether this is being done. The specifics of how much time, how many people, and what the funding level should be must be addressed in the context of the individual organization.

[4]Similarly, the concept of competitive advantage relates to the methods that appear later. For example, quality personnel, facilities and infrastructure, leadership, cycle time and responsiveness, and capacity for breakthroughs can contribute to competitive advantage.

[5]Concentration on the pillars is consistent with the literature reviewed by the committee. The authors of one article, for example, describe the characteristics of world-class organizations in terms of “the major pillars that seem necessary to support world-class stature” (Luthans et al., 1994).

applicable to an Army RD&E organization: (1) customer focus, (2) resources and capabilities, (3) strategic vision, (4) value creation, and (5) quality focus. Each pillar is discussed in more detail below.

Customer Focus Pillar

Customer focus means being able to identify, anticipate, and respond to customer needs both now and in the future. This focus is on internal as well as external customers.

In the external arena, customer focus means anticipating customer (e.g., soldier) needs and developing goods and services that both meet and exceed customer expectations. As a result, the customers are more than pleased with the results; they express both surprise and delight with the efforts of the organization to provide for their needs. In the internal arena, customer focus is manifested through the cooperation and coordination of effort. Members of the RD&E organization must understand their jobs collectively and be aware of how they must interact to accomplish goals efficiently and effectively. Customer satisfaction and customer involvement are crucial to success.

For an Army RD&E organization that has DoD-wide responsibilities, market diversification from Army-unique products to products that satisfy multicustomer (i.e., multiservice, other federal agencies, and U.S. allies) needs is also important. In addition, organizational structures, processes, and jobs must be carefully evaluated and designed (or redesigned) to eliminate red tape and ensure a smooth flow of operations that support the customer. Information systems must be designed to monitor customer reactions and predict changing needs, and this information should be fed back into the operation. These features make for a seamless organization in which all departments and personnel cooperate and customers are delighted with the results.

Resources and Capabilities Pillar

Resources and capabilities are the assets and talents with which the RD&E organization creates value for the customer. At the center of this pillar is the quality of personnel, people who work directly for the organization. Their RD&E capabilities, skills, and talents are critical to the success of the organization. Closely connected are the quality of the facilities and infrastructure, everything from applied information

technology and the use of external resources to important technologies used by each directorate (i.e., a wide range of assets from high-technology computers to standard office equipment). Also included are the current operating structure, which determines how the enterprise is organized; how computer links are created between military scientists and engineers and with outside sources; support services that are part of the RD&E network; safety and regulatory compliance as they relate to various resources; and the external support system available to research staff for specialized assistance (e.g., outside vendors, contractors, and the academic community). All of these contribute to an effective organizational climate that empowers personnel and encourages overall teamwork, thus enhancing world-class performance.

Another aspect of this pillar is the budget that supports these activities and influences the level of proficiency and expertise. World-class RD&E organizations have sufficient budgets to sustain high levels of performance.

Strategic Vision Pillar

A strategic vision is a mental view of the type of organization that senior-level management would like the enterprise to become (Wheelen and Hunger, 1995). In a world-class organization this vision is communicated indelibly to all personnel so that they share the same mental view, which must be translated into key elements that will make the vision a reality. For example, to the extent that an RDEC wants to become a leader in quality and service, essential aspects of quality and service must be pinpointed for improvement,[6] and appropriate measurements must be developed to monitor critical areas of progress.

There are several ways to communicate a strategic vision, all of which are related to effective organizational leadership. One is through training and development programs. Another is through carefully developed organizational channels. A third is through a reward and recognition system that reinforces desired behavior.

[6]To illustrate this point, the committee notes that the vision of the Mobility Directorate at the Natick RDEC is "to be the global leader for providing quality solutions for the mobility needs of warfighters and peacekeepers" (Doucette, 1996).

The strategic vision and the mission should be aligned and set the stage for the plan to follow. A typical sequence of activities follows. The vision helps determine the mission, from which the objectives and strategy are formulated in a way that ensures anticipatory strategic planning (e.g., anticipating contingencies and managing turbulence without compromising the mission). Then the strategy is implemented, and control procedures are used to determine results and make changes through effective leadership. The vision also helps ensure stakeholder buy-in.[7]

Value Creation Pillar

Value creation is the ability to produce or increase benefits perceived by customers so they feel they are getting more value than they expected or previously received (Porter, 1985). Paying customers usually perceive this value based on a cost-benefit determination. If customers receive benefits without paying directly, the perceived value is often based on a comparison of previous and current benefits.

Value creation often depends largely on customer perception, and certain features and characteristics of a product may account for a large part of the value being created (Bounds et al., 1994). For example, if soldiers are given new boots specially designed to keep their feet warm, they may perceive these boots to be far better than the previous ones. However, if the new boots are heavier and more difficult to buckle than the previous ones, they may be perceived as poorer than the previous ones even if they keep the user's feet warm.

An important aspect of value creation is cycle time and responsiveness. As the time needed to create and deliver a product decreases, the product is supplied faster or supplied to more people, thus creating overall greater value from the completed product.

Another aspect of value creation is the proper portfolio of elements for marketing a product. For example, packaging that keeps food fresh can add to the value of the product. However, if the food is not very tasty, freshness may add little, if any, value. So there must be a proper

[7]The *American Heritage Dictionary of the English Language* defines stakeholder as "one who has a share or an interest, as in an enterprise." In the context of an Army RD&E organization, stakeholders include both internal and external customers as well as interested parties who do not use the products of the RD&E organization directly.

mix of complementary elements based on the requisite product performance.

The value of work in progress is influenced by customer perception of prior RD&E programs and the ability of product managers to meet customer requirements and deliver products on time and on budget. Greater value may be assigned to RD&E programs that have historically enjoyed higher customer satisfaction, and this value may translate into a strong argument for stabilizing RD&E funding.

Quality Focus Pillar

Quality is a distinctive attribute of a good or service that is valued by a customer; quality focus is the ability to continue striving for higher quality. The commitment to quality often results in breakthroughs.

One way world-class organizations achieve a quality focus is by continuous improvement (Hodgetts, 1996). There are two distinct, yet interdependent, approaches to continuous improvement. One is innovation, which results in dramatic increases in quality brought about by new inventions, technological breakthroughs, and the application of new theories. The other is constant improvement, which is characterized by small but continual increases in quality. Both involve structured processes.

Other ways to promote quality focus are (1) effective training and development programs that help participants learn new and better ways of doing things and, in the process, help create a learning environment; (2) empowering people to redesign their jobs to increase quality; and (3) benchmarking, which compares current performance with the performance of other enterprises.[8]

Finally, quality focus can be created and sustained through a carefully crafted reward and recognition system that encourages continuous improvement and rewards those who participate and contribute to bottom-line results.

[8]There are two kinds of benchmarking. One, known as competitive benchmarking, involves identifying similar RD&E organizations that are judged best in class and copying practices that will increase quality. The other, known as generic benchmarking, involves targeting improvements (e.g., reducing cycle time) and examining how they are achieved in competitive and noncompetitive industries. These efforts often result in information that can be used to improve operations.

TABLE 3-1 Important Features of the Five Pillars

Pillars	Characteristics
Customer Focus	Customer Satisfaction
	Customer Involvement
	Market Diversification
Resources and Capabilities	Personnel Quality
	Budget
	RD&E Capabilities, Skills, Talents
	Use of External Resources
	Important Technologies
	Organizational Climate
	Information Technology
	Facilities and Infrastructure
Strategic Vision	Alignment of Vision and Mission
	Anticipatory Strategic Planning
	Stakeholder Buy-In
	Leadership
Value Creation	Proper Portfolio
	Product Performance
	Cycle Time and Responsiveness
	Value of Work in Progress
Quality Focus	Capacity for Breakthroughs
	Continuous Improvement
	Commitment to Quality
	Structured Processes
	Learning Environment
	Quality of Research

Summary Determinations

After reviewing the ideas discussed above, the committee determined that certain features of each pillar characterize the essence of that pillar. These features are important to the development of characteristics and metrics in Chapter 4 and are summarized in Table 3-1.

REFERENCES

American Heritage. 1992. *American Heritage Dictionary of the English Language.* 3rd Ed. Boston and New York: Houghton Mifflin.

Bounds, Greg, Lyle Yorks, Mel Adams, and Gipsie Ranney. 1994. *Beyond Total Quality Management.* New York: McGraw-Hill.

Brown, Warren and David Gobeli. 1992. Observations on the Measurements of R&D Productivity: A Case Study. IEEE Transactions on Engineering Management. 39 (4): 325–331.

Business Plan. 1995. U.S. Army Soldier Systems Command Business Plan. FY96-01. Volume 2, Appendix F. September.

Doucette, Edward, 1996. Mobility Capability Area Overview. U.S. Army Soldier Systems Command, Natick RD&E Center. February 27.

Dimancescu, Dan. 1991. *The Seamless Enterprise: Making Cross-Functional Management Work.* New York: Harper Collins.

Hamel, Gary and C. K. Prahalad. 1994. *Competing for the Future.* Boston: Harvard Business School Press.

Hodgetts, Richard. 1993. *Blueprints for Continuous Improvement.* New York: American Management Association.

Hodgetts, Richard. 1996.*Implementing TQM in Small and Medium-Sized Organizations.* New York: Amacom.

Luthans, Fred. 1993. Meeting the New Paradigm Challenges through Total Quality Management . Management Quarterly. 34: 2–13.

Luthans, Fred, Richard Hodgetts, and Sang Lee. 1994. New Paradigm Organizations: From Total Quality to Learning to World-Class. Organizational Dynamics. 22 (3): 5–19.

Luthans, Fred, Michael Rubach, and Paul Marsnik. 1995. Going beyond Total Quality: The Characteristics, Techniques, and Measures of Learning Organizations. International Journal of Organizational Analysis. 3 (1): 24–44.

Matheson, David, James Matheson, and Michael Menke. 1994. Making Excellent R&D Decisions. Research-Technology Management. 37 (6): 21–24.

McArthur, Doug. 1994. Practice World-Class Technology. Datamation. 40 (18): 100.

McGill, Michael, John Slocum, and David Lei. 1992. Management Practices in Learning Organizations. Organizational Dynamics. 21 (1): 15–17.

Porter, Michael. 1985. *Competitive Advantage.*New York: Free Press.

Ransley, Derek and Jay Rogers. 1994. A Consensus on Best R&D Practices. Research-Technology Management. 37 (2): 19–26.

Senge, Peter. 1990. *The Fifth Discipline.* New York: Doubleday.

Wheelen, Thomas and David Hunger. 1995. *Strategic Management and Business Policy.* 5th ed. Reading, Mass.: Addison-Wesley.

4

Characteristics and Metrics for a World-Class Army Research, Development, and Engineering Organization

Working from the discussion of pillars in Chapter 3, the committee developed characteristics and descriptions of the metrics associated with them.

CHARACTERISTICS

For the purposes of this study, characteristics are the distinguishing qualities, properties, or features of the pillars. The previous discussion of the five pillars ended with Figure 3-1, which designated 25 important features. These features characterize the pillars, and the committee believes they represent the distinguishing qualities of each pillar. Accordingly, the committee judged these 25 features to be the characteristics most relevant to an Army RD&E organization. A discussion of these characteristics and how they can be assessed appears below. The discussion follows a pillar-by-pillar format, with particular emphasis on determining metrics for evaluating the characteristics of each pillar.

Customer Focus Pillar

Customer focus is directed toward internal customers (e.g., product development teams) and external customers (e.g., soldiers). Both groups of customers can be surveyed to ascertain their satisfaction with the technological solutions and products delivered, the timeliness of delivery, and the quality of technical capabilities and support provided. Customer involvement in setting program objectives and following program progress can also be evaluated.

Although an RDEC must focus on the primary markets it serves, the committee believes that some market diversification (i.e., looking to related markets for technology or products) is proper for any RD&E organization. Indeed, in the private sector world-class RD&E organizations seek to exploit fully the results of their research and product development. Market diversification has merit especially for an Army RD&E organization that has DoD-wide or even broader responsibilities. The extent of market diversification can be determined by examining such things as (1) the penetration and extension of markets for products and technologies and (2) whether these markets lead to expanded or entirely new lines of business. However, the committee notes that market diversification must be considered carefully in the case of Army RDECs because they exist primarily to support their Army missions. Also, RDECs rely on government funding, which is usually authorized to satisfy specific government needs rather than to diversify markets served by individual organizations.

Measuring customer satisfaction and customer involvement in research, development, and engineering, and the nature and appropriateness of market diversification, indicates how well the RDEC is connected with and focused on the long-term and short-term needs of the various customers the RDEC serves.[1]

Resources and Capabilities Pillar

Resources and capabilities can be evaluated in terms of personnel (i.e., human resources); facilities and infrastructure (i.e., physical resources); budget (i.e., financial resources); RD&E capabilities, skills, and talents (i.e., intellectual resources); the use of external resources; important technologies for each directorate; applied information technology; and organizational climate. Internal (e.g., staff and management) and external (e.g., peer, higher headquarters, and customer) reviews can be conducted periodically to assess resources and capabilities. These reviews may include analyses of the core technical programs, evaluations of employee morale and the research climate,

[1] Other indicators can be used to assess customer focus (e.g., an organization's success at anticipating unstated customer needs or how well an organization “hears” the voice of the customer in determining overall direction). However, the committee decided that, for an Army RDEC, it is preferable to concentrate on satisfaction, involvement, and diversification.

and assessments of the ability and effectiveness of program managers to acquire technology from outside vendors (i.e., reach "make versus buy" decisions). Measuring the quality and quantity of the human, physical, and financial resources and the core capabilities of the RDEC gives an indication of the ability and power of the RDEC to achieve world-class results. A positive organizational climate is most often correlated with high productivity (Miller et al., 1996).

Strategic Vision Pillar

The strategic vision must be shared with (i.e., communicated to and discussed with) and understood by staff and stakeholders alike. The vision must then be translated into action. How well this is done depends on the quality of the leadership of the RDEC. Reviews to assess strategic vision should include assessing RDEC leadership. Internal and external (e.g., peer) reviews can determine if the strategic vision and the mission are aligned. They can also determine if anticipatory strategic planning is sufficient to develop future Army and joint service products rapidly. To assess stakeholder buy-in, important classes of stakeholders must first be identified; then the extent to which buy-in by particular stakeholders is critical and the degree to which buy-in is obtained can be assessed. Measuring the quality of the strategic vision of the RDEC (i.e., the extent to which the vision and mission are aligned, to which planning is anticipatory, and to which stakeholders "live" the vision) will give a reading of the enduring capability of the RDEC to plan and achieve world-class results.

Value Creation Pillar

Value creation is often a perception. Perceived values are based on comparisons of the benefits (or lack thereof) of previous products with current products or of the properties of products and costs. Another perception is whether the right products are being delivered to the right place at the right time. Reviews of the breadth of RD&E (i.e., the portfolio of programs), the performance of products and the benefits of services, cycle time and responsiveness, and the value of work in progress are all important to assessing value creation (Miller et al., 1996). Reviews can be both internal and external evaluations of programs in progress, products developed, or services delivered. Measuring the

extent to which the RD&E organization produces outstanding, meaningful results (i.e., creates value for customers) yields an understanding of the present and potential impact of the organization.

Quality Focus Pillar

Several important characteristics are associated with quality focus. First is a capacity for scientific, technological, and engineering breakthroughs. This characteristic can be assessed, in part, by reviewing past performance (e.g., how many breakthroughs have already occurred). Next is the ability to improve continuously, which can be assessed by reviewing specific efforts to improve processes and products. Commitment to quality products and services must be assessed at all levels, from topmost management to the lowest working level. To improve the quality of work, work processes must first be understood, defined, and (to a degree) structured. Structured processes (i.e., working in a disciplined and organized fashion) can be assessed by examining processes and results. Reviews can determine the ability of staff members and the organization as a whole to learn, acquire knowledge (and capabilities), and use this knowledge to achieve outstanding results. Finally, the quality of research can be assessed by expert reviews on several levels (e.g., to determine whether high standards of technical excellence are being maintained). Measurements of all these characteristics can give an overall assessment of the focus on quality in an Army RD&E organization.

METRICS

For the purposes of this study, metrics are defined as standards for measuring the characteristics of each pillar. Before applying metrics in a particular situation, it is necessary to understand some aspects of metrics in general. This understanding is revealed by the answers to several questions.

Who, What, Why, When, and How

Metrics can be used in many ways for evaluating an RD&E operation (IRI, 1996). Long lists of metrics have been developed, but selecting

the most pertinent metrics is important. Critical questions can be asked about using metrics, the answers to which are applicable to Army RDECs.

Who develops the metrics?

Metrics can be established by the involved group (e.g., an RDEC or its directorates) or by others interested in the performance of the group. The metrics must be understood by those making assessments and by those being assessed.

What specific metrics should be developed?

Different sets of metrics are meaningful to different groups. Metrics must be useful for the organization; specific metrics will drive the behavior and actions of people within the organization. For an RD&E organization, metrics should foster improvement and be related to the vision and mission of the organization.

When selecting metrics one must keep in mind that RD&E efforts are part of a system (Brown and Svensen, 1988). Figure 4-1 shows input into the system, which comes from various sources (e.g., personnel, dollars, equipment, scientific knowledge) and moves through RD&E processes to produce output (e.g., reports, patents, concepts). Product output is converted by receivers into outcome (e.g., new products, services, cost savings, benefits for soldiers).[2]

Metrics can be developed to measure (1) the quality of input, (2) the operation of RD&E processes, (3) the quality of output, and (4) the value of outcome. Also, metrics can be developed that relate these four items to the past, present, and future. For example, variations on one measure of an RD&E organization's output might be the number of patents used in the last five years (past), number of patents filed (present), and the number of patent disclosures anticipated during the next five years (future).

[2]The portrayal of RD&E as a system is not meant to exclude the myriad of interactions with external stakeholders, especially customers. The diagram is useful for isolating several key RD&E processes. However, from a larger perspective (e.g., an entire business), the RD&E system is only a subsystem.

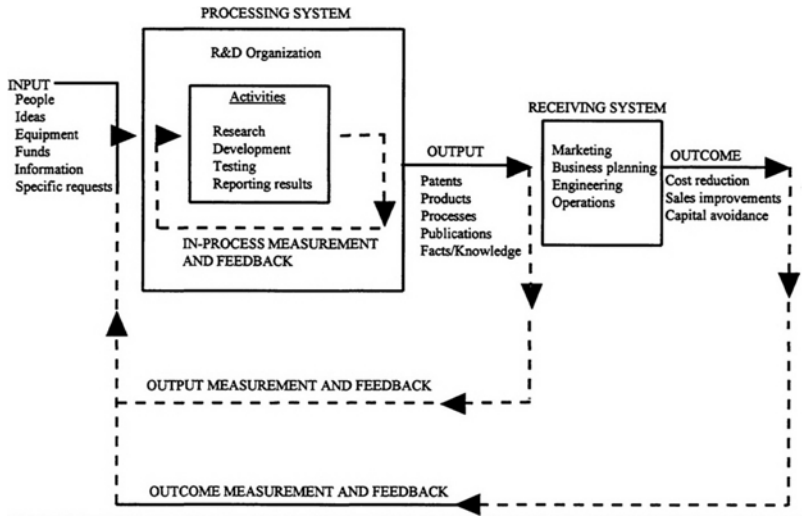

FIGURE 4-1 Research, development, and engineering as a system.

Why use metrics?

Metrics can help an organization assess and determine business or technical objectives, encourage changes, and serve as mechanisms for planning, screening (e.g., setting priorities for improvement), and managing RD&E programs. Metrics can also measure contributions from management, research scientists and engineers, and support staff toward developing, producing, and delivering products.

When should metrics not be used?

The wrong metrics can be harmful. Some metrics may actually limit performance or lead to inappropriate behavior, actions, or results (e.g., metrics based on false cause-effect relationships or wrong work-process models).

When should metrics be developed?

Ideally, metrics should be developed as part of the process of setting objectives or part of the evaluation of how well objectives have been met.

How are metrics developed?

Metrics can be developed collectively or individually, and they can be tailored to match the unique environment of the group or organization being assessed.

Referring to metrics described by the Industrial Research Institute (IRI, 1996) and others (Roussel et al., 1991; Davidson and Prudent, 1996), the committee developed a set of metrics to assess Army RD&E organizations like the Natick RDEC. Four metrics were developed for each of the 25 characteristics identified at the beginning of this chapter.

Of paramount concern during the development of the metrics was the committee's desire to emphasize the importance of demonstrated commitment by the organization's senior leadership (and, where applicable, the next level of command) to attaining and maintaining world-class performance throughout the RD&E organization. Without this commitment, attaining world-class performance will be impossible.

Applying Metrics

The 100 metrics described below can be used to monitor improvements and assess the Natick RDEC in terms of world-class performance. The metrics can also be used by Natick RDEC or other RDEC personnel for self-evaluation or by higher-level Army commands for evaluating other RD&E organizations.

In other situations metrics are used to provide numerical measurements, such as the number of patents written per year or the number of Ph.D.s on staff. Although these measures clearly are relevant to the performance of an RDEC, the committee does not believe that numbers, by themselves, accurately describe the many facets of RDEC performance.[3] Accordingly, the metrics chosen for this assessment are based on qualitative descriptors for four levels of performance (Adler

[3]"Numerical indexes are easily understood and readily compared.... However, there are also some serious drawbacks associated with quantitative measures that counterbalance their virtues....They don't work well in professional groups, such as R&D organizations, where much of the work is characterized by uncertainty and variability…" (Brown and Gobeli, 1992).

et al., 1992).[4] These levels are poor, adequate, good, and excellent.[5] The committee believes for an organization to be deemed world-class, performance must be predominantly excellent.

The committee also considered the category of best-in-class, which is a level of performance beyond excellent. Best-in-class is not included in the following metrics because descriptors for this category apply to unique situations (e.g., an organization or process that is, indeed, the very best) and might not be applicable in a situation where there are no comparisons.

Table 4-1, Table 4-5 summarize, pillar by pillar, the committee's metrics and the four levels of performance for each characteristic. These tables are not necessarily all inclusive; additional tailored characteristics and metrics may be necessary for some evaluations. The descriptors should be looked upon as conceptual guides that can be modified for specific situations.

The results of assessments can be recorded as illustrated in Table 4-6. Overall assessments for each pillar would be arrived at on the basis of judgments of the assessments for each characteristic in that pillar. The committee believes that good or excellent performance in each characteristic, and excellent overall performance in all five pillars, are necessary for an organization to be judged world-class.

The results might also be presented in graph form in typical “spider diagrams” (see Figure 4-2). Spider diagrams may have several uses. For example, Figure 4-2 could be a convenient summary showing if an RDEC approaches or achieves world-class performance on the basis of the pillars alone. A more complicated diagram could include radials for each of the 25 characteristics. Spider diagrams for each directorate could provide visual comparisons. In the case of multiple assessments, a spider diagram for the Natick RDEC could be compared with diagrams for other RDECs.

[4]Many recent metrics (e.g., the Industrial Research Institute's Technology Value Program) that began with the Adler article now use the four-stage model; hence the committee adopted this model to be more consistent with the current literature and the practice of several companies.

[5]The committee also considered using the terms Stage 1, etc. to designate levels of performance. However, the committee was concerned that using numbered stages might lead to a “numbers game” and an inflexible scoring system; hence the committee decided to use words. The words do have some negative and positive connotations, which are intended.

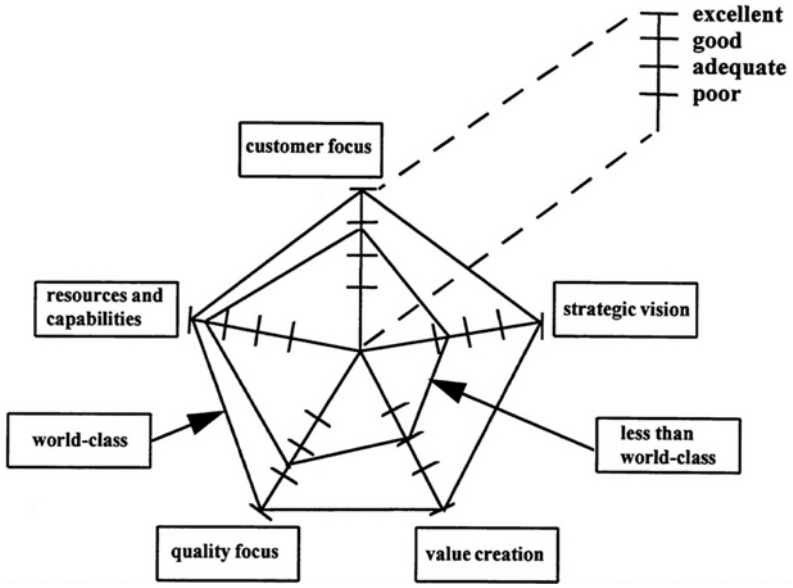

FIGURE 4-2 Spider diagram.

It should be noted that the committee has implicitly given equal weight to all five pillars. Under some circumstances, it may be appropriate to assign greater weight to one pillar or another.

Finally, the committee observes that application of the metrics in this report need not be limited to organizations striving to attain world-class performance. For example, if the metrics are used for self-assessment or self-understanding, they should be used in the context of an organization's role, responsibilities, and goals. If the organization's goals do not include world-class performance, then the organization could choose to use the metrics and approach the assessment in a different way. In some cases an organization could decide to use the metrics as a guide for self-assessment and develop its own definitions of poor, adequate, good, or excellent. Also, an organization might wish to focus on some characteristics or pillars more than others. This adaptation process in itself can be important for self-improvement.

REFERENCES

Adler, Paul, William McDonald, and Fred MacDonald. 1992. Strategic Management of Technical Functions. Sloan Management Review. vol. 33 (2): 19–37.

Brown, Warren and David Gobeli. 1992. Observations on the Measurements of R&D Productivity: A Case Study. IEEE Transactions on Engineering Management. 39 (4): 325–331.

Brown, Mark and Raynold Svenson. 1988. Measuring R&D Productivity. Research-Technology Management. 31 (4): 67–71.

Davidson, Jeffrey and Ann Lorette Prudent. 1996. Quality Deployment in R&D Organizations. Research-Technology Management. 39 (1): 49–55.

IRI. (Industrial Research Institute). 1996. Measuring the Effectiveness of R&D: A set of 50+ metrics available on a searchable disk. Available from IRI, Suite 1100, 1550 M Street, N.W., Washington, D.C., 20005-1708. (Phone: 202-296-8811).

Miller, Joseph, Parry Norling, and John Collette. 1996. Research/Technology Management: Leading, Managing, and Getting Results. Kirk-Othmer *Encyclopedia ofChemical Technology.* Volume R. In press.

Roussel, Philip, Kamal Saad, and Tamara Erickson. 1991. *Third Generation R&D.* Cambridge, Mass.: Harvard Business School Press.

TABLES 4-1 THROUGH 4-6

TABLE 4-1 Metrics of the Customer Focus Pillar

Characteristics	Performance Level	Metrics
Customer Satisfaction	Poor	Less than satisfied or dissatisfied with a. strategy used to develop the product or service, appropriateness of the technological solutions, fulfillment of operational capability requirements b. technical capability, quality, and performance of the service or product c. product cycle time and delivery time of the first equipped unit d. technical support for fielded products developed at the RD&E organization e. technical capabilities of the product or service of the RD&E organization
	Adequate	Satisfied with all of a–e (met expectations)
	Good	Very satisfied with a–e (exceeded expectations)
	Excellent	Delighted with a–e (beyond normal expectations)
Customer Involvement	Poor	No consideration was given to involving either internal or external customers in program planning, evaluation, or early "results" (prototype) testing.
	Adequate	Internal or external customers are at times consulted on various aspects of research programs or are involved primarily in program reviews.
	Good	Internal or external customers are from time to time involved in setting program objectives and following progress; there are opportunities for customer feedback.
	Excellent	Customers feel completely involved, almost like partners in the effort; they feel they can and do have a major impact in the life-cycle development of the product or service.

Market Diversification	Poor	Although diversification is addressed in strategic and business plans, senior management has not effectively broadened the customer base; products are developed only for the Army; few joint service RD&E programs are in place.
	Adequate	RD&E programs result in products for the Army and the other uniformed services; the organization provides products to other federal agencies; some of the budget is devoted to developing partnerships with industry and academia.
	Good	The organization is assigned DoD lead on joint programs; a significant amount of the budget is devoted to partnerships with industry and academia; research partnerships yield products that fulfill military needs and fill a void in the needs of other federal agencies.
	Excellent	As a center of excellence, the organization's products serve a wide range of customers, including DoD, other U.S. government organizations, and global allies of the United States; much technology is transferred between the organization and the private sector; industrial and academic partnerships result in the rapid transfer of cutting-edge technology between the organization and its partners; high-quality products are developed, manufactured, and distributed to global customers.

TABLE 4-2 Metrics of the Resources and Capabilities Pillar

Characteristics	Performance Level	Metrics
Personnel Quality	Poor	Work is below standard throughout the organization; there are inadequate technical skills; program planning and management are poor.
	Adequate	Work meets expectations; work force has adequate skills to get results in a timely manner; opportunities to improve and upgrade skills are minimal; few resources are programmed for improving technical skills.
	Good	Work usually exceeds expectations; newly hired employees bring critical new skills and capabilities; present RD&E personnel devote at least a small percentage of their work time to upgrading or acquiring skills, and this training is reflected in annual performance appraisals; the Army gives special recognition to RD&E personnel; personnel are well connected with the scientific and technical community outside the organization.
	Excellent	Work consistently exceeds expectations (of those with major interests in the work of the organization); new skills and capabilities are regularly introduced into the organization; newly hired personnel bring new, state-of-the-art methods into the organization; personnel are encouraged to devote a significant amount of their work week to improving and acquiring technical skills; personnel are recognized for their accomplishments by individuals and organizations outside the Army; career structures support the development of technologists in a wide range of needed disciplines; personnel are noted for effective use of both external and internal resources.

Budget	Poor	Research and program support budgets are constrained; research programs are consistently underfunded; out-year budget projections are flat or decrease; mid-year budget cuts are routine; programs are abandoned, with resulting inefficiencies.
	Adequate	Although budgets are at the recommended levels, major research programs are constantly in jeopardy because of uncertainties about year-to-year funding; no new major construction or programs are funded even though budgets finally prove to be adequate for maintaining ongoing programs.
	Good	The organization consistently finds ways to get more done with less; resources are leveraged with other government agencies; the organization periodically takes the lead in DoD-wide or similar programs; collaborative programs with industry and academic groups are cultivated; some funding is provided to support new research initiatives, acquire new equipment, and construct or renovate laboratory facilities.
	Excellent	The outstanding work of the organization is recognized by prompt funding at desired levels; the organization is asked to accelerate RD&E programs and initiate new missions when additional funding is available; program managers obtain the absolute best value with their budget; resources leveraged with other organizations and agencies are recognized as force multipliers; the organization maintains a backlog of high-quality yet-to-be-funded projects.

RD&E Capabilities, Skills, Talents	Poor	Technical skills, capabilities, and talents are inadequate to support current and future customer requirements; few new techniques and skills are acquired via new hires or continuing education and retraining of personnel; personnel cannot fully operate, maintain, or utilize available equipment; continuing education is not promoted, encouraged, or funded.
	Adequate	Plans are developed and funding is provided for maintaining the present core capabilities for the future; personnel are trained to operate and maintain equipment and use equipment as specified by the manufacturer; personnel skills are recognized as current and competent for their technical specialties.
	Good	The organization possesses the skills and talents to fulfill customer requirements for the foreseeable future; new and innovative techniques, skills, and processes are incorporated into the RD&E processes; newly acquired skills result in improved product engineering, manufacturing, or performance; new personnel are recruited to bring state-of-the-art techniques into the organization; personnel are encouraged to participate in formal continuing education programs; members of the research staff are encouraged to participate in professional societies, serve on external committees, etc.; program managers recognize new skills that will benefit their programs, and they plan for the acquisition of these skills and talents.
	Excellent	The research and support staffs are recognized as possessing superb technical and administrative skills and talents; many members of the support staff are recognized as artisans of their trade; research personnel incorporate state-of-the-art techniques into their research and develop pioneering methods of their own; a clearly articulated plan describes how needs and voids in core capabilities are identified and filled; new capabilities that must be developed are also addressed and acted upon; a growing inventory of skills is maintained.

Use of External Resources	Poor	Work is contracted outside the organization on an ad hoc basis with little or no planning; contract managers do not ensure that statements of work are fulfilled on time or on budget; products and services provided by contractors and partners contribute incrementally to the organization's mission.
	Adequate	Partnerships are developed with a wide range of groups to enable work to be done outside the organization; work done by others is contracted primarily based on the other party's willingness to do the work; products and services obtained from external sources fulfill the statement of work; products complement internal research programs.
	Good	The organization is recognized as a "smart buyer" of services and work of other parties; personnel appreciate the quality of the work that is contracted; the extent of leverage (i.e., the ratio of the cost to do the work at the organization to the contracted cost) is appreciated; external research programs enhance internal programs and result in leap-ahead technology.
	Excellent	Partnerships and contracts with organizations recognized as the best in their field complement RD&E programs and result in leap-ahead (and occasional breakthrough) technological advances; skills and abilities of the external organization cannot be duplicated in the organization in a cost-effective manner; the value of partnerships is widely recognized inside and outside the RD&E organization.

Important Technologies	Poor	There are no systematic programs or processes for introducing, managing, or assessing research technologies in the research program.
	Adequate	Base technologies being developed or used in the research program are necessary for fulfilling technological needs but offer little differentiation in product performance from other alternatives; important technologies are recognized, developed, and used, but technology development is not advanced.
	Good	Pacing technologies are being developed or used in the research program; these technologies have the potential to change significantly the nature of the research program, but they are not yet embodied in products; incorporation of pacing technologies results in leap-ahead developments.
	Excellent	RD&E programs are anticipatory; development and incorporation of new technology to support RD&E and product development are planned and adequately funded; new areas of research and technology are appreciated, and researchers understand the implications of particular research programs; new scientific discoveries are frequently translated into pacing technologies within the organization.

Organizational Climate	Poor	The work environment is acknowledged by management and staff to be poor; personnel are preoccupied with furloughs, early retirement, and downsizing initiatives; personnel equate re-engineering to organizational instability; initiating risky programs is discouraged; management punishes failure by withholding resources.
	Adequate	The work environment is perceived as professional and collegial; personnel enjoy their work and say it is meaningful; responsibilities are clear, and teamwork and collaborative efforts are evident; managers tolerate innovation and occasionally empower their staffs, teams, and groups; personnel are recognized for their contributions; although anxious about reorganization and downsizing, individuals feel relatively secure about their jobs.
	Good	Work and organizational climate is considered good; bold and innovative thinking is encouraged and rewarded; research personnel are fully empowered to set goals and pursue original and innovative solutions, but they do not fear failure; the organization is recognized as possessing a "can do" attitude.
	Excellent	Management and staff perceive the organizational climate as excellent; there is clarity of purpose and vision; the staff is secure; no hint of fear is present, and rewards and recognition motivate individuals and teams to make excellent contributions; management encourages the development of new work environments that result in increased productivity.

Information Technology	Poor	Computer hardware and software are not available at every work station; software and hardware are two generations or more out of date; personnel cannot communicate electronically or transfer data internally or externally; personnel are poorly trained and hesitant to learn new applications; funding for information technology and user training is inadequate.
	Adequate	Information technology is used as a tool by research and support personnel, and it increases productivity and ultimately decreases the organization's overhead; acquisition of new hardware and software is adequately funded; training and technical support are available; personnel are comfortable with the available technology and are electronically connected internally and externally.
	Good	An information technology strategy guides program direction; research, support, and administrative systems are integrated; information technology enhances the effectiveness of the RD&E allowing work to be done in entirely new ways; information technology is credited with recent advances in research programs; hardware and software are state-of-the-art; technical support is abundant; the staff is educated in the use and application of the technology.
	Excellent	Information technology enables rethinking how RD&E is done, and technical breakthroughs, previously thought of as being impossible, are within reach; the products include information-technology components.

Facilities and Infrastructure	Poor	Facilities and equipment are inadequate, poorly maintained, and out-of-date; no new investments in equipment and facilities are forecast;. preventive maintenance is seldom performed; safety and regulatory compliance are rarely addressed.
	Adequate	Facilities are judged adequate to meet the needs of the organization; there is a schedule for periodic maintenance and upgrading of equipment; safety and regulatory compliance policies are in place, but audits, inspections, and training are limited.
	Good	Research and support facilities are clean, spacious, and comfortable; facilities are environmentally controlled year round; equipment is upgraded or replaced routinely; preventive maintenance and service contracts are well funded; relatively new technical capabilities are acquired, and user training is provided; there is evidence that safety and regulatory compliance are important (e.g., statistics are maintained, periodic inspections are made versus appropriate standards, and training is emphasized).
	Excellent	Facilities and equipment are exceptional; there is timely access to equipment and facilities, which aid personnel in many unexpected ways (e.g., the latest technologies allow them to look at problems in new ways; specialized analytical equipment opens new horizons; there is sufficient equipment to meet user needs); critical programs are supported with state-of-the-art equipment; there is pride in the installation's records in safety and regulatory compliance, ample resources are devoted to inspections and training, and employees continually strive for better safety and regulatory compliance.

TABLE 4-3 Metrics of the Strategic Vision Pillar

Characteristics	Performance Level	Metrics
Alignment of Vision and Mission	Poor	Vision and mission statements are not articulated well, nor are they linked; senior management has difficulty communicating vision and mission statements through command briefings, annual plans, or business plans to staff members and customers.
	Adequate	Vision and mission statements are articulated and understood by most employees; a research strategy is developed using these statements as a guide; research programs, resources, and management support are aligned, in general, with the research strategy.
	Good	The organization's strategic vision is inspiring, and the vision and mission are in harmony with each other; the vision and mission provide a "guide to action" for all programs; management support and resources are aligned with the research strategy.
	Excellent	The strategic vision and management's translation of this vision into a research strategy yields superior products and services; the alignment of resources with the research strategy is readily apparent.

Anticipatory Strategic Planning	Poor	No strategic planning process is implemented, or the strategic plan is ineffective.
	Adequate	A strategic planning process is in place, and business plans and annual plans are implemented; senior management enlists research and support staff assistance to draft and implement the strategic plan through the business and annual plans; the plans are communicated to the staff.
	Good	A robust planning process is in place, with broad involvement across the organization; the resulting planning document is used to measure progress throughout the year; contingency or alternative plans are developed to accommodate rapid changes in customer needs, the environment, or resources.
	Excellent	Plans for human resources, information technology facilities, budget, and travel are fully integrated into strategic plans; the planning horizon for the strategic plans is sufficient to anticipate major Army and joint service needs; multiple examples demonstrate a high degree of flexibility within the organization, which has reacted rapidly to either major opportunities or critical customer needs.

Stakeholder Buy-In	Poor	The strategic vision and research plan either have not been communicated to the RD&E stakeholders or have not been articulated well and are misunderstood; stakeholder response to the vision and research plan is either negative or indifferent.
	Adequate	A strategic vision is spelled out and understood by most stakeholders; the vision makes all major initiatives readily understandable.
	Good	The strategic vision "speaks" to all stakeholders even if they have not been involved in creating it; customers and disinterested parties understand the research plan and advocate providing adequate resources to implement the plan.
	Excellent	The strategic vision is so clearly articulated that stakeholders lobby Army and DoD planners to implement the research plan fully; stakeholder support for the organization's vision and the research plan are so strong that resources are reprogrammed from other accounts to implement the vision.

Leadership	Poor	Commitment of the senior leadership to the strategic vision or research plan is poorly communicated to the staff; administrative and product development managers are not involved in planning the direction of future research or developing the business plan; personnel are suspicious or do not trust the organization's leadership; stakeholders view the senior leadership as ineffectual and reactive.
	Adequate	The strategic vision and research plan are understood by the staff; resources (i.e., time, personnel, and dollars) are aligned to meet these plans; the staff trusts senior leadership and is receptive to new ideas and re-engineering opportunities.
	Good	Management and staff co-develop plans that are understood and embraced by staff and stakeholders alike; ideas flow freely and in both directions between management and staff.
	Excellent	The leadership has created an air of excitement and commitment throughout the entire laboratory; bold and creative ideas are encouraged and funded; RD&E successes are rapidly exploited, and ideas are rewarded; failure is considered an opportunity to learn.

TABLE 4-4 Metrics of the Value Creation Pillar

Characteristics	Performance Level	Metrics
Proper Portfolio	Poor	Products are developed that do not meet customer needs; products have poor customer acceptance; customers perceive that commercial alternatives are cheaper, perform better, and are more durable.
	Adequate	An analytical process to examine the product portfolio is used to design and field products that have greater value and soldier acceptance; results of the analytical process lead to modifications in product design; major changes may be made after fielding the initial product.
	Good	Portfolio analyses of a program are an integral part of the strategic planning process; there is broad and active customer involvement in the portfolio analysis; programs yield products that have significant customer acceptance, meet or exceed customer requirements, and demonstrate increased value compared to current products or commercial alternatives; minor changes in product design occur after initial fielding.
	Excellent	Portfolio analyses result in RD&E processes that yield products and services with excellent value, performance, and customer acceptance.

Product Performance	Poor	Products do not meet customer requirements (e.g., in terms of weight, volume, function, durability, or maintainability); customers complain that product performance does not meet the developer's claims; products are not suitable for use in certain locations or environmental extremes.
	Adequate	Products meet customer requirements, needs, and expectations.
	Good	Products fully meet or exceed customer requirements; products are perceived as better than the ones they replace.
	Excellent	Products not only exceed customer expectations, but product performance includes some pleasant, unexpected surprises (e.g., reduced maintenance requirements, longer shelf life, longer mean time to failure, resource savings).

Cycle Time and Responsiveness	Poor	Cycle time for project completion is longer than anticipated; milestones are routinely missed; program delays result in increased end-item cost; research programs do not anticipate customer needs; management and staff are not flexible to modifications of product requirements.
	Adequate	Elapsed time from project initiation to project completion is measured and can be reliably forecasted; research programs are described as being on-time and on-budget.
	Good	RD&E programs are initiated and completed significantly faster than similar government or commercial programs; research staff is responsive to "quick fixes" for troops, and numerous examples are readily available for major products; senior management ensures that adequate resources are reprogrammed to fulfill quick-fix requests.
	Excellent	RD&E programs are initiated and completed substantially (e.g., one third) quicker than similar government or commercial programs; innovative processes and technical solutions reduce typical quick-fix response times by nearly half; the staff monitors foreign and domestic industrial and academic research for solutions to new and unanticipated technical problems; commanders directly and indirectly express gratitude for responsive quick fixes.

Value of Work in Progress	Poor	No evaluations of historical RD&E programs are available for comparison to current programs; no methodology is in place to assess current RD&E programs; customer perception of prior RD&E programs is predominantly critical and negative, and little or no value is placed upon the current programs by the customers.
	Adequate	A database on select historical RD&E programs and all current programs is available; current RD&E programs are vividly described, and these descriptions are used during peer-review discussions to justify programs and prioritize personnel and budget requests; customer perception of prior RD&E programs is generally positive; customer perception of current RD&E programs is positive (i.e., the products and services will generally meet user requirements and be delivered on time and on budget).
	Good	A database is maintained on all past major projects (e.g., for the last decade) and their primary and secondary impacts; the database is used for comparison with current RD&E programs; leadership creates a scale to rate continuously the potential value of current programs compared with previous programs and show improvements; customers rate RD&E programs as very good (i.e., products are expected to fully meet or exceed customer requirements; products are perceived as likely to be better than the ones they replace).
	Excellent	A complete historical database and evaluation methodology are used to demonstrate the value of the organization's products and services; data are used to justify and defend program expenditures; customers rate products and services as excellent (e.g., product performance exceeds customer expectations); product performance exceeds anything projected to be available from domestic and foreign sources for at least several years.

TABLE 4-5 Metrics of the Quality Focus Pillar

Characteristics	Performance Level	Metrics
Capacity for Breakthroughs	Poor	RD&E programs are routine and unimaginative; there is no evidence of imaginative or innovative solutions being applied to RD&E tasks; resources are directed to meeting specific customer requirements only.
	Adequate	RD&E programs are characterized by steady but incremental improvement; several innovative solutions can be pointed out; minimal funding is available for programs that anticipate future military requirements.
	Good	Although most programs are characterized by incremental improvements in technology, the organization has demonstrated several leap-ahead improvements; the organization encourages and funds opportunities to seek truly innovative, moderate-risk solutions.
	Excellent	Unexpected innovation based on breakthroughs in technology occur fairly regularly among internal and external (cooperative) RD&E programs; moderate- and high-risk research that offers high return receives stable funding; numerous examples of breakthrough research are cited from the previous five to ten years.

Continuous Improvement	Poor	There is no tangible evidence of senior management commitment to continuous improvement; the need and ability to focus on continuous improvement are recognized, but not funded; products and services show incremental changes; innovations are not rewarded; solutions from industry and academia are discounted as "not invented here."
	Adequate	Quality of the work is discussed and several measures of quality are used routinely; innovative solutions are encouraged; staff members frequently make suggestions for improvement; several changes are made (and documented) each month for improving the work and the output of the organization.
	Good	The organization takes steps to improve work processes and RD&E results significantly; quality audits are performed periodically by internal and external review groups; numerous improvements can be pointed out; productivity is an important topic of discussion; report cards are issued annually by senior leadership; senior managers have the resources to enact recommendations.
	Excellent	Greater productivity, enhanced research and product quality, improved customer involvement and satisfaction, and continuing education of the work force are areas of primary interest to senior management; the concepts of continuous improvement and excellent product value are embedded in the goals of each RD&E and support function; there is a systematic analysis of research and support processes to eliminate non-value-added activities; research personnel are renowned for finding innovative solutions to technically difficult problems.

Commitment to Quality	Poor	Management espouses a commitment to quality, but no formal process to review and evaluate quality is in place; some quality-related results are managed by exception; the quality of products and services varies between RD&E units in the organization.
	Adequate	Management is investing resources for total quality training and implementation; the variability of products and services is being measured and tracked; personnel are aware of the importance of quality.
	Good	Total quality implementation is a major goal in the organization's strategic plans; a framework and methodology for measuring and assessing total quality is in place; measurable objectives for work-process improvement are established; there are methods (e.g., statistical process controls) to improve effectiveness and product quality with existing resources.
	Excellent	The commitment to total quality is inherent and pervasive throughout the organization; the focus of all measurements is on optimizing the RD&E processes to deliver value; frameworks, such as ISO 9000/2 (international quality standards), Baldrige criteria, or locally developed systems, are used for assessment; recommendations to improve quality are immediately funded and implemented.

Structured Processes	Poor	Work processes and procedures are understood and milestones are established, but there is no system of internal or external review; project management results in products or services that are delivered late and over budget; delays result in termination of projects; disciplined approaches to defining problems and the scientific method are rarely used.
	Adequate	Work processes and procedures are monitored; project costs and milestones are closely tracked; processes are established to improve quality incrementally, contain or reduce RD&E cost, and reduce product cycle time; disciplined approaches and the scientific method are used most of the time.
	Good	Program managers are flexible and adaptive; senior leadership and staff are receptive to innovative ideas for improving work processes and procedures; product quality and customer focus mean continuous improvement; disciplined approaches and the scientific method are used consistently.
	Excellent	The senior leadership strives to identify and incorporate best business practices into the organization; processes are considered flexible and not overly restrictive, prescriptive, or bureaucratic; management is focused on achieving superior performance and product quality; emphasis on cross-project management ensures timeliness and the proper allocation of resources; disciplined approaches to problem solving include an extensive network linked to Army technological resources worldwide; the scientific method is strictly followed.

Learning Environment	Poor	Senior leadership is characterized as reactive; little if any learning takes place on an organizational basis; some managers and staff learn from mistakes.
	Adequate	Senior leadership recognizes and communicates the importance of organizational learning; management and staff learn from mistakes and from others; personnel are well networked both inside and outside the organization; teams on one project teach teams assigned to other projects; new skills and techniques are acquired through new hires and continuing professional education.
	Good	Organizational learning is characterized as adaptive; the organizational climate is conducive to learning; personnel are rewarded and encouraged for taking risks and entrepreneurial initiatives despite occasional mistakes; personnel learn from others and by doing; management experiments with new organizational concepts to discover new ways of doing things.
	Excellent	Organizational learning is adaptive and anticipatory; research and technical capabilities continually expand, and management anticipates change; traditional and innovative methodologies are used to measure and evaluate organizational learning.

Quality of Research	Poor	Research and technology programs are not generally aligned with customer requirements and needs; records of research methodology and results are poor; although recorded in technical reports, data are not published in peer-reviewed journals or cited by other scientists in academia or industry; research results cannot be replicated by scientists and engineers outside the organization.
	Adequate	Research and technology programs are aligned with customer requirements and needs; research methodology and results are peer-reviewed and published as both technical reports and journal articles; the research staff is invited to participate in scientific meetings and workshops; research results are easily replicated by other laboratories.
	Good	The research and technology programs are recognized by peers as being of very high caliber; several programs are among the best in the federal government and are described as innovative and original; some patents are awarded.
	Excellent	The quality of the research and technology programs is considered to be among the best in the world; basic research not only fulfills customer needs, but also anticipates future requirements, thus reducing cycle time for new products; research and technology programs are innovative and state-of-the-art; new procedures, processes, and materials are developed by personnel; numerous patents are issued for RD&E innovations.

TABLE 4-6 Organizational Assessment

Component	Assessment: Poor	Adequate	Good	Excellent
Customer Focus Pillar				
Customer Satisfaction	____	____	____	____
Customer Involvement	____	____	____	____
Market Diversification	____	____	____	____
Pillar Assessment:	____	____	____	____
Resources and Capabilities Pillar				
Personnel Quality	____	____	____	____
Budget	____	____	____	____
RD&E Capabilities, Skills, Talents	____	____	____	____
Use of External Resources	____	____	____	____
Important Technologies	____	____	____	____
Organizational Climate	____	____	____	____
Information Technology	____	____	____	____
Facilities and Infrastructure	____	____	____	____
Pillar Assessment:	____	____	____	____
Strategic Vision Pillar				
Alignment of Vision and Mission	____	____	____	____
Anticipatory Strategic Planning	____	____	____	____
Stakeholder Buy-In	____	____	____	____
Leadership	____	____	____	____
Pillar Assessment:	____	____	____	____
Value Creation Pillar				
Proper Portfolio	____	____	____	____
Product Performance	____	____	____	____
Cycle Time and Responsiveness	____	____	____	____
Value of Work in Progress	____	____	____	____
Pillar Assessment:	____	____	____	____
Quality Focus Pillar				
Capacity for Breakthroughs	____	____	____	____
Continuous Improvement	____	____	____	____
Commitment to Quality	____	____	____	____
Structured Processes	____	____	____	____
Learning Environment	____	____	____	____
Quality of Research	____	____	____	____
Pillar Assessment:	____	____	____	____

5

Conclusions and Recommendations

The committee has developed the following conclusions and recommendations based on this study.

CONCLUSIONS

Conclusion 1. The phrase "world-class" is widely used to describe products and services. This phrase, however, can reasonably mean different things to different people. Therefore, if the phrase "world-class" is to be useful as a vision, it must be defined, tailored, and characterized in detail.

Conclusion 2. A world-class R&D organization is one that is recognized by peers and competitors as among the best in the field on an international scale, at least in several key attributes.

Conclusion 3. A world-class Army RD&E organization is one that excels in several key attributes by matching core competencies to its mission, thereby fulfilling the needs of soldiers as well as, or better than, similar organizations anywhere in the world.

Conclusion 4. Efforts to reach or maintain world-class performance require the demonstrated commitment of the full chain of command, from topmost management to the lowest level.

Conclusion 5. World-class R&D organizations are likely to excel in certain fundamental attributes, which are based on demonstrated

commitment. These attributes, often called pillars, are customer focus, resources and capabilities, strategic focus, value creation, and quality focus.

Conclusion 6. The five pillars are the basis of 25 characteristics that the committee believes are most relevant to an Army RD&E organization (see discussion of the characteristics in Chapter 4).

Conclusion 7. Metrics with qualitative descriptors for four levels of performance (i.e., poor, adequate, good, and excellent) of the 25 characteristics are the preferred means of determining the extent to which an RD&E organization has achieved world-class performance. (The metrics appear in Table 4-1, Table 4-5.)

Conclusion 8. Good or excellent performance for each characteristic, and excellent overall performance for all five pillars, are believed to be necessary for an organization to be judged world-class.

RECOMMENDATIONS

Recommendation 1. The concepts, characteristics, and metrics developed in this study should be used to assist the committee to assess the Natick RDEC.

Recommendation 2. These concepts, characteristics, and metrics should be considered by the Army or outside reviewers for use in assessing other Army RD&E organizations.

Recommendation 3. Army RD&E organizations should consider using these concepts, characteristics, and metrics for self-evaluation.

Recommendation 4. The concepts developed in this study should be considered by RD&E organizations in general for making assessments and self-evaluations. Some tailoring of the characteristics and metrics will probably be needed to suit specific organizations, be they inside or outside the DoD.

Recommendation 5. The concept of a world-class organization should be used principally as an internal focusing mechanism for

achieving excellence rather than as an external mechanism for advertising the virtues of an organization.

Appendix

Meetings and Discussions

PANEL MEETINGS

December 11-12, 1995
Washington, D.C.

Objectives: Review statement of task; approve the project plan; approve the outline and study concept, as articulated in the draft report concept; continue gathering data by discussing world-class research and development with experts from industry, academia, and government; make writing assignments and schedules for chapters of the report.

Presenters:

Robert Stempel, NAE, General Motors (retired)

Lance Davis, Defense Research and Engineering (Laboratory Management/ Technology Transition)

David Gobeli, Oregon State University

James Gover, Sandia National Laboratory

Fred Luthans, University of Nebraska, Lincoln

Derek Ransley, Chevron Research and Technology Company

Richard Smith, U.S. Army Research Office

January 25–26, 1996
Washington, D.C.

Objectives: Review, discuss, and revise, as necessary, chapter 1, chapter 5 of the report. Discuss next steps in report realization. Discuss report concept and program plan for Phase 2.