INSTITUTE FOR DEFENSE ANALYSES

Weapon-Specific Strategic Material Estimation Process (WSSMEP)

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Executive Summary

This annotated briefing and associated Microsoft Excel file demonstrate the practical operation and theoretical basis of the Weapon-Specific Strategic Material Estimation Process (WSSMEP). A previous version of this briefing was presented to Defense Logistics Agency (DLA) representatives in July 2014. It is intended as a high-level overview. Some data inputs to WSSMEP are proprietary or classified, but the model itself is not.

WSSMEP is a modeling tool used to estimate the demand for the strategic and critical materials (S&CM) associated with production of a particular U.S. weapons system. For example, WSSMEP can be used to estimate the amount of tungsten required by the industrial base to build an M-1 tank. The algorithms and calculations of WSSMEP have long been used as a part of the Risk Assessment and Mitigation Framework – Strategic Materials (RAMF-SM), an analytical process used to determine, among other things, what materials in what quantities should be considered for inclusion in the National Defense Stockpile (NDS). WSSMEP has also been used to support Congressionally mandated reports about, for example, the dependence of major U.S. weapons systems on rare earth elements.

In the logic of WSSMEP, a weapon can be thought of as the sum of industrial output from each economic sector needed to produce it. For example, the production of a tank places demand on the metallurgical sector, the electronics sector, and so forth. The Production Process Matrix (PPM) defines U.S. weapons systems in terms of their required output from each of 360 economic sectors. Importantly, this matrix measures the economic output needed for the production of a weapon, *not* just the weapon itself, meaning that it includes tool and die, building maintenance, and so forth. The economic sectors come from the Interindustry Large-scale Integrated and Dynamic (ILIAD) model, an input/output model of the U.S. economy run by the Interindustry Forecasting Project at the University of Maryland (INFORUM).

The PPM itself is the product of the Defense Translator and the Leontief Inverse Matrix. The Defense Translator is a set of vectors, each of which corresponds to a U.S. weapon. The vector components specify percentages of system purchase price that go to companies in a particular economic sector. Because these values are percentages, they should sum to 1. Defense Translators are determined by the Office of the Secretary of Defense (OSD), Cost Assessment and Performance Evaluation (CAPE). The Leontief Inverse Matrix (developed by Nobel Prize-winning economist Wassily Leontief (1906–1999)) is a measure of economic requirements by industry. In other words, how much input from other economic sectors is required to produce a fixed amount of output in another industry? It is computed using INFORUM data. Multiplying the Defense Translator and Leontief Inverse Matrix results in the PPM, which measures economic output needed in each industry to produce a particular weapon.

Each economic sector also requires a certain amount of materials to produce a fixed amount of output. For example, the automobile industry requires X quantity of iron to produce Y amount of output. The Material Consumption Ratios (MCRs) define the quantities of material needed to produce $1 billion of output in each economic sector. MCRs are computed from data provided by the U.S. Geological Survey (USGS), the Department of Commerce (DOC), and industry subject matter experts (SMEs). A separate MCR is developed for each combination of material of interest and industry sector.

Multiplying a weapon's PPM vector by the appropriate MCR vector results in the material quantities needed to produce $1-billion worth of a weapon. Multiplying by the weapon unit price and dividing by unit conversion factors result in the material quantities needed to produce one unit of the weapon. To summarize the mathematical operations used in WSSMEP:

$$\textit{Material Required} = (\textit{Weapon Price} \times \textit{PPM} \times \textit{MCR})/\textit{Unit Conversion Factors}.$$

Since WSSMEP essentially consists of vector algebra operations, it can be—and has been—programmed in a variety of computing languages. This annotated briefing is intended to be used in conjunction with a Microsoft Excel implementation of WSSMEP. It uses entirely notional data to avoid classification restrictions but otherwise reproduces the operations described in this document and used in production versions of WSSMEP. This approach should allow users to understand and experiment with WSSMEP. Step-by-step instructions for entering data and running the Excel model are contained in the main body of this document.

Contents

Appendixes

Weapon-Specific Strategic Material Estimation Process (WSSMEP)

Weapon-Specific Strategic Material Estimation Process (WSSMEP)

December 2, 2014

Robert J. Atwell Jr.
Eleanor L. Schwartz
Thomas J. Wallace
James S. Thomason, Project Leader

An earlier version of this briefing was presented to Defense Logistics Agency (DLA) representatives at the Institute for Defense Analyses (IDA) facilities on July 31, 2014. It has since been updated with additional information and annotations.

IDA | Introduction

- The Weapon-Specific Strategic Material Estimation Process (WSSMEP) allows questions such as the following to be answered:
  - How much beryllium is needed to produce an F-35?
  - How many different rare earth materials are needed to produce an *Arleigh Burke* destroyer?
  - What is the dollar cost of strategic and critical materials in the production of an M1A2 tank?

1. Introduction

The questions in this slide can be encountered in several different contexts:

- Analysis supporting the National Defense Stockpile (NDS) Requirements Report (RR) relies on estimation of material shortfalls, which are partially attributable to U.S. weapon casualties and expenditures in a given combat scenario. The loss of platforms and munitions requires the production of replacements, which increases demand for strategic and critical materials (S&CM) and possibly increases material shortfalls. Thus, an accurate estimation of the material requirements associated with the production of a particular weapon plays a key role in determining overall U.S. material demand, possible shortfalls, and mitigation strategies. The Weapon-Specific Strategic Material Estimation Process (WSSMEP) is a tool for making such estimates.
- Congress has periodically shown interest in the S&CM demand associated with weapons production. For example, in the National Defense Authorization Act for Fiscal Year 2011, Congress required the Secretary of Defense to submit a report on supply and demand for rare earth materials in defense applications. IDA assisted in the production of this report and used WSSMEP to assess the role of rare earth materials in prominent U.S. weapons systems. See Thomason et al. (2011).

Background

- WSSMEP is a model for estimating the quantities of strategic and critical materials needed to build specific weapon systems. It is part of the material demand estimation process used in preparing the National Defense Stockpile (NDS) Requirements Report (RR) and has been used for many years.
- WSSMEP can be run as a stand-alone Excel model. This briefing uses such a stand-alone version (available on compact disc (CD) and designed to be used in conjunction with this presentation) to better illustrate the model's logic.
  - IDA Research Staff Member Eleanor Schwartz is the original developer of WSSMEP (both the embedded and the stand-alone Excel versions).
  - IDA Research Associate Tom Wallace created a non-proprietary version based on Schwartz's original model.
- Some data inputs to WSSMEP are proprietary, but the model itself is not. This presentation and the associated Excel file use entirely notional data, which should facilitate user understanding of the modeling logic without creating the need for extra data security procedures.
- More detailed reference documents are listed at the end of this briefing.

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2. Background

The stand-alone, non-proprietary model of WSSMEP was provided to DLA representatives on July 31, 2014.

Conceptual Overview

- A weapon can be thought of as the sum of the industrial output from each economic sector needed to produce it. For example, the production of a tank places demand on the metallurgical sector, the electronics sector, and so forth. The Production Process Matrix (PPM) defines U.S. weapons systems in terms of their required output from each of 360 economic sectors. Importantly, this matrix measures the economic output needed for producing a weapon, *not* just the weapon itself, meaning that it includes tool and die, building maintenance, and so forth.
- Each sector requires a certain amount of materials to produce a fixed amount of output. For example, the auto industry requires X quantity of iron to produce Y amount of output. The Material Consumption Ratio (MCR) defines the quantity of material needed to produce $1 billion of output in each of the Interindustry Large-scale Integrated and Dynamic Model's (ILIAD) 360 economic sectors. A separate MCR is developed for each combination of material of interest and industry sector.
  - ILIAD is an input/output model of the U.S. economy run by the Interindustry Forecasting Project at the University of Maryland (INFORUM) and widely used by the Bureau of Economic Analysis (BEA).
- Multiplying a weapon's PPM vector by the appropriate MCR vector results in the material quantities needed to produce $1-billion worth of a weapon. Multiplying by the weapon unit price and dividing by unit conversion factors result in the material quantities needed to produce one unit of the weapon:

Materials Required = (Weapon Price × (PPM × MCR))/Unit Conversion Factors

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3. Conceptual Overview

This slide introduces key WSSMEP concepts in a general fashion. More detailed treatment is given in later slides.

WSSMEP Operation

- The following sections will walk through the operation of the WSSMEP model, including
  - Required data inputs,
  - Internal model calculations,
  - Data sources, and
  - Sources for more detailed documentation material.
- The Excel file Final_WSSMEP_For_DLA_No_PI.xlsx is the version that will be examined in this document.

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4. WSSMEP Operation

The Excel file is on a compact disc (CD) associated with this briefing and is available from the IDA Control and Distribution Department. IDA provided the Excel file to the DLA on July 31, 2014. The version of WSSMEP examined in this document, as is implied by its filename, contains no classified or proprietary information and uses notional data.

IDA | Step 1: Weapon Data

- First, the user must define the weapons to be studied (a maximum of seven). The user inputs the following values to the “Weapon Data” sheet:
  - – Weapon reference numbers
    - ▪ Used as shorthand reference for keeping track of different weapons
  - – Weapon names
  - – Per-unit weapons cost
    - ▪ Procurement cost. Before entering costs into WSSMEP, the user should deflate them to a common base year using factors from the Department of Defense (DOD) Comptroller’s Office Green Book. This cost usually is in thousands of dollars.

User declares weapons to study

	A	B	C
1	Weapon Reference Number	Weapon Name	Per-Unit Cost in Thousands of Constant Dollars
2	1	MiG-31	$ 10,000.00
3	2	T-90	$ 10,000.00
4	3	SS-N-25	$ 10,000.00
5	4	Ka-52	$ 10,000.00
6	5	BMP-3	$ 10,000.00
7	6	BM-30	$ 10,000.00
8	7	SA-21	$ 10,000.00

Input Weapon Data | Input Material Data | Input PPM | Input MCR | Calculations | Results Summary

Each WSSMEP sheet requiring user input is labeled as such.

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A. Required Data Inputs

1. Weapons To Be Studied

The “Weapon Reference Number” shown in this slide is a generalization. In practice, IDA uses Major End Item (MEI) and Major Equipment Type (MET) numerical codes. The generalized name is accurate, however, in the sense that MEI and MET are simply reference numbers for weapons systems in larger databases and do not carry much informational content on their own.

IDA | Step 2: Material Data (1 of 2)

- Second, the user must enter data on which materials to include in the WSSMEP analysis. The user inputs the following values into the "Material Data" sheet (see table on next slide):
  - Material
    - Shorthand name
  - Long name
    - Full name of material
  - Units
    - Standard unit of measurement for material
  - Price
    - Defense Logistics Agency (DLA) per-unit price for material
  - Goal and Cost
    - Only used if a legally mandated quantity of material must be bought
  - Conversion Factor for Short Tons
    - Used to convert disparate units into a single, comparable unit (short tons). These cells are auto populated via a VLOOKUP formula that compares the "Units" column to a conversion table and generates the appropriate conversion factor.

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2. Materials To Include in the WSSMEP Analysis

The sponsor typically determines what materials will be studied.

IDA | Step 2: Material Data (2 of 2)

User has declared materials to study (units, price, and so forth).

	A	B	C	D	E	F	G	H	I	J	K
1	**Material**	**Long Name**	**Units**	**Price**	**Goal**	**Cost**	**Conversion Factor for Short Tons**			**Short Ton Conversion Look-up Table**	
2	ALMNM_LITH	Aluminum Lithium Alloys	Metric Tons	$10,000.00	0	0	1.1023115			Short Tons	1
3	ALMNM_OXIDE	Aluminum Oxide Fused Crude	Short Tons	$10,000.00	0	0	1			Short Dry Tons	1
4	ANTIMONY	Antimony	Short Tons	$10,000.00	0	0	1			Short Tons Pb	1
5	BERYL	Beryl Ore	Short Tons	$10,000.00	0	0	1			Short Tons Ni	1
6	BERYLLIUM_COPPER	Beryllium Copper Master Alloy	Short Tons	$10,000.00	0	0	1			Short Tons V	1
7	BERYLLIUM_METAL	Beryllium Metal	Short Tons	$10,000.00	0	0	1			Metric Tons	1.1023115
8	BISMUTH	Bismuth	Pounds	$10,000.00	0	0	0.0005			Metric Tons Sr	1.1023115
9	BORON	Boron	MT Oxide	$10,000.00	0	0	1.1023115			Long Tons	1.12
10	CERIUM	Cerium	MT Oxide	$10,000.00	0	0	1.1023115			Pounds	0.0005
11	CHROMIUM_FER	Chromium Ferro (Ferrochromium)	Short Tons	$10,000.00	0	0	1			Pounds Co	0.0005
12	CHROMIUM_METAL	Chromium Metal	Short Tons	$10,000.00	0	0	1			Pounds Cb	0.0005
13	COBALT	Cobalt	Pounds Co	$10,000.00	0	0	0.0005			Pounds Ta	0.0005
14	COLUMBIUM	Columbium	Pounds Cb	$10,000.00	0	0	0.0005			Pounds W	0.0005
15	CSM	CSM - Chlorosulfonated Polyethylene	Metric Tons	$10,000.00	0	0	1.1023115			Kilograms	1.1023115
16	DYSPROSIUM	Dysprosium	MT Oxide	$10,000.00	0	0	1.1023115			MT Oxide	1.1023115
17	ERBIUM	Erbium	MT Oxide	$10,000.00	0	0	1.1023115			Troy Oz.	3.42857E-05
18	EUROPIUM	Europium	MT Oxide	$10,000.00	0	0	1.1023115				
19	FLRSPR_ACID	Fluorspar Acid Grade	Short Tons	$10,000.00	0	0	1				
20	FLRSPR_METAL	Fluorspar Metallurgical Grade	Short Tons	$10,000.00	0	0	1				
21	GADOLINIUM	Gadolinium	MT Oxide	$10,000.00	0	0	1.1023115				
22	GALLIUM	Gallium	Kilograms	$10,000.00	0	0	1.1023115				

Input Weapon Data | **Input Material Data** | Input PPM | Input MCR | Calculations | Results Summary

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This slide shows that the user has declared the materials that will be studied, including units, price, and so forth.

Step 3: Production Process Matrix (PPM) (1 of 2)

- The user then inputs the PPM, which requires additional methodological explanation. The PPM is the product of the Defense Translator and the Leontief Inverse Matrix.
  - The Defense Translator is a set of vectors, each of which correspond to a weapon. The vector components specify percentages of system purchase price that go to companies in a particular economic sector. Because these values are percentages, they should sum to 1. Defense Translators are determined by the Office of the Secretary of Defense (OSD), Cost Assessment and Performance Evaluation (CAPE). The many zero values correspond to sectors that do not contribute to the production of a particular weapon.
  - The Leontief Inverse Matrix is a measure of economic requirements by industry. In other words, how much input from other economic sectors is required to produce a fixed amount of output in a particular economic sector. It is based on INFORUM data. It is computed by subtracting the "A" matrix (direct coefficients) from the "identity" matrix (a matrix with 1 in the diagonal and 0 in all other fields) and taking the inverse.
- Multiplying the Defense Translator and Leontief Inverse Matrix results in the PPM, which measures the amount of economic output needed in each industry to produce a particular weapon. WSSMEP does not perform this calculation. The calculation to derive the PPM must be performed beforehand, allowing the user to input the PPM into WSSMEP.

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3. The Production Process Matrix (PPM)

The third step in the data entry process is inputting the PPM.

Step 3: Production Process Matrix (PPM) (2 of 2)

In this example, there are 7 weapons × 360 economic sectors, which equals 2,520 values for the user to input

	A	B	C	D	E
1	Weapon Reference Number	ILIAD Sector Number	Value		
2	1	1	0.0217391		
3	1	2	0.0161290		
4	1	3	0.0129870		
5	1	4	0.0101010		
6	1	5	0.0116279		
7	1	6	0.0416667		
8	1	7	0.0243902		
9	1	8	0.0142857		
10	1	9	0.0476190		
11	1	10	0.0212766		
■ ■ ■					
2516	7	355	0.7145683		
2517	7	356	0.2497515		
2518	7	357	0.1824826		
2519	7	358	0.6511839		
2520	7	359	0.6979614		
2521	7	360	0.4583828		

Input Weapon Data | Input Material Data | **Input PPM** | Input MCR | Calculations | Results Summary

This example shows 7 weapons and 360 economic sectors, which means that the user has to input 2,520 values. All of the values in this slide are notional.

IDA | Step 4: Material Consumption Ratio (MCR)

- Next, the user inputs the MCR
  - The MCR equals the amount of given material (by mass) required to produce $1 billion of output in given economic sector.
  - MCRs are computed from consumption and economic information. Sources include proprietary company data, the United States Geological Survey (USGS), the Department of Commerce (DOC), and subject matter expert (SME) interviews.
  - Material demand encompasses all aspects of production, *not* just the weapon itself.

In this example, user has declared, among other things, that Sector 113 requires 5,289 metric tons of aluminum lithium alloy to produce $1 billion of output

	A	B	C
1	ILIAD Sector	Material	Material Demand (Units) Per $B of Sector Output
2	113	ALMNM_LITH	5289
3	33	ALMNM_LITH	1468
4	35	ALMNM_OXIDE	8347
5	310	ALMNM_OXIDE	8533
6	256	ANTIMONY	2054
7	199	ANTIMONY	4990
8	272	BERYL	5593
9	58	BERYL	9400
10	126	BERYLLIUM_COPPPER	4421
11	309	BERYLLIUM_COPPPER	1865

Input Weapon Data | Input Material Data | Input PPM | Input MCR | Calculations | Results Summary

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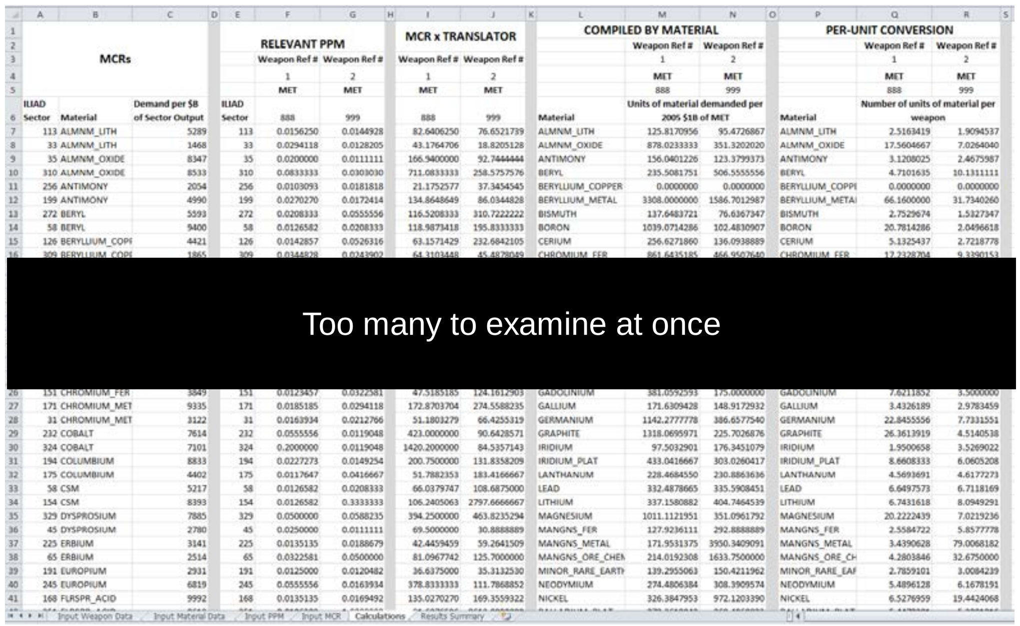
4. The Material Consumption Ratio (MCR)

The fourth step in the data entry process is inputting the MCRs. Not all materials have MCRs. The demand for some materials—mostly proprietary ones that have strongly articulated defense demands—is calculated using a different methodology. These materials cannot be assessed using WSSMEP.

As with the PPM, MCRs encompass all aspects of production, not just the weapon itself. These aspects of production include tool and die, building maintenance, and so forth. Some consumers of WSSMEP analysis are interested in the material content of the weapon alone, often referred to as "flyaway" material demand. WSSMEP does not natively support such analysis. Separating the weapon from its production would require sector-by-sector data on the ratio of "flyaway" industrial production and material demand to "production" industrial production and material demand. As far as the authors know, such data do not exist.

IDA | Step 5: Calculations

- When the user has input all of the necessary data, WSSMEP automatically calculates material requirements on the “Calculations” sheet. No user input is required to execute the operations.
- The slides on the following pages detail the operations step by step.



	A	B	C	E	F	G	I	J	L	M	N	P	Q	R
1–5	MCRs				RELEVANT PPM		MCR x TRANSLATOR		COMPILED BY MATERIAL			PER-UNIT CONVERSION		
					Weapon Ref # 1	Weapon Ref # 2	Weapon Ref # 1	Weapon Ref # 2		Weapon Ref # 1	Weapon Ref # 2		Weapon Ref # 1	Weapon Ref # 2
					MET	MET	MET	MET		MET 888	MET 999		MET 888	MET 999
6	ILIAD Sector	Material	Demand per $B of Sector Output	ILIAD Sector	888	999	888	999	Material	Units of material demanded per 2005 $1B of MET		Material	Number of units of material per weapon	
7	113	ALMNM_LITH	5289	113	0.0156250	0.0144928	82.6406250	76.6521739	ALMNM_LITH	125.8170956	95.4726867	ALMNM_LITH	2.5163419	1.9094537
8	33	ALMNM_LITH	1468	33	0.0294118	0.0128205	43.1764706	18.8205128	ALMNM_OXIDE	878.0233333	351.3202020	ALMNM_OXIDE	17.5604667	7.0264040
9	35	ALMNM_OXIDE	8347	35	0.0200000	0.0111111	166.9400000	92.7444444	ANTIMONY	156.0401226	123.3799373	ANTIMONY	3.1208025	2.4675987
10	310	ALMNM_OXIDE	8533	310	0.0833333	0.0303030	711.0833333	258.5757576	BERYL	235.5081751	506.5555556	BERYL	4.7101635	10.1311111
11	256	ANTIMONY	2054	256	0.0103093	0.0181818	21.1752577	37.3454545	BERYLLIUM_COPPER	0.0000000	0.0000000	BERYLLIUM_COPPI	0.0000000	0.0000000
12	199	ANTIMONY	4990	199	0.0270270	0.0172414	134.8648649	86.0344828	BERYLLIUM_METAL	3308.0000000	1586.7012987	BERYLLIUM_METAI	66.1600000	31.7340260
13	272	BERYL	5593	272	0.0208333	0.0555556	116.5208333	310.7222222	BISMUTH	137.6483721	76.6367347	BISMUTH	2.7529674	1.5327347
14	58	BERYL	9400	58	0.0126582	0.0208333	118.9873418	195.8333333	BORON	1039.0714286	102.4830907	BORON	20.7814286	2.0496618
15	126	BERYLLIUM_COPI	4421	126	0.0142857	0.0526316	63.1571429	232.6842105	CERIUM	256.6271860	136.0938889	CERIUM	5.1325437	2.7218778
16	309	BERYLLIUM_COPI	1865	309	0.0344828	0.0243902	64.3103448	45.4878049	CHROMIUM_FER	861.6435185	466.9507640	CHROMIUM_FER	17.2328704	9.3390153
26	151	CHROMIUM_FER	3849	151	0.0123457	0.0322581	47.5185185	124.1612903	GADOLINIUM	381.0592593	175.0000000	GADOLINIUM	7.6211852	3.5000000
27	171	CHROMIUM_MET	9335	171	0.0185185	0.0294118	172.8703704	274.5588235	GALLIUM	171.6309428	148.9172932	GALLIUM	3.4326189	2.9783459
28	31	CHROMIUM_MET	3122	31	0.0163934	0.0212766	51.1803279	66.4255319	GERMANIUM	1142.2777778	386.6577540	GERMANIUM	22.8455556	7.7331551
29	232	COBALT	7614	232	0.0555556	0.0119048	423.0000000	90.6428571	GRAPHITE	1318.0695971	225.7026876	GRAPHITE	26.3613919	4.5140538
30	324	COBALT	7101	324	0.2000000	0.0119048	1420.2000000	84.5357143	IRIDIUM	97.5032901	176.3451079	IRIDIUM	1.9500658	3.5269022
31	194	COLUMBIUM	8833	194	0.0227273	0.0149254	200.7500000	131.8358209	IRIDIUM_PLAT	433.0416667	303.0260417	IRIDIUM_PLAT	8.6608333	6.0605208
32	175	COLUMBIUM	4402	175	0.0117647	0.0416667	51.7882353	183.4166667	LANTHANUM	228.4684550	230.8863636	LANTHANUM	4.5693691	4.6177273
33	58	CSM	5217	58	0.0126582	0.0208333	66.0379747	108.6875000	LEAD	332.4878665	335.5908451	LEAD	6.6497573	6.7118169
34	154	CSM	8393	154	0.0126582	0.3333333	106.2405063	2797.6666667	LITHIUM	337.1580882	404.7464539	LITHIUM	6.7431618	8.0949291
35	329	DYSPROSIUM	7885	329	0.0500000	0.0588235	394.2500000	463.8235294	MAGNESIUM	1011.1121951	351.0961792	MAGNESIUM	20.2222439	7.0219236
36	45	DYSPROSIUM	2780	45	0.0250000	0.0111111	69.5000000	30.8888889	MANGNS_FER	127.9236111	292.8888889	MANGNS_FER	2.5584722	5.8577778
37	225	ERBIUM	3141	225	0.0135135	0.0188679	42.4459459	59.2641509	MANGNS_METAL	171.9531375	3950.3409091	MANGNS_METAL	3.4390628	79.0068182
38	65	ERBIUM	2514	65	0.0322581	0.0500000	81.0967742	125.7000000	MANGNS_ORE_CHEI	214.0192308	1633.7500000	MANGNS_ORE_CH	4.2803846	32.6750000
39	191	EUROPIUM	2931	191	0.0125000	0.0120482	36.6375000	35.3132530	MINOR_RARE_EARTI	139.2955063	150.4211962	MINOR_RARE_EAI	2.7859101	3.0084239
40	245	EUROPIUM	6819	245	0.0555556	0.0163934	378.8333333	111.7868852	NEODYMIUM	274.4806384	308.3909574	NEODYMIUM	5.4896128	6.1678191
41	168	FLRSPR_ACID	9992	168	0.0135135	0.0169492	135.0270270	169.3559322	NICKEL	326.3847953	972.1203390	NICKEL	6.5276959	19.4424068

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B. Internal Model Calculations

After all of the necessary data have been input, WSSMEP automatically calculates material requirements. The operations are executed without additional user input.

Operation 1

- Excel automatically pulls the input data from the “Input MCR sheet” and recreates these data on the “Calculations” sheet.

Values

MCRs		
ILIAD Sector	**Material**	**Demand per $B of Sector Output**
113	ALMNM_LITH	96

Formulas

MCRs		
ILIAD Sector	**Material**	**Demand per $B of Sector Output**
='Input MCR'!$A2	='Input MCR'!$B2	='Input MCR'!$C2

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Slides 12–16 detail the operations step by step.

IDA | Operation 2

- Excel also automatically retrieves relevant PPM values by searching the “Input PPM” sheet for a particular weapon/sector combination.
  - This is an array formula. If the user modifies it, he/she must press CTRL + SHIFT + ENTER to reexecute.

Values

RELEVANT PPM VALUES	
Weapon Ref #	1
Weapon Name	MiG-31
ILIAD Sector	
113	0.0066000

Formulas

Weapon Ref #	='Input Weapon Data'!$A$2
Weapon Name	=VLOOKUP(F$4,'Input Weapon Data'!$A$2:$C$8,2)
ILIAD Sector	
=A7	=INDEX('Input PPM'!$A$2:$C$2633,MATCH(1,('Input PPM'!$A$2:$A$2633=$F$4)*('Input PPM'!$B$2:$B$2633=$E7),0),3)

Operation 3

- Excel then multiplies the MCR vector by the relevant PPM vector.
  - This sum represents the amount of material required *by a specific economic sector* to produce $1-billion worth of the weapon.

Values

MCR x RELEVANT PPM VALUES		
Weapon Ref #		1
Weapon Name		MiG-31
ILIAD Sector	**Material**	
113	ALMNM_LITH	0.6336000
33	ALMNM_LITH	0.0990000

Formulas

MCR x RELEVANT PPM VALUES		
Weapon Ref #		='Input Weapon Data'!$A$2
Weapon Name		=VLOOKUP(P$4,'Input Weapon Data'!$A$2:$C$8,2)
ILIAD Sector	**Material**	
=A7	=B7	=$C7*F7

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IDA | Operation 4

- Excel compiles material requirements for the entire weapon by summing across all economic sectors.
  - This sum represents the amount of material required *across all sectors* to produce $1-billion worth of the weapon.

Values

COMPILED BY MATERIAL			
Weapon Ref #	1	2	3
Weapon Name	MiG-31	T-90	SS-N-25
Material	**Units of material demanded per $1B of weapon**		
ALMNM_LITH	0.7326000	0.6627000	0.4866000

Formulas

COMPILED BY MATERIAL	
Weapon Ref #	='Input Weapon Data'!$A$2
Weapon Name	=VLOOKUP(Y$4,'Input Weapon Data'!$A$2:$C$8,2)
Material	**Units of material demanded per $1B of weapon**
='Input Material Data'!A2	=SUMIF($B$7:$B$10000,$X7,$P$7:$P$10000)

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IDA | Operation 5

- Lastly, Excel multiplies by the unit price of the weapon and conducts unit conversion to derive a per-unit material requirement.

Values

PER-UNIT CONVERSION

Weapon Ref #	1
Weapon Name	MiG-31
Material	**Number of units of material per weapon**
ALMNM_LITH	0.0073260
ALMNM_OXIDE	0.0057020
ANTIMONY	0.0073860
BERYL	0.0076500

Formulas

PER-UNIT CONVERSION

Weapon Ref #	='Input Weapon Data'!$A$2
Weapon Name	=VLOOKUP(AH$4,'Input Weapon Data'!$A$2:$C$8,2)
Material	**Number of units of material per weapon**
=X7	=$Y7*'Input Weapon Data'!$C$2/(10^6)

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Sheet 6: Results Summary

- The "Results Summary" sheet shows material requirements for one unit of the weapon, expressed either in the mass unit associated with the particular material, short tons (for ease of comparison), and material cost.

	Material Name	Long Name	Units	Weapon Reference Number 1: MiG-31 — REQUIREMENTS Amount in Units	Amount in Short Tons	Amount in Dollars	Weapon Reference Number 2: T-90 — REQUIREMENTS Amount in Units	Amount in Short Tons	Amount in Dollars
8	ALMNM_LITH	Aluminum Lithium Alloys	Metric Tons	0.0073260	0.0080755	7.3260000	0.0066270	0.0073050	6.6270000
9	ALMNM_OXIDE	Aluminum Oxide Fused Crude	Short Tons	0.0057020	0.0057020	5.7020000	0.0064490	0.0064490	6.4490000
10	ANTIMONY	Antimony	Short Tons	0.0073860	0.0073860	7.3860000	0.0053640	0.0053640	5.3640000
11	BERYL	Beryl Ore	Short Tons	0.0076500	0.0076500	7.6500000	0.0056550	0.0056550	5.6550000
12	BERYLLIUM_COPPER	Beryllium Copper Master Alloy	Short Tons	0.0100280	0.0100280	10.0280000	0.0073000	0.0073000	7.3000000
13	BERYLLIUM_METAL	Beryllium Metal	Short Tons	0.0013900	0.0013900	1.3900000	0.0042650	0.0042650	4.2650000
14	BISMUTH	Bismuth	Pounds	0.0061700	0.0000031	6.1700000	0.0038480	0.0000019	3.8480000
15	BORON	Boron	MT Oxide	0.0062610	0.0069016	6.2610000	0.0021830	0.0024063	2.1830000
16	CERIUM	Cerium	MT Oxide	0.0047700	0.0052580	4.7700000	0.0038580	0.0042527	3.8580000
17	CHROMIUM_FER	Chromium Ferro (Ferrochromium)	Short Tons	0.0037720	0.0037720	3.7720000	0.0040700	0.0040700	4.0700000
18	CHROMIUM_METAL	Chromium Metal	Short Tons	0.0009440	0.0009440	0.9440000	0.0023650	0.0023650	2.3650000
19	COBALT	Cobalt	Pounds Co	0.0108990	0.0000054	10.8990000	0.0106800	0.0000053	10.6800000
20	COLUMBIUM	Columbium	Pounds Cb	0.0004770	0.0000002	0.4770000	0.0007470	0.0000004	0.7470000

C. Data Sources

All data are automatically referenced from other sheets. No user input is required.

IDA | WSSMEP Notes

- WSSMEP can be run for any weapon that has a Defense Translator vector *and* uses materials that have MCRs. However, because not all weapons have Defense Translator vectors and not all materials have MCRs, a not-insignificant portion of the U.S. arsenal cannot be analyzed with WSSMEP.
- WSSMEP is dynamic. It must be updated in response to new materials, new Defense Translators, new MCRs, and so forth.
- WSSMEP is conceptually simple and can be—and, in fact, has been—programmed in formats other than Excel.

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5. WSSMEP Notes

WSSMEP can be run for any weapon that has a Defense Translator vector *and* uses materials that have MCRs. It is dynamic and must be updated to reflect new processes, and it can be run in formats other than Microsoft Excel. For example, some components of WSSMEP are found in the Forces Mobilization Model (FORCEMOB), which is programmed in Fortran.

WSSMEP vs. Other Methods for Material Requirements (1 of 3)

WSSMEP is one method for determining material requirements, but it is not the sole or even primary way of doing so. Consider the following points (items 1–7):

1. The calculation of material requirements and shortfalls has three main stages:
   a. Step A, in which required U.S. economic production during a national emergency is calculated;
   b. Step B, in which material requirements implied by this production are computed
   c. Step C, in which these material requirements are compared against U.S. and foreign supplies to identify shortfalls.
2. WSSMEP, which calculates the industrial production levels needed for a particular weapon *and* the material requirements thereof, thus spans Steps A and B.
3. Material requirements analysis must take into account “base” defense, “conflict” defense, essential civilian, and emergency investment needs. Base defense refers to normal Future Years Defense Plan (FYDP)-level spending, while conflict defense refers to the need to regenerate specific forces lost or expended in the conflict scenario.

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6. WSSMEP vs. Other Methods for Material Requirements

WSSMEP is one method for determining material requirements, but it is not the sole or even primary way of doing so, as discussed in slides 20 and 21.

WSSMEP vs. Other Methods for Material Requirements (2 of 3)

4. WSSMEP, which is narrowly focused on per-unit weapons requirements, does not support the analysis of base defense, essential civilian, or emergency investment needs. WSSMEP is not designed, for example, to assess the material requirements from base force maintenance and operations or from domestic automobile production.
5. For these reasons, the Forces Mobilization Model (FORCEMOB) also is used to calculate production and material requirements for analysis supporting NDS RRs. Like WSSMEP, FORCEMOB uses PPMs and weapon costs to calculate production requirements for Major End Items (MEIs) lost in a conflict scenario. However, FORCEMOB takes into account base defense, civilian, and investment demands not modeled in WSSMEP, all of which require extensive preprocessing and modeling. FORCEMOB aggregates the weapon-specific production estimates into these broader tiers of demand and outputs aggregated production estimates. These estimates then are used to derive material requirements in a separate step.
6. A main value proposition of WSSMEP is less labor than the aforementioned “normal” method of calculating material requirements. WSSMEP’s narrow focus on per-unit weapon requirements means, for example, that no ILIAD or Long-term Interindustry Forecasting Tool (LIFT) runs are required and that a separate step is not needed for computing material requirements based on industrial production levels.

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WSSMEP vs. Other Methods for Material Requirements (3 of 3)

7. As such, WSSMEP can be thought of as reporting the results of a subset of FORCEMOB and the “normal” material demand computation. It isolates the impact of weapons production on S&CM requirements, rather than rolling it up into broad tiers of demand. In this sense, WSSMEP is useful to explicitly report weapon-specific results within RAMF-SM. It also is useful in other circumstances. Periodically, Congress and/or the sponsor have shown interest in the material requirements of key weapons systems. WSSMEP (which focuses on single weapons) may be better suited to calculate this than the normal process (which focuses on aggregate categories of demand).

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IDA | Further Reference

WSSMEP

Schwartz, Eleanor. "Weapons-Specific Strategic Material Estimation Process." Alexandria, VA: Institute for Defense Analyses, 2013.

Thomason, Jim, Jim Bell, Eleanor Schwartz, Bob Atwell, Dick Van Atta, Nicholas Karvonides, Zack Rabold, Tiki Mitchell, et al. "Key Materials for High-Priority Weapons Systems and Assessing Risks to Their Supply: A Report for the US Defense National Stockpile Center." Alexandria, VA: Institute for Defense Analyses, 2008.

Defense Translators

Lloyd, Justin. "RAMF-SM Defense Translator Update Summary." Alexandria, VA: Institute for Defense Analyses, 2013.

Material Consumption Ratios

Schwartz, Eleanor. "Material Consumption Ratios and the Computation of Material Demand from Industrial Demand." Alexandria, VA: Institute for Defense Analyses, 2013.

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7. Further Reference

This slide provides sources for more detailed documentation material.

Appendix A
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Appendix B
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Thomason, James S., Robert J. Atwell, D. Sean Barnett, James P. Bell, Michael F. Fitzsimmons, Nicholas S. J. Karvonides, Julie C. Kelly, et al. “Strategic and Critical Materials 2013 Report on Stockpile Requirements.” IDA Paper NS P-4901. Alexandria, VA: Institute for Defense Analyses, 2013.

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Schwartz, Eleanor. “Material Consumption Ratios and the Computation of Material Demand from Industrial Demand.” Alexandria, VA: Institute for Defense Analyses, 2013.

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Appendix C
Abbreviations

BEA	Bureau of Economic Analysis
CAPE	Cost Assessment and Performance Evaluation
CD	compact disc
DLA	Defense Logistics Agency
DOC	Department of Commerce
DOD	Department of Defense
FORCEMOB	Forces Mobilization Model
FYDP	Future Years Defense Plan
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
NDS	National Defense Stockpile
OSD	Office of the Secretary of Defense

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14. ABSTRACT

The Weapon-Specific Strategic Material Estimation Process (WSSMEP) is a modeling tool used to estimate the demand for strategic and critical materials generated by production of a U.S. weapons system. This annotated briefing is intended to train a new user on operation of WSSMEP. It is intended to be used in conjunction with a training version of WSSMEP available on CD from IDA Control and Distribution

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