Strategic and Critical Materials 2011 Report on Stockpile Requirements

Under Secretary of Defense
for
Acquisition, Technology and Logistics

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Executive Summary

Background

This 2011 National Defense Stockpile (NDS) Requirements Report on strategic and critical materials is submitted to Congress by the Department of Defense (DOD) pursuant to Section 14 of the Strategic and Critical Materials Stock Piling Act (see Appendix 4). Section 14 requires that NDS requirements be based on: (1) a military conflict scenario consistent with the scenario used by the Secretary of Defense in budgeting and defense planning purposes; and (2) those materials necessary to replenish or replace, within three years of the end of the conflict scenario, all munitions, combat support items, and weapon systems that would be required after such a military conflict.

As have prior NDS Requirements Reports, this report continues to focus chiefly upon estimating U.S. vulnerabilities with respect to strategic and critical materials pursuant to the terms of the Stock Piling Act. DOD will propose continuing, on an interim basis, a traditional stockpiling approach for a number of materials that manifest significant vulnerabilities in this report. Concurrently, however, this assessment and report represent the start of a fundamentally new approach to DOD's analysis of U.S. material vulnerability and mitigation options. As DOD's new Strategic Materials Security Program (SMSP) is developed, DOD and its interagency partners will need Congressional support to collaborate in prompt, intensive and fundamental assessments of the most prudent, practical, cost-effective remedies—to include but not be confined to traditional stockpiling—in order to mitigate the nation's serious U.S. strategic and critical materials vulnerabilities in the months and years ahead. Other remedies to be considered in the emerging SMSP will include immediate plausible substitution possibilities, contingency surge reserves (rolling inventories), contingency arrangements to accelerate ramp-up time to full capacity production levels and help ensure U.S. priority access (at least within the United States but also with close friends and allies), potential loan guarantees and investments in U.S. production capacity, longer range substitution possibilities (away from vulnerable materials), and other approaches as well. These are some of the remedies that the U.S. government may want to pursue itself or, even better, develop and implement in partnership with friends and allies, especially those with strong mutual interests in promoting strategic and critical material security. Remedies developed in peacetime can be available for implementation during a conflict to prevent shortfalls that could otherwise occur without them.

Overall, and consistent with Stockpiling Act, the defense planning scenarios approved by DOD for use in this study are aligned with the force planning framework articulated in DOD's latest National Defense Strategy and the 2010 Quadrennial Defense Review (QDR).[1] For purposes of the study, the 2011 Base Case builds upon the best available DOD-approved analytic products (as of May 2010) that most closely represent elements of the QDR Force Sizing Construct (FSC). Although it does not conform completely to the FSC, it specifies multiple contingencies occurring more or less concurrently during the conflict year, namely: (1) a catastrophic attack on a U.S. city by a foreign terrorist organization or rogue state; (2) two major overseas (state vs. state) conflicts; and (3) several significant counter-insurgency activities. (See classified appendices.) The base case scenario as outlined here has been developed in coordination with the Office of the Under Secretary of Defense for Policy to ensure consistency with the strategic guidance.

Material vulnerability assessments in this 2011 study employ the same basic methodologies as have previous NDS requirements report studies (e.g., 2003 and 2005). Demands for goods and services are projected on a time-phased basis for all military, industrial, and essential civilian uses of strategic and critical materials under the specified scenario. For the 2011 Base Case, this means projections postulated for the conflict year and each of the three regeneration years. Associated essential demands for strategic and critical materials are then determined and compared to time-phased projections of available domestic and foreign material supplies (all in the scenario context) in order to identify any material shortfalls.[2] The analysis considers likely scenario-specific supply conditions, including the political and economic reliability of foreign sources. Projected shortfalls in reliable material supplies in the Base Case serve as initial vulnerability assessments for establishing appropriate mitigation strategies. In previous reports, such mitigation strategies have been restricted to traditional stockpiling. In this report, as noted above, initial examples will be offered of other potential strategic material risk-mitigation strategies.

Chapters One and Two of this report will identify projected shortfalls under varying scenario assumptions. The 2011 Base Case assessment, which focuses upon a major National Security Emergency consistent with the mandated scenario in the Stock Piling Act, is presented in Chapter One. Chapter Two will present an alternative scenario that addresses a range of serious potential supply disruptions in more of a peacetime (but hardly business as usual) context. (Bear in mind that neither of these cases is a prediction of future events. Rather, each one postulates a set of conditions for which DOD and the Nation should plausibly be prepared.) Chapter Three then will discuss potential mitigation strategies and several examples to address some of the identified vulnerabilities in the Base Case and the Alternative Case.

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[1] See *The National Defense Strategy*, Department of Defense, 2008 and The 2010 QDR Report.

[2] A "shortfall" may be thought of as less available supply of a material (not counting NDS inventories) than essential demands for the material in the scenario. A "shortage" may be thought of as arising if there is a shortfall of a material and insufficient NDS inventory of that material to cover the shortfall. In particular, if there is zero inventory, all shortfalls are shortages.

2011 Base Case Findings

The Base Case analysis presented in this report assesses 70 materials and identifies "shortfalls" for 28 of them. Shortfalls, defined as inadequacies in projected supplies of materials in the scenario compared to essential scenario demands (military, industrial, and essential civilian) for materials, amount to $2.013 billion—*not counting NDS inventories*.[3] After including NDS inventories for those materials with shortfalls, net *shortages* of these materials total $1.776B. The 70 materials include 51 materials that were assessed in the 2005 Requirements Report to Congress, plus 19 "new" materials. The group of 51 includes 36 "standard" materials for which demands are estimated using indices called Material Consumption Ratios (MCRs), based on material consumption information from the Department of Commerce,[4] as well as 15 "specialty" materials whose demands have been estimated in previous reports (and will again be assessed) using a "proxy" MCR methodology. Nineteen materials that have been newly designated by DOD components as important to examine are also assessed in this study. These new materials include a number of rare earths, high performance fibers, and lithium. A proxy MCR is also used for almost all of these "New" materials.

For some initial perspective on these 2011 Base Case shortfalls, consider that, in the aggregate, they represent less than one percent of the estimated total essential defense and civilian demand ($300.8B) for these 70 materials over the 2011 Base Case (four-year) scenario. In line with this general observation, the defense shortfalls ($42M) in this 2011 Base Case also represent a small percentage (less than one percent) of overall DOD demands ($20.3B) for these 70 materials in this case.[5] Moreover, essential civilian shortfalls of these materials ($1.972B) also represent a similarly small percentage (less than one percent) of overall essential civilian demands for these materials ($280.5B) in the 2011 Base Case.

"Top Ten" 2011 Base Case Shortfall Materials

For some initial specificity about the individual materials manifesting 2011 Base Case shortfalls, Table ES-1 shows the "Top Ten" Base Case shortfall materials among the 70 that are assessed in this report, ranked by dollar value of their shortfalls. These Top Ten comprise $1.589B (79percent) of the overall $2.013B in shortfalls for the Base Case. Table ES-1 also shows that the NDS has no inventories at all for seven of these Top Ten, very limited inventories for two of them (tantalum and tin), and ample inventory for one—tungsten.

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[3] Materials are evaluated using September-November 2010 prices. See Chapter One, Table 2, for a full list of the 70 materials assessed and the 28 having Base Case shortfalls.

[4] See Appendix 8 for a description of MCRs and the "Proxy MCR" approach.

[5] Seven of the materials examined exhibit defense shortfalls, with a total defense shortfall value of $42.03M. They are: beryllium metal ($4.78M), IM-6 carbon fiber ($0.38M), columbium ($21.15M), dysprosium ($1.61M), europium ($3.45M), terbium ($6.78M), and yttrium ($3.88M).

Table ES-1. Top Ten 2011 Base Case Shortfalls, and Associated Shortages

Strategic Material	Important Defense Uses	Base Case Shortfall in $M (Defense)	NDS Inventory in $M	(Shortage) Or Surplus in $M	Import Dependence (percent)	Top Foreign Producers
Tantalum	Capacitors Superalloys	332 (0)	0.16	(332)	100	Australia, Brazil, China, Japan
Tin	Solder, Alloys	319 (0)	64	(255)	80	Peru, Bolivia, China, Indonesia
Antimony	Flame retardants, Batteries	250 (0)	0	(250)	93	China, Bolivia, Mexico
Neodymium	Magnets, Lasers	163 (0)	0	(163)	100	China
Tungsten	Cutting tools, Superalloys	138 (0)	238	100	63	China, Canada, Germany, Bolivia
Aluminum Oxide	Abrasives	128 (0)	0	(128)	100	China, Russia
Fluorspar, Acid Grade	Hydrofluoric Acid	78 (0)	0	(78)	100	China, Mexico, South Africa
Bauxite, Refractory Grade	High temperature applications	65 (0)	0	(65)	100	Jamaica, Brazil, Guinea, Australia
Yttrium	Displays and lighting	60 (4)	0	(60)	100	China, Japan, France
Manganese Metal	Wireless communications equipment	56 (0)	0	(56)	100	China, Australia, South Africa
Top Ten Subtotal		1,589 (4)		(1,387) -- sum of shortages		

Table ES-1 also reveals several other striking features of the Top Ten 2011 Base Case shortfalls. First, (as is true overall for the Base Case) the defense sector shortfalls among these Top Ten represent a very small percentage of the Top Ten shortfalls: $4M of $1.589B, less than one percent of the total Top Ten shortfall. Second, China is currently a key foreign producer of all but one of these Top Ten shortfall materials. Third, all of these materials do have important defense sector applications. Fourth, this study has examined a total of seven rare earth materials; notably, two (neodymium and yttrium) of the Top Ten shortfall materials in this Base Case are rare earths, a category of materials that has recently been of interest and concern to the Congress and parts of the Executive Branch.[6] Worth mentioning is that the other five rare earths (dysprosium, europium, praseodymium, samarium and terbium) studied in this Base Case also present shortfalls. Indeed, the 2011 Base Case assessment strongly suggests the importance of continued, deeper and broader analyses of potential U.S. vulnerabilities with regard to rare earths. For example, while the rare earth data used in this report are the best that were available to DOD in preparing this assessment, they are still preliminary. Thus, they should be compared closely with any new evidence before significant mitigation investments are made with regard to such materials. To this end, Section 843 of the FY 11 National Defense Authorization Act directs the Secretary of Defense to undertake an assessment of the supply and demand for rare earth materials in defense applications and identify which, if any, rare earth materials may be deemed critical to military equipment and may be subject to supply disruption based on events outside the control of the Government of the United States.

Overall 2011 Base Case Shortfalls Compared to NDS Inventories

Of the 28 materials with 2011 Base Case shortfalls, seven had *some* NDS inventory, as of 30 September 2010, that may be used to at least partially "cover" their respective shortfalls. Of these seven, only two (tungsten and beryllium metal), had enough NDS inventory to fully cover their shortfalls. Moreover, the other 21 (of 28) materials with 2011 Base Case shortfalls have no NDS inventories at all. In sum, 26 of the 70 materials assessed have what are defined in this report as Base Case "shortages": less NDS inventory than their Base Case shortfalls.

The "Key 13" Materials

Also noteworthy at the outset is that, of the 70 materials examined here, 13 had sales of their NDS inventories suspended/curtailed starting in January of 2008, owing to earlier DOD concerns about potential shortfalls of the kind to be presented here. A number of these 13 materials do indeed manifest 2011 Base Case shortfalls. Table ES-2 lists these 13 materials, along with summary 2011 Base Case shortfall and shortage assessments and some other basic information.

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6 Several recent Congressional hearings and a GAO (April 2010) study have highlighted the dependence of the United States upon Chinese sources of rare earths and called for closer attention to the issue as well as for options to deal with it.

Table ES-2. Key 13 Materials

Key 13 Material	Shortfall in $M in Base Case (Defense Shortfall?)	Shortage in $M in Base Case	Defense Uses	Key Foreign Producers
Beryllium Metal	$18 M (Yes)	0	Computer, IT and nuclear applications	United Kingdom, Kazakhstan, Kenya, Ireland
Chromium, Ferro	0	0	Steel alloys, Superalloys	South Africa, India, Kazakhstan, Russia
Chromium Metal	0	0	Steel alloys, Superalloys	South Africa, India, Kazakhstan, Russia
Cobalt	0	0	Superalloys	Dem. Rep. Congo, Canada, Norway, Russia, China
Columbium	$21M (Yes)	($21M)	Steel alloys	Brazil, Canada
Germanium	$17M (No)	($0.13M)	Fiber optics, Infrared optics, Electronics	Belgium, China, Russia, Germany
Iridium	$17M (No)	($16M)	Catalysts, Capacitors	South Africa, Canada
Manganese, Ferro	0	0	Steel alloys	South Africa, China
Platinum	0	0	Catalysts, Capacitors	South Africa, Canada
Tantalum	$332M (No)	($332M)	Capacitors	Australia, Brazil, China, Japan
Tin	$319M (No)	($255M)	Alloys, Containers	China, Indonesia
Tungsten	$138M (No)	0	Electrodes, cutting tools, Superalloys	China, Russia, Bolivia, Germany, Canada
Zinc	0	0	Galvanizing, Alloys	China, Peru, Mexico, Ireland
Total, Key 13	$862M	($624M)		

Seven of the “key 13” materials do exhibit shortfalls in the 2011 Base Case, with those shortfalls amounting to $862M (of the $2.013B total shortfalls for 28 materials). These seven all had *some* inventory remaining as of 30 September 2010. Only two, beryllium metal and tungsten, had enough NDS inventory to fully cover their estimated Base Case shortfalls. The other five of the “key 13” materials with 2011 Base Case shortfalls (Columbium, Iridium, Tantalum, Tin, and Germanium) thus manifest Base Case shortages, as indicated in Table ES-2 (and will be detailed in Chapter One).

Why the Larger 2011 Base Case Shortfalls?

The estimated shortfalls under 2011 Base Case conditions represent a significant increase compared to estimated 2005 Base Case shortfalls as presented in the last full (2005) NDS Requirements Report.[7] This significant increase reflects two major changes relative to the 2005 NDS Base Case: (1) updated data, e.g., a new set of DOD planning contingencies (from the 2010 QDR), new material supply estimates from the U.S. Geological Survey, new country reliability estimates from the Defense Intelligence Agency, new macroeconomic estimates for the economy from the Council of Economic Advisors, and new demand-side information for materials from the Department of Commerce; (2) new, more realistic supply-side assumptions (than were used in the 2005 study) regarding such key factors as the time likely to be needed for the U.S. to start obtaining mobilization-level domestic and foreign supplies in the first phases of the Base Case scenario. The new supply-side assumptions were reviewed and approved by an Office of the Secretary of Defense-Joint Staff advisory panel in September 2010. The new supply-side assumptions are the main factor driving the higher shortfalls in this 2011 Base Case. A sensitivity case for the 2011 Base Case that is otherwise the same as the 2011 Base Case but uses 2005-like supply-side assumptions illustrates the point: material shortfalls in the 2011 Base Case total $2.013B; shortfalls in that 2005-like sensitivity case for those same 70 materials total approximately $391M, or only about 19 percent of the 2011 Base Case shortfalls. (Appendix 6 provides details.)

An Alternative Scenario

Although the 2011 Base Case is expected to be the primary case of interest to the Congress in this report, Section 14 of the Stock Piling Act mandates that DOD also estimate NDS shortfalls using alternative scenarios that are potentially more serious than those of the Base Case. Analyses of defense sector shortfalls for one such alternative scenario, a “peacetime” supply disruption scenario (PSD1)[8] indicate that material shortfalls could occur for the defense sector with respect to 40 of the same 70 materials that were assessed in the 2011 Base Case. In

[7] 2005 Base Case shortfalls totaled $157M in 2005 prices ($239M in 2010 prices).

[8] An earlier set of estimates for such a scenario was provided to the Congress in DOD’s April 2009 NDS Reconfiguration Report (Appendix C, Table 1).

PSD1, DOD would need to rely for up to a year only upon normal U.S. and assured foreign supplies (as identified by the Defense Intelligence Agency) in order to meet its ongoing, regular demands for materials. Estimated aggregate shortfalls for these 40 materials range up to $637M for DOD alone under the PSD1 scenario assumptions. (These shortfalls represent more than fifteen times the DOD shortfalls for these 70 materials in the 2011 Base Case.) While the disruptions posited under PSD1 seem very unlikely to occur all at once, they nevertheless offer an aggregate starting point for considering the strategic material resource implications of numerous potential disruptions that DOD could have to address in the months and years ahead—incidents such as natural disasters, industrial accidents, strikes by miners, political upheavals in supplying countries, terrorist sabotage abroad, or deliberate supply disruptions by major foreign producers as has recently occurred with respect to Chinese exports of rare earths to Japan.

Table ES-3 presents the Top Ten shortfalls in the Alternative Case, along with inventory and shortage/surplus estimates for these Top Ten.

Among the 40 materials exhibiting shortfalls in PSD1 are nine of the "key 13" materials mentioned above. These nine shortfalls represent $125M of the $637M in shortfalls in this alternative scenario.

2011 Base Case Summary

2011 Base Case assessments presented to Congress in this report indicate that current NDS inventories by themselves are inadequate and out of balance to address U.S. material vulnerabilities in view of plausible emerging security challenges. Tables 1 through 3 in Chapter One indicate that of the $2.013B in shortfalls (Table 2), NDS inventories of $1.304B (see Table 1) cover only approximately $0.238B of those shortfalls, leaving $1.776B in shortages after the relevant NDS inventories (~$0.238B) have been "used" to directly offset shortfalls. The remaining inventories—about a billion dollars worth—are thus "excess" or surplus material inventories, in the sense that they are not directly applicable (not the right materials) to cover the projected shortfalls. Even assuming that those excess inventories are sold and the revenues are used to buy materials now estimated to be in shortage in the 2011 Base Case, this effort would still leave about $0.710B of shortages.

Recommendations

In light of these 2011 Base Case assessments, this report recommends suspending *all* further sales of NDS inventories for the 28 materials that have Base Case shortages. The report also recommends at least temporarily retaining NDS sales revenues from other NDS materials (that have uncommitted excess inventories) in order to cover as many of the estimated shortages among those 28 materials as possible.

Table ES-3. Top Ten 2011 Alternative Case Shortfalls, and Associated Shortages

Strategic Material	Important Defense Uses	Defense Shortfall in $M	NDS Inventory in $M	(Shortage) Or Surplus in $M	Import Depen-dence (percent)	Top Foreign Producers
Titanium Sponge	Guided missiles & Space vehicles	142	0	(142)	67	Kazakhstan, Japan, China, Ukraine
Lead	Small arms ammunition, Batteries, Radios	93	0	(93)	0	Australia, China, Ireland, Mexico, Peru, Portugal
Aluminum Metal	Aircraft, Ammunition, Aircraft/missile parts/equipment	71	0	(71)	18	Canada, Russia, Brazil, Venezuela
Silver	Photographic equipment, Electrical machinery	49	0	(49)	63	Mexico, Canada, Peru, Chile
Platinum (Platinum Group)	Radios, Communication equipment	48	11	(37)	89	Canada, South Africa
Palladium (Platinum Group)	Radios, Communication equipment	37	0	(37)	47	Russia, South Africa, United Kingdom, Belgium
Tin	Electronic components, Aircraft & missile engines	25	64	39	80	China, Indonesia
Antimony	Ammunition, Batteries	20	0	(20)	93	China, Mexico, Belgium
Rhodium (Platinum Group)	Aircraft, Electrical machinery, Nuclear reactors	15	0	(15)	93	South Africa
Neodymium	Magnets (PGMs, C4ISR), Lasers	13	0	(13)	100	China
Top Ten Subtotal		513	75	(477) -- sum of shortages		

The Way Ahead

DOD, in conjunction with its interagency partners, will collaborate vigorously to find the most prudent, cost-effective ways to mitigate risks from these shortages, as well as to expand systematic vulnerability assessments of this kind, to include additional materials that appear likely to have shortfalls under the conditions represented by this Base Case and/or by other important planning scenarios. Additional rare earths, for example, beyond the seven that have been examined in this specific study, look to be strong candidates for closer assessment. More broadly, while the materials assessed in this report represent a very important subset of strategic materials, there are many others of current and emerging importance to DOD—a variety of alloys, ceramics, smart and nano-materials for example—that warrant careful consideration as well. Under its new SMSP, DOD will be expanding its systematic assessments of materials such as these as quickly as practicable.

As mentioned above, Chapter Three of this report will outline several possible risk/vulnerability mitigation strategies—in addition to stockpiling—that may be used in the months and years ahead to address these shortfalls and shortages. Strategies include ways to potentially reduce demands for these materials as well as ways to increase the availability of key supplies of them. Chapter Three will also offer several preliminary examples. For instance, there might be practical ways for the U.S. government to arrange beforehand with key domestic and/or friendly foreign suppliers of materials in shortfall to more quickly ramp-up production of and provide greater U.S. access to those materials than assumed in the 2011 Base Case. Such strategic planning efforts could significantly reduce U.S. vulnerability to a number of the 2011 Base Case material shortfalls. If a full risk assessment and mitigation analysis of the Base Case shortfalls—under the new SMSP—indicates that there are more cost-effective strategies than traditional stockpiling, then DOD, along with its interagency partners, will present these options and recommendations to the Congress with all deliberate speed (beginning in late 2011).

Chapter One:
Base Case Findings

Introduction

This 2011 Report on National Defense Stockpile (NDS) Requirements for strategic and critical materials is submitted to Congress by the Department of Defense (DOD) pursuant to Section 14 of the Strategic and Critical Materials Stock Piling Act (50 U.S.C. § 98h-5), as amended (see Appendix 4). This document includes both the Report on NDS Requirements and the list of national emergency planning assumptions used in estimating requirements as called for by Section 14 of the Stock Piling Act.

Section 14 mandates that NDS requirements be founded upon a Base Case that is four years in duration and that uses: (1) a military conflict scenario consistent with the scenario used by the Secretary of Defense in budgeting and defense planning purposes; and (2) those materials necessary to replenish or replace, within three years of the end of the scenario, all munitions, combat support items, and weapon systems that would be required after such a military conflict. Also, the Base Case must include all other essential defense and civilian needs in the context of the overall planning scenario.

The defense planning scenarios made available for use in the 2011 Base Case are consistent with the force planning framework articulated in The 2010 Quadrennial Defense Review (QDR) and the National Defense Strategy, which include an explicit requirement to consider defense of the U.S. homeland.[1] For purposes of the study, the 2011 Base Case builds upon the best available DOD-approved analytic products (as of May 2010) that most closely represent elements of the QDR Force Sizing Construct (FSC). Although it does not conform completely to the FSC, it specifies multiple contingencies occurring more or less concurrently during the conflict year, namely: (1) a catastrophic attack on a U.S. city by a foreign terrorist organization or rogue state; (2) two major overseas (state vs. state) conflicts; and (3) several significant counter-insurgency activities. (See classified appendices.) The base case scenario as outlined here has been developed in coordination with the Office of the Under Secretary of Defense for Policy to ensure consistency with the strategic guidance.

The 2011 Report was prepared by the Defense Logistics Agency (DLA), with the support of the Office of the Deputy Assistant Secretary of Defense (Industrial Policy), the Office of the Under Secretary of Defense for Policy, the Office of the Director of Cost Analysis and Program

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[1] See *The National Defense Strategy*, Department of Defense, 2008 and QDR 2010.

Evaluation , the Joint Staff, and the Military Departments on scenario development (including supply-side assumptions) and military requirements, and with the support of a number of civilian agencies on essential civilian requirements and other key data.

The present chapter discusses study methodologies and Base Case findings. The chapter ends with an exposition of the national emergency planning assumptions used in estimating requirements as required by Section 14 of the Stock Piling Act.

Methodologies

General Approach

The basic methodologies employed in developing this report are the same as those used in previous DOD Reports on NDS Requirements (2003 and 2005). The material shortfalls are estimated via a three step quantitative methodology, with an associated suite of databases and computer models. The first step is to project demand on the economy for manufactured goods and services related to the military, industrial, and essential civilian sectors during the particular scenario.[2] The second step is to estimate the quantities of strategic and critical materials needed to produce these goods and services. Two different methods can be used for the second step.[3] The third step estimates the amounts of domestic and reliable foreign supplies of strategic and critical materials available in the scenario, and compares them, on a time-phased basis, to the material demands computed in the second step. Any projected supply gaps (shortfalls) are identified. These shortfalls can become candidate goals for NDS inventory levels or targets to address with other mitigation strategies.

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[2] In the study, the economic sectors are defined as follows:

Military Sector - The military sector includes military goods required during the emergency. This sector also includes a portion of the materials needed for replacement parts and equipment for existing government-owned industrial facilities, and new plant and equipment for government-owned facilities required in the manufacture of military goods if production occurred at normal (non-emergency) rates. The other two sectors include the additional new plant and equipment needed to produce at levels sufficient to meet emergency military demands.

Industrial Sector - The industrial sector covers the construction of new plants and/or the manufacture of new equipment in the private sphere to overcome bottlenecks caused by accelerated production during a national security emergency. These bottlenecks are estimated by comparing defense-related and essential civilian requirements to the emergency operating capacity of existing plant and equipment. (In practice, this sector may be thought of most appropriately as the “emergency investment” sector.)

Essential Civilian Sector - The essential civilian sector includes goods and services for general civilian use, excluding those considered nonessential for stockpile purposes (discussed further below). This sector includes a portion of the replacement parts and equipment for existing industrial facilities and new plant and equipment required in the manufacture of these goods if production occurred at normal (non-emergency) rates.

[3] For over half (37) of the 70 materials studied, the material requirements are estimated using indices called material consumption ratios, MCRs, that are developed with the assistance of the Department of Commerce and the U.S. Geological Survey (USGS). For the remaining materials, an analogous process (a “proxy” MCR approach) is used. The MCR and proxy MCR approaches and algorithms are detailed in Appendix 8 and in IDA paper P-4593, Volume 1.

Time-phased demand-supply analyses are conducted for each of 70 specific strategic and critical materials. Assessments of supply shortfalls for each of these materials are carried out in the context of a Base Case. This report is based on current databases for all key information employed to estimate NDS requirements, including:

- Reliability assessments of foreign countries that produce materials that would be imported by the United States to meet needs during the scenario period (Defense Intelligence Agency and OSD (Policy) assessments);
- Production capacity data for strategic material facilities in the U.S. and abroad from the U.S. Geological Survey (USGS) and U.S. industry; and
- Material consumption ratios and other related data used to determine demands for materials, with input from the Department of Commerce and the USGS.

The military conflicts for the NDS Base Case scenario begin with limited warning time and together last for approximately one year (exact periods are classified); this first conflict year is then followed by a three-year regeneration period.[4] Therefore, the total NDS scenario time is roughly four years. The Base Case is assumed to cover the period 2011-2014. For technical estimation purposes, the NDS scenario is played several years earlier than the future period specified by the formal DOD military planning scenario.[5]

Supply-Side Assumptions for Base Case

On the supply side, a critical consideration is the reliability of material supplies sourced overseas. As in previous NDS Requirements Reports, DOD imposes reductions in estimated imports of strategic materials based specifically on (classified) reliability assessments of foreign suppliers in the context of the Base Case scenario. These assessments consider both the willingness of foreign governments to supply materials to the U.S. during the specified scenarios and the ability of foreign economies to produce and deliver anticipated materials. Where countries are judged *unable* to supply their materials to global markets, those materials are deemed unavailable to the U.S. (Countries may be unable to provide materials in quantities that might be expected based on their nominal supply capacities due to several scenario-related

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[4] If any military hardware items are only partially completed at the end of the scenario, demand amounts for the completed portions are included for purposes of estimating NDS requirements.

[5] This modification preserves the essentials of the scenario while minimizing a "supply-demand mismatch" problem that had arisen in some earlier Reports. Both the problem and this modification to address it were first described in the 1999 NDS Report to Congress. In short, playing the NDS Base Case scenario well into the future had led to a significant supply-demand "data" mismatch: projected peacetime growth in demand for materials in an expanding U.S. economy was not accompanied by comparable expected growth in estimated supplies of strategic and critical materials. This problem arose specifically because DOD's estimates of future growth in the U.S. economy use the same long-term forecasting models other Federal Government economists employ, while material supply data are estimated by the USGS based on interviews with and printed information from company officials worldwide. While the latter information may be reliable in the short run, it does not often take into account the ways that production facilities worldwide respond to changes in the market in the long run.

factors—such as extra political instability, labor unrest, or breakdowns in transportation or power infrastructures.) On the other hand, where governments are judged unwilling to sell materials specifically to the U.S. in the context of the scenario but are judged willing to sell materials to others on the open market, it is assumed in the Base Case that, after a six-month delay, the U.S. could still start acquiring some of the unwilling country's materials through third-parties on the global market. The assumption here is that, with few exceptions, it would be very difficult for unwilling countries to sustain indefinitely an anti-U.S. embargo for materials that they are actively supplying to global markets generally. Whether a country is judged unwilling or unable to supply depends on the respective scores assigned by the reliability raters, both for the year of combat and, separately, for the subsequent three years of regeneration.

A second important supply-side consideration is the share of foreign supplies that the U.S. can expect to acquire. Other countries, especially our allies and friends, will need a portion of available materials to meet their own needs. Accordingly, the Base Case limits the U.S. share of the scenario-specific estimates of reliable foreign production to the larger of two measures: (A) its current share of foreign production; (B) its share of the combined Gross Domestic Products (GDPs) of a group of countries deemed relevant.

A third important supply-side consideration concerns how rapidly the United States and reliable foreign suppliers are able to increase material production from current levels to mobilization levels. The 2011 Base Case assumption is that moving to mobilization levels will take, on average, about a year—to obtain all necessary additional skilled labor, production equipment, permits and funding.

A fourth important supply-side consideration concerns the availability of material production from countries that are postulated as wartime adversaries in the Base Case. Supplies from such wartime adversaries are assumed to be unavailable to the United States during the conflict year. The availability of such supplies in subsequent years is assumed to be a function of their reliabilities, and the other relevant scenario considerations mentioned above.

A final important supply-side consideration in the 2011 Base Case concerns the assumed usability of materials produced by countries that are "market dominators" (MDs)—those foreign countries producing more than half of global production. As in past Requirements Reports, the 2011 Base Case assumption is that an MD's production may not be counted upon at all by the United States to meet essential defense demands, but an MD's production may be counted upon by the United States to meet essential civilian demands. The reason for this is the belief it is especially risky to depend upon supplies from a single foreign source (an MD) rather than from a variety of such sources, given the greater potential for accidents, natural disasters, or deliberate sabotage that are not otherwise explicitly accounted for in the scenario to disrupt a single source by comparison with multiple sources. Such dependence is assumed in the 2011 Base Case to be unacceptably risky in regard to meeting essential defense demands, but an alternative, plausible assumption could extend this restriction to essential civilian demands as well.[6] (Of course, if a Base Case scenario was to arise and MDs were able and willing to supply materials for defense, that would be so much the better.)

Demand-Side Assumptions for the 2011 Base Case

As in past reports, this report assumes that all ongoing defense demands for goods and services, as well as all major items that are attrited and consumed in the classified Base Case scenario, will need to be produced, and therefore that the strategic materials needed to produce them must be available to the United States during the time period.

Consistent with past reports, this report also assumes that the preponderance of civilian demands for goods and services projected by the Council of Economic Advisors for this 2011-2014 period will need to be met. At the same time, the Base Case does make reductions in the projected demand for some goods and services for the civilian sector, in order to preclude stockpiling for items that would be considered nonessential during the conflict and regeneration period.[7] These reductions in civilian demands are consistent with the requirements of the Stock Piling Act that considers only essential civilian needs in stockpiling. In this regard, this report does not assume that the Federal Government would necessarily impose wide and detailed regulations to ration nonessential goods and services during the four-year scenario period. The market economy might provide these goods and services at the level estimated in the peacetime forecast, employing less material-intensive substitutes, such as by substituting more plastic and glass containers for aluminum-intensive items, and by seeking to import more end-use goods in the emergency, such as cars or electronics, rather than producing as many of them here as in peacetime. However, consistent with the statutory guidance, the NDS will not be structured to ensure the availability of *nonessential* items at high levels by stockpiling materials for their production.

As did the last (2005) Base Case, the Base Case for 2011 again includes a significant homeland recovery program. During year one of the 2011 Base Case scenario, a terrorist group or rogue state stages a catastrophic attack on a U.S. city. In addition to substantial human casualties and disruption of the local economy, the targeted area suffers a major loss of fixed assets and consumer durables.[8] The 2011 Base Case assumes a three-year homeland recovery

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6 See Appendix 6 for assessments of the impact that this dominator factor can have on Base Case findings.

7 The reductions are based on certain essential civilian demand factors recommended by a civilian agency working group (see Appendix 2).

8 The prospect of mass domestic casualties raises the question of whether various drugs such as morphine should be studied as potential NDS requirements. In fact, the NDS did stock opium gum until DOD determined, in the 1990s, that there was no NDS requirement. Since 1999, the Strategic National Stockpile (SNS) at the Centers for Disease Control and Prevention has emerged as that Federal agency tasked to provide medicine and medical supplies during a public health emergency. The SNS has focused particularly on the capability to respond to chemical and biological terrorist attacks, but its broad mission includes radiation and nuclear attacks as well as other national emergencies.

program to replace/rebuild those assets, beginning with year two of the scenario. Civilian spending for recovery is considered essential in the sense discussed in the previous paragraph.

2011 Base Case Findings

The 2011 Base Case constitutes the core of the vulnerability study and its shortfall findings serve as candidate requirements for purposes of determining recommended goals for NDS inventory levels (or as targets for other plausible mitigation strategies). This section provides projected shortfalls (and shortages) under 2011 Base Case assumptions.

This Base Case analysis identifies material shortfalls with a cumulative value of $2.013B and includes shortfalls for 28 specific materials—considering projected military, industrial, and essential civilian needs.[9] This finding reflects analyses of requirements and supply conditions for 70 strategic and critical materials. Depending particularly on the nature of available data (see Appendix 8), the study process varied by group of material as follows:

- Thirty-six "standard" materials were analyzed with computer models using regular Material Consumption Ratios (MCRs);
- Fifteen "specialty" materials were analyzed with computer models using "proxy" MCRs;
- Nineteen "new" Materials, not analyzed prior to 2009 (mostly analyzed with computer models using "proxy" MCRs).

However, taxonomy of the materials can be made according to material type: metals of various kinds, ores, non-metals, and so forth. Tables 1 through 3 organize the 70 materials into seven different types: metals, rare earths, precious metals, ores and compounds, miscellaneous non-metals, alloys, and high-performance fibers. For reference, Appendix 9 provides an alphabetical list of the materials examined and indicates the group and type for each.

Table 1 lists the 70 materials and the NDS inventories of these materials (if any) as of September 30, 2010. (For definitions of the unit abbreviations in the table, see Appendix 3.) The "key 13" materials (for which NDS sales of inventory were at least partially suspended in early 2008 out of initial availability concerns) are underlined in Table 1.

Table 2 identifies shortfall estimates for the 28 (of these 70) materials that do manifest them in the Base Case. Table 2 also underlines again all of the "key 13" materials, whether or not they manifest shortfalls in this Base Case. Seven of the key 13 materials do exhibit shortfalls in this Base Case; the other six of these 13 do not have shortfalls in this Case.

Finally, Table 3 presents estimates of the net shortages or surpluses of NDS inventories to cover the estimated Base Case shortfalls, both in quantity terms and in dollar value.

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[9] The $2.013B Base Case shortfall only assumes the availability of mining capability that is already active or that is currently expected to become active during the Base Case time frame, whether foreign or U.S. Without significant pre-planning and contingency contract arrangements, the timelines for activating new assets are assumed to be too long to be relevant for Base Case assessments.

Table 1. Materials Examined in the 2011 NDS Study, with Current NDS Inventories[a]

Material Name	Units	NDS Inventory, Sept. 30, 2010	
		in Units	in $M[b]
Metals (26)			
Aluminum Metal	ST	0	$0.00M
Antimony	ST	0	$0.00M
Beryllium Metal[c]	ST	123	$30.95M
Bismuth	LB	0	$0.00M
Cadmium	LB	0	$0.00M
Chromium Metal	ST	4,886	$67.30M
Cobalt	LB Co	663,709	$15.66M
Columbium	LB Cb	22,156	$0.51M
Copper	ST	0	$0.00M
Gallium	KG	0	$0.00M
Germanium	KG	16,362	$17.29M
Hafnium	MT	0	$0.00M
Indium	Tr Oz	0	$0.00M
Lead	ST	0	$0.00M
Lithium	MT	0	$0.00M
Manganese Metal, Electrolytic	ST	0	$0.00M
Mercury[d]	FL	128,705	$0.00M
Molybdenum	LB	0	$0.00M
Nickel	ST	0	$0.00M
Tantalum	LB Ta	3,802	$0.16M
Tin	MT	4,020	$64.00M
Titanium Sponge	ST	0	$0.00M
Tungsten	LB W	37,822,564	$238.00M
Vanadium	ST V	0	$0.00M
Zinc	ST	8,255	$19.87M
Zirconium Metal	ST	0	$0.00M
Subtotal: Metals			**$453.74M**
Rare Earths (7)			
Dysprosium	MT oxide	0	$0.00M
Europium	MT oxide	0	$0.00M
Neodymium	MT oxide	0	$0.00M
Praseodymium	MT oxide	0	$0.00M
Samarium	MT oxide	0	$0.00M
Terbium	MT oxide	0	$0.00M
Yttrium	MT oxide	0	$0.00M
Subtotal: Rare Earths			**$0.00M**

Table 1. Materials Examined in the 2011 NDS Study, with Current NDS Inventories (continued)

Material Name	Units	NDS Inventory, Sept. 30, 2010	
		in Units	in $M[b]
Precious Metals (7)			
Iridium (Platinum Group)	Tr Oz	568	$0.25M
Palladium (Platinum Group)	Tr Oz	0	$0.00M
Platinum (Platinum Group)	Tr Oz	8,380	$11.15M
Rhenium	LB	0	$0.00M
Rhodium (Platinum Group)	Tr Oz	0	$0.00M
Ruthenium (Platinum Group)	Tr Oz	0	$0.00M
Silver	Tr Oz	0	$0.00M
Subtotal: Precious Metals			**$11.40M**
Ores and Compounds (11)			
Aluminum Oxide Fused Crude	ST	0	$0.00M
Bauxite Metal Grade Jamaica & Suriname	LDT	0	$0.00M
Bauxite Refractory	LCT	0	$0.00M
Beryl Ore[e]	ST	1	$0.00M
Chromite, Chemical, Refractory, and Metallurgical Grade Ore	SDT	0	$0.00M
Fluorspar, Acid Grade	SDT	0	$0.00M
Fluorspar, Metallurgical Grade	SDT	0	$0.00M
Manganese Dioxide Battery Grade Natural	SDT	0	$0.00M
Manganese Dioxide Battery Grade Synthetic	SDT	0	$0.00M
Manganese Ore, Chemical & Metallurgical Grades	SDT	0	$0.00M
Zirconium Ores and Concentrates	SDT	0	$0.00M
Subtotal: Ores and Compounds			**$0.00M**
Misc. Non-Metals (4)			
Boron	MT oxide	0	$0.00M
Rubber (natural)	LT	0	$0.00M
Silicon Carbide	ST	0	$0.00M
Tellurium	MT	0	$0.00M
Subtotal: Misc. Non-Metals			**$0.00M**
Alloys (6)			
Beryllium Copper Master Alloy	ST	0	$0.00M
Chromium, Ferro	ST	170,247	$325.33M
Manganese, Ferro	ST	407,050	$513.38M
Specialty Steel—300M	ST	0	$0.00M
Specialty Steel—Armor Steel	ST	0	$0.00M
Specialty Steel—M50	ST	0	$0.00M
Subtotal: Alloys			**$838.71M**

Table 1. Materials Examined in the 2011 NDS Study, with Current NDS Inventories (concluded)

Material Name	Units	NDS Inventory, Sept. 30, 2010	
		in Units	in $M[b]
High Performance Fibers (9)			
Carbon Fiber—AS-4	MT	0	$0.00M
Carbon Fiber—IM-6	MT	0	$0.00M
Carbon Fiber—IM-7	MT	0	$0.00M
Carbon Fiber—T-300	MT	0	$0.00M
Carbon Fiber—T-700	MT	0	$0.00M
Kevlar	LB	0	$0.00M
Nomex	LB	0	$0.00M
Quartz (Silica) Fiber—High Purity	MT	0	$0.00M
S-2 Fiberglass	MT	0	$0.00M
Subtotal: High Performance Fibers			**$0.00M**
Total: All 70 Materials			**$1,303.85M**

a Materials in the "key 13" set are underlined.

b In September 30, 2010 dollars. Dollar valuations represent "realizable stockpile values" as of September 30, 2010, and might be higher or lower than the current market value. In general, NDS commodities are subject to substantial price fluctuations depending on changing market conditions.

c Beryllium metal. The inventory encompasses 16 tons of vacuum-cast metal plus 107 tons of hot-pressed powder (HPP) metal.

d Mercury. This report projects that the realizable stockpile value of the NDS mercury inventory is zero although other parties continue to trade in this commodity.

e Dollar valuation of beryl ore inventory is zero to two decimal places.

Table 2. Base Case Shortfalls for Materials Examined in the 2011 NDS Study[a]

Material Name	Units	Base Case Shortfalls	
		in Units	in $M[b]
Metals (26)			
Aluminum Metal	ST	0	$0.00M
Antimony	ST	26,010	$249.70M
Beryllium Metal	ST	70	$17.74M
Bismuth	LB	5,346,241	$50.52M
Cadmium	LB	0	$0.00M
Chromium Metal	ST	0	$0.00M
Cobalt	LB Co	0	$0.00M
Columbium	LB Cb	938,000	$21.41M
Copper	ST	0	$0.00M
Gallium	KG	1,352	$0.91M
Germanium	KG	16,489	$17.43M
Hafnium	MT	0	$0.00M
Indium	Tr Oz	1,808,757	$32.07M
Lead	ST	0	$0.00M
Lithium	MT	0	$0.00M
Manganese Metal, Electrolytic	ST	17,029	$56.37M
Mercury	FL	0	$0.00M
Molybdenum	LB	0	$0.00M
Nickel	ST	0	$0.00M
Tantalum	LB Ta	7,832,446	$332.14M
Tin	MT	20,010	$318.57M
Titanium Sponge	ST	3,113	$44.30M
Tungsten	LB W	21,890,577	$137.75M
Vanadium	ST V	0	$0.00M
Zinc	ST	0	$0.00M
Zirconium Metal	ST	0	$0.00M
Subtotal: Metals			**$1,278.88M**
Rare Earths (7)			
Dysprosium	MT oxide	172	$51.59M
Europium	MT oxide	82	$51.43M
Neodymium	MT oxide	2,162	$163.21M
Praseodymium	MT oxide	88	$6.37M
Samarium	MT oxide	40	$1.37M
Terbium	MT oxide	45	$27.12M
Yttrium	MT oxide	1,520	$60.02M
Subtotal: Rare Earths			**$361.11M**
Precious Metals (7)			
Iridium (Platinum Group)	Tr Oz	38,133	$16.55M
Palladium (Platinum Group)	Tr Oz	0	$0.00M
Platinum (Platinum Group)	Tr Oz	0	$0.00M
Rhenium	LB	17,968	$38.71M
Rhodium (Platinum Group)	Tr Oz	0	$0.00M
Ruthenium (Platinum Group)	Tr Oz	0	$0.00M
Silver	Tr Oz	0	$0.00M
Subtotal: Precious Metals			**$55.26M**

Table 2. Base Case Shortfalls for Materials Examined in the 2011 NDS Study (concluded)

Material Name	Units	Base Case Shortfalls	
		in Units	in $M[b]
Ores and Compounds (11)			
Aluminum Oxide Fused Crude	ST	258,512	$128.16M
Bauxite Metal Grade Jamaica & Suriname	LDT	0	$0.00M
Bauxite Refractory	LCT	119,734	$65.09M
Beryl Ore	ST	3,450	$0.25M
Chromite, Chemical, Refractory, and Metallurgical Grade Ore	SDT	0	$0.00M
Fluorspar, Acid Grade	SDT	268,225	$77.79M
Fluorspar, Metallurgical Grade	SDT	0	$0.00M
Manganese Dioxide Battery Grade Natural	SDT	0	$0.00M
Manganese Dioxide Battery Grade Synthetic	SDT	0	$0.00M
Manganese Ore, Chemical & Metallurgical Grades	SDT	0	$0.00M
Zirconium Ores and Concentrates	SDT	0	$0.00M
Subtotal: Ores and Compounds			**$271.28M**
Misc. Non-Metals (4)			
Boron	MT oxide	0	$0.00M
Rubber (natural)	LT	0	$0.00M
Silicon Carbide	ST	78,347	$43.27M
Tellurium	MT	0	$0.00M
Subtotal: Misc. Non-Metals			**$43.27M**
Alloys (6)			
Beryllium Copper Master Alloy	ST	173	$3.18M
<u>Chromium, Ferro</u>	ST	0	$0.00M
<u>Manganese, Ferro</u>	ST	0	$0.00M
Specialty Steel—300M	ST	0	$0.00M
Specialty Steel—Armor Steel	ST	0	$0.00M
Specialty Steel—M50	ST	0	$0.00M
Subtotal: Alloys			**$3.18M**
High Performance Fibers (9)			
Carbon Fiber—AS-4	MT	0	$0.00M
Carbon Fiber—IM-6	MT	W	$0.38M
Carbon Fiber—IM-7	MT	0	$0.00M
Carbon Fiber—T-300	MT	0	$0.00M
Carbon Fiber—T-700	MT	0	$0.00M
Kevlar	LB	0	$0.00M
Nomex	LB	0	$0.00M
Quartz (Silica) Fiber—High Purity	MT	0	$0.00M
S-2 Fiberglass	MT	0	$0.00M
Subtotal: High Performance Fibers			**$0.38M**
Total: All 70 Materials			**$2,013.37M**

a Materials in the “key 13” set are underlined.

b In Sept.-Nov. 2010 dollars/prices. Dollar valuations for materials with inventory in the stockpile represent “realizable stockpile values” as of September 30, 2010, and might be higher or lower than the current market value.

Table 3. Base Case NDS Inventory Surpluses or Shortages (in parentheses) for Materials Examined in the 2011 NDS Study[a]

Material Name	Units	Inventory		NDS Surplus (Shortage)	
		in Units	in $M[b]	in Units	in $M[b]
Metals (26)					
Aluminum Metal	ST	0	$0.00M	0	$0.00M
Antimony	ST	0	$0.00M	(26,010)	($249.70M)
Beryllium Metal	ST	123	$30.95M	52	$13.21M
Bismuth	LB	0	$0.00M	(5,346,241)	($50.52M)
Cadmium	LB	0	$0.00M	0	$0.00M
Chromium Metal	ST	4,886	$67.30M	4,886	$67.30M
Cobalt	LB Co	663,709	$15.66M	663,709	$15.66M
Columbium	LB Cb	22,156	$0.51M	(915,843)	($20.90M)
Copper	ST	0	$0.00M	0	$0.00M
Gallium	KG	0	$0.00M	(1,352)	($0.91M)
Germanium	KG	16,362	$17.29M	(128)	($0.13M)
Hafnium	MT	0	$0.00M	0	$0.00M
Indium	Tr Oz	0	$0.00M	(1,808,757)	($32.07M)
Lead	ST	0	$0.00M	0	$0.00M
Lithium	MT	0	$0.00M	0	$0.00M
Manganese Metal, Electrolytic	ST	0	$0.00M	(17,029)	($56.37M)
Mercury	FL	128,705	$0.00M	128,705	$0.00M
Molybdenum	LB	0	$0.00M	0	$0.00M
Nickel	ST	0	$0.00M	0	$0.00M
Tantalum	LB Ta	3,802	$0.16M	(7,828,644)	($331.97M)
Tin	MT	4,020	$64.00M	(15,990)	($254.57M)
Titanium Sponge	ST	0	$0.00M	(3,113)	($44.30M)
Tungsten [c]	LB W	37,822,564	$238.00M	15,931,987	$100.25M
Vanadium	ST V	0	$0.00M	0	$0.00M
Zinc	ST	8,255	$19.87M	8,255	$19.87M
Zirconium Metal	ST	0	$0.00M	0	$0.00M
Subtotal: Metals			**$453.74M**		**($1,041.43M)**
Rare Earths (7)					
Dysprosium	MT oxide	0	$0.00M	(172)	($51.59M)
Europium	MT oxide	0	$0.00M	(82)	($51.43M)
Neodymium	MT oxide	0	$0.00M	(2,162)	($163.21M)
Praseodymium	MT oxide	0	$0.00M	(88)	($6.37M)
Samarium	MT oxide	0	$0.00M	(40)	($1.37M)
Terbium	MT oxide	0	$0.00M	(45)	($27.12M)
Yttrium	MT oxide	0	$0.00M	(1,520)	($60.02M)
Subtotal: Rare Earths			**$0.00M**		**($361.11M)**
Precious Metals (7)					
Iridium (Platinum Group)	Tr Oz	568	$0.25M	(37,565)	($16.30M)
Palladium (Platinum Group)	Tr Oz	0	$0.00M	0	$0.00M
Platinum (Platinum Group)	Tr Oz	8,380	$11.15M	8,380	$11.15M
Rhenium	LB	0	$0.00M	(17,968)	($38.71M)
Rhodium (Platinum Group)	Tr Oz	0	$0.00M	0	$0.00M
Ruthenium (Platinum Group)	Tr Oz	0	$0.00M	0	$0.00M
Silver	Tr Oz	0	$0.00M	0	$0.00M
Subtotal: Precious Metals			**$11.40M**		**($55.02M)**

Table 3. Base Case NDS Inventory Surpluses or Shortages (in parentheses) for Materials Examined in the 2011 NDS Study (continued)

Material Name	Units	Inventory		NDS Surplus (Shortage)	
		in Units	in $M[b]	in Units	in $M[b]
Ores and Compounds (11)					
Aluminum Oxide Fused Crude	ST	0	$0.00M	(258,512)	($128.16M)
Bauxite Metal Grade Jamaica & Suriname	LDT	0	$0.00M	0	$0.00M
Bauxite Refractory	LCT	0	$0.00M	(119,734)	($65.09M)
Beryl Ore	ST	1	$0.00M	(3,449)	($0.25M)
Chromite, Chemical, Refractory, and Metallurgical Grade Ore	SDT	0	$0.00M	0	$0.00M
Fluorspar, Acid Grade	SDT	0	$0.00M	(268,225)	($77.79M)
Fluorspar, Metallurgical Grade	SDT	0	$0.00M	0	$0.00M
Manganese Dioxide Battery Grade Natural	SDT	0	$0.00M	0	$0.00M
Manganese Dioxide Battery Grade Synthetic	SDT	0	$0.00M	0	$0.00M
Manganese Ore, Chemical & Metallurgical Grades	SDT	0	$0.00M	0	$0.00M
Zirconium Ores and Concentrates	SDT	0	$0.00M	0	$0.00M
Subtotal: Ores and Compounds			**$0.00M**		**($271.28M)**
Misc. Non-Metals (4)					
Boron	MT oxide	0	$0.00M	0	$0.00M
Rubber (natural)	LT	0	$0.00M	0	$0.00M
Silicon Carbide	ST	0	$0.00M	(78,347)	($43.27M)
Tellurium	MT	0	$0.00M	0	$0.00M
Subtotal: Misc. Non-Metals			**$0.00M**		**($43.27M)**
Alloys (6)					
Beryllium Copper Master Alloy	ST	0	$0.00M	(173)	($3.18M)
<u>Chromium, Ferro</u>	ST	170,247	$325.33M	170,247	$325.33M
<u>Manganese, Ferro</u>	ST	407,050	$513.38M	407,050	$513.38M
Specialty Steel—300M	ST	0	$0.00M	0	$0.00M
Specialty Steel—Armor Steel	ST	0	$0.00M	0	$0.00M
Specialty Steel—M50	ST	0	$0.00M	0	$0.00M
Subtotal: Alloys			**$838.71M**		**($3.18M)**

Notes:

a For materials where NDS inventory is insufficient to cover the shortfall, the net shortage is shown in parentheses. Total shortages, *not* including *surpluses*, appear at the bottom of each subgroup, and overall. Materials in the "key 13" set are <u>underlined</u>. Surpluses are shown without parentheses.

b In Sept.-Nov. 2010 dollars. Dollar valuations for materials with inventory in the stockpile represent "realizable stockpile values" as of September 30, 2010, and might be higher or lower than the current market value.

c. Tungsten amounts are combined during analysis; however, during the AMP development process they are treated separately by the Market Impact Committee.

Table 3. Base Case NDS Inventory Surpluses or Shortages (in parentheses) for Materials Examined in the 2011 NDS Study (concluded)

Material Name	Units	Inventory		NDS Surplus (Shortage)	
		in Units	in $M[b]	in Units	in $M[b]
High Performance Fibers (9)					
Carbon Fiber—AS-4	MT	0	$0.00M	0	$0.00M
Carbon Fiber—IM-6	MT	0	$0.00M	W	($0.38M)
Carbon Fiber—IM-7	MT	0	$0.00M	0	$0.00M
Carbon Fiber—T-300	MT	0	$0.00M	0	$0.00M
Carbon Fiber—T-700	MT	0	$0.00M	0	$0.00M
Kevlar	LB	0	$0.00M	0	$0.00M
Nomex	LB	0	$0.00M	0	$0.00M
Quartz (Silica) Fiber—High Purity	MT	0	$0.00M	0	$0.00M
S-2 Fiberglass	MT	0	$0.00M	0	$0.00M
Subtotal: High Performance Fibers			**$0.00M**		**($0.38M)**
Total: All 70 Materials			**$1,303.85M**		**($1,775.68M)**

Report Required by Section 14(b) of Stock Piling Act: National Emergency Planning Assumptions

Section 14(b) of the Stock Piling Act directs that the DOD describe the content of a number of specified national emergency planning assumptions used to estimate requirements for NDS. Information on each of the planning assumptions mentioned in Section 14(b) is provided below.

Length of Assumed Emergency

The military conflict for which material requirements are calculated lasts for roughly one year. (See Classified Appendix 1 for details.)

Intensity of Conflict

(See Classified Appendices 1 and 2.)

Military Force Structure to Be Mobilized

The scenario assumes that (1) the warning time is too short to build new forces and (2) that the U.S. has sufficient forces in being to meet the requirements of defeating the enemy.

Losses from Enemy Action

(See Classified Appendix 2.)

2011 Base Case Demand for 70 Strategic and Critical Materials (Military Demands)

The 2011 Base Case scenario considers (1) a catastrophic attack on a U.S. city by a foreign terrorist organization or rogue state; (2) two major state-on-state conflicts; and (3) several persistent counter-insurgency contingencies. In the 2011 Base Case, the U.S. plans to continue with its regular Fiscal Year 2011-2015 FYDP acquisitions as well as to regenerate key weapon systems and munitions lost after the short-warning major conflicts and other contingencies. (See Classified Appendices 1 and 2.)

Of the 70 strategic and critical materials assessed in this Base Case, the dollar value of those 70 that are needed over the entire four year Base Case scenario for the manufacture of goods and services in the military sector is $20.270B in Fall 2010 dollars. This total comprises $15.586B for (36) standard materials, $0.481B for (15) specialty materials, and $4.202B for (19) "new" materials. 2011 Base Case demand by this (military) sector represents approximately seven percent of the overall four-year Base Case scenario demand ($300.8B) for these 70 materials.

2011 Base Case Demand for Strategic and Critical Materials (Industrial Investment Demands)

The industrial sector is limited to materials needed to meet requirements for new plant and equipment to overcome any capacity shortfalls caused by accelerated production of defense goods during the four-year emergency scenario period. Of the strategic and critical materials assessed, the value of those needed in the economy for the manufacture of goods and services for this purpose is at least $0.066B (Fall 2010 dollars). Note that this total is for 36 standard materials; the methodology does not yet compute industrial sector demands for specialty or new materials (except lithium, which has a minuscule amount of emergency industrial investment demand).

2011 Base Case Demand for 70 Strategic and Critical Materials (Essential Civilian Demands)

Of the 70 strategic and critical materials assessed in the Base Case, the dollar value of those materials that are needed over the four-year scenario period in the economy for the manufacture of essential goods and services for the civilian sector is $280.513B (Fall 2010 dollars). This total is comprised of $264.541B for standard materials, $9.549B for specialty materials, and $6.423B for new materials. Demand by this sector represents approximately 93 percent of the overall Base Case scenario demand ($300.8B) for these 70 materials.

Available Foreign Supplies with Adjustments

The available supplies of strategic and critical materials from foreign sources are defined as those expected to be available to the U.S. during the military conflict year, and the subsequent regeneration period—after accounting for supplier country reliability, the U.S. market-share,[10]

[10] In this analysis, the term "U.S. market share" means the fraction of foreign supply that the U.S. obtains. This factor is structured to acknowledge that the United States will "reserve" some of the world supply for our allies

supplier country war damage, shipping losses and "market dominator" (MD) criteria.[11] (The list of such supplies available during the roughly one year of mobilization and military conflict and each year of regeneration can be provided upon request.)

Domestic Production of Materials

Total domestic production levels are estimated for strategic and critical materials during the roughly one year of military conflict and three years of regeneration. The estimates can be provided upon request.

Civilian Austerity Measures

The scenario assumes that the Federal Government will take no regulatory measures to curtail or prevent the production of nonessential civilian goods and services. Nevertheless, there are decrements imposed on normal projected Council of Economic Advisors civilian sector demands for the period—decrements imposed to eliminate nonessential civilian goods and services—in accordance with the requirements of the Stock Piling Act. (These decrements are based on the advice of a civilian sector working group, and are described in Appendix 2.)

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and friends, rather than just attempting to obtain and consume it all. In the models used in the current analysis, the value of the market share fraction varies by material and by year of the scenario.

[11] In addition to the U.S. market share, the following decrement factors are applied to foreign supply. War damage factors simulate the inability of a country damaged by war to produce materials. Shipping loss factors represent the losses of materials in transit to the United States (due to foreign hostility). Reliability factors assess a country's willingness to supply materials to the U.S., which can affect the timeliness of supply, as well as the country's ability to supply, based on the stability of its political and economic infrastructure. Market Dominator tests limit the defense usability of extremely dominant single foreign producer countries. In the models used in the current analysis, all these factors vary by supplier country and year of the scenario.

Chapter Two:
Alternative Scenarios

Introduction and Findings

As noted in Chapter One, the Stock Piling Act, as amended, requires that the Department of Defense (DOD) report on the effects of alternative scenarios. This chapter will report on the results of an Alternative Case based on a peacetime supply disruption scenario (PSD1) that lasts for one year and represents a composite supply disruption case. Key assumptions are that regular military demands in this scenario may only be met by regular supplies from suppliers deemed wholly (100 percent) reliable according to Defense Intelligence Agency (DIA) country reliability estimates for such a case.

Table 4 provides shortfall estimates in the PSD1 Case for the 70 materials. These shortfall estimates are for the defense sector only. Table 5 shows the material shortages or surpluses in this case, i.e., the shortfall amounts minus the National Defense Stockpile (NDS) inventory amounts (inventories as shown in Table 1 in Chapter One). Tables 4 and 5 are parallel in structure to Tables 2 and 3 in Chapter One.

Table 4 indicates that material shortfalls could occur in PSD1 for 40 of the 70 materials that were assessed. Estimated shortfalls for these 40 materials could range up to $637M for DOD alone in PSD1. Among the 40 materials exhibiting shortfalls in PSD1 are nine of the key 13 materials mentioned above. These nine shortfalls represent $125M of the $637M shortfalls in this alternative scenario.

Table 5 shows that inventory shortages could occur in PSD1 for 33 of the 70 materials. As Table 5 indicates, the total value of the shortages (not counting surpluses) is $563M. Surpluses could occur for 10 of these materials. The total value of the surpluses is $1,230M, so the net total value of the surpluses and shortages is $667M.

Table 4. Peacetime Supply Disruption (PSD1) Case: Defense Sector Shortfalls for Materials Examined in the 2011 NDS Study[a]

		Shortfall Amounts	
Material Name	**Units**	**in Units**	**in $M[b]**
Metals (26)			
Aluminum Metal	ST	33,308	$70.71M
Antimony	ST	2,043	$19.61M
Beryllium Metal	ST	15	$3.78M
Bismuth	LB	362,030	$3.42M
Cadmium	LB	0	$0.00M
Chromium Metal	ST	673	$9.27M
Cobalt	LB Co	0	$0.00M
Columbium	LB Cb	0	$0.00M
Copper	ST	0	$0.00M
Gallium	KG	1,697	$1.14M
Germanium	KG	3,717	$3.93M
Hafnium	MT	0	$0.00M
Indium	Tr Oz	233,006	$4.13M
Lead	ST	45,392	$92.82M
Lithium	MT	0	$0.00M
Manganese Metal, Electrolytic	ST	695	$2.30M
Mercury	FL	186	$0.00M
Molybdenum	LB	0	$0.00M
Nickel	ST	175	$3.59M
Tantalum	LB Ta	259,619	$11.01M
Tin	MT	1,597	$25.42M
Titanium Sponge	ST	9,976	$141.98M
Tungsten	LB W	1,472,462	$9.27M
Vanadium	ST V	270	$6.51M
Zinc	ST	0	$0.00M
Zirconium Metal	ST	17	$0.95M
Subtotal: Metals			**$409.84M**
Rare Earths (7)			
Dysprosium	MT oxide	8	$2.51M
Europium	MT oxide	18	$11.34M
Neodymium	MT oxide	169	$12.76M
Praseodymium	MT oxide	5	$0.32M
Samarium	MT oxide	2	$0.07M
Terbium	MT oxide	7	$4.24M
Yttrium	MT oxide	112	$4.42M
Subtotal: Rare Earths			**$35.66M**
Precious Metals (7)			
Iridium (Platinum Group)	Tr Oz	8,389	$3.64M
Palladium (Platinum Group)	Tr Oz	61,773	$37.06M
Platinum (Platinum Group)	Tr Oz	35,848	$47.69M
Rhenium	LB	1,401	$3.02M
Rhodium (Platinum Group)	Tr Oz	6,563	$15.09M
Ruthenium (Platinum Group)	Tr Oz	28,840	$5.05M
Silver	Tr Oz	2,613,592	$48.80M
Subtotal: Precious Metals			**$160.35M**

Table 4. Peacetime Supply Disruption (PSD1) Case: Defense Sector Shortfalls for Materials Examined in the 2011 NDS Study (concluded)

Material Name	Units	Shortfall Amounts in Units	Shortfall Amounts in $M [b]
Ores and Compounds (11)			
Aluminum Oxide Fused Crude	ST	15,400	$7.64M
Bauxite Metal Grade Jamaica & Suriname	LDT	0	$0.00M
Bauxite Refractory	LCT	4,997	$2.72M
Beryl Ore	ST	0	$0.00M
Chromite, Chemical, Refractory, and Metallurgical Grade Ore	SDT	0	$0.00M
Fluorspar, Acid Grade	SDT	16,759	$4.86M
Fluorspar, Metallurgical Grade	SDT	0	$0.00M
Manganese Dioxide Battery Grade Natural	SDT	0	$0.00M
Manganese Dioxide Battery Grade Synthetic	SDT	35	$0.08M
Manganese Ore, Chemical & Metallurgical Grades	SDT	0	$0.00M
Zirconium Ores and Concentrates	SDT	0	$0.00M
Subtotal: Ores and Compounds			**$15.29M**
Misc. Non-Metals (4)			
Boron	MT oxide	0	$0.00M
Rubber (natural)	LT	0	$0.00M
Silicon Carbide	ST	7,328	$4.05M
Tellurium	MT	1	$0.20M
Subtotal: Misc. Non-Metals			**$4.25M**
Alloys (6)			
Beryllium Copper Master Alloy	ST	60	$1.10M
<u>Chromium, Ferro</u>	ST	5,688	$10.87M
<u>Manganese, Ferro</u>	ST	0	$0.00M
Specialty Steel—300M	ST	0	$0.00M
Specialty Steel—Armor Steel	ST	0	$0.00M
Specialty Steel—M50	ST	0	$0.00M
Subtotal: Alloys			**$11.97M**
High Performance Fibers (9)			
Carbon Fiber—AS-4	MT	0	$0.00M
Carbon Fiber—IM-6	MT	0	$0.00M
Carbon Fiber—IM-7	MT	0	$0.00M
Carbon Fiber—T-300	MT	0	$0.00M
Carbon Fiber—T-700	MT	0	$0.00M
Kevlar	LB	0	$0.00M
Nomex	LB	0	$0.00M
Quartz (Silica) Fiber—High Purity	MT	0	$0.00M
S-2 Fiberglass	MT	0	$0.00M
Subtotal: High Performance Fibers			**$0.00M**
Total Defense Shortfall: All 70 Materials			**$637.36M**

a Materials in the "key 13" set are <u>underlined</u>.

b In Sept.-Nov 2010 dollars. Dollar valuations for materials with inventory in the stockpile represent "realizable stockpile values" as of September 30, 2010, and might be higher or lower than the current market value.

**Table 5. Peacetime Supply Disruption (PSD1) Case:
NDS Inventory Surpluses or Shortages (in parentheses) for Materials Examined
in the 2011 NDS Study[a]**

		Inventory		NDS Surpluses (Shortages)	
Material Name	**Units**	**in Units**	**in $M [b]**	**in Units**	**in $M [b]**
Metals (26)					
Aluminum Metal	ST	0	$0.00M	(33,308)	($70.71M)
Antimony	ST	0	$0.00M	(2,043)	($19.61M)
Beryllium Metal	ST	123	$30.95M	108	$0.00M
Bismuth	LB	0	$0.00M	(362,030)	($3.42M)
Cadmium	LB	0	$0.00M	0	$0.00M
Chromium Metal	ST	4,886	$67.30M	4,214	$0.00M
Cobalt	LB Co	663,709	$15.66M	663,709	$0.00M
Columbium	LB Cb	22,156	$0.51M	22,156	$0.00M
Copper	ST	0	$0.00M	0	$0.00M
Gallium	KG	0	$0.00M	(1,697)	($1.14M)
Germanium	KG	16,362	$17.29M	12,645	$0.00M
Hafnium	MT	0	$0.00M	0	$0.00M
Indium	Tr Oz	0	$0.00M	(233,006)	($4.13M)
Lead	ST	0	$0.00M	(45,392)	($92.82M)
Lithium	MT	0	$0.00M	0	$0.00M
Manganese Metal, Electrolytic	ST	0	$0.00M	(695)	($2.30M)
Mercury	FL	128,705	$0.00M	128,519	$0.00M
Molybdenum	LB	0	$0.00M	0	$0.00M
Nickel	ST	0	$0.00M	(175)	($3.59M)
Tantalum	LB Ta	3,802	$0.16M	(255,817)	($10.85M)
Tin	MT	4,020	$64.00M	2,423	$0.00M
Titanium Sponge	ST	0	$0.00M	(9,976)	($141.98M)
Tungsten	LB W	37,822,564	$238.00M	36,350,102	$0.00M
Vanadium	ST V	0	$0.00M	(270)	($6.51M)
Zinc	ST	8,255	$19.87M	8,255	$0.00M
Zirconium Metal	ST	0	$0.00M	(17)	($0.95M)
Subtotal: Metals			**$453.74M**		**($358.01M)**
Rare Earths (7)					
Dysprosium	MT oxide	0	$0.00M	(8)	($2.51M)
Europium	MT oxide	0	$0.00M	(18)	($11.34M)
Neodymium	MT oxide	0	$0.00M	(169)	($12.76M)
Praseodymium	MT oxide	0	$0.00M	(5)	($0.32M)
Samarium	MT oxide	0	$0.00M	(2)	($0.07M)
Terbium	MT oxide	0	$0.00M	(7)	($4.24M)
Yttrium	MT oxide	0	$0.00M	(112)	($4.42M)
Subtotal: Rare Earths			**$0.00M**		**($35.66M)**

**Table 5. Peacetime Supply Disruption (PSD1) Case:
NDS Inventory Surpluses or Shortages (in parentheses) for Materials Examined
in the 2011 NDS Study (continued)**

		Inventory		NDS Surpluses (Shortages)	
Material Name	**Units**	**in Units**	**in $M [b]**	**in Units**	**in $M [b]**
Precious Metals (7)					
Iridium (Platinum Group)	Tr Oz	568	$0.25M	(7,821)	($3.39M)
Palladium (Platinum Group)	Tr Oz	0	$0.00M	(61,773)	($37.06M)
Platinum (Platinum Group)	Tr Oz	8,380	$11.15M	(27,468)	($36.54M)
Rhenium	LB	0	$0.00M	(1,401)	($3.02M)
Rhodium (Platinum Group)	Tr Oz	0	$0.00M	(6,563)	($15.09M)
Ruthenium (Platinum Group)	Tr Oz	0	$0.00M	(28,840)	($5.05M)
Silver	Tr Oz	0	$0.00M	(2,613,592)	($48.80M)
Subtotal: Precious Metals			**$11.40M**		**($148.96M)**
Ores and Compounds (11)					
Aluminum Oxide Fused Crude	ST	0	$0.00M	(15,400)	($7.64M)
Bauxite Metal Grade Jamaica & Suriname	LDT	0	$0.00M	0	$0.00M
Bauxite Refractory	LCT	0	$0.00M	(4,997)	($2.72M)
Beryl Ore	ST	1	$0.00M	1	$0.00M
Chromite, Chemical, Refractory, and Metallurgical Grade Ore	SDT	0	$0.00M	0	$0.00M
Fluorspar, Acid Grade	SDT	0	$0.00M	(16,759)	($4.86M)
Fluorspar, Metallurgical Grade	SDT	0	$0.00M	0	$0.00M
Manganese Dioxide Battery Grade Natural	SDT	0	$0.00M	0	$0.00M
Manganese Dioxide Battery Grade Synthetic	SDT	0	$0.00M	(35)	($0.08M)
Manganese Ore, Chemical & Metallurgical Grades	SDT	0	$0.00M	0	$0.00M
Zirconium Ores and Concentrates	SDT	0	$0.00M	0	$0.00M
Subtotal: Ores and Compounds			**$0.00M**		**($15.29M)**
Misc. Non-Metals (4)					
Boron	MT oxide	0	$0.00M	0	$0.00M
Rubber (natural)	LT	0	$0.00M	0	$0.00M
Silicon Carbide	ST	0	$0.00M	(7,328)	($4.05M)
Tellurium	MT	0	$0.00M	(1)	($0.20M)
Subtotal: Misc. Non-Metals			**$0.00M**		**($4.25M)**
Alloys (6)					
Beryllium Copper Master Alloy	ST	0	$0.00M	(60)	($1.10M)
Chromium, Ferro	ST	170,247	$325.33M	164,560	$0.00M
Manganese, Ferro	ST	407,050	$513.38M	407,050	$0.00M
Specialty Steel—300M	ST	0	$0.00M	0	$0.00M
Specialty Steel—Armor Steel	ST	0	$0.00M	0	$0.00M
Specialty Steel—M50	ST	0	$0.00M	0	$0.00M
Subtotal: Alloys			**$838.71M**		**($1.10M)**

Table 5. Peacetime Supply Disruption (PSD1) Case:
NDS Inventory Surpluses or Shortages (in parentheses) for Materials Examined in the 2011 NDS Study (concluded)

		Inventory		NDS Surpluses (Shortages)	
Material Name	**Units**	**in Units**	**in $M [b]**	**in Units**	**in $M [b]**
High Performance Fibers (9)					
Carbon Fiber—AS-4	MT	0	$0.00M	0	$0.00M
Carbon Fiber—IM-6	MT	0	$0.00M	0	$0.00M
Carbon Fiber—IM-7	MT	0	$0.00M	0	$0.00M
Carbon Fiber—T-300	MT	0	$0.00M	0	$0.00M
Carbon Fiber—T-700	MT	0	$0.00M	0	$0.00M
Kevlar	LB	0	$0.00M	0	$0.00M
Nomex	LB	0	$0.00M	0	$0.00M
Quartz (Silica) Fiber—High Purity	MT	0	$0.00M	0	$0.00M
S-2 Fiberglass	MT	0	$0.00M	0	$0.00M
Subtotal: High Performance Fibers			**$0.00M**		**$0.00M**
Total: All 70 Materials			**$1,303.85M**		**($563.27M)**

a For materials where NDS inventory is insufficient to cover the shortfall, the net shortage is shown in parentheses. Total shortages, *not including surpluses*, appear at the bottom of each subgroup and overall. Materials in the "key 13" set are underlined.

b In Sept.-Nov.2010 dollars. Dollar valuations for materials with inventory in the stockpile represent "realizable stockpile values" as of September 30, 2010, and might be higher or lower than the current market value.

Discussion

The Alternative Case (PSD1) presented here focuses upon defense needs in a composite peacetime supply disruption scenario in which DOD must rely only upon assured suppliers in order to meet a year's worth of its normal Future Years Defense Program/Plan) purchases in a one year scenario. This guideline is consistent with the principle articulated by the Office of the Secretary of Defense Strategic Materials Working Group during NDS reconfiguration assessment studies in the summer of 2008. While this is by no means the only alternative scenario that merits analysis under the DOD materials security program, it can serve as a composite benchmark to help DOD and the Congress better understand the vulnerabilities the Nation could face in dealing with a variety of potential individual supply disruption scenarios (e.g., natural disasters, political disruptions, terrorist attacks) in the years ahead.

In this spirit, the Alternative Case presented here may best be considered as a composite of a number of individual disruption cases that might plausibly occur. It seems exceedingly unlikely that the whole array of such individual cases in PSD1 would occur together at once.

Other Alternative Cases

Several variants of the alternative scenario are presented here. Each posits that DOD may obtain a larger than regular share of strategic materials from domestic and wholly reliable (assured) foreign producers during the one-year scenario. The first variant (PSD2) assumes that

DOD may get its regular share from domestic and wholly reliable sources during the first half of the year but twice its regular share from these sources during the second half of the year. The second variant (PSD3) assumes that DOD may get its regular share from these sources in the first half of the year but three times its normal share from these sources in the second half of the year.

The defense shortfalls in the first variant, PSD2, are smaller ($385M), as expected, than in PSD1 ($637M). The defense shortfalls in the second variant, PSD3, are even smaller ($300M) than in PSD1 ($637M).

These two variants suggest strongly the merits of proactive pre-planning and risk mitigation activities, including potentially working beforehand to increase the likelihood of supplies from additional foreign producers, producers that, while not necessarily judged to be wholly reliable, are still arguably highly reliable.

Three other variants of the PSD1 alternative scenario are presented here to illustrate further this kind of potential. PSD4 is the same as PSD1 except that regular defense shares of production from foreign suppliers that are deemed “highly reliable” (90-99 percent by DIA) are added to the regular shares available to defense in PSD1 from domestic suppliers and wholly reliable foreign suppliers. PSD5 is the same as PSD2 except that highly reliable suppliers are added to foreign supplies, as in PSD4. PSD6 is the same as PSD3 except that highly reliable suppliers are added to foreign supplies (as in PSD4).

The results for these three cases are as follows: PSD4 shortfalls are $293M; PSD5 shortfalls are $146M; and PSD6 shortfalls are $96M.

These overall PSD results suggest that if DOD can arrange for expeditious access to strategic materials beyond its regular shares from domestic and assured foreign suppliers, the problems illustrated in the PSD1 case may be alleviated significantly. Assessing these possibilities in significant, practical detail will be a major thrust of DOD’s Strategic Materials Security Program (SMSP) in the months and years ahead.

The next chapter (Chapter Three) now returns to a focus upon the 2011 Base Case and a preliminary discussion of the types of risk mitigation strategies that the SMSP will be pursuing in order to address the Base Case shortfalls and shortages identified in this report. Illustrations of promising mitigation initiatives for several of the materials that manifest 2011 Base Case shortfalls are provided in Chapter Three as well.

Chapter Three: Mitigation Strategies and Examples

Introduction

In the traditional National Defense Stockpile (NDS) program concept, stockpiling materials that are determined to be in shortfall in the Base Case is the remedy. In practice, however, other possible mitigation options/remedies may also be available to the U.S. government, in conjunction with material suppliers in the private sector, to address these shortfalls.

A major objective and mission of the new and evolving Strategic and Critical Materials Security Program (SMSP) is to identify the most cost-effective, prudent strategies for addressing identified material vulnerabilities and risks. Strategies developed in peacetime can be available for implementation during a conflict to mitigate shortfalls that could otherwise occur without them.

This chapter first provides an overview of some major types of remedies that may be appropriate in various cases within the SMSP construct. Several examples are then offered of assessments that can and should be undertaken in order to determine the relative cost-effectiveness of these alternative shortfall mitigation approaches for particular strategic materials.

Stockpiling and Alternatives

The traditional approach to mitigating the effects of wartime shortfalls in strategic and critical material supplies has been to stockpile the materials so that they would be available domestically were a war to occur. Stockpiling is effective in assuring material supplies. However, it has disadvantages, such as cost, impact on material markets, and the potential obsolescence of long-held stocks, that motivate the SMSP to explore alternative strategies to mitigate shortfalls.

This chapter describes alternative measures for mitigating material shortfalls arising from wartime scenarios that could potentially apply to any strategic and critical material. It then shows the potential utility of such measures by showing how they might be applied to four specific materials that experienced shortfalls in the 2011 Base Case scenario.[1]

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[1] Assessing the feasibility and cost-effectiveness of mitigation measures for materials definitively, so as to allow any of them to be implemented in lieu of stockpiling, will require additional investigation, analyses and other

Shortfall mitigation measures can work either by reducing the demand for a material or increasing its supply. We have identified the following measures, discussed in more detail below, which could be used to mitigate shortfalls in any Base Case or alternative scenario:

Demand Side

- Substitution
- Shift to imported goods
- More stringent civilian austerity/accepting risk for less important civilian demands

Supply Side

- Rolling inventories
- Concerted programs
- Other expansion of production capacity
- Contingency supply contracts
- Recycling
- War reserve materiel
- Increasing supplier reliabilities

A key aspect of assessing all of these measures is cost. However, in comparing different measures, it is important to distinguish between costs that would be incurred during peacetime and those would be incurred only if and when an emergency occurred. Peacetime costs must be funded during the planning period in preparation for a potential crisis. Funding for emergency costs can be delayed until a crisis occurs and might be avoided altogether if a crisis does not occur or if the material shortage in question does not emerge. Thus, costs incurred only during an emergency should be discounted appropriately for purposes of comparing alternative mitigation measures. Therefore, the discussion of alternative mitigation measure in this chapter distinguishes peacetime costs from potential costs during a crisis.

Demand Side Alternatives

Substitution

To reduce demand for materials in short supply, other materials that perform similar roles could be substituted for the material in question in its various applications. Some penalty in performance or cost would likely result. Substitution might not be feasible with military equipment for which designs are often complex and difficult to change; even allowing the use of substitutes close to the material in question in performance may be unacceptable. Even acceptable substitutes would likely take time to utilize, as product designs using the substitute material(s) were developed and their performance was ascertained. If wartime shortfalls in particular materials were feared, it might be sensible to develop alternative designs using substitutes that could be employed quickly in the event of a crisis. It is more likely that

efforts. Such efforts should be undertaken first for materials actually found to be in shortfall rather than for the entire set of materials analyzed for the SMSP.

substitutes could be used for essential civilian goods to minimize the impact of shortfalls and facilitate the use of scarce materials by the military (thereby reducing the need for the potentially disruptive invocation of the defense priorities and allocations system). Even for civilian applications, substitution should be relied on only if practical opportunities exist. In practice, this measure could be implemented either by simply allowing the civilian market to use substitutes as available or the government could promote the use of specific substitutes to reduce the effects of shortfalls on the civilian market or particular sectors thereof.

Shift to Imported Goods

If the U.S. economy experienced material shortages during a crisis, civilian consumers could be asked to rely more heavily on imported rather than American-made products containing the material in question. If imported products were available, the civilian market would presumably shift to them naturally as shortages in similar American-made products were experienced. This could make up for U.S. material shortages so long as total world demand for the materials needed to make the products did not exceed total world supply and so long as sufficient world capacity existed to meet the increased U.S. demand for imported goods. Reliance on imported goods could be an indirect way of mitigating the effect of embargoes of the United States by material suppliers, in that they would presumably continue to sell materials to third party country users which could manufacture goods and then sell them to U.S. users. In practice, this mitigation measure could be implemented by declining to stockpile materials found to be in shortfall if imported goods would be available to meet demands for goods ordinarily produced with those materials. Case BCS6 in Appendix 6 shows that increased reliance on imported goods from selected reliable supplier countries has the potential to significantly reduce material shortfalls in the Base Case scenario.

The United States could probably not rely on substitute imported goods to meet demands for weapon systems and military platforms; acceptable replacements for them likely would not exist in the global marketplace. However, goods obtained overseas could be used for applications like military construction or other non-weapon system uses. Thus, when considering the utility of imported goods to meet military demands, close attention should be paid to the nature of the goods to be imported.

More Stringent Civilian Austerity and Accepting Risk for Civilian Demands

Another way to mitigate scenario shortfalls would be to impose more stringent austerity measures on the civilian economy. While the Base Case imposes general austerity measures to determine essential civilian demand, the mitigation measure discussed here would examine more closely whether the particular goods and services affected by a specific material shortfall should be considered essential. If deemed not essential, this approach would directly reduce the civilian demand. Such reductions would only take place, however, after due consultation with appropriate civilian authorities, such as the civilian agency working group consulted in the ordinary NDS planning process (see Appendix 2). If the supply of materials turned out to be insufficient to meet total civilian demand, then consumers would have to pay higher prices for goods, turn to substitutes, divert demand to other goods and services, or simply do without, with resulting economic and political effects. This measure is similar to the substitution measures discussed above, except that its implementation would not depend on the availability of substitute materials or imported goods similar to the goods made with the material in question. Rather, unmet civilian demand would simply be allowed to shift to whatever the market made available. Analytically, this measure should be implemented based on transparent, objective criteria to ensure that truly essential civilian demand would be met during the crisis. Case BCS12 in Appendix 6 shows one example of the effect of increased austerity in total material shortfalls for the scenario.

A closely related alternative approach would be to take all of the assumptions of the Base Case related to material supply and demand and evaluate and potentially accept the risk that a material shortfall would occur. Depending on which essential civilian goods might be affected and the likelihood of the shortfall occurring, the risk might be acceptably low. For example, the projected availability of supply sometimes turns on postulated political decisions by supplier countries. Thus, available supply can be seen as taking on a probabilistic distribution; there are probabilities that suppliers would sell us materials promptly during the scenario and probabilities that they would not. Accepting risk would simply mean not taking measures to make up for supply potentially lost from certain suppliers. Depending on the consequences of the shortfall, the government could decide to accept the risk that it would occur. Accepting risk of a shortfall in lieu of stockpiling might be reasonable if the cost of stockpiling was significant, and the risk of the scenario occurring in the first place was low. Again, transparent, objective criteria should be used in assessing this mitigation alternative. Developing and applying a rigorous framework to assess such risks is an important part of the SMSP.

Supply Side Alternatives

Rolling Inventories

Rolling inventories can be a form of stockpiling in which material sufficient to cover projected shortfalls is kept on hand, either by the government or by private companies, but the material is used and refreshed periodically. This enables stocks to be kept up to date with respect to quality or suitability and potentially modified as the characteristics of the material needed for production of goods shift over time. Thus, this alternative would mitigate the risk inherent in stockpiling that a material stock could become obsolete.[2]

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[2] Another potential risk inherent in stockpiling is that the domestic industrial base that uses a material to manufacture products could atrophy for economic reasons. To mitigate that risk for products critical to national security, government programs could be used to maintain that industrial base either in government or private hands.

Concerted Programs

Concerted programs are special investments made during the NDS scenario (planned ahead of time) to build new or expand existing material production facilities. They may be employed in the United States or abroad. Concerted programs often represent the largest potential increases in new supply available for a material. The disadvantages of concerted programs are that they may be costly and the output from them is typically not available at the beginning of the scenario because it takes time to build new or expand existing facilities.

Other Facility Output Expansion

In addition to formal concerted programs, there may be other ways to expand output from existing material production facilities. In some cases, capacity could be activated or expanded by making less significant investments or increasing the staffing at a facility. As a general matter, the Base Case assumptions on production capacity should be analyzed in more depth for materials found to be in shortfall. A special effort should be made to ensure that all available and potential capacity is taken into account when the SMSP considers stockpiling or other investment recommendations.

In addition to making adjustments at facilities that now produce the material in question, facilities currently used to produce other materials that are in surplus might be shifted to producing the material in shortfall. This could be an option where similar (or even identical) facilities are used to produce different materials. Examples of such materials include specialty steels and superalloys, which can be produced using the same types of furnaces.

Contingency Supply Contracts

Another way to get the most out of existing material supplies worldwide and potentially mitigate shortfalls would be for the United States to enter into contingency contracts with reliable suppliers, and potentially agreements with supplier nations, to facilitate access to supplies if war occurred. First, long-term contracts could provide options for the United States to buy materials in the event of a crisis so as to assure supply. Such contracts could be paid for through the prices of the materials to be bought at the time or possibly through arrangements making the sellers preferred sources in peacetime (in the latter case, there would be no monetary costs to the U.S. government). Such contracts could be backed up or facilitated in advance by agreements such as memoranda of understanding with supplier nation governments. The net effect in NDS modeling terms would be to boost supply by giving the U.S. a larger share than assumed in the Base Case for the materials produced by nations where we had such contracts.[3] This would help resolve shortfalls caused, for example, when supplies coming from unreliable supplier nations are delayed.

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[3] When the United States enters into long term contracts with suppliers or memoranda of understanding with supplier nation governments, these arrangements should normally increase the estimated reliability of supplier nations in the vulnerability assessments

A second way contracts could increase available material supplies would be for the United States to enter into contracts to pay suppliers to keep production capacity "warm," i.e., in a state in which it could be ramped up more quickly in time of crisis. In modeling terms, this could be thought of as an accelerated concerted program. Similar to the first kind of contract, these agreements could be paid for through the price of the material purchased at the time of crisis or by making the supplier a preferred source during peacetime.

Recycling

Efforts could be made to mitigate shortfalls by increasing the amount of material recycled domestically both before and during an emergency. Scrap can generally be recovered from material and component production processes and from discarded components. The extent of recovery is typically driven by the economics of the production cycle and the market for the material in question. In some cases the potential for recycling is limited by the technology available to recover materials from particular forms or to separate them from contaminants; research and development to improve those processes would be useful. Facilities might or might not have to be built or expanded to enable increased recycling. In the United States, laws could be passed to require recycling in the event of an emergency. During peacetime, financial incentives could be created to promote recycling or laws and regulations could require recycling as a means to conserve resources. Recycling capacity developed during peacetime would be available during wartime so long as it did not depend on imported scrap feed material that would not be available during wartime.

War Reserve Materiel

Reserves of war materiel (weapon systems, munitions and other consumables, and components thereof) could be established and maintained to obviate the need for reconstitution after a conflict.[4] The reserves would effectively reduce scenario military demand and thus mitigate the effects of or prevent material shortfalls. Such reserves could be periodically rolled over to keep inventories current over time. This approach might be attractive for systems with long production times that could not be regenerated within the time span of the scenario. It might be less attractive with expensive systems or components that would be at risk of becoming obsolete.

One challenge with taking this approach to mitigating shortfalls is identifying exactly which military systems contain the material in short supply. While DOD makes efforts to track the material content of some major weapon systems, the data are often incomplete. Available data are sufficient to estimate the impact on aggregate material needs of lower military demand during a scenario (reduced by the presence of the war reserve materiel), but such data may not be

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[4] See Department of Defense Instruction 3110.06, *War Reserve Materiel (WRM) Policy* (June 23, 2008).

sufficient to determine which specific systems containing the material in question would have their production limited by the shortage.

Increasing Supplier Reliabilities

One final way to reduce potential material shortfalls is to take measures to make supplier countries more reliable. If such peacetime efforts proved successful, the Base Case could make more optimistic assumptions about what supplies would be available from those countries in an emergency. Steps to increase reliability could include building relationships during peacetime with key supplier nations on several broad fronts, such as government to government, military to military, business to business, or people to people. Those efforts may increase reliability by decreasing anti-U.S. sentiment in the supplier country. More directly related to material suppliers, such measures could include entering into long-term contracts for material purchases that could be beneficial to suppliers because they could eliminate fluctuations in and uncertainty regarding demand. National-level efforts take time to develop, and thus they might not bear fruit within the time frame of a particular scenario, and their effectiveness can be hard to project, but they might be worth exploring if certain nations that were less than entirely reliable were found to supply several key materials to the United States. Contractual measures could bear fruit in the short term, but their effectiveness would depend on the reliability of the supplier nation's government. Because supplier reliabilities are classified, we do not discuss measures to increase reliability in the specific examples below.

Examples of Alternative Shortfall Mitigation Measures Applied to NDS Materials

The alternative material shortfall mitigation measures discussed above can potentially be applied to any material analyzed for the NDS and found to be in shortfall. This section offers examples showing how they might be applied to four materials found to be in shortfall in the 2011 NDS Base Case scenario: columbium, tantalum, carbon fiber IM-6, and terbium rare earth oxide. Their principal applications and their Base Case scenario shortfalls are shown below.

- **Columbium (Niobium)**
  - Used as a strengthening agent in steels and superalloys
  - 2011 Base Case shortfall: 938,000 pounds ($21M) (military applications)
- **Tantalum**
  - Used in electronic equipment (capacitors) and in high-temperature and corrosion-resistant alloys
  - 2011 Base Case shortfall: 7.8 million pounds ($332M) (civilian applications)
- **Carbon Fiber IM-6**
  - Used in V-22 and C-17 aircraft
  - 2011 Base Case shortfall: $382K (military applications)
- **Terbium (Rare Earth Oxide)**
  - Used in phosphors for lighting, metal alloys for magnets and other applications
  - 2011 Base Case shortfall: 45 MT ($27M) (military and civilian applications)

The potential applicability of each shortfall mitigation measure, its potential effectiveness in mitigating the shortfall, and its estimated cost (where known) are summarized in the following table. The applications of the mitigation measures to each material are discussed in further detail below. Note that the examples presented below are designed to illustrate the use of mitigation measures but further study is needed for a proper evaluation.

Table 6. Summary of Examples of Material Shortfall Mitigation Measures

Material and Measures	Potential Effectiveness	Estimated Cost
Columbium		
Rolling Inventory	Eliminates shortfall	$21M (peacetime)
Supply Contracts	Eliminates shortfall if producer nations are amenable	Potentially none to USG
Recycling	Potentially reduces shortfall	TBD (peacetime and/or crisis)
War Reserve Materiel	Possibly reduces shortfall but difficult to identify specific DOD system requirements	TBD (peacetime)
Tantalum		
Substitution	Eliminates most of shortfall	Potentially none to USG
Imported Goods	Eliminates most of shortfall; possibly limited by world material supply	Potentially none to USG
Austerity/Risk	Eliminates most of shortfall	Potentially none to USG
Rolling Inventory	Reduces shortfall; possibly limited by ability to identify specific demands for components containing tantalum	$332M (peacetime)
Concerted Programs	Potentially eliminates roughly half of scenario shortfall; more development needed	Previously estimated at $50M (peacetime and/or crisis)
Output Expansion	Eliminates 35percent of shortfall	TBD (peacetime and/or crisis)
Supply Contracts	Could eliminate shortfall by up to 40percent if supplier nations amenable	Potentially none to USG
Recycling	Potentially eliminates ~10 percent of shortfall; more potential if recycling of capacitors developed	TBD (peacetime and/or crisis)
Carbon Fiber IM-6		
Rolling Inventory	Eliminates shortfall	Potentially none to USG
Supply Contracts	Eliminates shortfall	Potentially none to USG

Table 6. Summary of Examples of Material Shortfall Mitigation Measures (concluded)

Material and Measures	Potential Effectiveness	Estimated Cost
Terbium[5]		
Substitution	May reduce shortfall but significant performance tradeoffs for some applications and not applicable for other applications	Potentially none to USG
Imported Goods	May reduce shortfall but applicable to some applications and not others	Potentially none to USG
Austerity/Risk	Can reduce civilian shortfalls	Potentially none to USG
Concerted Programs	Potentially reduces shortfall but impact unknown	One example cited could possibly double U.S. REO production in 12 mo[6]/$100M to $200M (peacetime and/or crisis)
Output Expansion	Potentially reduces shortfall but impact unknown	Various examples include $280M DOE loan guarantee; $3M to $5M DOD ManTech/Title III programs (peacetime and/or crisis)
Supply Contracts	Potentially reduces shortfall if supplier nations are amenable but impact unknown	Potentially none to USG
Recycling	Potentially reduces shortfall but impact unknown	TBD (peacetime and/or crisis)
War Reserve Materiel	Potentially reduces shortfall but difficult to identify specific DOD system requirements	TBD (peacetime)

5 Because of the uncertainty regarding the form of terbium imports and the military and civilian uses of terbium in the United States, it is difficult to ascertain how much any given measure would mitigate the terbium shortfall in the Base Case scenario.

6 In September 2010, Molycorp estimated that it could double its production capacity within 12 months after reaching its currently planned capacity of 20,000 MT in 2012. Molycorp subsequently announced in January 2011 that it plans on doubling its capacity by the end of 2013, at a cost of approximately $250M.

Columbium

Most Promising Shortfall Mitigation Measures
Short Term (can prepare and activate quickly)
Contingency contracts – could eliminate shortfall at potentially no cost if suppliers amenable
Rolling inventories – could eliminate shortfall if military demands were precisely identified
Longer Term (require more time to prepare and/or activate)
Recycling – could reduce shortfall significantly with development of superalloy old scrap recycling
War Reserve Materiel – could reduce shortfall with identification of specific DOD system requirements

Columbium (niobium)[7] is used as a strengthening agent in steels and superalloys. It shows a shortfall of 938,000 pounds (worth $21M) in the 2011 Base Case scenario, all in the scenario's first year. Most of the world's columbium is produced by a dominant supplier (Brazil). DOD planning assumptions prohibit dominant supplier materials from being relied upon to meet military demands during the NDS scenario. This causes a shortfall for columbium for military and extraordinary investment demand in the 2011 Base Case[8].

Because the projected columbium shortfall would be for military usage and extraordinary investment, alternative shortfall mitigation measures are essentially limited to the supply side. As noted above, because military demand for the scenario cannot be reduced and because of the difficulty of using substitute materials for producing military systems or obtaining substitute systems to meet military demands, demand-related shortfall mitigation alternatives are generally not applicable to mitigating military shortfalls.[9]

As a first alternative to stockpiling, DOD could buy a supply of columbium to be used in rolling inventories (totaling 938,000 pounds) with vendors who use the material to make military products. Those would mostly be producers of steels and superalloys used in applications like jet engines. Such inventories would cost $21M (plus storage and refreshing costs) and would be rolled over from time to time to maintain the columbium in forms currently used by industry.

Another alternative potentially useful for mitigating the shortfall would be entering, most likely during peacetime, into contingency contracts with Canadian suppliers, and potentially an agreement with the Canadian government, to allow the United States access to all of the

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7 This report uses the name columbium rather than niobium to be consistent with traditional NDS and U.S. Geological Survey usage.

8 Case BCS11 in Appendix 6 shows that if the U.S. defense sector is deemed able to rely on supplies from market dominators under certain conditions, then there would be no shortfall in columbium in the 2011 Base Case.

9 Columbium might be an exception to this general rule, in that titanium, molybdenum, and vanadium may be substituted for it in superalloys. See, for example, the U.S. Geological Survey's Minerals Yearbook 2004 (2004), p. 61.3. Some such substitute alloys may be approved for use in DOD systems. Upon further investigation and confirmation, this would allow for the use of substitute materials that would reduce military demand for columbium during the NDS scenario.

Canadian columbium supply—or at least all Canadian columbium exports—during the scenario (at least the first year thereof). Finding a practical way to increase the U.S. market share for Canadian columbium from the Base Case value of 26 percent up to 40 percent would eliminate the columbium shortfall.[10]

A third alternative possibly useful for mitigating the columbium shortfall is accounting for supply from recycling. The U.S. Geological Survey (USGS) supply data for columbium do not include any U.S. recycling because available data are limited.[11] However, an estimate prepared by USGS in 1998 reported that approximately 1,000 MT (2.2 million pounds) of columbium was recovered per year from old scrap when U.S. annual consumption was approximately 4,000 MT per year.[12] While current data are limited, the 1998 estimate might indicate how much columbium could be recovered from old scrap. If that estimate was correct, it would be more than enough to eliminate the shortfall. Thus, further efforts to ascertain how much columbium could be recovered from old scrap and how it could be recovered in the event of a conflict, might be worthwhile to undertake soon, before the conflict might occur.

The last alternative measure to consider for mitigating the columbium shortfall in the Base Case scenario would be maintaining an appropriate reserve of war materiel, such as columbium-containing military end items. However, with columbium it might be difficult to determine what to maintain in the reserve as it would require data on the columbium content of the end items. That data might be particularly difficult to obtain because columbium is mostly used as an additive to steels and superalloys in very small fractions, often less than 0.1 percent. Thus, while potentially effective, at least theoretically, maintaining a war reserve is unlikely to be a practical shortfall mitigation alternative for columbium.

[10] U.S. market share of foreign production is ordinarily estimated using a bidding model based on U.S. GDP relative to the GDPs of other material consumers. Under this mitigation option, the United States would essentially be switching from consuming 940,000 pounds of Brazilian columbium to consuming an additional 940,000 pounds of Canadian columbium. Little additional bidding should be required to make that switch, as the Brazilian supply that the United States would ordinarily consume would immediately become available to other consumers who would ordinarily consume the Canadian supply that the United States was seeking to obtain.

[11] Conversation with USGS specialist for columbium and tantalum, John Papp (Sept. 29, 2010).

[12] Larry D. Cunningham, "Columbium (Niobium) Recycling in the United States in 1998," in Scott F. Sibley, ed., *Flow Studies for Recycling Metal Commodities in the United States* (1998), pp. I2 and I4.

Tantalum

Most Promising Shortfall Mitigation Measures
Short Term (can prepare and activate quickly)
Substitution/imported goods/austerity – could significantly reduce shortfall related to civilian demand
Contingency contracts – could reduce shortfall by up to 40 percent if suppliers amenable
Longer Term (require more time to prepare and/or activate)
Output expansion – could reduce shortfall by up to 35 percent at lower cost if feasibility confirmed
Concerted program – previously estimated to reduce shortfall by approximately 50 percent at cost of $50M

Tantalum is used in electronic equipment (capacitors) and in high-temperature and corrosion-resistant alloys. It shows a shortfall of 7.8 million pounds (worth $332M) in the 2011 Base Case scenario, related entirely to civilian usage. Thus, alternative shortfall mitigation measures to consider include both demand-side and supply side possibilities.

The first potential demand side measure would be substituting other materials for tantalum. Substitutes must be available in sufficient quantities and must not experience shortfalls during the NDS Base Case scenario. Tantalum's main applications are capacitors in personal electronics, superalloys in aircraft engines and parts, and medical and surgical equipment. Potential substitutes in those applications include, respectively: aluminum; molybdenum; and glass, titanium, and zirconium.[13] The feasibility of substitution would depend on how much performance would be lost in each application and whether the substitutes would be acceptable in the civilian marketplace.

The government could allow the civilian market to rely on imported goods rather than guaranteeing a supply of tantalum to produce such goods here. For some applications (personal electronics and medical equipment), imports may be highly substitutable. For aircraft engines, substitution may be more difficult because of specific aircraft design requirements. A potential obstacle is that U.S. tantalum demand during the scenario is projected to exceed current annual world production.[14] Worldwide shortages would limit the availability of tantalum-containing imports. Similar to relying on imports, the government might apply more stringent austerity measures to the personal electronics sector and not assure a supply to cover shortfalls there.[15]

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[13] See Larry D. Cunningham, "Tantalum Recycling in the United States in 1998," in Scott F. Sibley, ed., *Flow Studies for Recycling Metal Commodities in the United States* (1998), p. J3; U.S. Geological Survey, *Mineral Commodity Summaries 2010*, p. 163 (2010).

[14] High U.S. tantalum demand in the scenario is caused by the rapid growth in the civilian sectors that use the material projected in the aftermath of the severe 2008-09 recession.

[15] The Base Case scenario already imposes an austerity factor of 50 percent on the personal electronics sector. This alternative measure would reflect a further increase of that factor, which would only be imposed after consultation with appropriate civilian authorities.

The first supply side shortfall mitigation measure would be obtaining rolling inventories sufficient to cover the shortfall (7.8 million pounds). This might be challenging with tantalum because it tends to be used in very small quantities in many products (e.g., capacitors in personal electronics and as a minor additive to superalloys used in aircraft engines). The government would have to identify where in the tantalum supply chain it would be most efficient to maintain the inventories. Such inventories would cost $332 M (plus storage and refreshing costs) and would be rolled over from time to time to maintain their currency.

The second supply side measure would be a concerted program. The USGS previously found that mine capacity in Australia could be expanded at a cost of $50 million and the expanded output from the program, in total, would be sufficient to eliminate approximately half of the shortfall in the 2011 Base Case scenario (see also Case BCS17 in Appendix 6). The mine capacity and cost estimates are somewhat dated now, but as of earlier in 2010 the two Australian mines in question remained closed (and hence potentially to be re-opened). Therefore, there is currently insufficient information to rely on this potential program to mitigate the shortfall, but sufficient potential exists to warrant its evaluation to determine its capacity for doing so and what it would cost.

Another similar measure would be expanding output at existing facilities. The potential for this option is suggested by recent tantalum production levels 30 percent higher than last year's.[16] Production at those levels would eliminate about 35 percent of the projected annual shortfall. Industry experts believe that tantalum production would increase in response to rising demand.[17]

Contingency supply contracts could allow the United States access to all Australian tantalum exports during the scenario. This would increase the U.S. market share for Australian tantalum from about 30 percent to 100 percent. That would reduce the Base Case shortfall by over 40 percent. Contingency contracts could also accelerate the expansion of Australian mine capacity described above. They might be paid for monetarily or by making Australian producers preferred suppliers to the United States. The cost effectiveness of such contracts would depend on the price negotiated with tantalum suppliers.

A final alternative could be accounting for or possibly expanding supply from recycling. USGS supply data do not include any U.S. recycling because information is limited, but former estimates suggest that approximately 90 MT (200,000 pounds) of tantalum are recycled annually.[18] That would represent 9 percent of the maximum scenario-year shortfall. Increases in recycling are possible but current potential is limited, in that most scrap tantalum is contained in discarded electronic components, for which recycling processes are not well-developed.

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[16] U.S. Geological Survey, *2008 Minerals Yearbook, Niobium (Columbium) and Tantalum* [Advance Release] (2008), p. 52.7 (http://minerals.usgs.gov/minerals/pubs/commodity/niobium/myb1-2008-niobi.pdf).

[17] Conversation with USGS specialist John Papp.

[18] Ibid; Cunningham, "Tantalum Recycling in the United States in 1998," pp. J2 and J4.

Carbon Fiber IM-6

Most Promising Shortfall Mitigation Measures
Short Term (can prepare and activate quickly)
Contingency contracts – little to no cost to suppliers and customers
Rolling inventory – could rapidly reduce shortfall within days to weeks
Longer Term (require more time to prepare and/or activate)
Expand capacity – qualifying existing production lines for multiple DOD requirements would provide a significant hedge at cost ranging from $300K to $1M

IM-6 is an aerospace grade of carbon fiber used to manufacture light weight and high strength polymer based composite materials. IM-6 is a proprietary product developed and produced by a sole U.S.-based manufacturer, the Hexcel Corporation. Because IM-6 is a proprietary product, this report excludes certain details about IM-6 supply, demand, production capacity and particulars about shortfall mitigation examples.

Hexcel is by far the largest supplier of carbon fiber to DOD and it also supplies diverse commercial markets globally (e.g. civilian aircraft, industrial equipment, and recreational products). Hexcel created IM-6 specifically for use in U.S. military aircraft, namely the V-22 and C-17, and there are no other uses for IM-6 currently. Hexcel manufactures fibers and their precursor at two U.S. factories and at one foreign plant in Spain. The company has multiple production lines although not all of Hexcel's production capacity is DOD-qualified to produce fibers for U.S. military uses.

While assessing IM-6 for this report, a relatively small shortfall was estimated during the first year of the Base Case scenario. While the quantity of material in shortfall is not publicly reported for proprietary reasons, the cost of the material in shortfall is estimated at $381,912. It should be noted that given the size of the shortfall relative to Hexcel's significant production capacity and manufacturing flexibility, the company could readily produce needed quantities of IM-6 in very short order (e.g. on the order of weeks to a few months or less).[19]

Examples of specific alternative measures to mitigate an IM-6 shortfall are generally limited to the supply side since this material is currently only used in defense. Demand side measures (e.g. substitution, imports and austerity measures), are not immediately relevant to IM-6 in the Base Case scenario. While all of the supply side options could potentially be used, two are most promising for the near-term: contingency contracting and establishment of a rolling inventory.

[19] Planning assumptions relied upon under the Base Case scenario do not allow for increases in material production in the first year of the scenario unless the capability to do so is well documented.

Under contingency contract provisions, DOD could potentially consolidate V-22 and C-17 IM-6 demand and work with upper tier supply chain customers to establish slightly larger than average annual "blanket-type" purchase orders for IM-6, with contingency provisions for a surge in demand. Suppliers who buy IM-6 could then exercise those contingency provisions to buy increased quantities of IM-6 during a national emergency.

Typically in this industry, carbon fiber customers only pay for product produced and shipped under annual blanket order contracts. Customers generally do not pay producers for products available under a blanket order contract unless buyers authorize shipment and take possession of purchased materials. Therefore the use of contingency contract like agreements, through blanket type orders, might have little or no costs associated with them other than paying for materials actually shipped. However, it is important to note that the estimated Base Case shortfall represents a relatively small volume of material and utilizing blanket type orders with contingencies for larger volumes of material could have cost implications for both suppliers and customers. It is also important to note that IM-6 production capacity is also used to manufacture other fibers for military and commercial markets. Because military orders for IM-6 and other fibers would most likely be Defense Priorities and Allocation System-rated, some adjudication of priorities might prove necessary.

Another potential shortfall mitigation measure would be a rolling inventory maintained at the Hexcel facility, particularly given the relatively small size of the Base Case shortfall compared to the significant amount of IM-6 that could be quickly produced. With the use of batch like production, typical manufacturing volumes and common inventory levels, a rolling inventory could potentially be made available at little to no cost. If the Base Case shortfall was substantially larger, costs associated with a rolling inventory could be incurred by Hexcel and hence DOD.

Other supply side measures, in particular expanding capacity, are not likely relevant to IM-6 and the Base Case. However, such mitigation options could be important to other carbon fibers produced by Hexcel (including those assessed in this report), potentially based on different scenarios as well. For those cases, one lower-cost and less time-consuming option relative to building new production lines would be qualifying existing lines for defense uses.

To conclude, IM-6 product and production characteristics, combined with Base Case assessment parameters and the fact that IM-6 is only used for U.S. military applications, would make mitigating future shortfalls most amenable to the supply side options given. Since IM-6's producer has significant manufacturing capacity and production flexibility, the use of contingency contracting like agreements and/or a vendor managed rolling inventory appear to be most promising and cost-effective.

Terbium Rare Earth Oxide

Most Promising Shortfall Mitigation Measures
Short Term (can prepare and activate quickly)
Substitution, imports and austerity measures to decrease civilian demand
Rolling inventories of oxide or intermediate forms (i.e. phosphors and metals) at end-user factories
NDS inventories of key products containing terbium (e.g. magnets) required for essential needs
Longer Term (require more time to prepare and/or activate)
Expand capacity by reconstituting rare earth value chains (e.g. mines-to-magnets) and recycling

Terbium (Tb) is a heavy rare earth element (REE) that is primarily used in two mostly commercial applications: (1) phosphors for fluorescent lighting and, to a lesser extent, television and computer displays, and (2) high temperature resistant neodymium iron boron (NdFeB) magnets, such as those used in electric motors and generators. Military uses for phosphors and related materials include night vision equipment, laser targeting systems and avionic displays. Applications for terbium-doped magnets include actuators and motors for precision guided munitions. Although DOD uses small quantities of terbium, critical requirements exist for which there are limited, and in some cases no, suitable substitutes other than possibly alternative REEs that may also experience shortfalls in the Base Case scenario.

China currently controls over 95 percent of the world's mining and processing of rare earth oxides (REOs) including terbium. New sources being developed include those in the United States by Molycorp and in Australia by Lynas Corp. It is estimated that 2010 global terbium demand (305 MT) will exceed supply (278 MT) by 27 MT and that the imbalance will increase to 81 MT in 2015[20]. Most of the world's phosphor production and all NdFeB magnet manufacturing is located outside the U.S. and heavily concentrated in China. Other downstream industries whose end-use products increasingly depend on REOs are also no longer dominated by the United States. U.S. demand for terbium REO is estimated at 41 MT ($40M) for 2011 and is expected to rise to 44 MT by 2014[21]. Based on the breakdown in demand in the industrial sectors that consume terbium, military demand is estimated to constitute 13 percent to 18 percent of total demand.

Demand-side options for mitigating potential shortfalls in terbium used in phosphors for fluorescent lighting include: substitution, imports and civilian austerity. Examples of substitution measures include U.S. manufacturing of light-emitting diodes that may use less terbium, or manufacturing earlier generations of fluorescent lamps or incandescent lights, which use no terbium. Austerity and import measures could include consumers reducing consumption (e.g. leaving every other light socket empty) or relying on imported compact fluorescent lamps.

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20 Dudley J. Kingsnorth, Industrial Minerals Company of Australia (IMCOA)

21 Daniel J. Cordier, U.S. Geological Survey (USGS)

Military and civilian consumers could also rely more heavily on imports of terbium-containing phosphors.

Supply-side options for mitigating potential shortfalls in terbium include: concerted programs, contingency contracts, and war reserves. In the longer-term, the United States could also consider expanding domestic capacity to produce REE-containing products and recycling.

A potential concerted program would be for the U.S. government (USG) to contract with Molycorp to double its mining and REO processing capabilities. As of September 2010, Molycorp's business plan called for producing at full capacity (20,000 MT annually) by the latter part of 2012. With additional funding of $100M to $200M, Molycorp could potentially double its capacity within approximately 12 months (by 2013) from the time it reached its currently planned level of full production.[22] While this significantly exceeds the cost of stockpiling the Base Case terbium shortfall, Molycorp would be producing a wide range of REOs, (which could mitigate shortfalls in other REOs), and a doubling of U.S. capacity would provide broad long-term opportunities for decreasing future REO supply chain vulnerabilities of importance to DOD and key commercial sectors.

In addition, the USG could enter into contingency contracts to purchase future terbium production (and thereby increase U.S. market share) from Australia (Lynas) during a national emergency. Australian mines are expected to begin producing significant quantities of REEs, including terbium, in the near future. Given that new mines outside the U.S. have likely sold out near-term future capacity through recent "off-take" contracts, and these supplies might likely be expected to already support some level of military and essential civilian demands, foreign contingency contracts would have to be closely coordinated with off-take agreements already in place.

In a related vein, while DOD stockpile analyses do not ordinarily consider the assurance of material supplies for foreign industrial producers, the current situation concerning REEs might warrant such analysis. Because the United States does not manufacture all of the REE metals and alloys needed, for example, to support production of NdFeB magnets for U.S. defense systems and munitions and essential civilian goods, the United States imports those products and would likely continue to do so during a national emergency in the near-term. That creates a risk that foreign industrial producers important to meeting U.S. defense needs might be unable to do so because of a worldwide REE shortage. Such a situation might warrant the United States directing assured terbium supplies to those foreign producers instead of the United States.

Because there are gaps in the domestic manufacturing industrial base, any NDS inventories needed to offset the terbium shortfall could include semi-finished products that contain terbium.

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[22] In September 2010, Molycorp estimated that it could double its production capacity to 40,000 MT within 12 months after reaching its currently planned capacity of 20,000 MT in 2012. Molycorp subsequently announced in January 2011 that it plans on doubling its capacity by the end of 2013, at a cost of approximately $250M.

For example, the NDS might stock NdFeB magnets that use terbium if U.S. production of the magnets themselves is unlikely.

In the longer term, the United States might consider expanding domestic capacity to produce REE-containing products, including intermediate value added materials and end-use items, particularly those used in military or essential civilian applications. Assuring raw material supplies of REOs during a national security emergency would not be sufficient to satisfy demands if the United States lacks the capacity to produce (and cannot be assured of importing) products that employ the REEs. There are a number of ways to expand capacity. For example, DOD has authority to invest with industry in new technology development and manufacturing capacity utilizing the Defense Manufacturing Technology program and the Title III program of the Defense Production Act. Examples of more extensive measures could include: public-private consortia (e.g. SEMATECH), contractor operated "trusted foundries," and USG owned and operated industrial facilities (e.g. munitions plants). Growing public discussion about possible national policy and strategies concerning strategic materials, manufacturing competitiveness and innovation capacity could encompass these as well as other initiatives relevant to mitigating shortfalls and related supply chain risks.

In sum, several supply-side and demand-side options exist for mitigating terbium shortfalls. In most instances, they also mitigate risks related to (and in some cases beyond) other REOs as well. Furthermore, these examples recognize that defense and essential civilian needs and industrial bases are seldom mutually exclusive.

Conclusion

While stockpiling is the traditional remedy under the NDS program concept, several other possible mitigation options/remedies may also be available to the U.S. government to address the material shortfalls found in the 2011 Base Case scenario. Indeed, a major objective and mission of the SMSP is to identify the most cost-effective, prudent strategies for addressing identified material vulnerabilities and risks. The alternative shortfall mitigation measures discussed in this Chapter may constitute useful parts of such strategies.

This overview of mitigation examples for columbium, tantalum, carbon fiber IM-6, and terbium has shown that options such as substitution, civilian austerity, rolling inventories, special supply contracts, recycling, and war reserve materiel, could mitigate and in some cases eliminate shortfalls that could require hundreds of millions of dollars of stockpiled materials to mitigate otherwise. Demand side options like substitution tend to be useful to mitigate shortfalls in materials used to meet civilian rather than military demands, but supply side options have no such limits. Some options, like concerted programs for increasing capacity at U.S. or foreign production facilities, can be more expensive, but other options, like entering into contracts to obtain more materials from reliable suppliers in the event of a crisis, may not be very expensive at all. For some materials, like terbium, shortfall mitigation options may be limited because of the circumstances of the scenario, but maintaining war reserve materiel stocks may provide a way to minimize or eliminate the military aspects of such shortfalls.

This overview provides examples of some major types of shortfall remedies that may be appropriate under various circumstances within the SMSP construct. Because this is a first effort at identifying and assessing mitigation options, more work needs to be done to determine which options are most cost-effective. However, this discussion points to some kinds of assessments that can and should be undertaken in order to determine which shortfall mitigation measures would be best for any particular strategic material experiencing a shortfall in a scenario. DOD intends that the SMSP will follow up on this initial effort by undertaking such assessments for materials found to be of particular concern. As noted at the beginning of this report, if a full risk assessment and mitigation analysis of the Base Case shortfalls indicates that there are more cost-effective strategies than traditional stockpiling, then DOD, along with its interagency partners, will present these options and recommendations to the Congress beginning in late 2011.

Appendix 1
Précis of Assumptions
for 2011 Base Case Analysis

Appendix 1
Précis of Assumptions
for 2011 Base Case Analysis

This appendix provides a précis of the key assumptions made in the 2011 Base Case. The assumptions are discussed as follows.

- Supply-side Assumptions:
  - Supply from Enemy Combatants
  - Supply from Unwilling Countries
  - Foreign Infrastructure Reliability
  - Foreign Production Capacity
- Demand-side Assumptions:
  - Economic Growth
  - Defense Demand
  - Essential Civilian Demand
  - Homeland Recovery

Supply from Enemy Combatants

Enemy combatant states will not be considered available to supply materials to the U.S. for a period of time surrounding the conflict, due to some combination of enemy embargoes, U.S. sanctions, and potential war damage. The Base Case assumes that the no-supply period lasts for a year (and that their supplies are simply unavailable to the United States).[1]

Supply from Unwilling Countries

Some foreign governments, not necessarily directly involved in combat, may be judged partially or completely *unwilling* to supply materials to the U.S. as a result of the contingency. While the U.S. is assumed in the Base Case to eventually obtain its normal

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[1] The no-supply period is influenced by political and economic factors and need not coincide exactly with the period of combat.

share of the "unwilling fraction" of those materials even from unwilling sources—by dealing with third parties on global markets—such indirect acquisitions will be subject to non-trivial delays.[2] The proportion of a country's materials deemed unreliable due to unwillingness (and thus subject to a delay) depends on the degree of its hostility, as indicated by a score assigned to that country by the country reliability raters (see discussion in Chapter One). For the Base Case, the delay for subject materials is assumed to be six months.

Foreign Infrastructure Reliability

Some foreign economies, not necessarily directly involved in combat in the Base Case, may be judged more or less unable to supply the quantity of materials that they might normally provide based on their current production and production capacities. They may thus prove unreliable as a result of scenario-specific levels of political instability, labor unrest, or breakdowns in transportation or power infrastructures. Such scenario-specific problems are estimated by the reliability raters. Note that this construct (foreign infrastructure reliability) is separate from any estimated war damage. In the Base Case, reliability raters assign a proportion (0 to 100 percent) of a country's anticipated material output that is assumed to be lost due to this factor.

Foreign Production Capacity

Foreign material producers operating at less than full capacity could increase output during a contingency. Depending on the extent of global shortages and competition for supplies, the U.S. is assumed to be able to obtain its normal share of any increased output. The Base Case assumes that during the first year, the U.S. may acquire its normal share of estimated reliable, undamaged foreign production from countries that are not enemy combatants. After the first year of the scenario, the U.S. is assumed to be able to acquire its normal share of full-capacity output (after adjustments for reliability, war-damage and shipping losses).

Economic Growth

The study projects future U.S. demands for strategic and critical materials based, in part, on an official recent forecast of the U.S. economy. The Base Case utilizes the long-term macroeconomic forecast prepared by the President's Council of Economic Advisors and released as part of the Economic Report of the President in February 2010 This

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2 In general, the normal U.S. share is determined for the Base Case as the ratio of the U.S. Gross Domestic Products (GDP) to the collective GDP of the countries that demand the material. GDP is considered a rough proxy for buying power. If, however, the ratio of normal U.S. imports from a country to non-U.S. production is a larger number, then that is used as the normal share instead.

official forecast is used by the Administration to support policy and budgetary deliberations.

Defense Demand

Demand for goods and services used by the defense sector consists of two parts. The first part corresponds to regular, ongoing defense budget and Future Years Defense Program (FYDP) demand, and demands upon each of 360 sectors of the U.S. economy are estimated using special economic forecasting models (from the INFORUM organization at the University of Maryland). The inputs to these models are set to be consistent with the FYDP (FY11-15). The second part corresponds to goods and services needed to rebuild key weapons lost and consumed in the postulated Base Case conflict scenario. These demands are estimated using data from the Assistant Secretary of Defense for Cost Assessment and Program Evaluation, as well as information from INFORUM.

Essential Civilian Demand

The study uses certain essential civilian demand factors (see Appendix 2) to determine the portion of projected civilian demand that should be considered essential and thus be included in the essential demands for the Base Case. The Base Case utilizes factors that are less stringent in the first (combat/conflict) year than in the subsequent three years of regeneration.

Homeland Recovery

A catastrophic attack on a major U.S. city by a foreign terrorist organization or rogue state would cause substantial destruction of fixed assets and consumer durables. The Base Case assumes (based on a structured estimation process) that a homeland recovery program to replace lost assets would require a total of at least $100 billion in private and government spending over the three regeneration years. These recovery demands are treated as essential. They are apportioned between the defense and essential civilian demand sectors for estimation and tracking purposes in this study.

Appendix 2
Essential Civilian Demand Factors

Appendix 2
Essential Civilian Demand Factors

Introduction

The statute governing the National Defense Stockpile (NDS) requires that the Biennial Report on Stockpile Requirements set forth the National Security Planning Assumptions used by the Secretary of Defense in determining recommendations for stockpile requirements.[1] Two of the planning assumptions specified in the statute address civilian requirements, namely:

- The military, industrial, and *essential civilian* requirements to support the national emergency
- *Civilian austerity* measures required during the mobilization period and military conflict

This appendix describes the process established by DOD, after consultation with a civilian agency working group, to determine which civilian requirements should be considered essential.[2] The process uses percentage reduction factors to identify the portions of projected normal civilian demands deemed nonessential[3]. Essential civilian requirements are calculated by reducing projected demands by the percentages specified in the reduction factors. Only the decremented demands are considered essential and used in the determination of requirements for strategic and critical materials (SCM).

The reduction factors serve to support key national security objectives while limiting potentially costly requirements for strategic and critical materials. Requirements that are deemed essential can be grouped according to the following purposes:

- Procuring goods and services for defense;
- Sustaining supporting industries;
- Maintaining national economic strength;

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1 See U.S. Code 50, § 98h-5.

2 Civil departments and agencies invited to participate in the essential civilian demand decision process included Agriculture, Commerce, Energy, Health and Human Services, Homeland Security, Housing and Urban Development, Interior, Labor, the Office of Management and Budget, State, Transportation, and Treasury.

3 Events during the crisis would influence civilian demands, both positively and negatively, across the four-year scenario. However, essential civilian demands are calculated based on forecasts of normal peacetime demands.

- Providing government services;
- Maintaining an adequate civilian standard of living; and
- Recovering from an attack on the U.S. homeland.

Reduction factors are defined for 78 types of personal consumption and 31 types of construction, as shown on Table 2-1 on the following pages.[4] As indicated on the table, the factors are generally lower during year one of the four-year scenario. This allows for a period of transition to help the civilian sector adjust to developing material shortages.

Personal Consumption Expenditures

The first 78 spending categories listed on Table 2-1 represent types of personal consumption. Generally, large reduction factors are specified for the various types of consumer durable goods, up to 75 percent for new automobiles, leisure vehicles, and jewelry. Consumer durables are targeted because their production is especially intensive in the use of SCMs.[5] In light of potential energy shortages, gasoline and foreign travel are also targeted.

For a number of personal consumption categories, a "+" sign is displayed in lieu of a reduction factor. These sectors generally represent nondurable goods and services, sectors that make relatively little use of SCMs. It is presumed that these items will be available in ample supply and that consumers will offset reductions in spending on consumer durables by spending more on these items. That is, spending in these categories will exceed projected normal spending.

A reduction factor of zero is indicated for a number of sectors. These sectors generally represent necessities and are mainly nondurable goods and services that do not make intensive use of SCMs. The zero reduction factors indicate that projected spending is considered essential and that consumer spending will be in line with normal projections.

Construction

The last 31 spending categories shown on Table 2-1 represent various types of construction. Because construction generally makes intensive use of SCMs, the reduction factors for some of these categories are quite high, rising to 67.5 percent for

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[4] These particular spending categories reflect the level of detail available in the simulation models used for the DOD NDS study, namely the LIFT and ILIAD input-output models developed by INFORUM at the University of Maryland.

[5] Note that spending to replace consumer durables damaged during an attack on the U.S. homeland is considered essential. Similarly, construction to replace damaged assets is considered essential. The reduction factors on Table 2-1 do not apply to such spending on homeland recovery.

residential construction and 50 percent for several commercial sectors. However, all government construction is considered essential as is private construction of transport, communications, and energy infrastructure. In these cases, the reduction factor is zero and spending is presumed to be in line with normal projections.

Table 2-1. Percentage Reduction Factors to Eliminate Nonessential Spending[6]

Personal Consumption Categories		Conflict	Regeneration		
		Year 1	Year 2	Year 3	Year 4
1	New Cars	50.0	75.0	75.0	75.0
2	Used Cars	25.0	50.0	50.0	50.0
3	New & Used Trucks	25.0	50.0	50.0	50.0
4	Tires & Tubes	25.0	50.0	50.0	50.0
5	Auto Accessories & Parts	15.0	15.0	15.0	15.0
6	Furniture, Mattresses, Bedsprings	25.0	50.0	50.0	50.0
7	Kitchen, Household Appliances	25.0	50.0	50.0	50.0
8	China, Glassware, Tableware, Utensils	25.0	50.0	50.0	50.0
9	Radio, TV, Records, Musical Instruments	25.0	50.0	50.0	50.0
10	Floor Coverings	25.0	50.0	50.0	50.0
11	Durable House furnishings	25.0	50.0	50.0	50.0
12	Writing Equipment	25.0	50.0	50.0	50.0
13	Hand Tools	25.0	50.0	50.0	50.0
14	Jewelry	50.0	75.0	75.0	75.0
15	Ophthalmic & Orthopedic Appliances	0.0	0.0	0.0	0.0
16	Books & Maps	25.0	50.0	50.0	50.0
17	Wheeled Goods & Durable Toys	25.0	50.0	50.0	50.0
18	Boats, Recreational Vehicles & Aircraft	50.0	75.0	75.0	75.0
19	Food, Off Premise	0.0	0.0	0.0	0.0
20	Food, On Premise	0.0	0.0	0.0	0.0
21	Alcohol, Off Premise	0.0	0.0	0.0	0.0
22	Alcohol, On Premise	0.0	0.0	0.0	0.0
23	Shoes & Footwear	+	+	+	+
24	Women's Clothing	+	+	+	+
25	Men's Clothing	+	+	+	+
26	Luggage	+	+	+	+
27	Gasoline & Oil	25.0	50.0	50.0	50.0
28	Fuel Oil & Coal	0.0	0.0	0.0	0.0
29	Tobacco	+	+	+	+
30	Semi-durable House furnishings	+	+	+	+

[6] The values (including zeroes) in the table represent the percentage decrements imposed on projected civilian spending to eliminate non-essential items. For personal consumption, those categories with +'s are augmented proportionally so that total consumption across all the categories remains at the projected total level.

Table 2-1. Percentage Reduction Factors to Eliminate Nonessential Spending (Continued)

Personal Consumption Categories		Conflict	Regeneration		
		Year 1	Year 2	Year 3	Year 4
31	Drug Preparations & Sundries	+	+	+	+
32	Toilet Articles & Preparations	+	+	+	+
33	Stationery & Writing Supplies	+	+	+	+
34	Non-durable Toys & Sport Supplies	+	+	+	+
35	Flowers, Seeds, Potted Plants	+	+	+	+
36	Cleaning Preparations	+	+	+	+
37	Lighting Supplies	+	+	+	+
38	Household Paper Products	+	+	+	+
39	Magazines & Newspapers	+	+	+	+
40	Other Non-durables	+	+	+	+
41	Owner Occupied Space Rent	+	+	+	+
42	Tenant Occupied Space Rent	+	+	+	+
43	Hotels, Motels	+	+	+	+
44	Other Housing	0.0	0.0	0.0	0.0
45	Electricity	0.0	0.0	0.0	0.0
46	Natural Gas	0.0	0.0	0.0	0.0
47	Water & Other Sanitary Services	+	+	+	+
48	Telephone & Telegraph	+	+	+	+
49	Domestic Services	+	+	+	+
50	Household Insurance	+	+	+	+
51	Other Household Operations: Repair	+	+	+	+
52	Postage	0.0	0.0	0.0	0.0
53	Auto Repair	+	+	+	+
54	Bridge, Tolls, etc.	+	+	+	+
55	Auto Insurance	+	+	+	+
56	Taxicabs	+	+	+	+
57	Local Public Transport	+	+	+	+
58	Intercity Railroad	+	+	+	+
59	Intercity Busses	+	+	+	+
60	Airlines	+	+	+	+
61	Travel Agents, Other Transportation Services	0.0	0.0	0.0	0.0
62	Laundries & Shoe Repair	+	+	+	+
63	Barbershops & Beauty Shops	+	+	+	+
64	Physicians	0.0	0.0	0.0	0.0
65	Dentists & Other Professional Services	0.0	0.0	0.0	0.0

Table 2-1. Percentage Reduction Factors to Eliminate Nonessential Spending (Continued)

Personal Consumption Categories		Conflict	Regeneration		
		Year 1	Year 2	Year 3	Year 4
66	Private Hospitals & Sanitariums	+	+	+	+
67	Health Insurance	+	+	+	+
68	Brokerage & Investment Counselors	+	+	+	+
69	Bank Service Charges & Services	+	+	+	+
70	Life Insurance	+	+	+	+
71	Legal Services	+	+	+	+
72	Funeral Expenses, Other Personal Business	+	+	+	+
73	Radio & TV Repair	+	+	+	+
74	Movies, Theatre, Spectator Sports	+	+	+	+
75	Other Recreational Services	+	+	+	+
76	Education	+	+	+	+
77	Religious & Welfare Services	+	+	+	+
78	Foreign Travel	50.0	75.0	75.0	75.0

Table 2-1. Percentage Reduction Factors to Eliminate Nonessential Spending (Concluded)

Construction Categories		Conflict	Regeneration		
		Year 1	Year 2	Year 3	Year 4
1	1 Unit Residential Structures	50.0	67.5	67.5	67.5
2	2 Or More Unit Residential Structures	50.0	67.5	67.5	67.5
3	Mobile Homes	0.0	0.0	0.0	0.0
4	Additions & Alterations	50.0	67.5	67.5	67.5
5	Hotels, Motels, Dormitories	25.0	50.0	50.0	50.0
6	Industrial	25.0	50.0	50.0	50.0
7	Offices	25.0	50.0	50.0	50.0
8	Stores, Restaurants, Garages	25.0	50.0	50.0	50.0
9	Religious	25.0	50.0	50.0	50.0
10	Educational	0.0	0.0	0.0	0.0
11	Hospital & Institutional	0.0	0.0	0.0	0.0
12	Miscellaneous Nonresidential Buildings	25.0	50.0	50.0	50.0
13	Farm Buildings	0.0	0.0	0.0	0.0
14	Mining Exploration Shafts & Wells	0.0	0.0	0.0	0.0
15	Railroads	0.0	0.0	0.0	0.0
16	Telephone & Telegraph	0.0	0.0	0.0	0.0
17	Electric Light & Power	0.0	0.0	0.0	0.0
18	Gas & Petroleum Pipes	0.0	0.0	0.0	0.0
19	Other Structures	0.0	0.0	0.0	0.0
20	Highways & Streets	0.0	0.0	0.0	0.0
21	Military Facilities	0.0	0.0	0.0	0.0
22	Conservation	0.0	0.0	0.0	0.0
23	Sewer Systems	0.0	0.0	0.0	0.0
24	Water Supply Facilities	0.0	0.0	0.0	0.0
25	Residential (Public)	0.0	0.0	0.0	0.0
26	Industrial (Public)	0.0	0.0	0.0	0.0
27	Educational (Public)	0.0	0.0	0.0	0.0
28	Hospital (Public)	0.0	0.0	0.0	0.0
29	Other Buildings (Public)	0.0	0.0	0.0	0.0
30	Misc. Public Structures	0.0	0.0	0.0	0.0
31	Broker's Commission (Residential Structures)	50.0	67.5	67.5	67.5

Appendix 3
Abbreviations

Appendix 3
Abbreviations

Av Oz	-	Avoirdupois Ounce (28.350 Grams)
C	-	Carbon
Cb	-	Columbium (Niobium)
Co	-	Cobalt
ct	-	Carats
FL	-	Flasks (76 Pounds)
KG	-	Kilograms
LB	-	Pounds
LB Cb	-	Pounds of Contained Columbium
LB Co	-	Pounds of Contained Cobalt
LB Ta	-	Pounds of Contained Tantalum
LB W	-	Pounds of Contained Tungsten
LCT	-	Long Calcined Tons
LDT	-	Long Dry Tons
LT	-	Long Tons (2240 Pounds)
MT	-	Metric Tons (2204.6 Pounds)
MT Oxide	-	Metric Tons of Oxide
Ni	-	Nickel
Pb	-	Lead
PC	-	Pieces
SDT	-	Short Dry Tons
Si	-	Silicon
ST	-	Short Tons (2000 Pounds)
ST V	-	Short Tons of Contained Vanadium
Ta	-	Tantalum
Tr Oz	-	Troy Ounces
V	-	Vanadium
W	-	Tungsten

Appendix 4
Strategic and Critical Materials Stock Piling Act, Sec. 14, Biennial Report on Stockpile Requirements
(50 U.S.C. § 98h-5)

Appendix 4
Strategic and Critical Materials Stock Piling Act, Sec. 14, Biennial Report on Stockpile Requirements (50 U.S.C. § 98h-5)

(a) Not later than January 15 of every other year, the Secretary of Defense shall submit to Congress a report on stockpile requirements. Each such report shall include—

(1) the Secretary’s recommendations with respect to stockpile requirements; and

(2) the matters required under subsection (b).

(b) Each report under this section shall set forth the national emergency planning assumptions used by the Secretary in making the Secretary's recommendations under subsection (a)(1) with respect to stockpile requirements. The Secretary shall base the national emergency planning assumptions on a military conflict scenario consistent with the scenario used by the Secretary in budgeting and defense planning purposes. The assumptions to be set forth include assumptions relating to each of the following:

(1) The length and intensity of the assumed military conflict.

(2) The military force structure to be mobilized.

(3) The losses anticipated from enemy action.

(4) The military, industrial, and essential civilian requirements to support the national emergency.

(5) The availability of supplies of strategic and critical materials from foreign sources during the mobilization period, the military conflict, and the subsequent period of replenishment, taking into consideration possible shipping losses.

(6) The domestic production of strategic and critical materials during the mobilization period, the military conflict, and the subsequent period of replenishment, taking into consideration possible shipping losses.

(7) Civilian austerity measures required during the mobilization period and military conflict.

(c) The stockpile requirements shall be based on those strategic and critical materials necessary for the United States to replenish or replace, within three years of the end of the military conflict scenario required under subsection (b), all munitions, combat support items, and weapons systems that would be required after such a military conflict.

(d) The Secretary shall also include in each report under this section an examination of the effect that alternative mobilization periods under the military conflict scenario required under subsection (b), as well as a range of other military conflict scenarios addressing potentially more serious threats to national security, would have on the Secretary's recommendations under subsection (a) (1) with respect to stockpile requirements.

(e) The President shall submit with each report under this section a statement of the plans of the President for meeting the recommendations of the Secretary set forth in the report.

Appendix 5
Summary of Key Results for 2011 National Defense Stockpile (NDS) Requirements Report

Appendix 5
Summary of Key Results for 2011 National Defense Stockpile (NDS) Requirements Report

The key results of the study are summarized on Table 5-1. Total projected 2011 Base Case material shortfalls (for 70 materials over the four-year scenario period) are shown. While they are quite small relative to the overall 2011 Base Case U.S. demand for those materials over the four year scenario period ($300,849M), the 2011 Base Case shortfall values are nevertheless significant relative to the current value ($1,304M) of the total NDS inventory. The one-year defense shortfalls in the alternative scenario case ($637M) are also large relative to current NDS inventories of those materials: after applying inventories, $563M in shortages remain in this alternative case.

Table 5-1. 70 Strategic and Critical Materials: Key Results of 2011 Study

Potential Supply Shortfalls	**$ Millions (Fall 2010 Prices)**
2011 Base Case *(Chapter One)*	2,013
2005 Base Case *(2005 Report to Congress)*	239
2011 Alternative Scenario Case *(Chapter Two)* DOD Shortfalls only	637
Projected 4-Year U.S. Demand (2011 Base Case)	
Military	20,270
Industrial	66
Essential Civilian	280,513
Total	300,849
Current Inventory (70 materials)	1,304

Appendix 6
2011 Base Case Sensitivity Cases

Appendix 6
2011 Base Case Sensitivity Cases

This Appendix summarizes a number of sensitivity cases for the 2011 Base Case.

Introduction

Sensitivity cases can illustrate and clarify the sensitivity or fragility of the findings related to alternative assumptions. Thus, if there is uncertainty regarding the appropriateness of Base Case assumptions, sensitivity cases can illustrate the potential effects of being wrong in the selection of a Base Case assumption. If the Base Case findings are highly sensitive to the choice of assumptions, then decision makers should exercise caution regarding policy or investment decisions based on those assumptions. If, on the other hand, the Base Case findings are relatively insensitive to the choice of alternative plausible assumptions, that should provide more confidence that the Base Case results are robust, and serve as a strong basis for decision-making.

Sensitivity cases can also help identify potential opportunities to mitigate vulnerabilities and risks that a Base Case has identified.

For each sensitivity case, its shortfall results are determined by the following procedure.

1. Alter the inputs to the suite of quantitative models (see the Methodologies section in Chapter One) so that the new inputs are consistent with the changes in assumptions.
2. Rerun the models with the new inputs.
3. Note the shortfalls that the models compute and compare with the Base Case to determine the sensitivity to the change in assumptions.

Twenty different sensitivity cases are described below. A summary table of results appears after the descriptions.

2011 Base Case Sensitivity Cases

<u>BCS1</u>

One important sensitivity case (Base Case Sensitivity Case #1 or BCS1 for short) illustrates the potential benefit (in terms of shortfall mitigation) of planning, coordination and potential contingency contract arrangements with domestic U.S. producers to enable them to achieve full production capability in approximately six months versus the 2011 Base Case assumption of one year.

Rationale: Determine the potential vulnerability mitigation that could result from implementing actions and policies (before a national security emergency) that would enable the United States to ramp-up production capabilities as quickly as this sensitivity case assumes would be possible (i.e., six months rather than a year).

Results: A noticeable reduction in shortfalls occurs (a 15 percent reduction, down to $1,703M), and four of the 28 materials with shortfalls in the Base Case (titanium sponge, beryllium-copper master alloy, IM-6 carbon fiber, and praseodymium) no longer manifest shortfalls.

<u>BCS2</u>

A second important sensitivity case (BCS2) illustrates the impact on Base Case shortfalls of being able to achieve the same faster ramp-up to full production capacity (in six months) with foreign producers that are deemed reliable as well as with U.S. producers. (That is, the ramp-up time is six months for both U.S. and foreign producers, rather than the one year ramp-up time in the Base Case.)

Rationale: Determine the potential vulnerability mitigation that could result from implementing actions and policies (before a national security emergency) that would enable the United States and its major foreign suppliers as well to ramp-up their strategic material mining/production capabilities as quickly as this sensitivity case assumes would be possible.

Results: A noticeable reduction in shortfalls occurs (a 32 percent reduction, down to $1,377M), and seven of the 28 materials with shortfalls in the Base Case (titanium sponge, beryllium-copper master alloy, IM-6 carbon fiber, iridium, gallium, indium, and praseodymium) no longer manifest shortfalls.

<u>BCS3</u>

A third important sensitivity case (BCS3) illustrates the impact on Base Case shortfalls of interpreting the Base Case conflict planning scenario in a way that gives equal weight to two principal sub-cases in the Base Case: one that does and one that does not involve a major power adversary. (The inputs that are changed to model this case include weapon requirements, country reliabilities, and war damage factors.)

Rationale: a possible alternative Base Case could be founded upon this equally weighted scenario.

Results: The dollar value of the shortfalls in this sensitivity case is $988M, or about 49 percent of the current 2011 Base Case.

BCS4

A fourth important sensitivity case (BCS4) illustrates the impact upon Base Case shortfalls of a sudden loss of one particular U.S. domestic production capability.

Rationale: This case examines the fragility and dependence of the U.S. domestic supply base with regard to a single major domestic supplier.

Results are as follows: A significant (14 percent) increase in shortfalls (to $2,301M) results from the hypothetical loss of this one key U.S. SM supplier.

BCS5

A fifth sensitivity case (BCS5) shows the impact of a delay by a year in the schedule for Full Operational Capacity of that same domestic producer.

Rationale: Examine the fragility of the U.S. domestic supply base with regard to even a delay in the availability of SM products from the same single major U.S. supplier as considered in BCS4 (above).

Results: Overall shortfalls are noticeably affected. They become $2,205M, 110 percent of the Base Case.

BCS6

A sixth important sensitivity case (BCS6) illustrates the impact of being able to increase the U.S. imports of selected goods and services from key highly reliable trading partners in the course of the Base Case scenario.

Rationale: If there are SM shortfalls in a Base Case-like emergency, the United States could mitigate some of those shortfalls by choosing to import more finished products from other (reliable) countries, rather than stockpiling the SMs needed to produce those finished products in the United States. This could be especially promising with regard to some civilian goods. The current methodology allows this factor to be modeled for standard materials by adjusting the industrial imports.

Results: Shortfalls are notably reduced (down to $1,715M) through an approach of this kind (This represents a $298M reduction in shortfalls of standard materials.). A substitution strategy of this kind will be examined in more depth.

BCS7

A seventh useful sensitivity case (BCS7) depicts the impact of using 2005-like supply side assumptions in a case that is otherwise the same as the 2011 Base Case. These assumptions include: 6-month (not one year) unavailability of supply from enemy combatants, immediate production levels at full U.S. and foreign capacity, U.S. and Canadian concerted programs.

Rationale: This case assesses the impact of using the 2005-supply side assumptions in the 2011 Base Case results.

Results: Shortfalls in this sensitivity case are reduced by 81 percent (down to $391M), relative to the 2011 Base Case. Only six of the 28 materials with Base Case shortfalls manifest them in this case.

BCS8

An eighth important sensitivity case (BCS8) illustrates the impact upon shortfalls of not invoking any civilian austerity policies in the scenario.

Rationale: To illustrate the importance of this variable (strategy and policy) in the determination of NDS shortfalls.

Results: Shortfalls are notably higher ($2,590M) than in the Base Case ($2,013M).

BCS9

A ninth important case (BCS9) illustrates the impact of not being able to achieve any significant civilian sector austerity in the first year of the Base Case. In this case, there are no reductions in civilian demand for goods and services in the first year. The reductions for the second, third, and fourth years are as shown in Table 2-1.

Rationale: This case explores the sensitivity of the shortfalls to potential difficulties that the United States might have implementing assumed austerity in the first year of such an emergency.

Results: Shortfalls in this case are notably larger (127 percent of the Base Case, up to $2,565M). Comparing BCS8 and BCS9, the ability to achieve austerity in the first year is the overwhelmingly important contribution of austerity in this Base Case scenario.

BCS10

A tenth important the case (BCS10) illustrates the impact of not being able to fully obtain first priority for defense sector in the use of materials.

Rationale: The Base Case assumes that defense will be able to obtain priority claims upon all the materials it needs from available supplies. For any of several reasons, this priority may not be achieved immediately, or completely. This case explores the impact on defense shortfalls of a case positing more gradual acquisition of full priority by the defense sector. Specifically, materials from foreign sources in the first scenario year are not usable to offset defense demands.

Results: Without this kind of priority for defense, overall shortfalls are substantially larger than in the Base Case ($2,801M in BCS10 vs. $2,013M in the Base Case, a 39 percent increase). The high sensitivity of the Base Case to this variable suggests the extreme importance of effective planning and pre-planning for allocation of scarce strategic materials in emergencies, through mechanisms such as the Defense Priorities and Allocations System).

BCS11

An eleventh important case (BCS11) illustrates the impact of defense being able to use supplies from market dominators if those countries are both highly reliable and have at least two major production facilities for the material in question.

The Base Case makes the cautious assumption that defense should not count upon supplies from dominators that could, by some accident, for example, have critical SM production facilities knocked out. This case relaxes that assumption to allow defense to draw upon such dominators if they have a diversified production capability within their country.

Results: A slight reduction in overall shortfalls is manifested in this case, and there are no longer shortfalls of columbium.

BCS12

A twelfth important case (BCS12) illustrates the impact of being able to achieve full civilian austerity in all four years of the scenario, rather than in only the second through fourth years as the Base Case posits. (This case has full austerity in year 1, in contrast to the Base Case, which has partial austerity then, and case BCS9, which has no first-year austerity.)

The shortfalls are noticeably reduced in this case, down to 92 percent ($1,853M) of the Base Case shortfalls. Two of the 28 materials with shortfalls in the Base Case (beryllium-copper master alloy and gallium) no longer manifest them.

BCS13

A thirteenth important case (BCS13) explores the effect of a major U.S. domestic SM supplier being able to achieve full production capacity more quickly than is assumed in the Base Case.

A slight reduction in overall shortfalls occurs in this case (a drop to $1,937M, or 96 percent of total Base Case shortfalls).

BCS14

A fourteenth important case (BCS14) explores the effect on 2011 Base Case shortfalls of having potentially overestimated demand for an important category of SMs in the 2011 Base Case, the seven rare earths that are studied in this analysis. Case BCS14 reduces the Base Case rare earth demands by 25 percent.

Some uncertainty exists in the available data regarding U.S. demand for the seven rare earths studied. Data in the Base Case estimates may overestimate the regular demand for these materials for use to produce end-use goods in the United States. More analysis of the underlying data (chiefly from the U.S. Geological Survey) is needed.

Overall shortfalls are lower, down to $1,882M from $2,013M. Six of the seven rare earths continue to show shortfalls, albeit lower than in the Base Case; praseodymium no longer has a shortfall.

BCS15

A fifteenth important case (BCS15) explores the effect on 2011 Base Case shortfalls of using the country reliability values that were used in the 2010 interim study of National Defense Stockpile requirements.

Some uncertainty and judgment exists in the evaluation of country reliabilities. Examining variations in them can shed light on the reliability values' effect on the availability of materials supply and the resultant shortfalls.

In fact, the shortfall is similar to the 2011 Base Case. The shortfall dollar total is 1 percent higher, but one less material manifests a shortfall.

BCS16

A sixteenth important case (BCS16) explores the effect of adding concerted programs: restarting idle mines (or other such production facilities), expanding mines, or building new mining facilities. This could be accomplished by government payment. The U.S. Geological Survey provides information on concerted programs all over the world. Case BCS16 considers adding U.S. concerted programs.

In World War II, some concerted programs were undertaken and proved to be a source of additional material.

Shortfalls are down only slightly, to $1,942M, 96 percent of the Base Case shortfalls. This is probably because most shortfalls occur in the first year of the scenario. Concerted programs often do not produce any output until two or three years after they are arranged for.

BCS17

Case BCS17 is like case BCS16, but instead of just using U.S. concerted programs, it also includes Canadian and Australian ones. (The 2005 National Defense Stockpile study included U.S. and Canadian concerted programs—see case BCS7, above.)

Shortfalls drop considerably, to $1,755M, 87 percent of the Base Case shortfall. This is mostly due to an Australian concerted program in tantalum.

BCS18

An eighteenth important case (BCS18) explores the effect on 2011 Base Case shortfalls of a national emergency scenario that does not include homeland damage and where the weapons lost and expended in combat are not regenerated.

The conflict scenario has the potential to create considerable extraordinary demand on industry, and hence demand for materials. Changes in the particulars of the conflict scenario can lead to changes in material demand.

In this case, however, the shortfalls are $1,996M, 99 percent of the Base Case shortfalls.

BCS19 and BCS20

These two cases explore the effect of preferential U.S. access to unused foreign capacity in years 2 through 4 of the scenario. Case BCS19 assumes that the U.S. gets all the extra capacity; case BCS20 assumes the U.S. gets a substantial fraction of it (halfway between the peacetime share and all).

The U.S. might pay foreign sources to produce at capacity, rather than just at their regular production levels. In such a case, the U.S. could lay claim to this extra production amount. But it might take time to set such an arrangement in place, and it might take time for suppliers to ramp up to full production capacity. Therefore, the preferential access is considered to take place in the non-initial scenario years.

There is no change in shortfall from the Base Case. This is most likely because the vast majority of the Base Case shortfalls are in the first year of the scenario. Expanding supply in the subsequent years will have no effect on first year shortfalls. For materials with Base Case shortfalls in the subsequent years, supply expansion was not possible.

Together, these cases illustrate several major points regarding the Base Case and the potential benefit of developing mitigating options for the Base Case shortfalls.

First, these sensitivity cases all show effects that align with the hypothesized directions for those effects. Thus, for example, "eliminating" austerity results in larger, not smaller shortfalls. As a second example, if emergency production levels can be attained sooner than in the Base Case, the result is smaller, not larger, shortfalls.

Second, the 2011 Base Case shortfall results are indeed sensitive to the choice of some demand and supply side assumptions about which there is some legitimate uncertainty as to what are the most realistic values for the relevant variables (see BCS3 and BCS14, as examples). Overall, this suggests caution before pinning NDS investment or disinvestment decisions upon a point estimate. More research and analysis seem warranted.

Third, some of these sensitivity cases illustrate potentially promising risk mitigation strategies, assuming that they are relatively cost-effective compared to traditional stockpiling. For example, Cases BCS1, BCS2, BCS6, BCS11, BCS16, and BCS17 are all suggestive of promising mitigation options that should be examined for feasibility and relative costs.

Table 6.1: 2011 SM Base Case Shortfall Results and Effects of Various Sensitivity Cases

Case #	Case Summary	Number of Materials with Shortfall	Value of Shortfall ($M)	Percent of Base Case Shortfall
BC	Base Case	28	2,013	100
BCS1	Six month U.S. ramp-up to EOC	24	1,703	85
BCS2	Six month U.S. and foreign ramp-up to EOC	21	1,377	68
BCS3	Equally weighted conflict case	23	988	49
BCS4	Loss of one key U.S. producer	28	2,301	114
BCS5	Delay by a year in EOC of one key U.S. producer	28	2,205	110
BCS6	Higher U.S. goods and services imports from top partners	28	1,715	85
BCS7	2005-like supply assumptions	6	391	19
BCS8	No civilian austerity	31	2,590	129
BCS9	No first year civilian austerity	31	2,565	127
BCS10	Limited defense priority	37	2,801	139
BCS11	Defense can use resilient dominators	27	1,992	99
BCS12	Full austerity in first year	26	1,853	92
BCS13	Robust production by key U.S. firm	26	1,937	96
BCS14	Rare earth demands 25% lower	27	1,882	93
BCS15	2010 Interim Base Case (IBC1) country reliabilities	27	2,028	101
BCS16	Add U.S. concerted programs (CPs)	28	1,942	96
BCS17	Add U.S., Canadian, and Australian CPs	28	1,755	87
BCS18	No conflict regeneration	27	1,996	99
BCS19	U.S. gets all of other countries' expanded production (years 2-4)	28	2,013	100
BCS20	U.S. gets substantial preferential access to other countries' expanded production (years 2-4)	28	2,013	100

Appendix 7
2011 Alternative Case Sensitivity Cases

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2011 Alternative Case Sensitivity Cases

This Appendix summarizes the 2011 Alternative Case sensitivity case results.

As discussed in Chapter 2, the chief alternative case scenario examines a peacetime supply disruption scenario (named PSD1) that lasts for one year and represents a composite supply disruption case. Key assumptions are that:

1. Regular military demands in this scenario may only be met by regular supplies from U.S. sources and foreign suppliers deemed sufficiently reliable according to Defense Intelligence Agency (D) country reliability estimates for such a case.
2. Military demands do not take priority claim on available supply; only a certain share of available supply can be used to satisfy defense needs.

The defense shortfalls, i.e., the military demands unmet by supply under the above assumptions, were computed and reported.

As Chapter 2 notes, this chief alternative case assumes that only wholly reliable countries (as identified by DIA) can satisfy defense demand and that defense only gets its regular, peacetime share of material supply.

Some sensitivity cases are presented here that vary assumptions 1 and 2, above. Chapter 2 discusses the specific variations that were made. Table 7-1, below, presents the overall shortfall results of the sensitivity cases.

Table 7-1. Peacetime Supply Disruption (PSD) Sensitivity Case Results [a]

Case Code Name	Foreign Country Supplier Criterion	Defense Share of Supply	Number of Materials with Shortfall (of 70)	Total Shortfall ($M)
PSD1	Wholly reliable countries only	normal	40	$637
PSD2	Wholly reliable countries only	normal in first six months, twice normal thereafter	28	$385
PSD3	Wholly reliable countries only	normal in first six months, three times normal thereafter	25	$300
PSD4	Wholly and highly reliable countries	normal	29	$293
PSD5	Wholly and highly reliable countries	normal in first six months, twice normal thereafter	20	$146
PSD6	Wholly and highly reliable countries	normal in first six months, three times normal thereafter	15	$96

[a] Dollar valuations are made with material prices as of September-November 2010.

Appendix 8
Computing Material Demand from Industrial Demand

Appendix 8
Computing Material Demand from Industrial Demand

The procedure for computing demand for materials starts with the computation of demand for goods and services (industrial demand). From the demand for goods and services, the demand for the materials required to produce these goods and services is computed. Two different methods for computing the material demand are used, depending on the availability of certain data.

1. The first method uses what are called Material Consumption Ratios, or MCRs.
2. The second method, known as the "proxy MCR" approach, is used for those materials for which the information to construct MCRs is not available.

First, note that the demands on industry are organized by industry sector and year (sometimes, quarter), for each of the following categories:

- Military demand associated with the conflict scenario
- Base military demand (regular Future Years Defense Program/Plan)
- Essential civilian demand
- Industrial (emergency investment) demand (see footnote 2 of Chapter I)
- Imports
- Exports

Demand for repair of homeland damage, if relevant, is included partly in the base military demand and partly in the civilian demand.

A demand value (in millions of dollars) is shown for each combination of industry sector, time period, and category. Together, the industry sectors span the entire U.S. economy. Both material computation methods make use of the industrial demand values, but in different ways.

The Material Consumption Ratio (MCR) Method

MCRs are estimates, industry sector by industry sector, of how much of a given material (pounds of cobalt, for instance) is needed to produce a given amount of output ($1 billion of output) from each particular industrial sector. MCR data are available for those thirty-six materials referred to as the "standard" materials (Table 9-1, in Appendix 9, identifies those materials). In 2010, MCRs have also become available for lithium.

For a given combination of industry sector and material, the material consumption ratio is formed by dividing the amount of material that industry sector uses by the output amount of that sector. The output amounts come from the economic databases. The data on material usage by industry sector are developed by the International Trade Administration in the Department of Commerce (DOC), with consultation from commodity specialists at the Department of the Interior.

A more detailed explanation is as follows. Suppose that the Department of Commerce data indicate that industry *i* used a_{im} tons of material *m* in some given time span (generally, the process uses the most recent three-year period for which data are available). Also suppose that, according to the economic databases, industry *i* produced b_i billion dollars worth of output during that time span. (These are actual, historical data, not forecasts.) Then the ratio $\rho_{im} = a_{im}/b_i$ can be regarded as the amount of material *m* that industry *i* requires to produce a billion dollars of output. One can call the quantity ρ_{im} a material consumption ratio. Suppose that during some year of the scenario period, it is estimated that c_i billion dollars of output (in some category: defense, emergency investment, or civilian[1]) will be required from industry *i*. Then, assuming that the material consumption ratio remains constant over time, $c_i\rho_{im}$ tons of material *m* will be required to produce this output.

For each combination of category, industry, material, and scenario year, the appropriate MCR is multiplied by the corresponding industry output demand in billions of dollars to yield an amount of material. These resulting material amounts are summed over industry to give material demands for each combination of material, category, and scenario year.

The Proxy MCR Methodology

Some materials of interest to DOD—including the specialty and new materials listed in Table 1—have not had MCR studies conducted by DOC. For these materials, an alternate methodology is employed to estimate the demands for these materials that could arise in the context of a planning case. This methodology makes use of the industrial demand data and the following information, for each material:

1. Consumption: the total (civilian + military) U.S. consumption of the material for a recent year or years. This is assumed to be in some kind of peacetime or steady state case.
2. Application areas: list of applications the material is used in
3. Consumption by application: for each application area, the proportion of total U.S. consumption used in it

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[1] Net exports are added to the civilian demand, and the MCR is applied to the result.

4. Association of application areas with industry sectors: for each application area, the industry sectors associated with that application.

Information for items 1, 2, and 3 is obtained from subject matter experts (often, the U.S. Geological Survey commodity specialists; sometimes, industry sources). The information for item 4 is developed by economists familiar with the industrial sectoring scheme, working in conjunction with the subject matter experts as necessary. The information in these four items enables the material consumption amount to be apportioned among the industry sectors. A steady state material consumption amount in each sector can thus be computed. This association of material usage with industry sectors is similar in spirit, though not in detail, to the MCR approach; hence the term "proxy MCR."

The procedure makes use of two sets of industrial demands. The first set applies to the scenario of interest (for example, a scenario that includes some kind of conflict military demand but excludes non-essential civilian demand). The second set applies to a peacetime, steady-state case extending over the same time span. For each industry sector, one can form the ratio of the scenario industrial demand to the steady state industrial demand. This ratio of *industrial* demands is applied to the steady-state *material* consumption in that sector to compute an in-the-scenario material consumption value in that sector.[2]

The industrial demand values are also used

- to apportion the material consumption between military and civilian uses
- (optionally) to compute growth in material consumption (item 1) from the year for which the consumption data were collected to the current scenario year.

The result is a material demand value for the scenario for each combination of material, scenario year, category (military or civilian), and industry sector. Summing over industry sector yields total material demands for each combination of material, scenario year, and category.

[2] More precisely, such a ratio is computed for each combination of industry sector, category (military or civilian), and scenario year.

Appendix 9
Alphabetical List of Materials

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Alphabetical List of Materials

In Tables 1 through 5 of the main report, results for the materials analyzed are organized by material type: metals, rare earths, precious metals, and so forth. Table 9-1 presents an alphabetical list of the 70 materials examined. For each material, Table 9-1 indicates its type and also its group: standard, specialty, or new. This grouping has been discussed in the Executive Summary and Chapter 1. In brief, the standard materials are those for which demands are evaluated via Material Consumption Ratios (MCRs); the specialty materials use the proxy MCR methodology (see Appendix 8); and the new materials are those which the requirements process did not analyze prior to 2009. (Of the new materials, lithium demands are computed via MCRs, the others use the proxy MCR approach.) Table 9-1 also notes the materials that are in the “key 13” set (National Defense Stockpile inventory sales suspended in 2008).

Table 9-1. Alphabetical List of Materials Examined

	Material Name	Group	Material Type	Key 13?
1	Aluminum Metal	Standard	Metals	
2	Aluminum Oxide Fused Crude	Standard	Ores and Compounds	
3	Antimony	Standard	Metals	
4	Bauxite Metal Grade Jamaica & Suriname	Standard	Ores and Compounds	
5	Bauxite Refractory	Standard	Ores and Compounds	
6	Beryl Ore	Specialty	Ores and Compounds	
7	Beryllium Copper Master Alloy	Specialty	Alloys	
8	Beryllium Metal	Specialty	Metals	1
9	Bismuth	Standard	Metals	
10	Boron	Specialty	Misc. Non-Metals	
11	Cadmium	Standard	Metals	
12	Carbon Fiber—AS-4	New	High Performance Fibers	
13	Carbon Fiber—IM-6	New	High Performance Fibers	
14	Carbon Fiber—IM-7	New	High Performance Fibers	
15	Carbon Fiber—T-300	New	High Performance Fibers	
16	Carbon Fiber—T-700	New	High Performance Fibers	
17	Chromite, Chemical, Refractory, and Metallurgical Grade Ore	Standard	Ores and Compounds	
18	Chromium, Ferro	Standard	Alloys	1
19	Chromium Metal	Standard	Metals	1
20	Cobalt	Standard	Metals	1
21	Columbium	Standard	Metals	1
22	Copper	Standard	Metals	
23	Dysprosium	New	Rare Earths	
24	Europium	New	Rare Earths	
25	Fluorspar, Acid Grade	Standard	Ores and Compounds	
26	Fluorspar, Metallurgical Grade	Standard	Ores and Compounds	
27	Gallium	Specialty	Metals	
28	Germanium	Specialty	Metals	1
29	Hafnium	Specialty	Metals	
30	Indium	Specialty	Metals	
31	Iridium (Platinum Group)	Standard	Precious Metals	1
32	Kevlar	New	High Performance Fibers	
33	Lead	Standard	Metals	
34	Lithium	New	Metals	
35	Manganese Dioxide Battery Grade Natural	Standard	Ores and Compounds	
36	Manganese Dioxide Battery Grade Synthetic	Standard	Ores and Compounds	
37	Manganese, Ferro	Standard	Alloys	1
38	Manganese Metal, Electrolytic	Standard	Metals	
39	Manganese Ore, Chemical & Metallurgical Grades	Standard	Ores and Compounds	

Table 9-1. Alphabetical List of Materials Examined (concluded)

	Material Name	Group	Material Type	Key 13?
40	Mercury	Standard	Metals	
41	Molybdenum	Standard	Metals	
42	Neodymium	New	Rare Earths	
43	Nickel	Standard	Metals	
44	Nomex	New	High Performance Fibers	
45	Palladium (Platinum Group)	Standard	Precious Metals	
46	Platinum (Platinum Group)	Standard	Precious Metals	1
47	Praseodymium	New	Rare Earths	
48	Quartz (Silica) Fiber—High Purity	New	High Performance Fibers	
49	Rhenium	Specialty	Precious Metals	
50	Rhodium (Platinum Group)	Specialty	Precious Metals	
51	Rubber (natural)	Standard	Misc. Non-Metals	
52	Ruthenium (Platinum Group)	Specialty	Precious Metals	
53	S-2 Fiberglass	New	High Performance Fibers	
54	Samarium	New	Rare Earths	
55	Silicon Carbide	Standard	Ores and Compounds	
56	Silver	Standard	Precious Metals	
57	Specialty Steel—300M	New	Alloys	
58	Specialty Steel—Armor Steel	New	Alloys	
59	Specialty Steel—M50	New	Alloys	
60	Tantalum	Standard	Metals	1
61	Tellurium	Specialty	Misc. Non-Metals	
62	Terbium	New	Rare Earths	
63	Tin	Standard	Metals	1
64	Titanium Sponge	Standard	Metals	
65	Tungsten	Standard	Metals	1
66	Vanadium	Standard	Metals	
67	Yttrium	Specialty	Rare Earths	
68	Zinc	Standard	Metals	1
69	Zirconium Metal	Specialty	Metals	
70	Zirconium Ores and Concentrates	Specialty	Ores and Compounds	

Appendix 10
National Defense Stockpile (NDS) Requirements
Report History

Appendix 10
National Defense Stockpile (NDS) Requirements Report History

The Strategic and Critical Materials Stock Piling Act (50 U.S.C. 98 et seq.), Section 14, states: "Not later than January 15 of every other year, the Secretary of Defense shall submit to Congress a report on stockpile requirements." The 2005 NDS Requirements Report was submitted March 31, 2006. Subsequent requirements report submittals were impacted by the following events.

In 2006, at the request of Congress, the Department of Defense undertook a study of the DOD's current policy to dispose of material and determine whether the NDS should be re-configured to adapt to current world market conditions to ensure future availability of materials required for defense needs.

In August 2006, the Under Secretary of Defense for Acquisition, Technology and Logistics, notified Congress that based on the initial review and analysis further study was required, and that pending the completion of the in-depth study, the submission of the NDS Requirements Report would be deferred.

On April 14, 2009 the Defense Logistics Agency provided an interim response to the Section 14 requirement, noting the report was being delayed pending completion of the study of the reconfiguration of the NDS.

On April 24, 2009 the results of the in-depth study were reported to Congress in the Reconfiguration of the National Defense Stockpile Report to Congress.

The National Defense Authorization Act 2010, Section 1413, required the Secretary of Defense to provide a report to the congressional defense committees on any actions the Secretary planned to take in response to the recommendations contained in the report entitled "Reconfiguration of the National Defense Stockpile Report to Congress" dated April 2009.

In August 2010, the Under Secretary of Defense for Acquisition, Technology and Logistics, submitted the Strategic Materials Security Program (SMSP) Implementation Plan Report to Congress.