



INSTITUTE FOR DEFENSE ANALYSES

## **An Overview of Step 2 of the Risk Assessment and Mitigation Framework for Strategic Materials (RAMF-SM)**

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# Executive Summary

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The Strategic and Critical Materials Stock Piling Act calls for the establishment of a National Defense Stockpile (NDS) and requires biennial reports to Congress on stockpile requirements and recommendations. The Institute for Defense Analyses (IDA) assists the Defense Logistics Agency (DLA) in determining these requirements. IDA has developed an analytical process, the Risk Assessment and Mitigation Framework for Strategic Materials (RAMF-SM), to identify potential shortfalls of critical materials and assess mitigation strategies. Identification of the likely number and severity of shortfalls—Step 2 of RAMF-SM—is accomplished using a suite of models and data.

This summary provides an overview of the various Step 2 components. It can be used as a guide for the verification or reproduction of the 2015 NDS Base Case (i.e., national security emergency planning scenario) Step 2 run.

Under the assumptions of the 2015 NDS Base Case, a shortfall<sup>1</sup> occurs when material demand is greater than the supply available to the United States. To predict potential shortfalls, Step 2 estimates U.S. economic output during an emergency scenario, computes the material demand implied by such production, and assesses whether available material supplies will be sufficient to meet the material demand.

## Step 2-A: Economic Demand

Step 2 uses scenario-based analysis. Congress mandates a “Base Case” scenario consisting of 1 year of conflict followed by 3 years of regeneration. During this 4-year period, national resources are needed for defense, essential civilian demand, and emergency investment purposes. Modeling and simulation is used to translate those needs into specific material demands.

IDA uses the Council of Economic Advisors 10-year macroeconomic forecast to estimate the future peacetime U.S. economy. This forecast is used to calibrate the Interindustry Large-scale Integrated and Dynamic Model (ILIAD) and the Long-term Interindustry Forecasting Tool (LIFT), two input/output (I/O)-based, dynamic general equilibrium macroeconomic models developed and updated by the Interindustry Forecasting Project at the University of Maryland. LIFT and ILIAD characterize interdependencies across industrial sectors of the U.S. economy. These models show, for example, how much production in other sectors is needed to produce a given amount of

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<sup>1</sup> Any mention of estimated material shortfalls throughout this documentation refers to initial material shortfalls.

aerospace output. Applying Congressional and sponsor guidance to reflect the Base Case, IDA adjusts the peacetime ILIAD and LIFT simulation results to account for homeland damage, austerity measures (determined by the Department of Defense (DOD) after consultation with a civilian agency working group), and prioritization of military needs via invocation of the Defense Production Act.

The assumed military conflict, the force structure to be mobilized, and the losses resulting from enemy action are drawn from Defense Planning Scenarios<sup>2</sup> developed by the Office of the Undersecretary of Defense for Policy (OUSDP). The relative contributions of different economic sectors toward weapon production are specified in Defense Translator vectors provided by the Office of the Secretary of Defense – Cost Analysis and Program Evaluation (OSD-CAPE). Multiplying a Defense Translator vector and ILIAD I/O matrix data results in the Production Process Matrix (PPM), which measures the industrial base demand posed by production of a particular weapon.

Adjusted civilian and military industrial requirements then are fed into the Forces Mobilization Model (FORCEMOB),<sup>3</sup> which estimates U.S. economic output and production levels needed to meet conflict industrial requirements and the ability of the industrial base to produce this output. FORCEMOB computes production shortfalls and examines options to redress these shortfalls by more fully using existing capacity or undertaking emergency investment, which increases production capacity but also increases demand for strategic materials. IDA developed and has extensively documented and tested FORCEMOB, which has been used for almost two decades to assist in the preparation of NDS Requirements Reports to the Congress. FORCEMOB generates year-by-year forecasts of the economic production levels needed to support U.S. defense, civilian, and investment efforts in the context of the Base Case.

## **Step 2-B: Material Demand**

Translating production into material demands requires additional modeling. Material consumption ratios (MCRs) specify the types and quantities of materials required to produce a fixed amount of output in a particular industrial sector (e.g., how much aluminum is required for \$1 billion worth of aerospace production). Multiplying MCRs and production requirement information thus allows computation of material requirements for a specified scenario. MCRs are not available for some materials, in which case past material consumption information is used. MCRs typically are calculated based upon data from the U.S. Geological Survey (USGS) and Department of Commerce (DOC). For

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<sup>2</sup> These are consistent with what the Secretary of Defense uses for budgeting and defense planning purposes.

<sup>3</sup> The Forces Mobilization Model is so named because one of its original functions was to compute the weapon requirements for the national emergency scenario, in addition to computing the demands for industrial production. Now, as indicated, the weapon requirements are specified directly by the OSD.

some study-specific materials not normally studied by USGS or DOC, IDA consults directly with the material supplier(s) and other subject matter experts (SMEs).

The Requirements Creation Sub-Module multiplies MCRs by FORCEMOB-generated output. The result is a list of materials and quantities needed to support Base Case economic demand. For non-MCR materials, material consumption information is used to derive demand. Combining the computed demands for normal and defense-articulated materials thus results in total U.S. material demands, per year and category of demand (civilian, defense, and investment), under the specified conditions.

## **Step 2-C: Material Supplies and Shortfalls**

Overall U.S. material demands are then input into the Stockpile Sizing Module (SSM). The SSM calculates total material supplies available to the United States from all sources, given the specified Base Case conditions for supply availability and whether total supply satisfies demand (and if not, the resultant shortfall in both quantity and dollars) on a material-by-material basis. IDA developed, documented, and extensively tested the SSM, which has been used in support of NDS analysis for almost two decades.

Material supplies available to the United States include domestic sources and a percentage of foreign supplies. USGS and other SMEs provide information on domestic and foreign supplies of each material. Supply estimates are made on the basis of current production or on total capacity, depending on sponsor preference and study requirements. Each foreign country is assigned a political reliability code. Supplies from “assured” countries can be used for civilian, defense, and emergency investment needs, supplies from “reliable” countries can only be used for civilian needs, and supplies from “unreliable” countries cannot be used at all. OUSD-P and the Intelligence Community also specify foreign infrastructure reliability, anti-U.S. sentiment, war damage to material production facilities, and shipping losses due to enemy actions, all of which can decrease the share of foreign supply available to the United States. Under DOD’s Base Case assumptions for the 2015 NDS study, the United States could not rely on available foreign supply to offset its defense demands if that available foreign supply came from a country that is defined as a “foreign market dominator,” which is defined as a country that produces more than half of the global production of that particular material.<sup>4</sup> The United States competes for access to materials with other countries, and so a “market share” factor limits the proportion of foreign supply available to the United States.

The SSM uses the aforementioned factors to decrement foreign supply, calculates total supply available to the United States for each material and year of the scenario, and compares it against U.S. demand. If available supply cannot satisfy demand in a particular year, the material is considered to be in shortfall. SSM is time-phased: a shortfall in an

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<sup>4</sup> This calculation/assessment is made before applying any decrements to the initial supply estimates.

earlier year cannot be offset by surplus in a later year. SSM calculates the size (e.g., kilograms) and acquisition cost to DLA of each shortfall. Shortfalls are identified by year and category of demand (civilian, defense, and emergency investment).

## **Summation**

These substeps constitute Step 2 of the RAMF-SM process. During any analytical study, IDA will run numerous sensitivity cases on Step 2 to help policymakers better understand the potential opportunities to mitigate vulnerabilities and risks that were identified under the Base Case. Step 2's shortfall estimates and perturbation studies support the assessment of risks stemming from shortfalls (Step 3), identification of mitigation options (Steps 4 and 5), prioritization of options (Step 6), and the recommendation of an overall mitigation strategy.

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# 1. Introduction

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This document outlines the various components, processes, and data relationships of the Risk Assessment and Mitigation Framework for Strategic Materials (RAMF-SM) Step 2, which relies on a complex suite of models and data. Step 2 is complex because it attempts to rigorously answer a large, open-ended research question: what U.S. material shortfalls would occur during a national emergency? Disaggregating this question reveals the need for analysis, including scrutinizing macroeconomic trends, global trade, theater-level combat, material science, and international relations. Step 2 thus uses many specialized, high-fidelity modeling tools drawn from different academic disciplines. These tools are linked together into a hierarchical modeling effort in which one module's output is another's input. This simultaneously broad, deep, and "nested" architecture allows for shortfall estimates based on empirical analysis but is challenging to grasp in its entirety.

This document is intended to be used in conjunction with the Step 2 Flowchart (see Appendix A), which graphically depicts the described processes. Items in this document marked with bold and a bracketed number (e.g., **Economic Forecast [1]**) correspond to a flowchart entry.

The narrative portion of this document refers to RAMF-SM programs and data items by descriptive title, not exact filename. For example, **Economic Forecast [1]** is an Excel workbook named cea-713.xlsx. The descriptive title is used to preserve readability and to avoid confusion because filenames frequently change. However, to aid user verification and replication of Step 2, Appendix B provides a crosswalk between the flowchart number, its corresponding descriptive name, and the name of the file used in the 2015 National Defense Stockpile (NDS) study.<sup>1</sup> Detailed descriptions of the format, storage, access restrictions, and so forth of these files can be made available upon request.

The intent of this document is to provide a comprehensive, yet relatively brief and readable, overview of Step 2's individual components and processes. It is intended as a road map, not as an encyclopedia. If more knowledge of a particular point is needed, Appendix C provides references to detailed documentation.

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<sup>1</sup> In Appendix B, **Economic Forecast** is the descriptive name and **[1]** is the flowchart number.

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## 2. RAMF-SM Step 2 Overview

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### A. Step 2-A: Goods and Services Production Requirements

#### 1. Overview

The central model in Step 2-A is the Forces Mobilization Model (FORCEMOB), which computes yearly total goods and services production (i.e., economic) requirements in a national emergency scenario. FORCEMOB generates total goods and services requirements based on essential civilian and base military needs under normal peacetime conditions, plus economic demands stemming from the national emergency. FORCEMOB modeling includes the imposition of austerity measures, homeland event damage, regeneration of weapons lost and munitions expended in the conflict, and import or export disruptions. FORCEMOB also assesses and models options to eliminate production shortfalls (if extant): namely, more fully using the existing production capacity or investing in new production capacity. Running FORCEMOB with all its necessary input files generates U.S. industrial production requirements, which then can be used to calculate material requirements and potential shortfalls in Steps 2-B and 2-C.

Preparation of FORCEMOB input files is a labor-intensive effort, as the following sections detail.<sup>1</sup>

#### 2. Peacetime Estimates

The starting point for estimating production is a peacetime **Economic Forecast [1]**. After the President's Budget is released in February or March of a given year, the Institute for Defense Analyses (IDA) contacts the Council of Economic Advisors (CEA) to obtain detailed forecasts of the U.S. economy. Information from this detailed forecast is used to construct two files. **Macroeconomic Variables [2]** is an .mfx file that contains information on macroeconomic variables such as projected interest rates and unemployment. **Vectors and Matrices [3]** is a .vfx file that contains information on variables such as personal consumption, private construction, and government spending.

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<sup>1</sup> For more detailed documentation of FORCEMOB, see Robert Atwell et al., *Unclassified Tutorial for the Forces Mobilization Model (FORCEMOB)*, IDA Document D-5433 (Alexandria, VA: Institute for Defense Analyses, 2015) and Eleanor Schwartz et al., *Documentation of the Forces Mobilization Model (FORCEMOB) Versions 3.1 and 3.2*, IDA Paper P-2953 (Alexandria, VA: Institute for Defense Analyses, 1996).

These files are input into **LIFT** [4] and **ILIAD** [5], two macroeconomic models developed and updated by the Interindustry Forecasting Project at the University of Maryland (INFORUM).<sup>2</sup> LIFT and ILIAD are I/O-based dynamic general equilibrium macroeconomic models that simulate macroeconomic interdependencies across the U.S. industrial base. They characterize, for example, the degree to which aerospace production demands output from other sectors, such as mining and electronics. **Macroeconomic Variables** [2] and **Vectors and Matrices** [3] are input into **LIFT** [4] and produce **LIFT Vectors and Matrices** [6]. **Vectors and Matrices** [3] is input into ILIAD, which produces **ILIAD Vectors and Matrices** [7].

A utility program called G7 is used to manipulate ILIAD and LIFT output. G7 requires the use of scripting files (.add format) that specify what actions the program should perform. Two scripting files, nds15.add and pv.add (summarized on the Step 2 Flowchart in Appendix A as **Scripting Files** [8]) are used to input **LIFT Vectors and Matrices** [6] and **ILIAD Vectors and Matrices** [7] into **G7** [9].

Performing these steps yields the peacetime **Industrial Demands** [10]. This item consists of .dat files that contain information on U.S. economic demand across 360 industrial sectors for all years under study. The first file, out.dat, is total U.S. industrial output. The other files are civ.dat (civilian final demand), def.dat (defense final demand), exp.dat (export final demand), and imp.dat (import final demand). **Industrial Demands** [10] will later be used in calculating the total industrial production necessary during the Base Case, with industrial production, in turn, being used to calculate material requirements and shortfalls.

Running **G7** [8] with the described inputs also outputs **Historical Data** [11]. This consists of historical data (i.e., on past years) for final demand (fdhist.dat) and civilian demand (civhist.dat). These files are used in Step 2-B to calculate material consumption ratios and will not be examined in this section.

### 3. Non-essential Civilian Demand

The preceding forecast assumes peacetime, or steady-state, conditions. However, these conditions are insufficient for the analysis of a national emergency scenario during which the U.S. government may impose austerity measures to prioritize resources for national defense. The terms “austerity” and “austerity measures” merit closer examination. The Stock Piling Act specifies that the NDS is to be used to guarantee defense and essential civilian demands but does not specify exactly which civilian demands should be considered essential. Therefore, a key processing step for the NDS study is to determine

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<sup>2</sup> The Long-term Interindustry Forecasting Tool (LIFT) model is a dynamic general equilibrium representation of the U.S. economy. The Interindustry Large-scale Integrated and Dynamic Model (ILIAD) model further dissects the economy into 360 production sectors and computes the corresponding, time-varying input/output (I/O) matrices.

which civilian requirements are considered essential. The term “austerity” is often used in Step 2 as shorthand for the process of computing which civilian demands are essential. The term “austerity measures” refers to the situation in which the government chooses not to expend stockpiled materials on non-essential civilian demands, although private industries can still operate at full capacity if they are able to obtain enough materials on the open market.

The Department of Defense (DOD) consults with a civilian agency working group to make recommendations on **Austerity Measure Estimates [12]**, which are a set of percentage reduction factors that identify the portions of projected normal civilian demands (i.e., personal consumption and private construction) deemed nonessential. This civilian agency working group consists of senior leaders from 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.

Austerity measures generally are assumed to be time phased. In the first year of the scenario, these measures are assumed to not be fully implemented and, hence, have a less severe impact upon the economy; however, they become fully implemented and, hence, more severe for the second, third, and fourth years of the scenario. The civilian agency working group provides a minimum, middle, and maximum estimate of austerity measures. For the 2015 NDS study, the first year’s economic conditions are assumed to reflect a middle level of austerity, while subsequent years reflect a maximum level of austerity. The civilian agency working group also considers what portions of the civilian U.S. economy are essential and, hence, would not be subject to austerity measures. G7 and scripting files are used to manipulate this data. **Scripting Files [13]** (vamcreatebsvam.add and pv05.add) and a **Configuration File [14]** (vambsvam.cfg) are used to upload **Austerity Measure Estimates [12]** to **G7 [15]**.

These actions produce a file called bsvamfinal.vam, represented on the flowchart as **Total Austerity Modifiers [16]**. However, this file is not yet complete, because it still requires bridge matrices. A **Bridge Mapping [17]** .xlsx file is used to establish **Bridge Matrices - First Year [18]**. This file, along with the appropriate **Scripting File [19]** (loadbridges.add) is uploaded to **G7 [20]** and used to copy bridge matrices for all years under study, producing **Bridge Matrices - All Years [21]**, which is then applied to **Total Austerity Modifiers [16]**.

At this point, we have calculated the austerity measures to be applied but have not actually paired these measures with the peacetime economic forecast calculated in the previous subprocess. This pairing is accomplished by using **G7 [22]** to combine **Total Austerity Modifiers [16]** with **LIFT Vectors and Matrices [6]** and **ILIAD Vectors and Matrices [7]**. Doing so produces estimates of the effect of austerity measures on the economy. These **Austerity Effect Estimates [23]** consist of ausmax.dat, ausmid.dat, and

ausmin.dat files, which are in line with the estimates recommended by the civilian agency working group.

#### 4. Homeland Damage

The Stock Piling Act explicitly calls for stockpile analysis based on military scenarios used by the Secretary of Defense for planning and budgeting. If such a scenario were to include an attack on the U.S. homeland, the need to rebuild infrastructure would increase U.S. demand for strategic materials.

As a first step in modeling the effect of a homeland attack, **Homeland Damage Estimates [24]** are calculated. Homeland damage takes into account several factors, including

- the location of a homeland attack, which is taken from Defense Planning Scenarios developed by the Office of the Undersecretary of Defense for Policy (OUSD-P);
- data on national stocks of physical assets and durable goods (i.e., both private and government) and also civilian populations obtained from the Bureau of Economic Analysis (BEA) and the Census Bureau; and
- research on past homeland events such as 9/11 or Katrina to provide a basis for estimating damage to these assets.

Combining these factors allows assessment of the likely damage in a specified location.

A homeland attack may occur alongside austerity measures, with additive effect. As such, **Total Austerity Modifiers [16]** are uploaded along with **Homeland Damage Estimates [24]**, an appropriate **Scripting File [25]**, and **ILIAD Vectors and Matrices [7]** into **G7 [26]**. The scripting files are hausciv.add, which adds homeland recovery industrial demands to peacetime demands *without* considering austerity measures, and hausmax.add, which adds homeland recovery to demand estimates that have already been decremented for maximum austerity. Note that since a homeland attack occurs in the first year of the scenario, the damage recovery process is modeled beginning in the second year, when austerity measures are at their maximum level, which is why we only use hausmax.add and not hausmid.add, hausmin.add, and so forth under the current scenario assumptions. Process **G7 [26]** outputs (1) an estimate of the effect of a homeland attack on peacetime civilian, defense, and import demand and (2) an estimate of the effect of a homeland attack *combined with* austerity measures. The first estimate, **Homeland Effect Estimates [27]**, consists of hciv.dat, hdef.dat, and himp.dat. The second estimate, **Homeland & Austerity Effect Estimates [28]**, consists of hausmax.dat.

## 5. Combining Peacetime, Austerity, and Homeland Attack Demands

At this point, we have produced estimates of U.S. economic demand under peacetime, austerity, and homeland event conditions. Combining these demands into a single forecast of civilian and military demand is a necessary precondition to run FORCEMOB.

First, the Leontief inverse matrix must be generated. The Leontief inverse matrix is a measure of economic requirements by industry and is widely used in economic I/O analysis. It is computed by subtracting the “A” matrix (a  $360 \times 360$  I/O matrix that specifies interindustry input requirements) from the “identity” matrix (a matrix with 1s along the main diagonal and 0s elsewhere) and then taking the inverse. In Step 2, this computation is accomplished by inputting the **A Matrices** [29], which are provided by INFORUM, into the **Leontief Inverse Creation Program** [30], which performs the necessary matrix operations and then outputs the **Leontief Inverse Matrices** [31].<sup>3</sup> Note that there is one A Matrix and one Leontief inverse matrix for each year (e.g., a 2011 matrix, a 2012 matrix, and so forth), but they are *not* products of individual LIFT or ILIAD runs and, hence, do *not* vary across our different runs.

Then, **Industrial Demands** [10] and the **Leontief Inverse Matrices** [31] are input into the **Requirement Demand Creation Program** [32].<sup>4</sup> This program multiplies final demands for each ILIAD economic sector by the Leontief inverse matrices and then outputs a **Total Requirement Demands File** [33] that contains goods and services requirements for civilian demand, defense demand, imports, and exports. To model the effect of austerity measures, **Civilian Output** [34] is extracted and input along with **Austerity Effect Estimates** [23], **Homeland & Austerity Effect Estimates** [28], and the **Leontief Inverse Matrices** [31] into the **Austerity Total Requirements Creation Program** [35]. Note that only the civilian output file is used because only civilian demand has a portion that is considered nonessential. All defense demand is considered essential. The **Austerity Total Requirements Creation Program** [35] creates the **Total Austerity Requirements Demand File** [36], which is input along with the **Base Military Output** [37] file, the **Supply Output File** [38], (both of which are outputs from the **Requirement**

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<sup>3</sup> The input and output paths for the Leontieff Inverse Creation Program cannot exceed 70 characters in length.

<sup>4</sup> The path names for the .ctl files cannot exceed 50 characters in length. The user needs to save another copy of the invfname.txt file in the totaus directory. For the civilian austerity run (no homeland damage), files are pulled from the peacetime INFORUM run (e.g., civ, def, and so forth), INFORUM austerity post-processing (ausmax and so forth), and peacetime civilian demand after it has been multiplied through by the Leontief inverse matrices in the Requirement Demand Creation Program (civlp3.dat). The user then needs to run a second totaus program, which is homeland damage and max civilian austerity (t15ahld3), which uses INFORUM homeland damage (e.g., hciv.dat), INFORUM exports and output, homeland damage + max austerity (i.e., hausmax.dat), and peacetime homeland damage total requirements (t15hcivc.dat).

**Demand Creation Program [32]), and Civilian Output [34] into the Time Phased Requirements Creation Program [39].<sup>5</sup>**

The **Requirement Demand Creation Program [32]** and the **Austerity Total Requirements Creation Program [35]** must be run twice. The first run calculates total requirements demand, assuming civilian austerity (min, mid, and max) with no homeland damage. The second run applies a max austerity assumption and homeland damage.

The **Time Phased Requirements Creation Program [39]** creates three files that are used as input to FORCEMOB.<sup>6</sup> The **Base Military Requirements [40]** file contains data on the total U.S. economic requirements due to peacetime military spending, including all direct and indirect impacts from this spending, for each year of the time period under study.<sup>7</sup> In addition, this file includes requirements caused by a homeland damage event but does not include attrition or expenditures from specific combat scenarios. **Civilian Requirements [41]** contains total goods and services requirements, by year and industry, associated with civilian consumption.<sup>8</sup> Civilian consumption refers to all essential civilian (i.e., non-military) economic demands. Imports and exports are excluded, but investment is included. The **Supply Database File [42]** contains domestic production capabilities by year and industry, total goods and services imports, and exports.<sup>9</sup>

## 6. Weapons Regeneration

In a national emergency scenario, the United States must not only sustain its existing base military force, but must also regenerate assets lost or expended in conflict. This requirement for extra production increases demand for strategic and critical materials and, hence, may affect estimated material shortfalls.

Defense Planning Scenarios developed by OUSD-P specify the nature of the military conflict and losses due to enemy action. Attrition and casualty estimates are derived through DOD wargaming on theater combat models. Although IDA generally adheres to OUSD-P results (which are classified), conflict scenarios and losses often are

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<sup>5</sup> The \*.ctl input file specifies two paths: input and output. Thus, the various totreq and totaus files must be copied into this input directory before double-clicking on the application file (trdcmbn7).

<sup>6</sup> Actually outputs six files (four civilian, one military, and one supply).

<sup>7</sup> Includes basmilp3.dat for year 1 and t15hmlic.dat for years 2–4 and peacetime military requirements plus requirements from homeland damage.

<sup>8</sup> Four civilian files are outputted: (1) mid-level austerity in year 1 (cvamid3.dat) and max-level austerity in years 2–4 (cvamax3.dat); (2) peacetime civilian in year 1 (civlp3.dat) and civilian requirements from homeland damage in years 2–4 (t15hcivc.dat); (3) mid-level austerity in year 1 (cvamid3.dat) and max-level austerity and homeland damage in years 2–4 (t15amxh3.dat); and (4) max-level austerity in year 1 (cvamax3.dat) and max-level austerity in years 2–4 (t15amxh3.dat).

<sup>9</sup> Peacetime supply in year 1 (supplyp3.dat) and supply file from totreq homeland damage run (t15hsupc.dat)

parametrically varied in additional Step 2 runs to facilitate sensitivity analyses of their effect on estimated material shortfalls.

The Office of the Secretary of Defense – Cost Assessment and Performance Evaluation (OSD-CAPE) maintains a list of weapons as **Major End Items [43]**. The data on these weapons, which are used in computing material requirements, are needed in the form of their industrial base production requirements. Modeling their industrial requirements requires the use of the **Defense Translators [44]** developed by OSD-CAPE. Defense Translators are a set of vectors, each of which corresponds to a weapon. The vector components specify percentages of a system’s purchase price that go to companies in a particular economic sector (defined by the 360 ILIAD industrial sectors). Because these values are proportions, they should sum to 1. There are often many zero values, which correspond to sectors that do not contribute to the production of a particular weapon.

The **Defense Translators [44]** and the **Leontief Inverse Matrices [31]** are multiplied in the **PPM Creation Program [45]**. This FORTRAN program creates the **Production Process Matrix [46]**, or PPM, an input file for FORCEMOB.<sup>10</sup> The PPM characterizes the per-sector economic production required to produce a unit cost amount of a particular weapon (typically \$1 billion). Note that Major End Items (MEIs) must be mapped to Major Equipment Types (METs) for the PPM. The MET number indicates the particular Defense Translator vector that needs to be used for that MEI.<sup>11,12</sup> Since a certain number of months are needed to produce a given weapon, IDA economists have estimated a **Production Process Lead Times [47]** input file for FORCEMOB, which specifies the number of months required to produce each MET.

At this point, the “production cost” of weapons has been calculated, but we have not specified what weapons and quantities should be considered. The FORCEMOB input file **MEI Requirements [48]** provides this (classified) information, which is based on weapons attrition and expenditure estimates from Defense Planning Scenarios.

Because regeneration requirements are expressed in terms of quantity (e.g., 20 M1A2 tanks) and the PPM is expressed in terms of cost and output (e.g., some amount of production in multiple sectors to produce \$1 billion worth of M1A2 tanks), these measures must be converted to equivalent units. **Weapon Cost [49]** data provided by DOD (i.e., the Comptroller’s unclassified Green Book and also restricted databases to

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<sup>10</sup> Make sure that the path name is at least 60 characters (or at least make sure that Leontief Inverse is enough character spaces away from path name for program to run correctly and not read in comments).

<sup>11</sup> For the 2015 NDS study, there were 313 MEIs. These MEIs had to be mapped to METs for the PPM. There was space for 499 METs but not all were used for the 2015 NDS study.

<sup>12</sup> Place a copy of the \*.ppm output file into the FORCEMOB directory since it is one of the inputs needed.

which only IDA's Cost Analysis and Research Division has access) is developed into a **Cost File [50]** input file for FORCEMOB.

## 7. Emergency Investment and Extra Production

FORCEMOB is not a static model. If goods and services production estimates do not meet projected demand, FORCEMOB assesses and implements options for redressing this economic shortfall by more fully using the existing production capacity or undertaking emergency investment to expand capacity. This emergency investment increases production capacity in some sectors. It alleviates production shortfalls but also increases demand for output from other sectors, which could increase material demand and shortfalls.

To use existing capacity more fully, the current production level of the industrial base and spare capacity (if any) must be assessed. **Plant Capacity Data [51]** provided by the U.S. Census Bureau are organized in **Microsoft Excel [52]** by North American Industry Classification Systems (NAICS) code. The data **Sorted By NAICS Code [53]** are then fed along with an **NAICS to ILIAD Map [54]** into an **NAICS to ILIAD Conversion Program [55]**, which, as the name implies, maps the capacity estimates by NAICS codes to ILIAD industrial sectors. The sponsor determines what values should be used for missing data values. The end result is **Emergency Operating Capacity (EOC) Fractions [56]**, which essentially represent spare production capacity that could be used more fully in case of a national emergency. INFORUM provides information on **Output and Capital Stock Files [57]**, which are used in Excel to compute the ratio of output to capital (i.e., the amount of production gained with one additional unit of capital). This **Output to Capital Ratios [58]** file is combined with the **Emergency Operating Capacity (EOC) Fractions [56]** file to form the FORCEMOB input file **Q/K Ratios and EOC Fractions [59]**. To be clear, these concepts are distinct and are combined in a single FORCEMOB input file for convenience only. The **Mil-Civ Fungibility Factors File [60]** file is an optional but frequently used FORCEMOB input file that specifies the interchangeability of military and civilian productive capacity. The values to be used are based on sponsor judgment.

The **Private Equipment Bridge Matrix [61]** is a  $360 \times 66$  matrix<sup>13</sup> and is derived from the 2002 BEA benchmark I/O tables. This bridge matrix is used to calculate extraordinary investment requirements. The **Bridge Matrix Transformer [62]** is a utility program that reads in the bridge matrix and then outputs a **Reformatted Bridge Matrix [63]** that can be read in by the **Investment Distribution Creation Program [64]**, along with the **Leontief Inverse Matrices [31]**. The **Investment Distribution Creation**

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<sup>13</sup> This bridge matrix maps investment demands from 66 buying sectors to the 360 ILIAD industrial sectors.

**Program [64]** generates the **Investment Distribution File [65]**, which is a FORCEMOB input file that specifies the “investment demands” to expand production capacity for a given industry. Increasing capacity in a given industry generally requires contributions from many different industries. For example, building a new steel factory would place demands on cement, construction, electrical, and other industries. As with production calculations, the investment demand encompasses not only the products and services purchased by the investment amount, but also all of the goods that are necessary to produce those products and services.

The **Investment Sector Mapping [66]** file is a crosswalk between the 360 ILIAD industrial sectors to classes of industrial investment. The **Investment Lead Times [67]** file identifies the amount of time (in months) that are needed to build additional productive capacity for each of the 360 ILIAD industrial sectors. IDA estimates these values, both of which are necessary FORCEMOB input files.

## 8. Imports and Exports

The relative participation of the United States in international trade during a national emergency affects production and, hence, material demand requirements. Disruptions of imports due to shipping losses or hostile political relations could alter U.S. economic patterns. Alternately, restrictions on exports could preserve more resources for domestic use.

To model these dynamics in FORCEMOB, data on **U.S. Imports of Merchandise by Country [68]** are obtained from the Census Bureau. An **Extraction Program [69]** is used to extract import data by country and store these data as separate .prn files, summarized on the Appendix B crosswalk table as **Imports [70]**. These imports must be mapped from the Harmonized Tariff Schedule (HTS) coding to ILIAD sectors. To do so, **Imports [70]**, the **Leontief Inverse Matrices [31]**, and a **HTS to ILIAD Map [71]** (which, as implied by its name, maps HTS designations to ILIAD sectors) are input into the **HTS to ILIAD Conversion Program [72]**. This program aggregates imports by HTS and country and converts those imports into ILIAD industrial sectors.<sup>14</sup> The program outputs **Imports in ILIAD Format [73]**.

The preceding steps will calculate U.S. peacetime imports but do not account for conflict conditions that could decrease the share actually reaching the United States. These factors<sup>15</sup> are recorded in **Country List [74]**, **Shipping Losses [75]**, **Supply Political Reliability Factors [76]**, **War Damage Factors [77]**, **Pro-U.S. Factors [78]**,

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<sup>14</sup> To run the matrix 5c utility program, the following files are needed: read3a.prn (import file 1, 2012), read3a11.prn (import file 2, 2011), and read3a10.prn (import file 3, 2010).

<sup>15</sup> For the 2015 NDS study, the decrement factors applied to imports (Step 2-A) and materials (Step 2-C) are the same, but the models can accommodate different decrement factors.

and **Baseline Supply Amount** [79].<sup>16</sup> The definitions of these factors and the method in which they are applied are discussed in Step 2-C (see Section 2.C) of this document. For this current section (Section 2.A), it is most important to know that these factors decrease the share of imports going to the United States. Because these factors are coded according to countries and the import data are coded according to ILIAD sector, they must be reconciled to a common unit of analysis. This reconciliation is done by inputting **Imports in ILIAD Format** [73] and the previously listed decrement factors into the **Apply Country Decrements to ILIAD Sectors Program** [80]. This program characterizes each country's exports to the United States in terms of ILIAD sectors and applies the appropriate decrements. The program also requires a **Control Inputs File** [81] that lists the countries, industries, data files, and modeling parameters to be used, and an **Export Factors File** [82], whose values typically are determined by sponsor judgment. The program outputs the FORCEMOB input **Import/Export Factors File** [83]. This file will be used in FORCEMOB to adjust imports or exports by the specified factors.

## 9. Other FORCEMOB Inputs

The **Element File** [84] identifies the industry sectors and weapon types (i.e., MEIs) that underlie any FORCEMOB analysis. Most of this information is drawn from INFORUM and the conflict scenario assumptions that are specified in the Defense Planning Scenarios. The Element File must be named element.db.

The **Control Inputs File** [85] allows the user to control many parameters of a particular run of FORCEMOB, including the length of the scenario and the directories and files to use.

The **Run File** [86] lists the Control Inputs file to be used for a particular run of FORCEMOB and, as the file name implies, is used to run FORCEMOB (i.e., go to the command line and run the following: FORCEMOB runfilename).

The user must create an **MEI Inventory File** [87]. This file is a mandatory input for FORCEMOB but is not actually used in the current method. Therefore, the user should construct a null file (e.g., a file with the correct formatting but no real content).

## 10. Running FORCEMOB

Having prepared all necessary input files, the user can run **FORCEMOB** [88]. FORCEMOB needs to be run twice: one Base Case run (which includes conflict effects) and one "peacetime" run (which, as its name implies, does not include any conflict effects). The results of the peacetime run are used in Step 2-B to calculate an industrial

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<sup>16</sup> Baseline Supply Amount is the same as the **Supply Database File** [42].

sector relationship/ratio between the Base Case and peacetime. The peacetime run is set up differently from the Base Case run:

- It uses null files for the Cost File and MEI Requirements File (i.e., there are no conflict-related weapon requirements).
- It does not model emergency investment.
- It does not adjust imports and exports.
- It does not adjust for austerity and homeland damage.

One run of FORCEMOB performs the following operations:

- computes a time-phased schedule of weapon requirements associated with a conflict,
- translates these weapon demands into time-phased demands on industry,
- adds in civilian and base military industrial demands,
- determines the per-industry goods and services supply capacity (i.e., domestic production plus imports),
- compares goods and services demand to supply and determines if any shortfalls occur, and
- models the use of emergency investment to redress shortfalls and compute investment demand.

This process outputs total goods and services requirements, and these requirements will vary depending on whether it was a Base Case or peacetime run. A Base Case run outputs **Base Case FORCEMOB Requirements [89]**. A peacetime run outputs **Peacetime FORCEMOB Requirements [90]**. These requirements represent the total demand for industrial base production in the specified scenario, by year. These demands are disaggregated by category, including defense (consisting of base force requirements and extra requirements imposed by the conflict scenario), essential civilian, and emergency investment, as is shown on the flowchart (see Appendix A).<sup>17</sup>

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<sup>17</sup> Each FORCEMOB run, although not explicitly identified in either the flowchart or documentation, also outputs import and export requirements.

## B. Step 2-B: Material Demand

### 1. Overview

Step 2-B translates economic requirements into material demand.<sup>18</sup> For most materials, this translation of requirements is accomplished through the use of material consumption ratios (MCRs). MCRs specify how much of which materials is required to produce a given amount of output in a particular economic sector. MCRs represent material demand from all stages of production, not just the finished output. For example, the amount of iron required to *produce* \$1 billion worth of automobiles (taking into account tool and die, facilities, and so forth) is considerably higher than the iron content of the finished cars. For materials that have intensive defense uses, the MCR approach is not appropriate. An alternative material demand computation procedure is used instead.

### 2. Material Categorization

As a first step, the sponsor creates a list that specifies all of the materials to be studied.<sup>19</sup> The composition of this list changes for different Requirements Report (RR) cycles. These materials can be subdivided into two categories based on the availability of data concerning their applications and usage. **SL1 [91]**, or “Study List 1,” lists the materials for which the United States Geological Survey (USGS) and the Department of Commerce (DOC) provide data to IDA.<sup>20</sup> SL1 comprises most of the materials under study. **SL2 [92]**, or “Study List 2,” lists the materials for which USGS and the DOC do not provide data to IDA.

Material demands for these two categories are calculated in different ways. Requirements for SL1 materials are derived through a two-part process: one program calculates their MCRs and another program applies these MCRs to goods and services production requirements. Requirements for SL2 materials are calculated using an alternative procedure.

### 3. SL1 MCR Calculation

Several datasets are necessary to calculate MCRs. Information on **Material Consumption [93]** is obtained from USGS or DOC, both of which collect and maintain

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<sup>18</sup> For more information on material selection, categorization, and data collection, see appendices in James Thomason et al., *Analyses for the 2015 National Defense Stockpile Requirements Report to Congress on Strategic and Critical Materials*, IDA Paper P-5190 (Alexandria, VA: Institute for Defense Analyses, 2015).

<sup>19</sup> For the 2015 NDS study, the sponsor identified and selected materials of concern to the U.S. national security community. Those study materials that have sufficient data are assessed in RAMF-SM Step 2.

<sup>20</sup> For the DOC materials, this list (45 materials for the 2015 NDS study) is identified on the control input file for the mcr12ex3.exe utility program.

U.S. material consumption data. Where gaps exist in these data, IDA consults with subject matter experts (SMEs) in industry and government. The end result is a listing of total U.S. consumption by material for historical years.

Next, data on **Material Applications, Proportions, and ILIAD Sectors [94]** must be assembled. These data are also obtained from USGS, DOC, SME, and IDA information.<sup>21</sup> The term “applications” refers to the uses of the material in question (e.g., iron is used to make cars and planes). The term “proportions” refers to the percentage of material consumed per application (e.g., 70% of iron goes to cars and 30% goes to planes). Lastly, IDA economists map application areas to ILIAD sectors (e.g., plane production places demand on the electronics sector, machine sector, and so forth).

The last data item required is an **SL1 Denominator File [95]**. This file consists of peacetime production requirements that are obtained by running INFORUM model outputs based on the CEA forecast through the **Requirement Demand Creation Program [32]**. This input file is necessary to calculate the MCRs because the preceding steps only characterize material consumption by industry and do not compare this consumption to a fixed amount of goods and services production.

**SL1 [91], Material Consumption [93], Material Applications, Proportions, and ILIAD Sectors [94], and SL1 Denominator File [95]** are inputs into the **MCR Creation Programs [96]**. Since USGS and DOC provide their data in slightly different formats, two separate MCR creation programs are used.<sup>22</sup> These programs combine the aforementioned data and then output MCRs. Their separate output is hand-amalgamated into finished **MCRs [97]**.

#### 4. SL1 Material Requirements

SL1 MCRs can now be applied to goods and services production data to derive the total material requirements of that production.

**MCRs [97], Material Names [98], Inflation Factors [99]** (used to convert from millions of dollars to billions of dollars of reference-year dollars), **Base Case FORCEMOB Requirements [89]**, and a **Requirements Control Inputs File [100]** are inputs into the **Requirements Creation Sub-Module [101]**. This program estimates the total material requirements of the economic production levels calculated by FORCEMOB. The program outputs **SL1 Material Requirements [102]** (i.e., the amount

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<sup>21</sup> For the DOC materials (mcr12ex3.exe utility program), consumption is provided by material and NAICS code, which must be converted to INFORUM industrial sectors. (Proportions of total use can be calculated based on consumption figures provided.) For the USGS materials, application areas are provided and proportions of total use. IDA maps these application areas to the appropriate INFORUM industrial sectors.

<sup>22</sup> Note that mcr12ex3.exe utility program is used for DOC materials and that those materials provided by USGS are input into the specmcr4.exe utility program.

of each SL1 material that will be required under the scenario conditions and production levels specified in FORCEMOB). Requirements are generated for each category of demand (essential civilian, defense, and emergency investment) in each year.<sup>23</sup>

The aforementioned regular (MCR-based) material demand computation process accounts for defense and civilian demands but tacitly assumes that the defense-to-civilian ratio of material use is about the same as the defense-to-civilian ratio of goods and services production requirements, which is overwhelmingly civilian. This procedure might underestimate defense demand for materials that have a large proportion of defense use. Therefore, an alternate procedure (SL2 Material Requirements) was developed to compute demand for such materials.<sup>24</sup>

## 5. SL2 Material Requirements

Determining requirements for SL2 materials (those materials for which USGS and the DOC do not provide data to IDA) is conceptually similar to the SL1 MCR calculation but is different in the details. A single program, the **SL2 Material Demand Calculator [103]**, is used. The many inputs to this program are summarized on the flowchart as **SL2 Demand Inputs [104]** and described as follows:

- *Element file.* Identifies the ILIAD industrial sectors, weapon types, and start and end dates (the FORCEMOB **Element File [84]** is used).
- *Material consumption.* Historical (or possibly forecasted) by material.
- *Year span.* Range of years (by material) for which consumption data in the material consumption file are to be used to estimate material demands by application and year in the 4-year scenario period.
- *Material applications.* Applications by material with proportions of total use.
- *Application by industry.* Industry sectors (INFORUM) associated with the applications identified in **Material Applications, Proportions, and ILIAD Sectors [94]** file.
- **Base Case FORCEMOB Requirements [89].**
- **Peacetime FORCEMOB Requirements [90].**<sup>25</sup>
- *Military fractions.* The percent of each material and application pair that is used in defense applications.

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<sup>23</sup> The three output files from running the **Requirements Creation Sub-Module [101]** are the material requirements output report (hgfa418c.txt), the industry report (dgfa418c.txt), and the overall industry report (rgfa418c.txt).

<sup>24</sup> For the 2015 NDS study, these materials were all termed “SL2 materials.”

<sup>25</sup> The year span for the peacetime FORCEMOB data must encompass all the scenario years *and* all the years specified for any material in the year spans file, including historical years.

When the material application area data explicitly specify military use proportions, an alternative method for computing material demand is used. For each material application area, two fractions are specified: (1) the fraction of total material use associated with that application area and (2) the percentage used for military needs. Using these fractions, the historical material consumption for each application area, subcategorized as either military or civilian usage, is calculated from total material consumption records. The goods and services demand for each application area (categorized by ILIAD industry sector) is used to compute (1) the separate growth factors (from the historical period to the scenario period) for military and civilian use and (2) the military and civilian scenario adjustment factors (from peacetime conditions to national emergency conditions). Emergency investment goods and services demand, if present, is added to the defense demand when computing the defense adjustment factor. The growth and adjustment factors are independently applied to the historical material consumption amounts for military and civilian uses to project estimates of material demand for each application area over the scenario period. The procedure is repeated for each application and the results are summed to compute **SL2 Material Requirements [105]** (i.e., overall material demand amounts—defense and civilian—for each scenario year).

Combining both the **SL1 Material Requirements [102]** and the **SL2 Material Requirements [105]** results in **U.S. Requirements [106]**.

## **C. Step 2-C: Comparing Material Supply and Demand**

### **1. Overview**

Step 2-C uses the Stockpile Sizing Module (SSM) to calculate material supplies available to the United States for every year and material under study. These available supplies then are compared to the total material demand calculated at the conclusion of Step 2-B. If supply cannot satisfy demand, a material is judged to be in shortfall for that year.<sup>26</sup>

The SSM consists of an executable program and numerous input files. This section summarizes the content and construction of the input files and their role in SSM calculations.<sup>27</sup>

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<sup>26</sup> Some material supply is available to satisfy U.S. defense and civilian demands, and other available supply is only available to satisfy U.S. civilian demands.

<sup>27</sup> For more detailed documentation of the SSM, see Tara Santmire, *Stockpile Sizing Module Documentation for Version 4.4*, IDA Paper P-2867 (Alexandria, VA: Institute for Defense Analyses, 1997) and Robert Atwell et al., *Generic Unclassified Stockpile Sizing Module (SSM) Training and Testing for the National Defense Stockpile (NDS) 2015*, IDA Document D-5270 (Alexandria, VA: Institute for Defense Analyses, 2014).

## 2. Basic Information

The **Case File [107]** allows the user to control many basic parameters of a particular SSM run, including the length of the scenario and which input files to use. The **Run File [108]** specifies which data directory, output directory, and Case File to use for a particular SSM run and, as implied by its name, is used to load and run SSM. The **Basic Information [109]** input file lists the materials to be studied, their study units, the Defense Logistics Agency (DLA) price for each material, and the statutory goals (all of which are defined and approved by the sponsor). The **Material File [110]** identifies all of the materials that will be assessed in the SSM and acts as a “master list” of materials against which other input files can be checked. The **Country File [111]** lists all of the countries that are potential producers and/or consumers of materials. In practice, this list includes nearly all of the countries and territories of the world.

## 3. Demand

U.S. demand for each material of interest is input via the **U.S. Requirements [106]** file. As a reminder, this demand was calculated at the conclusion of Step 2-B. The file lists demands for SL1 and SL2 materials.

## 4. Determining Base Domestic and Foreign Material Supply

SSM calculates supply as domestic supply plus available foreign supply. The term “available” is used to represent the fact that conflict conditions could decrease the share of foreign material supply that the United States can plan to obtain and use.

USGS and other SMEs supply information for **U.S. Supply [112]**, an SSM input. Domestic supply consists of current production capacity, supply restarts (i.e., the amount available if currently closed facilities were restarted), and new supply starts (i.e., the amount available if entirely new production facilities, not currently planned, were constructed).<sup>28</sup> USGS and other SMEs also supply information on **Foreign Production of Materials [114]**, another SSM input. Foreign supplies of material can be calculated either on the basis of current (i.e., operational during the scenario period) production or total capacity, broken down by material and year.<sup>29</sup>

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<sup>28</sup> For the 2015 NDS study and in accordance with sponsor judgment, we considered current U.S. production capacity and secondary U.S. supply (i.e., recycled material).

<sup>29</sup> As with the assumption for U.S. supply, the 2015 Base Case assumes that concerted programs will not be available. Rather, it only assumes the availability of production capability that is already active or that is currently expected to become active during the 4-year Base Case.

Together, these input files represent the material supplies that would be available to the United States under totally idyllic conditions.<sup>30</sup>

## 5. Decrements

Given that Step 2 models a national emergency scenario, a number of factors could decrease the share of foreign supply available to the United States. SSM uses the input files described below to apply decrements to the amount of foreign supply available to the United States.

Supplies from different countries are not equally reliable. The **Supply Political Reliability Codes [115]** categorize countries as assured, reliable, or unreliable. Supplies from assured countries can be used for civilian, defense, and emergency investment needs; supplies from reliable countries can be used only for civilian needs; and supplies from unreliable countries cannot be used at all. These codes are based on discussions with the sponsor and on the State Department's State Sponsors of Terrorism list.

Wartime adversaries may seek to disrupt the free flow of trade through the global commons, reducing the amount of foreign materials that actually reach the United States. The **Supply Shipping Loss Factors [116]** file specifies the percentage of material lost in transit due to an attack/disruption from enemy countries. For example, a value of 90 indicates that 10% of material supply from that country is unavailable to the United States due to shipping losses. OUSD-P provides these values, which are classified, based on their Defense Planning Scenarios.

War damage to material production facilities could reduce the amount of output available to the United States. The **Supply War Damage Factors [117]** file specifies, for each year of the conflict scenario, the percentage of a country's material supply that is unavailable because of war damage to production facilities. IDA independently calculates these values, which are classified, based on the conflict parameters described in Defense Planning Scenarios.

Even if a country is not directly affected by the conflict and is willing to sell to the United States, a variety of factors could disrupt its ability to export materials, including labor unrest, political instability, and poor infrastructure. The **Supply Political Reliability Factors [118]** file specifies, for each year of the conflict scenario, the percentage of a country's material supply deemed unavailable to the United States because

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<sup>30</sup> The 2015 NDS Base Case assumes that during the first 6 months of the first scenario year, the United States can acquire the estimated steady-state production from U.S. producers. After the first 6 months of the scenario, the United States is assumed to be able to acquire the full-capacity output of U.S. producers. For foreign material producers, the Base Case assumes that the United States will be able to obtain its normal market share of any estimated reliable and undamaged foreign production from countries that are not defined as combat adversaries. After the first 6 months of the scenario, the United States is assumed to be able to acquire its normal share of full-capacity output.

of a lack of ability to provide materials. The Intelligence Community (IC) provides these values, which are classified.

A country opposed to the United States may deny it materials as a coercive political tactic. The United States may still be able to obtain materials from the country by purchasing on the world market through intermediaries, but these extra steps impose a delay in the arrival of supplies to the United States. The **Supply Pro-U.S. Factors [119]** file characterizes, for each year of the scenario, the percentage of supply from a country subject to delay because of anti-American orientation. For example, a value of 85 indicates that 15% of material supply from the country is subject to a delay. For planning purposes, any material that is delayed is considered unavailable to satisfy U.S. defense demands. The IC provides the factor, which is classified, for each country. Note that the **Supply Pro-U.S. Factors [119]** file only determines the percentage of supply from a country subject to delay and that the length of delay is determined by other input files.<sup>31</sup>

Because supplies that enter the world market may eventually reach the United States even if not intended by the supplying country, an algorithm is used to model gradual U.S. access to some of these supplies after a time delay. For planning purposes, the material that arrives after a delay is considered usable to satisfy civilian demand only. The calculations are performed separately for each combination of material, supplier country, and scenario year. First, the **Supply Political Reliability Factors [118]** file, the **Supply War Damage Factors [117]** file, the **Supply Shipping Loss Factors [116]** file, and the **U.S. Market Share [127]** (the computation of which is explained later in this subsection) are applied to decrement the material supply from the country in question. The fraction of the remaining supply that is delayed is one minus the **Supply Pro-U.S. Factors [119]** for that country. For the supply that is delayed, the delay time (in years) is computed as the delay factor of each country divided by the delay factor of the United States, times the scenario length in years, divided by the cutoff factor. A delay factor for each country is entered into SSM via the **Delay Time Adjustment Factors [120]** file. For the 2015 NDS study, the length of delay is assumed to be constant across countries; therefore, a constant factor is entered for each country to create a constant delay (i.e., a value of 1 for each country and year of the 4-year Base Case). The cutoff factor, which can be regarded as a number of years, is input via the **Case File [107]**.<sup>32</sup>

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<sup>31</sup> In the 2015 NDS study, the assumed delay is 6 months.

<sup>32</sup> If the cutoff factor is zero, all supply subject to delay is assumed to be delayed beyond the end of the scenario. Shipping loss factors are imposed for the scenario year(s) that correspond to the arrival time of the delayed material. The country strength measures are input on the fourth SSM input file. This file has been traditionally known as the gross domestic product (GDP) file. If the market shares are being computed in the SSM via the GDP ratio method, then the GDPs are input on this file. The GDPs can then do double-duty as the country strengths in the aforementioned formula. However, if the market shares are computed outside the SSM, then the values in the file can be any appropriate ones. To have a constant delay factor, one can simply input the same value (e.g., 1.0) for the strength measure for all countries,

The last major decrement is market share, which refers to the fraction of foreign supply that the United States can obtain. Market shares are necessary to account for the fact that other countries also demand materials and compete with the United States for access to them; therefore, the United States cannot expect to obtain all of the materials it needs. Market shares vary by material but not by country. As originally designed, market share was computed *within* SSM using a variety of input files, but the current practice is to calculate market share *outside* of SSM and then enter this share into SSM via a **U.S. Market Share [127]** input file. Under this current practice, market share is derived by using three distinct estimation methods to derive an initial peacetime market share and by selecting the method that produces the highest estimate. This value is entered into the **U.S. Market Share [127]** input file for the SSM run.

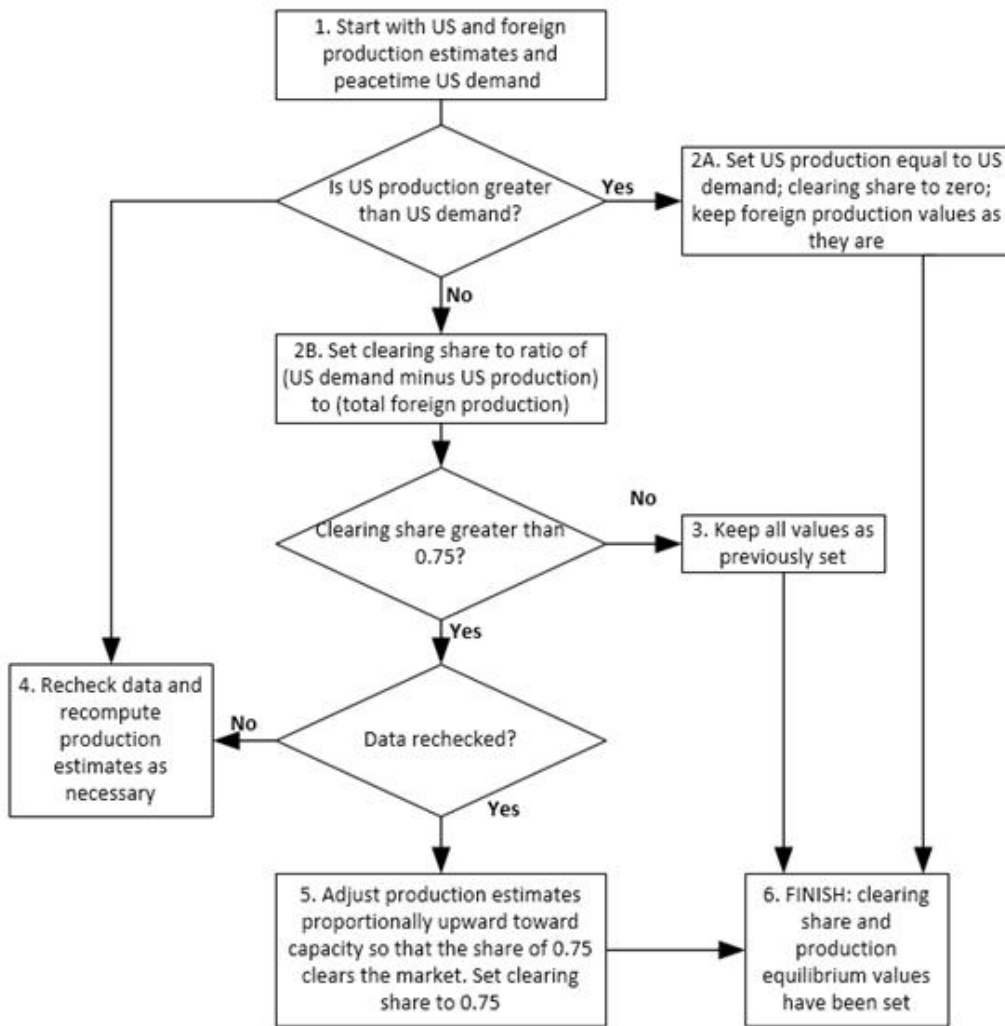
The first method of calculating market share is the “production” method. Market share for each material under study is defined as the ratio of **U.S. Imports [113]** to **Foreign Production of Materials [114]**. The program **Imports to Non-U.S. Production Ratio [122]** performs this calculation. The second method for calculating market share is the GDP method. Market share is defined as the ratio of the U.S. GDP vs. the GDP of all other demanding countries for a particular material in a particular year. To compute this ratio, the user inputs a list of **Countries Demanding Materials [123]** and their respective **GDPs [124]** into the **GDP Ratio Creation Program [125]** (an Excel spreadsheet program). GDPs are taken from the CIA World Factbook.<sup>33</sup> The third method is the **Peacetime Equilibrium Adjustment Process (PEAP) [126]**. PEAP is best understood visually, as seen in Figure 1. Of these three methods, the one that produces the highest value is selected as the **U.S. Market Share [127]** input file for SSM.

**Foreign Production to Capacity Ratios [121]**, an optional but frequently used SSM input file, lists the ratio of material production to material production capacity for each foreign producer. Every country and material combination has its own production to capacity ratio (e.g., France produces iron at 80% of capacity, Germany produces silver at 90%, and so forth). This information is used in modeling “extra sell,” which refers to the idea that in a national emergency, the United States could financially induce foreign producers to produce a larger than normal amount of material (“ramp-up”) and sell a larger than normal market share of this extra production to the United States. Note that this option was not used in the 2015 NDS Base Case run but can be used in excursion analyses.

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including the United States. The cutoff factor then governs the delay time. In a 4-year scenario, setting the cutoff factor to 800% models a delay time of 6 months.

<sup>33</sup> GDPs can be decremented by war damage factors. A war-damaged country might be less likely to demand material.



**Figure 1. Peacetime Equilibrium Adjustment Process (PEAP)**

Lastly, the user must input a number of **Null Files [128]**. These files are mandatory inputs to SSM but are not used in the current application of SSM; therefore, the user should enter them with proper formatting but no real content. The null files to enter are “Foreign Demanders of Material,” “Demand Factor War Damage,” and “Demand Factor Political Reliability.”

## 6. Running SSM

At this point, all relevant SSM input files have been created. Running SSM will compare U.S. yearly demand against available supply, which is domestic supply plus foreign supply minus all of the aforementioned decrements. **SSM [129]** outputs a variety of reports detailing **Shortfall Estimates [130]** by year for all materials under study, broken down between civilian, defense, and emergency investments.

**Appendix A**  
**Risk Assessment and Mitigation Framework for**  
**Strategic Materials (RAMF-SM) Step 2 Flowchart**

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The RAMF-SM Step 2 Flowchart is on the CD attached to the inside back cover of this document.

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## Appendix B

### Crosswalk of Descriptive Names to 2015 National Defense Stockpile (NDS) Requirements Report (RR) Filenames

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Flowchart Number	Descriptive Name	Filename(s)
1	Economic Forecast	cea-713.xlsx, fy2015_budget_request_overview_book.pdf
2	Macroeconomic Variables	nds15jb.mfx
3	Vectors and Matrices	nds15jb.vfx
4	LIFT	ldlift
5	ILIAD	iliad
6	LIFT Vectors and Matrices	jbnds15.vam
7	ILIAD Vectors and Matrices	jbnds15i.vam
8	Scripting Files	nds15.add, pv.add
9	G7	g7
10	Industrial Demands	out.dat, civ.dat, def.dat, exp.dat, imp.dat
11	Historical Data	fdhist.dat, civhist.dat
12	Austerity Measure Estimates	Appendix 3F_Reliability Protocol_1OCT2014.docx
13	Scripting Files	vamcreatebsvam.add, pv05.add
14	Configuration File	vambsvam.cfg
15	G7	g7
16	Total Austerity Modifiers	bsvamfinal.vam
17	Bridge Mapping	nds15-bridgemappings.xlsx
18	Bridge Matrices - First Year	derivative of nds15-bridgemappings.xlsx
19	Scripting File	loadbridges.add
20	G7	g7
21	Bridge Matrices - All Years	derivative of nds15-bridgemappings.xlsx
22	G7	g7
23	Austerity Effect Estimates	ausmax.dat, ausmid.dat, ausmin.dat
24	Homeland Damage Estimates	g7
25	Scripting File	hausmax.add, hausciv.add
26	G7	g7
27	Homeland Effect Estimates	hciv.dat, hdef.dat, himp.dat
28	Homeland & Austerity Effect Estimates	hausmax.dat
29	A Matrices	amalt08.dat, amalt09.dat... amalt23.dat

Flowchart Number	Descriptive Name	Filename(s)
30	Leontief Inverse Creation Program	invers4c
31	Leontief Inverse Matrices	imalt208.dat, imalt209.dat ... imalt223.dat
32	Requirement Demand Creation Program	totreq9d
33	Total Requirement Demands File	tradjp3.dat
34	Civilian Output	(peacetime) civilp3.dat (homeland) t15hcivc.dat
35	Austerity Total Requirements Creation Program	totaus
36	Total Austerity Requirements Demand File	(austerity, no hld) cvamax3.dat, cvamid3.dat, cvamin3.dat (austerity + hld) t15amxh3.dat
37	Base Military Output	(peacetime) basmilp3.dat (homeland) t15hmilc.dat
38	Supply Output File	(peacetime) supplyp3.dat (homeland) t15hsupc.dat
39	Time Phased Requirements Creation Program	trdcmbn7
40	Base Military Requirements	(Base Case) hdchmil.mil (peacetime) basmilp3.mil
41	Civilian Requirements	(Base Case) hdc1ner1.civ (peacetime) civilp3.civ
42	Supply Database File	(Base Case) hdchsup.sup (peacetime) supplyp3.sup
43	Major End Items	weapon_2015_work1.xlsx
44	Defense Translators	dtranc24.csv
45	PPM Creation Program	ppmgenr1
46	Production Process Matrix	ppmc2813.ppm
47	Production Process Lead Times	ldtc2513.ppl
48	MEI Requirements	(Base Case) rq15c13.mei (peacetime) null.mei
49	Weapon Cost	weapon_2015_work1.xlsx
50	Cost File	(Base Case) rq15c13.cst (peacetime) null.cst
51	Plant Capacity Data	emgrt1113_jbt.xlsm
52	Microsoft Excel	n/a
53	Sorted By NAICS Code	revised emg q2 2013 for dod (11-05-13).xlsx
54	NAICS to ILIAD Map	ilv5naic.csv
55	NAICS to ILIAD Conversion Program	crat2012
56	Emergency Operating Capacity (EOC) Fractions	emgrt1113.prn
57	Output and Capital Stock Files	nds15-bmjbforelly_jbt_qkf.xlsx
58	Output to Capital Ratios	nds15-bmjbforelly_jbt_qkf.xlsx
59	Q/K Ratios and EOC Fractions	(Base Case) emg0103a.qkf (peacetime) emg1113b.qkf
60	Mil-Civ Fungibility Factors File	fung50.mcf
61	Private Equipment Bridge Matrix	bm15wk1.csv
62	Bridge Matrix Transformer	bmwk2015
63	Reformatted Bridge Matrix	bmwk2015.out
64	Investment Distribution Creation Program	genidr15
65	Investment Distribution File	nov2013.idr
66	Investment Sector Mapping	grn365m.ism

<b>Flowchart Number</b>	<b>Descriptive Name</b>	<b>Filename(s)</b>
67	Investment Lead Times	grn365t.ilt
68	U.S. Imports of Merchandise by Country	imp_detl.txt (3 versions for 2010, 2011, 2012)
69	Extraction Program	read3a.exe
70	Imports	read3a.prn (2012); read3a11.prn (2011); read3a10.prn (2010)
71	HTS to ILIAD Map	hsxi365a.txt
72	HTS to ILIAD Conversion Program	matrix5c
73	Imports in ILIAD Format	mainou5i.csv
74	Country List	councod6.csv
75	Shipping Losses	rgfssl01.txt
76	Supply Political Reliability Factors	rgfifa01.txt
77	War Damage Factors	rgfiwd01.txt
78	Pro-U.S. Factors	rgfiuw01.txt
79	Baseline Supply Amount	hdchsup.sup
80	Apply Country Decrements to ILIAD Sectors Program	crefwka
81	Control Inputs File	t41814a.in
82	Export Factors File	exfc365a.txt
83	Import/Export Factors File	t41814a.fie
84	Element File	element.db
85	Control Inputs File	(Base Case) g15a418a.in (peacetime) pt1020.in
86	Run File	(Base Case) g15a418a.inf (peacetime) pt1020.inf
87	MEI Inventory File	(Base Case) null313.min (peacetime) null.min
88	FORCEMOB	fmnov2013
89	Base Case FORCEMOB Requirements	g15a418a.ppf, .pfc
90	Peacetime FORCEMOB Requirements	pt1020.ppf, .pfc
91	SL1	(mcr12ex3) mct327a.ctl (specmcr4.exe) sp4t325a.in
92	SL2	igfa418a.in
93	Material Consumption	(mcr12ex3) cons109.txt (specmcr4.exe) cnsmp314.txt
94	Material Applications, Proportions, and ILIAD Sectors	(mcr12ex3) ncinf109.txt, ncind109.txt (specmcr4.exe) apa32014.txt, api32014.txt, ys31314.txt
95	SL1 Denominator File	tradjp3.dat
96	MCR Creation Programs	mcr12ex3.exe, specmcr4.exe
97	MCRs	(mcr12ex3) mct327a.csv (specmcr4.exe) sp4t325a.csv, sp4t325a.txt
98	Material Names	s15mni01.txt
99	Inflation Factors	inf360.txt
100	Requirements Control Inputs File	hgfa418c.rqc
101	Requirements Creation Sub-Module	reqcrea30713.exe

<b>Flowchart Number</b>	<b>Descriptive Name</b>	<b>Filename(s)</b>
102	SL1 Material Requirements	hgfa418c.txt
103	SL2 Material Demand Calculator	newprox2
104	SL2 Demand Inputs	cnsmp311.txt, ys41714.txt, app2214.txt, api2214.txt, null7.txt, milfrac1.txt, elementdb.prn
105	SL2 Material Requirements	jgfa418a.out
106	U.S. Requirements	sgfa418c.txt
107	Case File	g15lrg01.cas
108	Run File	g15lrg01.sbf
109	Basic Information	basi616a.txt
110	Material File	material.txt
111	Country File	country.txt
112	U.S. Supply	rgfusp08.txt
113	U.S. Imports	mktwk50814_basecase.xlsx
114	Foreign Production of Materials	rgffsp20.txt
115	Supply Political Reliability Codes	rgfspc01.txt
116	Supply Shipping Loss Factors	rgfssl01.txt
117	Supply War Damage Factors	rgfswd02.txt
118	Supply Political Reliability Factors	rgffas02.txt
119	Supply Pro-U.S. Factors	rgfpru02.txt
120	Delay Time Adjustment Factors	delay15.txt
121	Foreign Production to Capacity Ratios	many variations: all start with string 'pcr' not used in base case
122	Imports to Non-U.S. Production Ratio	mktwk50814_basecase.xlsx
123	Countries Demanding Materials	mktwk50814_basecase.xlsx
124	GDPs	mktwk50814_basecase.xlsx
125	GDP Ratio Creation Program	mktwk50814_basecase.xlsx
126	Peacetime Equilibrium Adjustment Process (PEAP)	mktwk50814_basecase.xlsx
127	U.S. Market Share	rgfmks5.txt
128	Null Files	null01.txt, null02.txt, null03.txt
129	SSM	SSM1118.exe
130	Shortfall Estimates	many; goalsum.rpt and goalyear.rpt are widely used

## Appendix C

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## Appendix D

### Glossary

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BEA	Bureau of Economic Analysis
CEA	Council of Economic Advisors
DLA	Defense Logistics Agency
DOC	Department of Commerce
DOD	Department of Defense
EOC	Emergency Operating Capacity
FORCEMOB	Forces Mobilization Model
GDP	Gross domestic product
HTS	Harmonized Tariff Schedule
I/O	input/output
IC	Intelligence Community
IDA	Institute for Defense Analyses
ILIAD	Interindustry Large-scale Integrated and Dynamic Model
INFORUM	Interindustry Forecasting Project at the University of Maryland
LIFT	Long-term Interindustry Forecasting Tool
MCR	material consumption ratio
MEI	Major End Item
MET	Major Equipment Type
NAICS	North American Industry Classification Systems
NDS	National Defense Stockpile
OSD-CAPE	Office of the Secretary of Defense – Cost Assessment and Performance Evaluation
OSD-P	Office of the Undersecretary of Defense for Policy
PEAP	Peacetime Equilibrium Adjustment Process
PPM	Production Process Matrix
Q/K	output to capital
RAMF-SM	Risk Assessment and Mitigation Framework for Strategic Materials
RR	Requirements Report
SL1	Study List 1
SL2	Study List 2
SME	subject matter expert
SSM	Stockpile Sizing Module
U.S.	United States
USGS	United States Geological Survey

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