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Supply Chain Modeling for Fluorspar and Hydrofluoric Acid and Implications for Further Analyses

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About This Publication

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INSTITUTE FOR DEFENSE ANALYSES

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Supply Chain Modeling for Fluorspar and Hydrofluoric Acid and Implications for Further Analyses

D. Sean Barnett
Jerome Bracken

Executive Summary

This briefing presents the modeling of the supply chains for acid-grade fluorspar and hydrofluoric acid (HF) conducted by the Institute for Defense Analyses (IDA) to support the preparation of the *Strategic and Critical Materials 2015 Report on Stockpile Requirements* by the Defense Logistics Agency Strategic Materials (DLA SM).[1] It also notes other materials of interest to DLA SM where supply chain analysis could be helpful in assessing risks of possible material shortages associated with the downstream processing of raw materials.

Acid-grade fluorspar is projected to suffer a shortfall in the FY 2015 National Defense Stockpile (NDS) Requirements Report. In the United States, most acid-grade fluorspar is used to produce HF, which is used to make most of the fluorine-containing products in the United States. Thus, an adequate supply of fluorspar is needed to ensure the production of HF sufficient to meet U.S. demand for fluorine-containing goods. Imported HF is also a potential substitute for fluorspar and might be able to make up for its shortfall if the accessible global HF supply is sufficient.

This briefing describes an analysis of the fluorspar (calcium fluoride (CaF_2)) and hydrofluoric acid (aqueous hydrogen fluoride (HF)) supply chain using the Downstream Risk Assessment Methodology (DRAM). IDA developed DRAM, a methodology for analyzing material supply chains, to enable DLA to check the usability of any downstream (processed) materials nominated for stock-piling and to identify shortfalls of downstream materials even when no upstream material shortfalls exist.[2]

The fluorspar and the HF supply chains are analyzed using the same approach that IDA used on behalf of DLA SM to assess shortfalls for other materials that are candidates for stockpiling. The fluorspar analysis shows a gross (i.e., unmitigated) shortfall of 71,847 metric tons (MT) in the standard Base Case military conflict planning scenario in the first year (with no shortfalls in later years). The associated HF shortfall/surplus analysis shows a gross HF shortfall of 53,970 MT if the fluorspar shortfall is *not* mitigated (i.e., there are no shortfalls in later scenario years). The analysis also shows a gross HF shortfall of 22,150 MT even if the fluorspar shortfall

1 Department of Defense, *Strategic and Critical Materials 2015 Report on Stockpile Requirements* (Washington, DC: Office of the Under Secretary of Defense for Acquisition, Technology and Logistics, to be published).

2 D. Sean Barnett and Jerome Bracken, *Supply Chain Modeling: Downstream Risk Assessment Methodology (DRAM) Demonstration of Capability*, IDA Document D-5347 (Alexandria VA: Institute for Defense Analyses, to be published).

is completely mitigated. U.S. HF capacity and imported supply (under Base Case conditions) are not sufficient to meet demand. Thus, shortfalls of fluorspar and HF must be mitigated.

Following the approach taken for other materials in the FY 2015 NDS Requirements Report, potential market responses to the fluorspar and HF shortfalls have been evaluated to estimate net shortfalls for these materials. In both cases, it has been estimated that material conservation ("thrifting" in the language of the FY 2015 report) could reduce demand by about 15 percent, which would be sufficient to eliminate shortfalls of both materials. Thus, further government action is unlikely to be required to mitigate the shortfalls.

The fluorspar/HF case shows the value of supply chain analysis: identifying a shortfall in a downstream material form that exists because of inadequate domestic and foreign downstream material processing capacity. DLA could potentially experience shortfalls in many other materials of interest in their downstream forms because the downstream processing capacities exist in foreign countries or as possibly vulnerable single points of failure in their supply chains. Such materials could also potentially benefit from supply chain analysis.

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1. Introduction

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These Slides are Unclassified and Not Proprietary

Supply Chain Modeling for Fluorspar and Hydrofluoric Acid and Implications for Further Analyses

Dr. Sean Barnett

Dr. Jerry Bracken

November 24, 2014

Institute for Defense Analyses

This briefing presents the modeling of the supply chains for acid-grade fluorspar (calcium fluoride (CaF_2)) and hydrofluoric acid (aqueous hydrogen fluoride (HF)) conducted by the Institute for Defense Analyses (IDA) to support the preparation of the *Strategic and Critical Materials 2015 Report on Stockpile Requirements*[1] by the Defense Logistics Agency Strategic Materials (DLA SM). Almost all of the acid-grade fluorspar used in the United States is used to make HF, which, in turn, is the precursor for most fluorine-containing products made in the United States.[2,3]

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1 Department of Defense, *Strategic and Critical Materials 2015 Report on Stockpile Requirements* (Washington, DC: Office of the Under Secretary of Defense for Acquisition, Technology and Logistics, to be published).

2 U.S. Department of the Interior, *Mineral Commodity Summaries 2014* (Reston, VA: U.S. Geological Survey, 2014), 56–57. http://minerals.usgs.gov/minerals/pubs/mcs/2014/mcs2014.pdf.

3 U.S. Geological Survey, private communication, November 2013.

IDA | # Agenda

- Analytical Issue
- Background – Conditions of Analysis
  - Situation Concerning Fluorspar and Hydrofluoric Acid (aqueous HF)
  - NDS Base Case Scenario
- Fluorspar Analysis
- HF Analysis
- Combined Supply Chain Analysis and Shortfall Results
- Net Shortfall Assessment
- Conclusions of Fluorspar-HF Case Study and Further Recommendations

1

As outlined on the slide, this briefing presents IDA's work in modeling the supply chain for fluorspar and HF and assessing possible material shortfalls in the event of a national emergency. The briefing also makes recommendations for further analysis concerning other materials of interest to DLA SM for which supply chain analysis could be helpful in assessing risks of possible shortfalls associated with the downstream processing of raw materials.

2. Main Body

Analytical Issue

- Supply chain analysis for fluorspar (acid-grade) and hydrofluoric acid (HF)
  - Acid-grade fluorspar is a shortfall material for FY 2015 National Defense Stockpile (NDS) Base Case planning scenario
  - Most (95 percent) acid-grade fluorspar used in the United States is used to make HF
  - Thus, imported HF is a potential substitute for fluorspar and might be able to make up for some or all of fluorspar shortfall
  - However, HF supply must also be sufficient to meet U.S. demand, even if fluorspar supply is adequate (e.g., if fluorspar was stockpiled)
- Analysis performed using Downstream Risk Assessment Methodology (DRAM)
  - Reproduce Stockpile Sizing Module fluorspar shortfall calculations
  - Determine adequacy of HF supply
  - Determine extent to which HF might be able to substitute for fluorspar (and make up for fluorspar shortfall) or HF shortfall might require mitigation

2

This slide outlines the analytical issue and the approach taken to perform the analysis. The rationale for selecting the acid-grade fluorspar and HF supply chain for analysis was that acid-grade fluorspar is projected to suffer a shortfall in the Base Case planning scenario for the FY 2015 National Defense Stockpile (NDS) Requirements Report and is closely linked in the manufacturing process to HF, which is an important industrial chemical in the United States.[1] Almost all (approximately 95 percent)of the acid-grade fluorspar used in the United States goes into the production of HF, which, in turn, is the precursor for most fluorine-containing products made in the United States.[2] Thus, an adequate supply of fluorspar is needed to ensure that the production of HF is sufficient to meet U.S. demand for fluorine-containing goods. Imported HF, which is also a potential substitute for fluorspar, might be able to make up for some or all of the fluorspar shortfall if the accessible global HF supply is sufficient.[3]

The fluorspar and HF supply chain was analyzed using the Downstream Risk Assessment Methodology (DRAM). IDA developed DRAM, a methodology for analyzing material supply chains, to enable DLA to check the usability of any downstream (processed) materials nominated for stockpiling and to identify shortfalls of downstream materials even when no upstream material shortfalls exist.[4]

In the first step of the analysis, the fluorspar supply chain was modeled, and fluorspar supply and demand were analyzed using the same analytical approach that IDA uses on behalf of DLA SM to assess shortfalls for materials that are candidates for stockpiling. That approach is normally implemented within the Risk Assessment and Mitigation Framework for Strategic Materials (RAMF-SM).[5]The second step of RAMF-SM assesses material shortfalls under the planning scenario conditions specified by DLA, and, within that step, the Stockpile Sizing Module performs the shortfall calculations. The next step in the analysis estimated the HF supply (in light of the fluorspar supply) and HF demand, using the same approach that was used for fluorspar. The analysis was conducted to determine whether there was an HF surplus that would enable HF to substitute for fluorspar (and make up for the fluorspar shortfall) or an HF shortfall that would require mitigation.

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1 Department of Defense, *Strategic and Critical Materials 2015 Report on Stockpile Requirements,* 12.

2 U.S. Department of the Interior, *Mineral Commodity Summaries 2014* (Reston, VA: United States Geological Survey (USGS), 2014), 56-57.

3 Lower grade fluorspar is another possible substitute for acid-grade fluorspar for HF production.

4 D. Sean Barnett and Jerome Bracken, *Supply Chain Modeling: Downstream Risk Assessment Methodology (DRAM) Demonstration of Capability*, IDA Document D-5347 (Alexandria VA: Institute for Defense Analyses, to be published).

5 James S. Thomason et al, *Analyses for the 2015 National Defense Stockpile Requirements Report to Congress on Strategic and Critical Material,* IDA Paper P-5190 (Alexandria VA: Institute for Defense Analyses, to be published), Volume 1, Chapter 2.

Background – Conditions of Analysis

- **Fluorspar**
  - **Mineral fluorite (mostly calcium fluoride (CaF_2)), primary source of fluorine used in commerce; divided into two grades: acid-grade (> 97 percent CaF_2) and metallurgical-grade (≤ 97 percent CaF_2)**
  - **Acid-grade almost entirely (95 percent) used to make HF**
  - **U.S. supply almost all imported (from many countries)**
  - **Large increase in demand projected between now and 2017**
  - **Shortfall material for FY 2015 scenario (2017–2020)**
- **Hydrofluoric acid**
  - **Important industrial chemical; precursor to most fluorine-containing products made in the United States**
  - **Substitute for acid-grade fluorspar if available. In FY 2013 Base Case, imported HF supply covered entire fluorspar shortfall**
  - **U.S. normally imports HF in addition to fluorspar used to make HF. Domestic HF capacity not sufficient to meet U.S. HF demand**
- **FY 2015 NDS Base Case scenario**
  - **Scenario demand (economic growth, wartime austerity, increased defense demand)**
  - **Scenario supply (decrements to foreign supply)**

3

Fluorspar is a mineral, also known as fluorite, that consists mostly of calcium fluoride (CaF_2). It is the world's primary source of fluorine. Fluorspar is generally divided into two grades: acid-grade (which is greater than 97 percent CaF_2) and metallurgical-grade (which is less than or equal to 97 percent CaF_2). Almost all (approximately 95 percent) of the acid-grade fluorspar used in the United States goes into the production of HF, and almost all of the fluorspar used by the United States is imported (from many supplier countries).[6] For the main military conflict scenario used in planning for the FY 2015 NDS Requirements Report, in the Base Case, which begins in 2017, a large increase in U.S. demand for fluorspar, relative to current annual demand, is projected. Under the conditions of the Base Case, which includes the cutoff or reduction of supply from certain supplier countries, a fluorspar shortfall is projected to occur.[7]

Hydrofluoric acid is the aqueous solution of the compound, hydrogen fluoride, or HF. It is an important industrial chemical that serves as the precursor for almost all fluorine-containing products made in the United States. Because HF is needed to produce fluorine-containing goods, imported HF can serve as a substitute for fluorspar (which is normally mostly imported and almost all of which is converted into HF in the United States). The United States normally imports HF (usually in concentrated solutions as the acid) in addition to the acid-grade fluorspar used to make HF because the U.S. domestic HF capacity is not sufficient to meet U.S. HF demand.[8] However, significant quantities of HF are ordinarily available from foreign sources. Indeed, in the Base Case for the FY 2013 NDS Requirements Report, the imported HF supply was assessed as being sufficient to make up for the entire acid-grade fluorspar shortfall projected in that report.[9]

The planning basis for the fluorspar-HF analysis (and the analysis of the other stockpile candidates in the FY 2015 NDS Requirements Report) is the Base Case scenario. The Base Case is a four-year scenario, beginning in 2017, with one year of conflict followed by three years of recovery/regeneration. It includes baseline (Future Years Defense Program (FYDP)) defense sector demands plus those demands necessary to regenerate weapon systems lost and munitions expended in the conflict. It also includes essential civilian sector demands. Material supplies available to the United States from foreign countries may be decremented due to political reliability, war damage, or shipping losses.[10]

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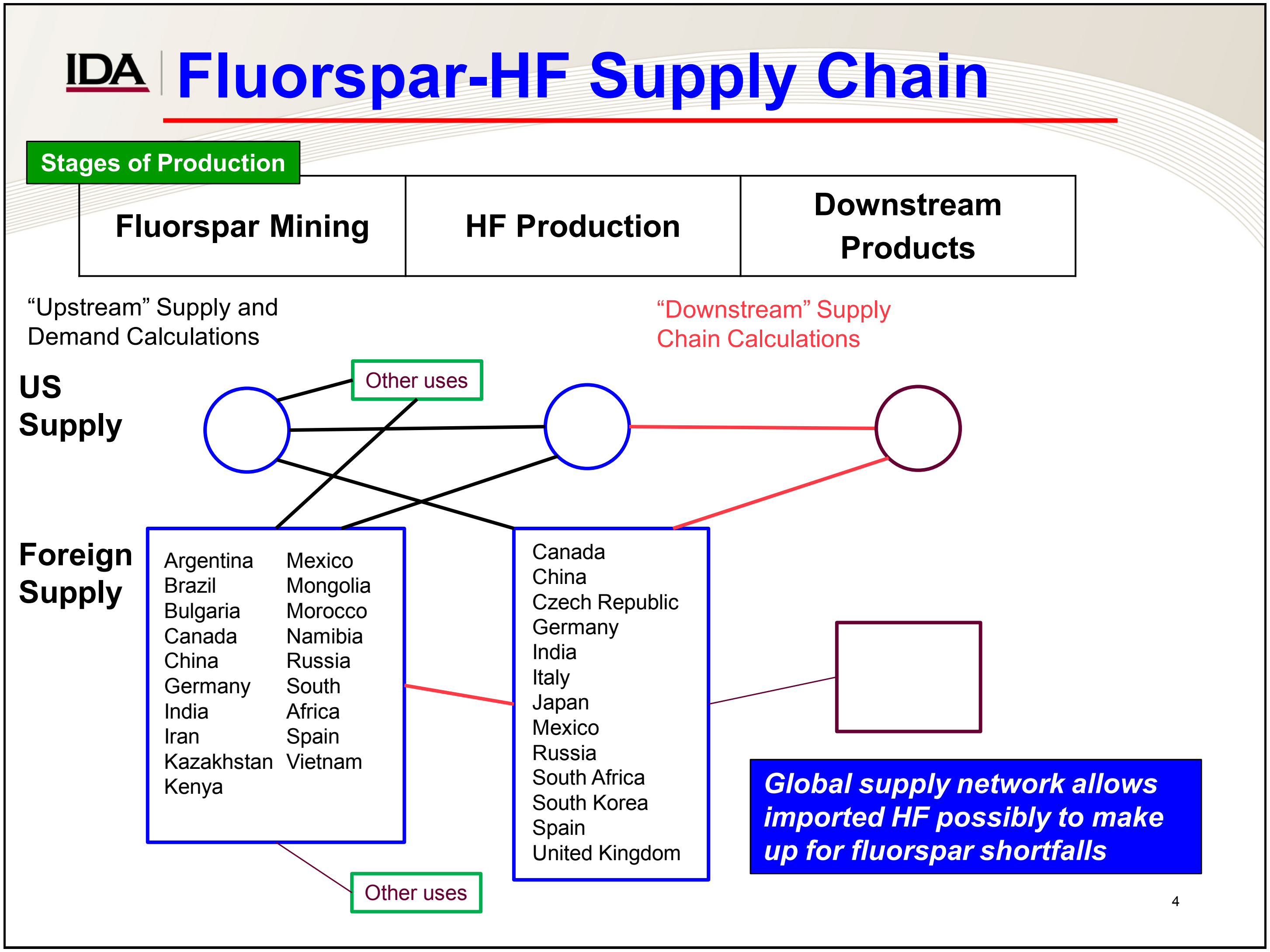
6 Roskill Information Services Limited, *Fluorspar: Global Industry Markets and Outlook*, 11th ed (London: Roskill, 2013), 19, 143.

7 Thomason, *Analyses for the 2015 National Defense Stockpile Requirements Report to Congress on Strategic and Critical Materials*, Volume 1 Chapter 3.

8 Roskill, *Fluorspar: Global Industry Markets and Outlook*, 142–144.

9 Department of Defense, *Strategic and Critical Materials 2013 Report on Stockpile Requirements* (Washington, DC: Office of the Under Secretary of Defense for Acquisition, Technology and Logistics, 2013), Appendix 9.

10 Thomason, *Analyses for the 2015 National Defense Stockpile Requirements Report to Congress on Strategic and Critical Materials*, Volume 1 Chapter 2.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Fluorspar-HF Supply Chain
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South Africa
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Other uses
Global supply network allows imported HF possibly to make up for fluorspar shortfalls
4

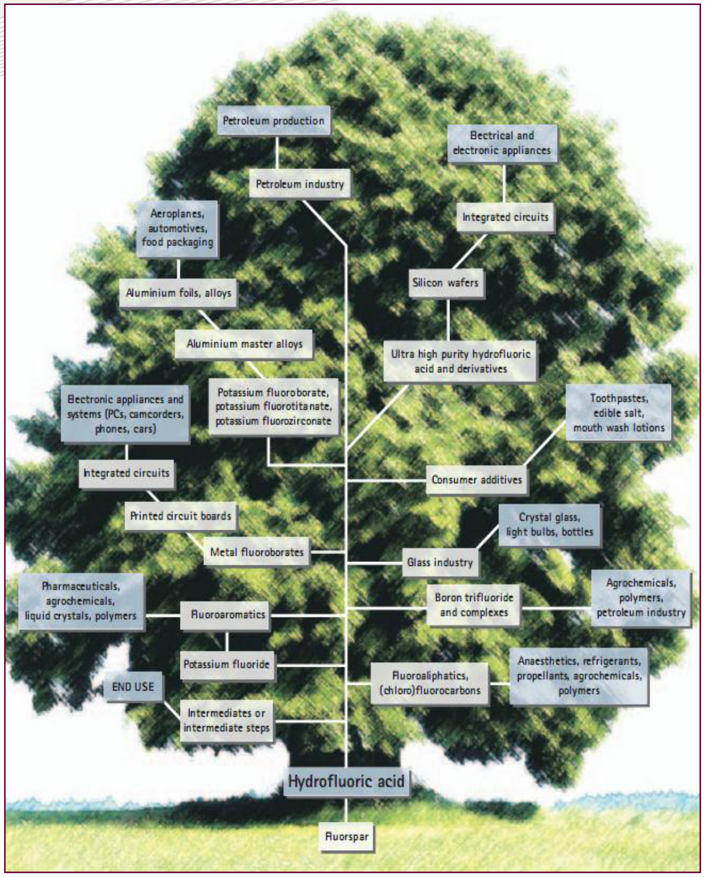
This slide depicts the global fluorspar/HF supply chain, as follows:

- The three stages of the chain considered in the analysis are listed across the top: Fluorspar Mining, HF Production, and (production of) Downstream Products (using HF).
- U.S. supply is represented by the blue circles, foreign supply is represented by the blue rectangles (with foreign producers listed),[11] and U.S. and foreign consumption of fluorspar for applications other than HF (e.g., aluminum production) is represented by the green rectangles.
- U.S. consumption of HF (to make fluorine-containing products) is represented by the maroon circle. Foreign consumption of HF is represented by the maroon rectangle.
- The lines depict material flows from fluorspar mining, to HF production, to downstream fluorine-containing products.
  - Black lines are material flows included in the supply and demand analysis conducted as part of the ordinary "upstream" material shortfall analysis.
  - Red lines are material flows included in the supply and demand analysis conducted as part of the "downstream" supply chain shortfall analysis.

[11] The USGS provides fluorspar supply data to IDA. For HF supply, see Roskill, *Fluorspar: Global Industry Markets and Outlook*, 162.

IDA

Selected Fluorine Products Supply Chains



Downstream Products

↑

HF Production

↑

Fluorspar Mining

5

This slide shows the supply chains for many important fluorine-containing products.[12,13] All of the chains begin with acid-grade fluorspar and HF and then branch downstream into many different types of intermediate and end-use products.

[12] EUROFLUOR Webpage, "A Snapshot of the Fluorine Industry: HF Applications," accessed December 29, 2014, http://www.eurofluor.org/hf-applications/.

[13] Roskill, *Fluorspar: Global Industry Markets and Outlook*, 163.

IDA Fluorspar Analysis

- **Shortfall analysis identical to RAMF-SM Step 2 (demand projection and Stockpile Sizing Module) for modeled materials**
- **Supply calculations**
  - **Estimated production and capacity for supplier countries by year**
  - **Production ramp-up effects**
  - **Foreign supplier decrements: ability, willingness, war damage, shipping losses (figures are classified)**
  - **U.S. market share: based on GDP or imports vs. foreign production**
- **Demand calculations**
  - **Forecast future demand: civilian (future economic output) and military (FYDP and conflict)**
  - **Civilian austerity measures**
- **Shortfall analysis**
  - **Demand minus supply = 71,847 metric tons (MT) in Base Case first year (no shortfalls in later years)**
  - **Shortfall possibly mitigated by imported HF (pending calculation)**

6

The supply chain analysis proceeded as follows. As noted, the shortfall analysis for fluorspar was identical to the analysis performed for other stockpile candidate materials using RAMF-SM and the Stockpile Sizing Module. Supply calculations included the estimated production and capacity for supplier countries by year, production ramp-up effects, and foreign supplier decrements based on ability, willingness, war damage, and shipping losses (values are classified). The U.S. market share of foreign materials, based on gross domestic product (GDP) or imports vs. foreign production, was also considered. Demand calculations included forecast future demand—civilian (future economic output) and military (FYDP and conflict demand)—and civilian austerity measures.[14] The shortfall analysis showed a fluorspar shortfall of 71,847 metric tons (MT) (79,198 short tons) in the Base Case scenario in the first year.[15] It showed no shortfalls in later years.[16] The next step was to model HF supply and demand and to determine whether the fluorspar shortfall could be mitigated by imported HF.

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[14] Thomason, *Analyses for the 2015 National Defense Stockpile Requirements Report to Congress on Strategic and Critical Materials,* Volume 1, Chapter 2.

[15] This analysis follows the convention used to calculate Base Case shortfalls in IDA Paper P-5190. In the FY 2015 NDS Requirements Report, the Base Case shortfall analysis excludes material supply from domestic sole sources ("single points of failure"). The United States is projected to have only one fluorspar mine operating during the Base Case scenario, so the fluorspar shortfall reported in the FY 2015 NDS Requirements Report is larger: 106,847 MT (117,779 short tons). If supply from the sole U.S. source had been excluded from the analysis in this document, the unmitigated fluorspar shortfall would have been 35,000 MT (38,581 short tons) larger, and the unmitigated HF shortfall would have been 15,909 MT (17,537 short tons) larger. IDA Paper P-5190 addresses the effects of single points of failure in Volume I, Chapter 5.

[16] In the later years of the scenario, supplier country reliabilities, U.S. access to formerly unavailable supply, and U.S. demand change such that materials experiencing shortfalls in the first year of the scenario may not experience shortfalls in later years.

HF Analysis

- Shortfall analysis is the same process as fluorspar, but supplier countries, capacities, and future production levels differ
- Supply calculations
  - Estimated production and capacity for supplier countries by year
  - Production ramp-up effects
  - U.S. HF production depends on adequate fluorspar supply
  - Foreign supplier decrements: ability, willingness, war damage, shipping losses (figures are classified)
  - U.S. market share: based on GDP or imports vs. foreign production
- Demand calculations
  - Based on fluorspar demand estimate (use of fluorspar to make HF)
- Shortfall/surplus analysis
  - Demand minus supply = 53,970 MT shortfall if fluorspar shortfall *not* mitigated (no shortfalls in later years)
    - Shortfall = 22,150 MT if fluorspar shortfall *is* mitigated. U.S. HF capacity and imported supply is not sufficient to meet demand
  - HF shows shortfall; cannot mitigate fluorspar shortfall and must, in turn, be mitigated

7

The shortfall analysis for HF followed the same process as that for fluorspar, but supplier countries, capacities, and future production levels differed. Supply calculations included estimated production and capacity for supplier countries by year, production ramp-up effects, and foreign supplier decrements based on ability, willingness, war damage, shipping losses (values are classified). The U.S. market share of foreign materials, based on GDP or imports vs. foreign production, was also considered. Importantly, supply estimates also accounted for the dependence of U.S. HF production on the adequacy of the fluorspar supply.[17] As with fluorspar, HF demand calculations included forecast future demand—civilian (future economic output) and military (FYDP and conflict demand)—and civilian austerity measures.

The shortfall/surplus analysis showed a gross (unmitigated) HF shortfall of 53,970 MT if the fluorspar shortfall is *not* mitigated (the analysis showed no shortfalls in later scenario years). The analysis also showed a gross HF shortfall of 22,150 MT even if the fluorspar shortfall *is* mitigated. U.S. HF capacity and imported supply (under Base Case conditions) are simply not sufficient to meet demand. Thus, unlike the situation assessed in the FY 2013 NDS Requirements Report, imported HF is projected not to be available to serve as a substitute for acid-grade fluorspar.[18] Indeed, HF shows a shortfall that, in addition to the fluorspar shortfall, must also be mitigated.

[17] Each unit of HF produced requires 2.2 units of fluorspar input (see Roskill, *Fluorspar: Global Industry Markets and Outlook*, 162). Foreign fluorspar production is sufficient to support foreign HF production.

[18] The change from FY 2013 appears to be driven by projected developments (increased demand) in the fluorspar/HF market under Base Case scenario conditions.

Combined Supply Chain Analysis and Shortfall Results

- **Because of link between fluorspar availability and HF production, fluorspar and HF are analyzed together as a supply chain to assess shortfall and shortfall mitigation possibilities**
- **Traditional shortfall analysis for fluorspar produced shortfall estimate of 71,847 MT in first year of Base Case scenario**
- **Traditional analysis for HF produced shortfall estimate of 53,970 MT in first year of scenario, if fluorspar shortfall is *not* mitigated**
- **If fluorspar shortfall *is* mitigated, HF analysis still shows shortfall of 22,150 MT because U.S. HF capacity and imported supply not sufficient to meet demand**
  - **Higher HF supply could theoretically make up for fluorspar shortfall, but such supply is not available in FY 2015 Base Case**
- **Results show value of supply chain analysis. Shortfall in downstream form exists because of inadequate domestic and foreign processing capacity (under Base Case conditions)**

8

This slide summarizes the supply chain analysis. Fluorspar showed a shortfall of 71,847 MT in the Base Case scenario in the first year. HF showed a shortfall of 53,970 MT in the first year if the fluorspar shortfall is not mitigated. If the fluorspar shortfall is mitigated, HF still shows a shortfall of 22,150 MT because U.S. HF capacity and imported supply are not sufficient to meet demand. (Recall that the United States ordinarily depends on domestically produced HF (from fluorspar) and imported HF to meet demands.) A higher HF supply could theoretically make up for the fluorspar shortfall, but such supply is not available in the FY 2015 Base Case. Thus, shortfalls of fluorspar and HF need to be mitigated under these conditions.

IDA | Net Shortfall Assessment

- Next step in analytical process after shortfall assessment is assessment of net shortfall or mitigation by market
- First step of net shortfall analysis is assessment of potential for thrifting or conservation
- For HF, following same method as for modeled materials for FY 2015 Stockpile Requirements Report, thrifting is estimated to be able to reduce demand by approximately 15 percent
  - HF thrifting factor = acid-grade fluorspar thrifting factor because demand follows from same applications
- Because HF gross shortfall = 6.5 percent of annual demand, thrifting can eliminate shortfall
- Further shortfall mitigation, if necessary, would include substitution possibilities (most likely for fluorine chemicals) and possibility of obtaining additional HF from market ("extra sell")

9

Following the approach taken for the modeled (upstream) materials in the FY 2015 NDS Requirements Report, the first step in considering the mitigation of the HF shortfall would be to assess potential market responses to it and estimate a net shortfall. The FY 2015 report explored three possibilities by which the market could reduce gross shortfalls: thrifting or material conservation, substitution, and expanding U.S. market share of materials available from foreign suppliers.[19] For HF, the thrifting factor that is applied to acid-grade fluorspar (which reduces demand by approximately 15 percent) can also be applied to HF because the industrial demand estimates from which the fluorspar thrifting factor is derived also govern HF demand. When that is done, because of the small size of the HF gross shortfall relative to the total U.S. HF demand (6.5 percent), the HF shortfall is eliminated (thrifting is also sufficient to eliminate the acid-grade fluorspar shortfall).

Further assessment of the possible use of substitutes for HF or further downstream fluorine-containing products and the possibility of obtaining additional supply above ordinary U.S. market share from particularly reliable supplier countries—although not conducted here—would also likely reduce the gross HF shortfall. Thus, government action is unlikely to be required to mitigate the HF shortfall under FY 2015 Base Case conditions.

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[19] Thomason, *Analyses for the 2015 National Defense Stockpile Requirements Report to Congress on Strategic and Critical Materials*, Volume 1, Chapter 4.

3. Conclusions and Recommendations

Conclusions of Fluorspar-HF Case Study and Further Recommendations

- Supply chain analysis can reveal shortfalls in downstream materials created by inadequate domestic and foreign raw material processing capacities
- Many materials of interest to NDS could potentially have downstream processing bottlenecks or vulnerabilities
  - Antimony, crude trioxide, crude trisulfide, metal
  - Bauxite, aluminum, alloys
  - Beryllium, metal, oxide, alloys
  - Boron, carbide
  - Carbon fibers
  - Chromium, ferrochromium, metal
  - Manganese, ferromanganese, metal
  - Rare earths, oxides, metals, alloys
  - Silicon carbide, fibers
  - Tungsten, concentrates, ammonium paratungstate, oxide, metal, alloys
  - Many other engineered materials

10

The fluorspar/HF case shows the value of supply chain analysis. The analysis identified a shortfall in a downstream material form that exists because of inadequate domestic and foreign material processing capacity (under Base Case scenario conditions) at a downstream stage of material processing (HF production). The supply chain analysis was necessary to identify the shortfall, which would not have been revealed by analysis of the upstream material (acid-grade fluorspar) alone. Supply chain analysis can also help DLA determine which form of a shortfall material to stockpile by ensuring that the form of the material can be used by U.S. industry (i.e., it does not require processing in a foreign country to which the United States would not have access under planning scenario conditions).

Many materials of interest to DLA could potentially experience shortfalls in their downstream forms because the downstream processing capacities upon which the United States relies for supply exist in foreign countries or as possibly vulnerable single points of failure in their supply chains. Such materials could potentially benefit from supply chain analysis. Specific commodity-type materials, similar to fluorspar and HF, that are or have been modeled as part of the NDS requirements process are listed in this slide along with some of their downstream forms.[1]

In addition to those materials, the supply chains of other, specialized engineered materials, like boron carbide, carbon fibers, silicon carbide fibers, and high purity yttrium oxide, were analyzed for the FY 2015 NDS Requirements Report.[2] Such materials are inherently "downstream" in that they are only created by the processing of one or more raw materials. They are often created for use in goods that serve small niches in the marketplace. As such, their supply chains are typically much smaller than those of widely used commodity-type materials, and the challenges in collecting data on and analyzing these specialized engineered materials are different. Nevertheless, DLA can benefit from the analysis of commodity and niche material supply chains in its efforts to mitigate material supply risks.

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1 Thomason, *Analyses for the 2015 National Defense Stockpile Requirements Report to Congress on Strategic and Critical Materials*, Volume 1, Chapter 3.

2 Ibid., Volume 1, Chapter 6; Volume 3, Appendix 9; and Volume 4, Appendix 14.

IDA

Further Recommendations (cont.)

- Materials of interest can be screened to identify possible supply chain vulnerabilities
  - Foreign dependence
  - Single points of failure
- DRAM logic can be used to assess chains to confirm vulnerabilities and ultimately determine shortfalls
  - Confirm absence of significant supply chain vulnerabilities
  - Identify chains cut by complete gaps
  - Quantitatively assess downstream material shortfalls
- Data collection can be challenging, but sources already exist in government and private sector for some materials
  - Additional/different sources should be explored
- Further supply chain analysis, like the fluorspar-HF case, should be considered to find and mitigate possible shortfall risks

11

To identify candidates for supply chain analysis, materials of interest can be screened for likely supply chain vulnerabilities. Downstream material processing that takes place outside of the United States or at single domestic facilities can suggest vulnerabilities that could give rise to shortfalls under NDS Base Case scenario conditions.

In developing the DRAM methodology, IDA also developed an approach for analyzing supply chains in phases to allow vulnerabilities to be identified without always having to perform a complete quantitative analysis. The approach consists of three steps taken in succession: confirming the absence of significant vulnerabilities, identifying supply chains cut by complete gaps, and quantitatively assessing shortfalls.[3]

Collecting sufficient data to analyze a material supply chain can be challenging because such data are sometimes not publically available. However, in this case, data were available, even for commodity-type materials that had many supplier countries around the world. Data can be found in sources such as government agencies and private sector market studies. Data availability should be thoroughly explored at the beginning of a study.

Again, this case shows the value of supply chain analysis. The analysis identified a shortfall in a downstream material form that exists because of inadequate domestic and foreign material processing capacity. The analysis was necessary to identify the shortfall, which would not have been revealed by analysis of the upstream material alone. Many other materials of interest to DLA could similarly experience shortfalls under similar planning scenario conditions. Thus, these kinds of analyses will continue to benefit DLA in its efforts to mitigate material supply risks.

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[3] Ibid., Volume 1, Chapter 6.

Appendix A
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Appendix B
Abbreviations

CaF_2	calcium fluoride
DLA SM	Defense Logistics Agency Strategic Materials
DRAM	Downstream Risk Assessment Methodology
FYDP	Future Years Defense Program
GDP	Gross Domestic Product
HF	hydrogen fluoride or hydrofluoric acid
IDA	Institute for Defense Analyses
MT	metric ton
NDS	National Defense Stockpile
RAMF-SM	Risk Assessment and Mitigation Framework for Strategic Materials
USGS	United States Geological Survey

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14. ABSTRACT

IDA modeled the supply chains for acid-grade fluorspar and hydrofluoric acid for the Strategic and Critical Materials 2015 Report on Stockpile Requirements for the Defense Logistics Agency Strategic Materials (DLA SM). Acid-grade fluorspar was projected to suffer a shortfall in the stockpile report. Most acid-grade fluorspar is used to produce hydrofluoric acid (HF), which is used to produce most fluorine-containing products. Imported HF can substitute for fluorspar if the accessible global HF supply is sufficient.

IDA analyzed the supply chain using the Downstream Risk Assessment Methodology (DRAM), using the same approach for assessing shortfalls for other materials analyzed for the stockpile report. Both fluorspar and HF exhibited gross (unmitigated) shortfalls in the standard Base Case military conflict scenario used for stockpile requirements planning. Potential market responses to the shortfalls were evaluated, and it was estimated that material conservation ("thrifting") could reduce demand sufficiently to eliminate both shortfalls.

The fluorspar/HF case shows the value of supply chain analysis: identifying a shortfall in a downstream material form that exists because of inadequate domestic and foreign downstream material processing capacity. Many materials of interest to DLA with downstream processing capacities in foreign countries could potentially benefit from similar analysis.

15. SUBJECT TERMS
supply chain, model, fluorspar, hydrofluoric acid, shortfall, substitution, Defense Logistics Agency, National Defense Stockpile, strategic materials, Institute for Defense Analyses, Downstream Risk Assessment Methodology, Risk Assessment and Mitigation Framework for Strategic Materials

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