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Pacific Northwest
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Understanding the Impact of the Secondary Market on Proliferation

July 2019

AM Sayre
TT Gray

U.S. DEPARTMENT OF ENERGY

Prepared for the U.S. Department of Energy
under Contract DE-AC05-76RL01830

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Executive Summary

Economic, technological, and social trends are changing the way consumers think about used commodities. As it becomes more expensive to source new materials, and consumers become more aware of the waste associated with the single-use economy, many consumers are more willing to consider used or remanufactured goods. Simultaneously, many new technological innovations are arising to make it more cost-effective to recycle and easier to find buyers who are willing to buy used or remanufactured commodities. Together, these changes have led to rapid growth in the secondary market and, along with it, a new potential threat: the export of used, dual-use commodities that could contribute to the development of weapons of mass destruction (WMDs) by secondary market resellers who are unaware of export control requirements.

While the export of WMD-related commodities is regulated throughout the commodity's lifetime, knowledge of those export control requirements is sometimes lost as commodities are sold and resold. Additionally, replacing older, used products with newer and better technologies does not necessarily mean that the "outdated" products cannot still contribute to a WMD development program. As such, the secondary market for listed commodities pose proliferation risks and export control challenges that may not be well understood by the U.S. Government. Furthermore, while measures may exist to mitigate the risks posed by the secondary market, those measures may not have been systematically integrated into U.S. export enforcement and outreach programs. This study assesses the secondary market to 1) identify dual-use commodities that present a higher risk for resale in secondary markets, and 2) outlines approaches for the U.S. Government to address gaps in existing research, outreach, training, and enforcement programs.

The project team defined the secondary market as the post-retail market for selling used, unwanted goods. This study focused on "listed" WMD-related commodities identified in the Commerce Control List (CCL) under the jurisdiction of the U.S. Department of Commerce and specifically those commodities that can contribute to the development, production, testing, or use of WMDs but that also have commercial applications. A total of 496 commodities under 175 Export Control Classification Numbers (ECCNs) were considered. Of those, 226 commodities (48 ECCNs) were identified as *Listed Commodities of Interest* to the secondary market. 30 commodities (7 ECCNs) were identified as high-interest to the secondary market that fell into four general categories: machine tools, mass spectrometers, and biological and chemical production equipment.

Generally, the project team found that high-interest listed commodities to the secondary market shared three important characteristics: 1) high resale value, 2) ability to be remanufactured or refurbished, and 3) adaptable. More specifically, in-depth analysis of each of the 30 high-interest listed commodities to the secondary market led to following findings:

- The potential to remanufacture previously unlisted machine tools to meet or exceed control specifications requires additional follow-on research.
- While less common than machine tools, mass spectrometers are frequently found on the secondary market.
- A few specific industries (oil and gas, pharmaceuticals) frequently contribute used dual-use mass spectrometers to the secondary market. Some companies in these industries may not be aware of export control requirements. Attention should therefore be applied to how these sales are being handled and whether licenses are being appropriately requested for export.
- Specialized chemical process equipment is prevalent on the secondary market because of industrial trends, high initial investments, and good reusability.

- Companies that specialize in the refurbishing and resale of glass-lined chemical processing equipment should be a priority for industry outreach.
- Biological process equipment is suitable for reuse and has been seen on the secondary market.
- The Do-It-Yourself (DIY) Bio community is an area where more outreach may be necessary because the secondhand market for biological process equipment is likely to continue growing.

Further, this research identified recommendations for incorporating the findings of this study into existing activities. While this study focused on used, listed commodities rather than the companies selling them, many sellers on the secondary market are less aware of export control requirements than their counterparts on the new market. To prevent the illegal export of used, listed commodities, it will be important to inform secondary market sellers, particularly those that specialize in the high-interest listed commodities of their export obligations. Findings from this study should be incorporated into existing outreach and training activities to promote secondary market compliance with export control regulations.

In addition, the project team recommends the following additional studies that may help the U.S. government better understand the threat posed by the secondary market for listed commodities:

- A quantitative analysis of export trade data on the secondary market to measure and validate the findings of this preliminary analysis;
- Deep dive assessments by small groups of relevant SMEs for selected *Listed Commodities of Interest* to the secondary market, such as machine tools or mass spectrometers;
- Analysis to identify the specific secondary market resellers that deserve outreach; and
- Analysis of the surplus or excess market and how it may be relevant to export controls.

With the incorporation of even some of these recommendations into existing U.S. enforcement activities and further research into the potential risks posed of secondhand dual-use commodities, the U.S. can continue to foster a healthy yet secure secondary market for listed dual-use commodities.

Acronyms and Abbreviations

BIS	Bureau of Industry and Security
CCL	Commerce Control List
CFR	Code of Federal Regulations
DIY	Do It Yourself
DOC	Department of Commerce
EAR	Export Administration Regulations
ECCN	Export Control Classification Number
MRI	Magnetic Resonance Imaging
OEM	original equipment manufacturer
SME	subject matter expert
WMD	weapon of mass destruction
SSE	superconducting solenoidal electromagnets

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1.0 Introduction

Economic, technological, and social trends are changing the way consumers think about used commodities. As technological innovation drives companies to update their equipment more frequently, and used equipment with equivalent capabilities becomes cheaper, many buyers are more willing to consider used or remanufactured goods. Simultaneously, many new technological innovations are arising to make it easier to find buyers who are willing to buy used or remanufactured commodities. Together, these changes have led to rapid growth in the secondary market and, along with it, a new threat: the potential export of used, dual-use commodities that could contribute to the development of weapons of mass destruction (WMDs) by secondary market resellers who are unaware of export control requirements.

While the export of WMD-related commodities is regulated throughout the commodity's lifetime, knowledge of those export control requirements is sometimes lost as commodities are sold and resold. However, replacing older, used products with newer and better technologies does not necessarily mean that the "outdated" products cannot be used to contribute to a WMD proliferation program. As such, the secondary market for listed commodities pose proliferation risks and export control challenges that may not be well understood by the U.S. Government. Furthermore, while measures may exist to mitigate the risks posed by the secondary market, those measures may not have been systematically integrated into U.S. export enforcement and outreach programs. This study assesses the secondary market to 1) identify dual-use commodities that present a higher risk for resale in secondary markets, and 2) outline approaches for the U.S. Government to address gaps in existing research, outreach, training, and assistance programs.

2.0 Background

The following sections provide the background necessary to understand the secondary market for listed commodities, with the ultimate objective of identifying *Listed Commodities of Interest* for the secondary market. A full definition of this term can be found in section 4.2.1 *Assessing Interest to the Secondary Market*. In short, commodities identified as *Listed Commodities of Interest* for the secondary market are those the project team has determined to be higher priority because they are:

1. likely to be reused,
2. likely to be found on the secondary market, and
3. can be distinguished from non-listed commodities.

To make this determination, the project team[1] defined and constrained two terms: 1) *Secondary Market* and 2) *Listed Commodities,* which are included in the next sub-sections. Based on those definitions, later sub-sections provide context regarding the legal controls for used listed commodities, the challenges posed by the secondary market, and a literature review.

[1] The project team includes the authors with support from SMEs interviewed for this study.

2.1 Secondary Market

For this study, the project team defined the secondary market as the post-retail market for selling used, unwanted goods. These goods can be used, remanufactured[1], or, in some cases, disposed (e.g., scrap). Unused goods sold as excess, or surplus, are excluded. One important source of secondary market goods is the original buyers who may come from industry, academia, or the federal government. Often, they can resell their used goods by connecting directly with a buyer. However, sometimes sellers want or need assistance to sell used commodities and may rely on a facilitator. Facilitators help connect sellers to new buyers and can include general and specialty resellers, auction houses (brick-and-mortar and online), scrap or recycling companies, and eCommerce sites. These organizations might connect the buyer and seller (e.g., Craigslist or eBay) or take full or partial ownership of the item to resell it (e.g., furniture consignment). When OEMs and distributors are included in this definition when selling used dual-use commodities.

2.2 Listed Commodities

The U.S. Government controls the export of various physical commodities and technical data for reasons related to national security, foreign policy, nonproliferation of WMD, international obligations, and others. Various U.S. agencies enumerate and set controls for different types of commodities and export-related activities, including the U.S. Department of State (military commodities), Department of Commerce (dual-use commodities), Department of Energy (nuclear technology), Nuclear Regulatory Commission (nuclear materials and equipment), and Treasury Department (finances and embargos). This study focuses on WMD-related dual-use commodities under the jurisdiction of the U.S. Department of Commerce, specifically those commodities that are important for the development, production, testing, or use of WMDs, but that also have commercial applications.

The U.S. Department of Commerce's (DOC) Bureau of Industry and Security (BIS) maintains the Commerce Control List (CCL) (15 CFR 774) within the Export Administration Regulations (EAR), which includes items (i.e., commodities, software, and technology) subject to the export licensing authority of BIS. For the purposes of this study, we will focus on commodities. Commodities are identified by a 5-character alpha-numeric designation called an Export Control Classification Number (ECCN). An ECCN is made up of four sections, the "Heading," "License Requirements," "License Exceptions," and "List of Items Controlled". Under each ECCN, BIS describes the items controlled, but is not consistent in where it places this description. Sometimes it is in the "Heading" next to the ECCN. For example, "2B120 Motion simulators or rate tables (equipment capable of simulating motion), having all of the following characteristics (see List of Items Controlled)". Sometimes the ECCN heading is sufficient to describe the commodities controlled; the subparagraphs go on to describe the technical specifications the item needs to meet in order to be listed. In other cases, the heading for an ECCN contains a summary and directs the reader to "see List of Items Controlled" for a complete list of items classified under that ECCN. For example, "2B350 Chemical manufacturing facilities and equipment, except valves controlled by 2A226, as follows (see List of Items Controlled)." The "List of Items Controlled" section describes all of the commodities that the ECCN controls. In this case 2B350 includes ten subparagraphs which describe discrete items lettered "a" to "j". In other cases, the reader must look deeper into the subparagraphs to identify the items controlled. For example, beryllium is described in

[1] Remanufacturing describes the process in which a recovered good, or core, is transformed through cleaning, testing, and other operations into a product that is tested and certified to meet technical and/or safety specifications and has a warranty similar to that of a new product. Different industries sometimes apply other terms, such as refurbishing, reconditioning, or rebuilding, to describe essentially the same process.

1C111.a.2.a.2. Typically, a commodity can be identified in the text directly preceding the words "having all of the following characteristics" under an ECCN.

It is common for one ECCN to include many similar or related. This ordering mechanism is beneficial to this study since it groups like commodities, but it is only an organizing factor; commodities are the real focus. For this study, the term *ECCN* refers to the 5-character parent designation (e.g., 1C354), while the term *listed commodity* refers to a discrete item controlled on the CCL. In this report, the term "listed" preceding a commodity name (e.g., "listed mass spectrometer") indicates that the item meets the control specifications enumeration in the CCL.[1] The process used to select commodities of interest for this study is described in section 4.0 *Methodology*.

This study does not consider non-listed commodities destined for proscribed end uses, such as a used tanker truck destined for use in a missile program (Kanemitsu, 2009). Such "non-listed" items are not enumerated on the CCL but are still subject to the EAR because of the proscribed end use and have the EAR designation of EAR99. While secondary market transfers of these commodities have been documented, the export control enforcement and implementation concerns are distinct from those of CCL listed commodities. Therefore, non-listed commodities are not considered.

2.3 Applicability of Export Control Regulations to Used Commodities

U.S. export control laws do not distinguish between new and used commodities. If a used commodity still meets the control specifications, it is still listed. The EAR states, in the Code of Federal Regulations (CFR) Chapter 15 Section 774 (15 CFR 774) Supplement No. 3 (d), that "the specifications in the [CCL] apply equally to new or used goods. In the case of used goods, an evaluation by [BIS] may be carried out in order to assess whether the goods are capable of meeting the relevant specifications."[2] No public documentation exists regarding how this assessment is conducted or the criteria that need to be met. For example, if a machine tool meets the control specifications under ECCN 2B001 but does not function and/or needs minor repairs, no published guidance exists to help the owner make a determination regarding export controls, aside from seeking a determination from the DOC. This study assumes that any item that meets the control specifications, when new, is listed, regardless of whether a used version can still meet those specifications. This issue will be revisited in section 7.7 *Future Research*.

2.4 Challenges Posed by the Secondary Market

Secondary markets, particularly eCommerce markets, challenge the enforcement of export control regulations on listed commodities. Zilinskas and Mauger (2015) capture this well:

> "Emarketplaces…create a niche by providing visibility and a degree of legitimacy for small and specialized vendors to sell products abroad. … In the past, companies wishing to enter foreign markets would have to send out expensive trade delegations to demonstrate their products in person. The harnessing of the Internet for commerce, notably through emarketplaces, has reduced the necessity of doing so. The rise in export control cases involving these spaces raise concerns that emarketplaces permit would-be proliferators 'to find suppliers who will not ask so many

[1] Listed commodities do not always require a license for export. The need for a license is determined based on the country of destination, end use, and end user. Therefore, the project team uses the word "listed" to indicate that the commodity meets the control specifications enumerated on the Commerce Control List.
[2] 15 CFR 774 Supplement No. 3 (d)

> questions.' Importantly, these low-profile actors are able to sell secondhand products through emarketplace websites" (Raymond A. Zilinskas & Philippe Mauger, 2015).

In comparison to OEMs, secondhand sellers may not be knowledgeable or about the products they sell or aware of the export control requirements that may apply, putting them at greater risk of unintentionally exporting a listed commodity without a required export license. Zilinskas and Mauger describe this challenge through an example in relation to product options as "a vendor who is trying to sell an obsolete cross-flow filtration system with variable disposable filters may not know that the system had been designed also to fit a larger filter cartridge whose size is equal to, or larger, than the size placing it [on the Australia Group control list]" (Raymond A. Zilinskas & Philippe Mauger, 2015). While the OEM may know this information from experience, a reseller likely will not have this knowledge. Additionally, some resellers are at even greater risk, such as liquidation companies who may have limited experience with the commodities being sold and who may not be able to differentiate between an honest and dishonest declaration of end use.

Further, cases involving the unlicensed export of dual-use commodities are difficult to prosecute. In comparison with military commodities[1], where the intent is clear, the dual-use nature of many non-military commodities introduces reasonable doubt. While cases involving the secondary market resale of military commodities have been successfully prosecuted (GAO, 2008), the research team was not able to identify prosecuted cases involving the secondary market resale of dual-use commodities. The secondary market introduces additional challenges to establishing intent because secondary market sellers are often less familiar with the products being sold and may not understand the potential dual applications of the listed commodities they sell. These challenges to prosecution highlight the importance of outreach to the secondary market regarding listed commodities.

Another challenge to the secondary market as it relates to export controls is the presence of a specific type of company – the facilitator. Facilitators offer a private platform (often emarketplaces in the modern secondary market) to connect buyers and sellers without the need for facilitators to take ownership of any commodities. While the facilitator makes is easier and faster for parties to connect, they also do not assume any legal liability for an export violation since they do not assume ownership of the commodity. As one expert summarized "generally speaking, the [emarketplace] has immunity in the United States…because it does not control the items. Ultimately, the legal responsibility falls on the buyer and/or seller…" (Council, 2014). Some facilitators have instituted systems and procedures on their platform to flag trades that may potentially violate U.S. regulations.[2] However, the sheer volume of trade and limited incentives mean that many facilitators are unlikely to concern themselves with export control requirements, absent regulatory changes to their responsibility. This study does not attempt to analyze or recommend changes to U.S. regulations with regards to facilitators but aims instead to highlight some of the challenges for export controls in the secondary market. The first step to highlighting these challenges is understanding which listed commodities are of interest to the secondary market. This will be address in the upcoming section 4.0 *Methodology.*

[1] Military-related commodities, also called defense articles are enumerated in the U.S. Munitions List (USML) (22 CFR 121) and regulated by the International Traffic in Arms Regulations (ITAR) overseen by the U.S. Department of State's Directorate of Defense Trade Controls.

[2] For example, eBay has developed the eBay Listing Violation Identification System (eLVIS), which is a keyword-based system for flagging potential violations of various regulations, including ITAR, FDA, etc.

3.0 Literature Review

In conducting a literature review for this study, the project team did not find a systematic assessment of the utility of secondhand dual-use commodities. While assertions suggested individual secondhand commodities can be and have been used, (Walker, 2010) the entire secondary market and its potential contributions of listed WMD commodities have not been systematically evaluated.[1] The closest study to such an assessment was performed by Stewart et. al., which analyzed the manufacturing base for 26 proliferation-sensitive items (Ian Stewart, Viski, & Gillard, 2018). Specifically, the study identified commodities suspected to have a secondhand or surplus market and commodities that can be excluded.[2] However, the study led by Stewart does not explain or justify its categorization, making it difficult for others to validate their methodology. Stewart's study excludes many key dual-use commodities including machine tools, but it is a worthy first step.

Several papers examine listed commodities on eCommerce sites, but they focus on new or surplus commodities rather than used (I. Stewart, 2014) (Raymond A. Zilinskas & Philippe Mauger, 2015). Zilinskas and Mauger highlight secondhand vendors for biological process equipment, but they do not offer a comprehensive study. Given the noted limitations of previous work, this Pacific Northwest National Laboratory (PNNL) study aims to provide a comprehensive review of all WMD-related dual-use commodities to identify those of high interest to the secondary market.

4.0 Methodology

The project team developed a preliminary research methodology based on principles of qualitative research using in-depth interviews and open-source research techniques. Acknowledging the variety of commodities included on the CCL, the project team intentionally narrowed the scope of commodities to appropriately focus interviews with subject matter experts (SMEs). Given that scope, the project team developed criteria that would identify the *Listed Commodities of Interest* for the secondary market. SME interviews were the primary means of collecting data for the analysis. The following sections elaborate the analysis scope, the research design and criteria for assessing interest to the secondary market and the interview methodology.

4.1 Identifying Dual-Use Commodities Relevant to WMDs

This analysis focused on commodities under the jurisdiction of the U.S. Department of Commerce as outlined in the CCL of the EAR (15 CFR 774), specifically commodities important for WMD development, production, testing, or use but that also have legitimate civilian applications.

The CCL includes hundreds of commodities, not all of which are applicable to WMDs (e.g., 0A980 Horses by sea). Each commodity on the CCL has one or multiple *Reasons for Control*, some of which are

[1] Based on expertise and experience of the authors and subject matter experts in general.

[2] Autoclaves, bellows-sealed valves, beryllium, calcium, capacitors, carbon fiber, controlled-atmosphere furnaces, flash x-ray devices, flow-forming machines, frequency inverters, high-strength aluminum, high-strength materials, high-speed cameras, heavy water, isostatic presses, maraging steel, mass spectrometers, neutron detectors, pressure transducers, radiation-shielded windows, reactor internals, reactor pressure vessels, remote manipulators, triggered spark gaps, vacuum pumps, and zirconium.

WMD-related.[1] The project team selected commodities, for which the *Reasons for Control* included the following:

- Nuclear nonproliferation
- Chemical and biological weapons, and
- Missile technology.

Further, the team also included those listed commodities which are derived from multilateral export control regime lists issued by the Nuclear Suppliers Group (dual-use list), Missile Technology Control Regime, Australia Group, and Chemical Weapons Convention.

As was introduced in section *2.2 Listed Commodities*, one ECCN can represent many controlled commodities. The project team therefore carefully reviewed each ECCN entry in order to identify the associated "List of Items Controlled". In cases where the "List of Items Controlled" included an item and its parts, the project team did not break it out into two commodities, as that level of detail was beyond the scope of the preliminary study.

Additionally, the project team excluded software and technology (ECCNs in Groups D and E within the CCL structure).[2] This exclusion is a practical matter: the project team focused only on physical commodities traded through a secondary market. The project team also excluded commodities subject to another agency's jurisdiction (e.g., 0A002 Propulsion equipment for nuclear reactors, which is subject to U.S. Department of State International Traffic Arms Regulations). Based on all these considerations, the team identified 496 discrete WMD-related commodities under 175 ECCNs.

As defined in section 2.1 *Secondary Market*, the project team deliberately excluded surplus or excess commodities in the secondary market, focusing only on used commodities. The project team assumes that entities selling excess commodities will have stronger industry connections with the OEMs for listed commodities and should better understand the licensing requirements associated with listed commodities. This assumption deserves validation in a follow-on study. However, given that most entities selling used listed commodities are expected to have limited knowledge of the associated export control requirements, the project team prioritized analysis on used listed commodities transacted through the secondary market.

4.2 Research Design

Based on the assumptions and exclusions noted in the previous sections, approximately 500 listed commodities remained for review and analysis by the project team. To prioritize the most important listed commodities for analysis, the project team designed a methodology for assessing which commodities are *Listed Commodities of Interest* for the secondary market.

[1] A complete list of the *Reasons for Control* is available in 15 CFR Part 738, CCL Overview and the Country Chart. https://www.bis.doc.gov/index.php/documents/regulation-docs/2254-part-738-commerce-control-list-overview-and-the-country-chart-1/file

[2] Technology refers to information necessary for the development, production, use, operation, installation, maintenance, repair, overhaul, or refurbishing (or other terms specified in ECCNs on the CCL that control "technology") of an item.

4.2.1 Assessing Interest for the Secondary Market

To transparently assess which listed commodities are of high interest to the secondary market, the project team defined the following criteria and related questions:

- **Reusability:** Is the commodity reusable?
- **Likelihood of Reuse:** What is the likelihood that the commodity will be reused?
- **Ability to Distinguish from Non-Listed Commodities:**[1] Is it possible to easily distinguish the listed commodity from non-listed commodities?
- **Frequency on the New Market:** What is the frequency of the listed commodity on the new market?
- **Demonstrated Presence on the Secondary Market:** Has the listed commodity been observed on the secondary market?
- **Other Considerations:** Are there regulatory or institutional considerations that make the listed commodity of particular interest to the secondary market?

The following sections elaborate on the project team's methodology to develop and assess each criterion listed above.

4.2.1.1 Reusability

A commodity's reusability is important for identifying used listed commodities sold on the secondary market. This criterion was designed to have a Yes-No answer. Listed commodities assessed to be *Not Reusable* were excluded from further consideration.

4.2.1.2 Likelihood of Reuse

The criterion *Likelihood of Reuse* closely follows the *Reusability* criterion. However, assessing the likelihood of reuse required specific framing boundaries to determine whether the used listed commodity would be desirable for WMD development, production, testing, or use. To maintain consistency in responses, the SMEs considered the following characteristics to assess the likelihood of reuse:

- **Need for Modification for Reuse:** Could the commodity be directly reused for WMD applications? A common SME response was that the commodity could be reused but only in very specific applications similar to how it was used when new. In most cases, the SMEs assessed that commodities reusable only in the same exact application, or with significant modification, had a low or no likelihood of reuse and were consequently removed from further consideration.
- **Ease of Modification for Reuse:** If modification is necessary for reuse, how easy would this be? This characteristic is connected to both the commodity and the expected technical expertise of someone willing to acquire a commodity for WMD applications on the secondary market. The SMEs

[1] This criterion is included to address the second objective of this study: to identify gaps in current research, outreach, training and enforcement for export controls on the secondary market. Industry and the enforcement community do not have the technical capability to distinguish some listed commodities from non-listed commodities, particularly when destructive analysis or other technical analysis is required. Therefore, those commodities were excluded as a practical matter, as any recommendations generated from this analysis would not be useful to industry or the enforcement community.

generally assessed that commodities that are more difficult to modify for reuse in WMD applications are less likely to be reused and were therefore excluded from further consideration.

- **Degraded Performance:** Will the degraded performance of a used commodity make reuse in a WMD application less likely? Following the *Reusability* criterion, many listed commodities are known to degrade in performance after use (e.g., ball bearings, triggered spark gaps). This degradation ties closely to how much the commodity was used, but in most cases, the SMEs assessed that used listed commodities with degraded performance were less likely to be reused and were also excluded from consideration.

4.2.1.3 Ability to Distinguish from Non-Listed Commodities

Listed commodities can be difficult to distinguish from non-listed commodities without specific knowledge of the listed and non-listed models of the commodity. It was not possible to identify any fixed commodity characteristics that make certain commodities easier to distinguish as listed or non-listed. However, consideration of the following characteristics assisted in assessing this criterion:

- **Inconsistency Between ECCN and OEM Language:** Many ECCNs' technical descriptions are not consistent with the terminology or parameters described on OEM marketing brochures or technical data sheets. For example, a pressure transducer manufacturer's description might include the range and accuracy but not specify the precise material of composition, which is an important component of the ECCN description language. On this basis, SMEs assessed some commodities as "not practical" for this study, and these commodities were excluded.
- **Destructive Analysis Required for Determination:** Some listed commodities are nearly indistinguishable from their non-listed counterparts without destructive analysis by a SME (e.g., carbon fiber) absent accompanying paperwork. Focusing on the secondary market for these commodities would yield a very low or no return on investment for compliance. Therefore, in order to further prioritize *Listed Commodities of Interest* to the secondary market, the project team excluded some listed commodities, for which the effort needed to identify them is neither efficient nor cost-effective.

This criterion was used to exclude listed commodities rather than as justification for including them.

4.2.1.4 Frequency on the New Market

Frequency on the New Market is another criterion defined for identifying *Listed Commodities of Interest* to the secondary market. Some listed commodities are rare on the new market, and, therefore, not likely to be sold on the secondary market. Quantitative analysis of the actual frequency of listed commodities in the secondary market is beyond the scope of this preliminary study. Instead, the project team used listed commodities' export frequency as a proxy to extrapolate the frequency of listed commodities on the secondary market. The team determined export frequency was the only way to approximate the trade in listed commodities since their domestic trade is not well documented. Listed commodities with a low or rare occurrence on the new market were excluded from this analysis.

4.2.1.5 Demonstrated Presence on the Secondary Market

The project team also considered one final criterion: *Demonstrated Presence on the Secondary Market* – that was closely related to *Likelihood of Reuse.* This criterion was important, because in a few cases, the SMEs had experience with listed commodities on the secondary market that had been reused in applications similar to WMD applications. In these cases, the SMEs assessed these commodities to be of greater interest to the secondary market, even when the other criteria above may have indicated otherwise.

4.2.2 Identifying Commodities of "High" Interest

To prioritize *Listed Commodities of Interest*, the project team developed a scale (High, Medium, Low) based on common characteristics of listed commodities and used items in general that are present on the secondary market. Characteristics of high-interest listed commodities include:

- **Value Retention:** Commodities that retain their value relatively well.
- **Quality Retention:** Commodities that retain their quality or performance.
- **Expensive when New:** Commodities that are relatively expensive when bought new. The seller may want to recoup initial expenses and the buyer may be looking for a deal.
- **Adaptable:** Commodities that may be adaptable to other working conditions and applications; they are not specifically designed to meet the buyer's needs.
- **Presence on the Secondary Market:** Commodities that have a large secondary market (i.e., numerous resellers, multiple instances, known cases).

Medium- and low-interest listed commodities were identified in relation to the above characteristics for high-interest listed commodities. Commodities that were less expensive when new, with a medium secondary market (fewer resellers, and fewer verified cases) were considered medium interest. Finally, the team defined low-interest commodities as those with little to no known secondary market.

4.3 Applying the Research Design

The following sections describe the process the project team used to apply the research design and evaluate each listed commodity based on the aforementioned criteria. The project team conducted SME interviews to gather information on each commodity and then performed a thorough review of highlighted commodities for additional research and prioritization, based on SME interviews.

4.3.1 Interview Methodology

Given the specialized nature of many listed commodities considered, the project team interviewed SMEs from various fields. In total, the project team interviewed 11 SMEs with expertise in broad areas such as biological and chemical production equipment, nuclear commodities, missile commodities, industrial equipment, and with specific technical expertise, including graphite and mass spectrometers.

Prior to each interview, the project team provided a list of questions to help the SMEs consider each of the criteria for identifying the *Listed Commodities of Interest* for the secondary market. The complete list of questions is included in 9.0 Appendix B. During the interviews, the project team used the feedback from the specific questions to lead each SME through the criteria discussed above to identify which listed commodities are of interest to the secondary market.

4.3.2 Review of Priority Commodities

Using the interviews and methodology discussed above, the project team excluded from the study more than two-thirds of WMD-related ECCNs, thereby identifying a shorter list of 48 ECCNs (226 commodities) for a thorough review. These commodities are listed in section 5.0 *Results*.

Each commodity was evaluated against the criteria listed in the research design, with greater weight given to presence on the secondary market. Presence on the secondary market was established through internet

searches for the commodities using the commodity name plus “used,” “reseller,” “remanufactured” or “refurbished” (e.g., machine tool reseller). When possible, the project team further focused the search using known listed model numbers in place of the commodity name (e.g., Diamond E-400). Visual verification of the item on the secondary market was essential for prioritizing these commodities. In some cases, presence on the secondary market could not be established and export data was used instead as a proxy indicator for presence on the secondary market.

This analysis aimed to understand and capture the frequency of these selected listed commodities on the secondary market. The conclusions of this review determined the priority listing of these commodities, which is discussed further in the next section.

5.0 Results

A total of 496 commodities under 175 ECCNs were considered. Of those, 226 commodities (48 ECCNs) were identified as *Listed Commodities of Interest* to the secondary market: 30 commodities (7 ECCNs) are high-interest, 11 commodities (8 ECCNs) are medium-interest, and 197 commodities (33 ECCNs) are low-interest. The project team excluded 258 commodities (127 ECCNs) for the following reasons:

- Not reusable (163 commodities)
- Unlikely to be reused (33 commodities)
- Rarely on the new market (37 commodities)
- Indistinguishable from non-listed commodities (25 commodities).

Each subsection includes a summary of the results, beginning with the commodity groups identified as *Listed Commodities of Interest*. See Appendix A *Commodities of Interest and Results* for a full list. An “x” in any column indicates that the characteristic was not considered before making a final determination because other criteria had already excluded the commodity from further consideration.

5.1 High-Interest Listed Commodities

Listed commodities of high interest for the secondary market include the following commodities:

- Machine tools (2B001.a-d, 2B201.a-c)
- Mass spectrometers (3A233.a-d)
- Chemical process equipment (2B350)
  - Chemical reactors (2B350.a)
  - Agitators (2B350.b)
  - Tanks (2B350.c)
  - Heat exchangers (2B350.d)
  - Distillation or absorption columns (2B350.e)
  - Valves (2B350.g)
  - Multi-walled piping (2B350.h)
  - Pumps (2B350.i)
- Vacuum pumps (2B231)
- Bellows seal valves (2A226)
- Biological process equipment (2B352)
  - Fermenters (2B352.b)
  - Centrifugal separators (2B352.c)
  - Cross flow filtration equipment (2B352.d)
  - Steam serializable freeze-drying equipment (2B352.e)
  - Protective and containment equipment (2B352.f)
  - Aerosol testing chambers (2B352.g)
  - Aerosol challenge testing chambers (2B352.h)
  - Spraying and fogging systems (2B352.i)

5.2 Medium-Interest Listed Commodities

Listed commodities of medium interest for the secondary market include the following commodities:

- Protective and detection equipment (1A004.a, 1A004.b, 1A004.c)
- Toxic gas monitoring systems (2B351.a, 2B351.b)
- Analog-to-digital converter (3A002.h)
- Accelerators (3A101.b)
- Frequency changers (3A225)
- High-voltage DC power supplies (3A226, 3A227)
- High-speed pulse generators (3A230)

5.3 Low-Interest Listed Commodities

Listed commodities of low interest for the secondary market include the following commodities:

- Biological Materials
  - Human pathogens, zoonosis, toxins (1C351) (105 materials)
  - Genetic elements, genetically modified organisms (1C353) (6 organisms)
  - Plant pathogens (1C354) (23 pathogens)
- Metals
  - Aluminum alloys (1C002.b.4, 1C202.a)
  - Titanium alloys (1C002.b.3, 1C202.b)
  - Tungsten (1C117.a, 1C226)
  - Hafnium (1C231)
  - Zirconium (1C234)
  - Molybdenum (1C117.b)
  - Depleted uranium (1A290)
- Graphite (1C298)
- Superconducting solenoidal electromagnets (3A001.e.3, 3A201.b)
- Gravity meters (1A290, 6A007, 6A107)
- Radiation-shielded windows (1A227)
- Composites production equipment (1B001.a-c, 1B101.a-b, 1B201)
- Furnaces (2B105, 2B226, 2B227.a-c)
- Remote manipulators (2B225)
- Cameras (6A003.a.3, 6A003.a.4, 6A003.a.6, 6A203.a-c)
- Lasers (6A005.a-d, 6A205.a-g)
- Accelerometers (7A001)
- Drone production facilities (9B610)

6.0 Analysis

Section 5.0 *Results*, included above, comprises a key output of this analysis – a prioritization of listed commodities of interest to the secondary market. Beyond the prioritized list, the project team performed detailed analysis on several of the high-interest listed commodity groups to identify trends, conclusions, and recommendations for actions and further research. While the project team did not perform detailed analysis on all of the medium- and low-interest commodity groups, some of these commodity groups did yield interesting analysis, which is included in Appendix C.

The subsections below identify the key characteristics for high-, medium-, and low-interest *Listed Commodities of Interest* for the secondary market, as defined by the project team. Additionally, the team identified key characteristics for excluding many listed commodities from further consideration. Finally, the project team identified several cross-cutting trends related to listed commodities on the secondary market, also included in the subsections below.

It is important to note that a number of specific companies are identified in the following sections for *illustrative purposes only* to demonstrate that there are listed commodities on the secondary market potentially sold by these companies. We did not evaluate and are not commenting on the export control compliance programs of these companies. The objective of this study is to raise awareness of the potential export of listed commodities on the secondary market without an export license, and the analysis below should not imply wrongdoing by any of the companies mentioned.

6.1 Listed Commodities of High Interest

High-interest listed commodities to the secondary market were generally identified as:

- Reusable,
- Having a high likelihood of reuse,
- Distinguishable from non-listed commodities, and
- Frequently sold or observed on secondary markets.

The importance of each criterion varied by commodity group. The following subsections describe those variations and the key characteristics identified by the project team to identify commodity groups of high interest for the secondary market.

The project team has identified the following characteristics likely to increase the desirability of buying or selling a commodity on the secondary market that could be used for a WMD application. This list of characteristics is not exhaustive and each of the characteristics may not apply to all high-interest listed commodities, but it does provide a quick reference for understanding which listed commodities may be relevant for the secondary market.

- **High Resale Value:** These commodities are expensive because they are usually specialized. Some are specially designed, making them less useable in other applications. Despite the specialized nature of these commodities, when a company chooses to replace a piece of equipment, they will often attempt to sell the old piece of equipment to recoup some of their costs.

- **Can be Remanufactured or Refurbished:**[1] In addition to commodities that retain their quality, commodities that can be refurbished or upgraded are also of high interest to the secondary market. This is particularly true for commodities containing smaller parts and electronics, where replacing a degraded component can extend the life of the larger commodity, similar to replacing parts in a car.
- **Adaptable:** These commodities are adaptable to other working conditions and applications. They are not specifically designed to meet only the buyer's needs.

Commodities in the high-interest category include:

- Machine tools (2B001.a-d, 2B201.a-c)
- Mass spectrometers (3A233.a-d)
- Chemical process equipment (2B350 a-e, g-i)
- Vacuum pumps (2B231)
- Bellows seal valves (2A226)
- Biological process equipment (2B352.b-i)

See Appendix A *Commodities of Interest and Results,* tab "High Interest" for a full list of commodities.

6.1.1 Machine Tools

Finding: The potential to remanufacture previously unlisted machine tools to meet or exceed control criteria is a serious issue that may require additional follow-on research.

Commodities referenced in this section include:

- 2B001.a-d, 2B201.a-c: Machine tools including turning machines, milling machines, grinding machines, and electrical discharge machines. See Appendix A for specific commodities

Of the commodities researched, machine tools are some of the most widely reused commodities. Machine tools are reusable, have a high likelihood of reuse, are distinguishable from non-listed commodities, and are frequently sold and observed on secondary markets. Machine tools have a high resale value and can be refurbished, resulting in numerous interested buyers and sellers. Nearly every manufacturing industry uses listed machine tools, including aerospace, automotive, general appliance, electronic, power generating, and defense industries. Large machine tools with wide applications in the aircraft, shipbuilding, and off-road vehicle industry rarely have sufficient accuracy to meet the control criteria and are therefore non-listed.

According to one industry study, the machine tool industry is strong, with consumption totaling $8.142 billion in 2017, up 6.8 percent from the previous year (Intelligence, 2017). Moreover, the industry has grown dramatically since the early 2000s. Growth was fueled by increasing international demand. In 2017, 12 of the top 15 countries that consume machine tools increased their consumption from the previous year, and, perhaps most importantly, China raised its 2017 machine tool consumption by $1.780

[1] While often used interchangeably, *remanufactured* and *refurbished* have very different meanings. According to the U.S. International Trade Commission, "Remanufacturing is an industrial process that restores end-of-life goods to their original working condition." On the other hand, refurbishing is less robust process, where some maintenance and testing may be performed, but the commodity is not usually disassembled.

billion in one year alone, corresponding to an increase of 6.3 percent. Given this strong international demand for machine tools, exports of secondhand machine tools, either used or refurbished, is expected to grow as well.

Machine tools' high resale value gives them a high return on investment. In 1992, the U.S. Department of Commerce approved 572 applications containing $454 million worth of machine tools, two of which were valued at $1.8 million each (*Export Controls and Nonproliferation Policy*, 1994). While more recent public data on consumption of listed machine tools is not available, this data from 1992 clearly demonstrates the incentives for buyers to purchase used machine tools. In fact, one machine tool reseller indicated that "buying used can generate a five- or six-figure cost savings since used [machine tools are] typically discounted at more than 30 percent off the original price" ("Why buy a used HAAS CNC Machine," 2017). The current average cost of new listed machine tools is upwards of $800,000.[1] Based on these numbers, a buyer could expect to save $240,000 by purchasing a used machine tool instead of a new one.

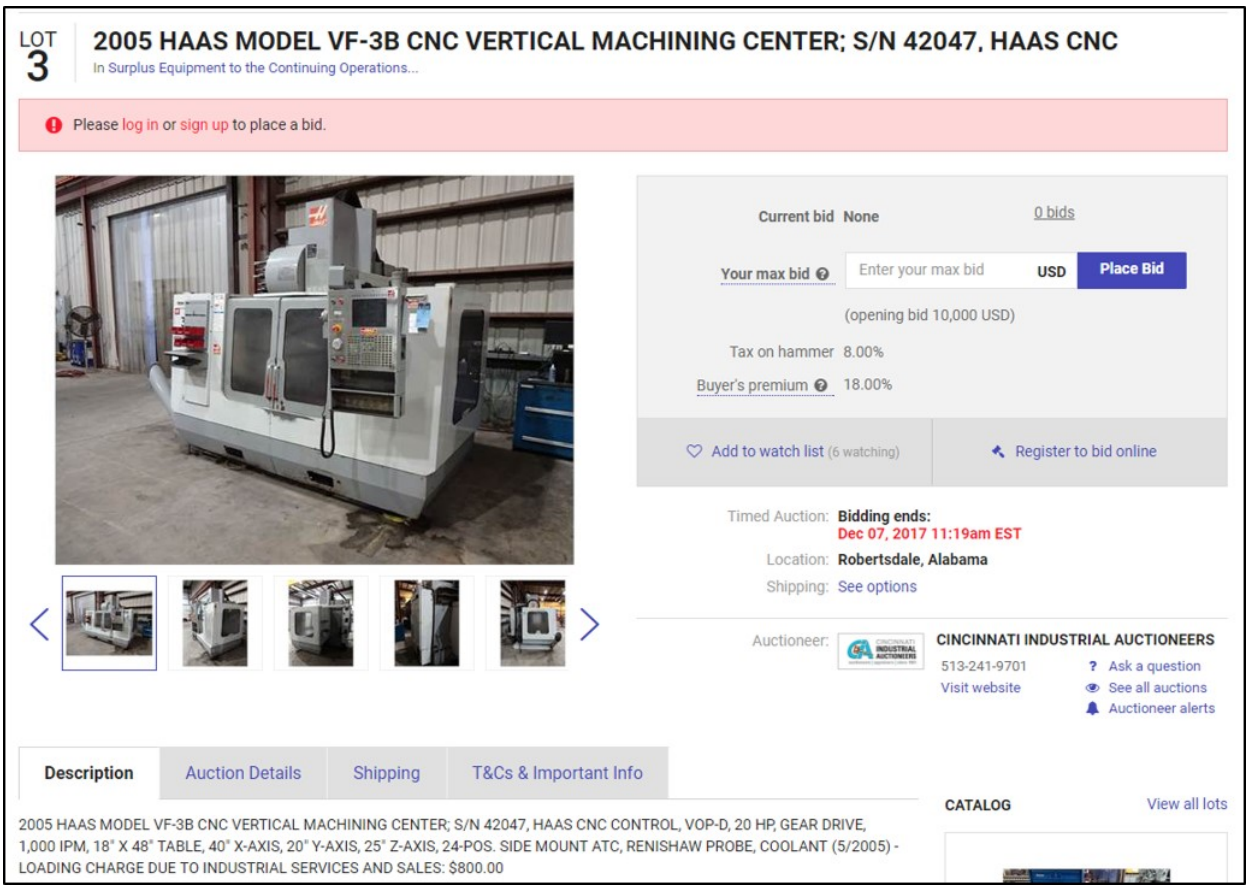

Figure 1. HAAS CNC Vertical Machining Center ("Bidspotter," 2017)

[1] Based on SME experience and previous interviews with OEMs.

Used machine tools are available from a variety of sellers including companies specializing in reselling machine tools such as Advanced Machinery[1], ABL Technology[2], Asset Exchange[3], CNC Exchange[4], and HGR Industrial Surplus[5], to name a few. Figure 1 features a machine tool for sale on Bidspotted, an online auction house. In one search, it was found that CNC Exchange, an online retailer specializing in used machine tools, had nine Haas manufactured machine tools for resale that likely meet control specifications.[6][7] Many companies offer remanufactured tools and services, posing a challenge to export controls related to machine tools and the secondary market. Additionally, with the development and spread of improved control software, it is in some cases possible to remanufacture or modify non-listed machine tools with new control software, allowing the machine to meet the technical specifications on the CCL.[8] This means that previously non-listed machine tools could become listed following remanufacturing. The following companies specialize in retrofits and remanufacturing: Hansford Parts and Products[9], Scott Machinery[10], and Texas Machine Tool International, LLC[11]. The possibility to remanufacture machine tools to meet or exceed control specifications requires further study, but, in any case, the remanufactured machine tool industry is strong and deserves attention. Many companies that use machine tools have exported their used equipment to recoup some of their investment; however, depending on the industry, these companies may not be aware of the requirements associated with exporting these used machine tools, as it is not their normal business model.

Based on the project team's research and SME interviews, a future study should take a deeper look at the market for used machine tools and the technical requirements for upgrading non-listed tools. Further, enforcement outreach should also focus on secondary market machine tools.

6.1.2 Mass Spectrometers

Finding: While less common than machine tools, mass spectrometers are frequently found on the secondary market.

Finding: A few specific industries (oil and gas, pharmaceuticals) frequently contribute used mass spectrometers to the secondary market. Given the likelihood that these mass spectrometers may be listed commodities and that these industries may not be aware of export control requirements, it may be valuable to understand how these sales are being handled and whether licenses are being appropriately requested for export.

Commodities referenced in this section include:

- 3A233.a-d: Mass spectrometers

[1] https://advanced-machinery.myshopify.com/
[2] http://www.abltechnology.com/en/
[3] http://www.assetexchangeinc.com/
[4] https://www.cncexchange.com/
[5] https://hgrinc.com/
[6] https://www.cncexchange.com/machinery-sale/all-machinery-sale?field_manufacturer_value=Haas
[7] These machine tools were reviewed by an SME with experience identifying listed machine tools. They indicated that the machine tools were likely listed.
[8] Interview with SME.
[9] Hansford Parts and Products. https://hpproc.com/
[10] Scott Machinery. https://www.scottmachinery.com
[11] Texas Machine Tool International. http://www.tmiusa.com/remanufacture.html

Mass spectrometers are used to monitor the performance of enrichment processes and to analyze compounds in reprocessing facilities. They also have civilian applications in analytical chemistry and the chemical and biomedical industry. A mass spectrometer features three components: an ion source, a mass analyzer, and a detector. The control language under 3A223 includes all these parts and components. This makes it difficult to separate mass spectrometer line items from the parts. However, given that there are relatively few listed mass spectrometer manufacturers, used items as a whole might be easier to identify in export data. Mass spectrometers are reusable, have a high likelihood of reuse, are distinguishable from non-listed commodities, and are frequently sold and observed on secondary markets. Used mass spectrometers have a very high resale value and can be remanufactured.

The global market for new mass spectrometers was valued at $4.6 billion in 2016 and is estimated to reach $7.9 billion by 2023 (Kunsel & Phalke, 2017). Mass spectrometers rank among the top listed commodities exported from the U.S. each year.[1] Key manufacturers of mass spectrometers include Agilent Technologies, Inc., Danaher Corporation, Waters Corporation, Bruker Corporation, Thermo Fisher Scientific, Inc., Perkin Elmer, Inc., Shimadzu Corporation, Kore Technologies, Ltd., Dani Instruments S.P.A., and Leco Corporation.

Similar to machine tools, mass spectrometers have a high resale value, thus companies are likely to resell used mass spectrometers to recoup their investment. As a result, many used or refurbished mass spectrometers are sold on eCommerce sites and by the manufacturers themselves. Specialized resellers are limited, but International Equipment Trading LTD[2] and LabX[3] are examples of companies with large supplies of used or refurbished mass spectrometers. Finally, SMEs noted that some industries generate more used mass spectrometers than others. Specifically, high-value industries, such as oil and gas or pharmaceuticals, typically spare no expense to have the very best and newest equipment. In comparison with most other industries, they are believed to sell used mass spectrometers more frequently.

It would be valuable for a future study to consider how the oil and gas and pharmaceutical industries are handling the sale of used mass spectrometers and if they are being controlled properly for export.

6.1.3 Chemical Process Equipment

Finding: Industrial trends, high initial investments, and good reusability result in great quantities of specialized chemical process equipment on the secondary market, and this is likely to continue.

Finding: Companies that specialize in the refurbishing and resale of glass-lined chemical processing equipment may be a priority for industry outreach, considering the high percentage of commodities expected to be listed.

Commodities addressed in this section include the following:

- 2B350 a-e, g-i: Chemical process equipment
- 2B231: Vacuum pumps
- 2A226: Bellows valves

[1] Based on SME interviews.
[2] https://ietltd.com/
[3] https://www.labx.com/

The project team identified chemical process equipment as a high-interest commodity group for the secondary market. Specifically, in this study, chemical process equipment refers to ECCN 2B350, which includes chemical reactors, agitators, tanks, heat exchangers, distillation or absorption columns, valves, pumps, and vacuum pumps. Two specific commodities, incinerators (2B350.j) and remotely operated filling equipment (2B350.f), are excluded from this list as they are specially designed and rare even on the new market. The project team has not observed multi-walled piping (2B350.h) for sale independently but assumes it is included in the sale of whole plants.[1] This section also includes vacuum pumps (2B231) and bellows valves (2A226) due to their similar characteristics.[2]

Chemical process equipment is of high interest to the secondary market primarily due to its high probability of reuse, given to its longevity, durability, and ability to be refurbished. According to several experts, some chemical process equipment is designed to last for decades (Council, 2014). Moreover, the chemical industry witnessed two important trends in recent years: 1) rapid growth focused in Asia where it was not previously located (see Figure 2) and 2) consolidation, with many companies specializing in the things they do best and contracting out other tasks. Altogether, these trends mean that the decommissioning and resale of chemical processing equipment is more common, and, consequently, more specialized chemical processing equipment may be available in the world market (Council, 2014). In fact, this trend is significant enough that the U.S. National Research Council released a report in 2014 stating, "Chemical manufacturing equipment never dies, but rather it comes back to life in some other form with some other use because of the significant initial investment that is made in these items" (Council, 2014, p. 11).

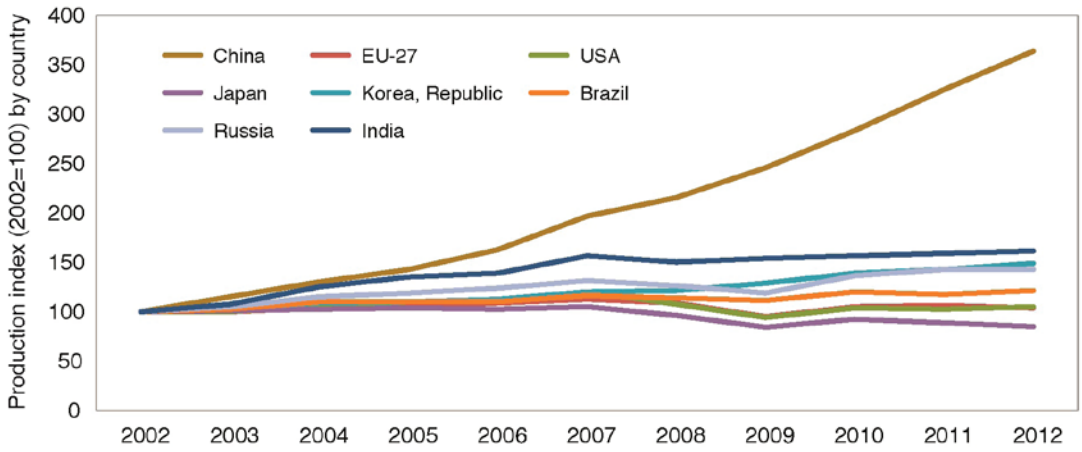

Figure 2. Production Trends in Chemical Processing, 2002-2012 (Council, 2014)

The high initial investment for chemical processing equipment also plays a large role in its likelihood of being reused. Even though decontamination and dismantlement can be expensive and time consuming, the return on investment can make the process worthwhile. Multiple resellers, auction houses, and specialty organizations sell or facilitate the sale of used equipment. For example, the Federal Equipment Company provides liquidation and auction services; they have at least 50 glass-lined reactors between

[1] It is not unusual to see entire used chemical processing plants for sale. While double-walled piping is not explicitly described in the description of these plants. It is possible that many of them may include double-walled piping. For more information, see: http://www.ippe.com/Plants

[2] Vacuum pumps are listed for nuclear nonproliferation under 2B231 and for chemical weapons under 2B350. Bellows valves (2A226) are controlled for both chemical weapons and nonproliferation.

100-20,000 liters for sale on their website.[1] Figure 3, below, shows search results for glass-lined reactors for sale by International Process Plants, totaling more than 200 items, many of which may be listed commodities.[2] Companies that specialize in plant dismantlement and relocation usually offer resale or "investment recovery" services.[3] In one case, R. Baker and Son recovered $4 million of process equipment by auctioning off components and equipment from a Kimberly Clark pulp mill (Son). Commodities included heat exchangers, agitators, and pumps, some of which may have been listed.

As with machine tools and mass spectrometers, a market for repairing and refurbishing chemical process equipment exists. For example, listed chemical processing equipment is often glass-lined, and the glass can develop defects or wear thin after years of use. Some such defects can be repaired using prefabricated repair kits of tantalum or tantalum alloy, or as a last resort the entire surface can be reglassed.[4] Reglassing is the complex process of repairing old, damaged or worn glass, returning affected equipment to a like-new state in only a few weeks.[5] The cost savings is said to be almost 50 percent of the list price of a new vessel. Given the economic incentives for refurbishing chemical processing equipment, a number of companies responded to this need, including De Dietrich Process Systems[6], Pfaudler[7], Empire Reglassing and Equipment[8], and Glasslined Technologies Inc.[9]

[1] For example, see: http://fedequip.com/inventory/Reactors/#/?_=1&filter.custitem_material_of_construction=Glass%20Lined&page=3

[2] http://www.ippe.com/Equipment/s/cl/Descr/glass

[3] For examples of these companies, see: Phoenix Equipment Corporation https://www.phxequip.com/resource-detail.39/process-plant-relocation-can-speed-expansion-save-money.aspx

[4] For more information on reglassing, see: https://www.ddpsinc.com/blog-0/what-is-reglassing-and-how-can-it-work-for-you

[5] Within the commodity group of chemical processing equipment, reaction vessels, agitators, storage tanks, containers, valves, and multi-walled piping can be reglassed.

[6] https://www.ddpsinc.com/de-dietrich-services/reglassing

[7] https://www.pfaudler.com/en/products/recondition-reglass

[8] https://www.empirereglassingandequipment.com/

[9] http://glasslined.us/

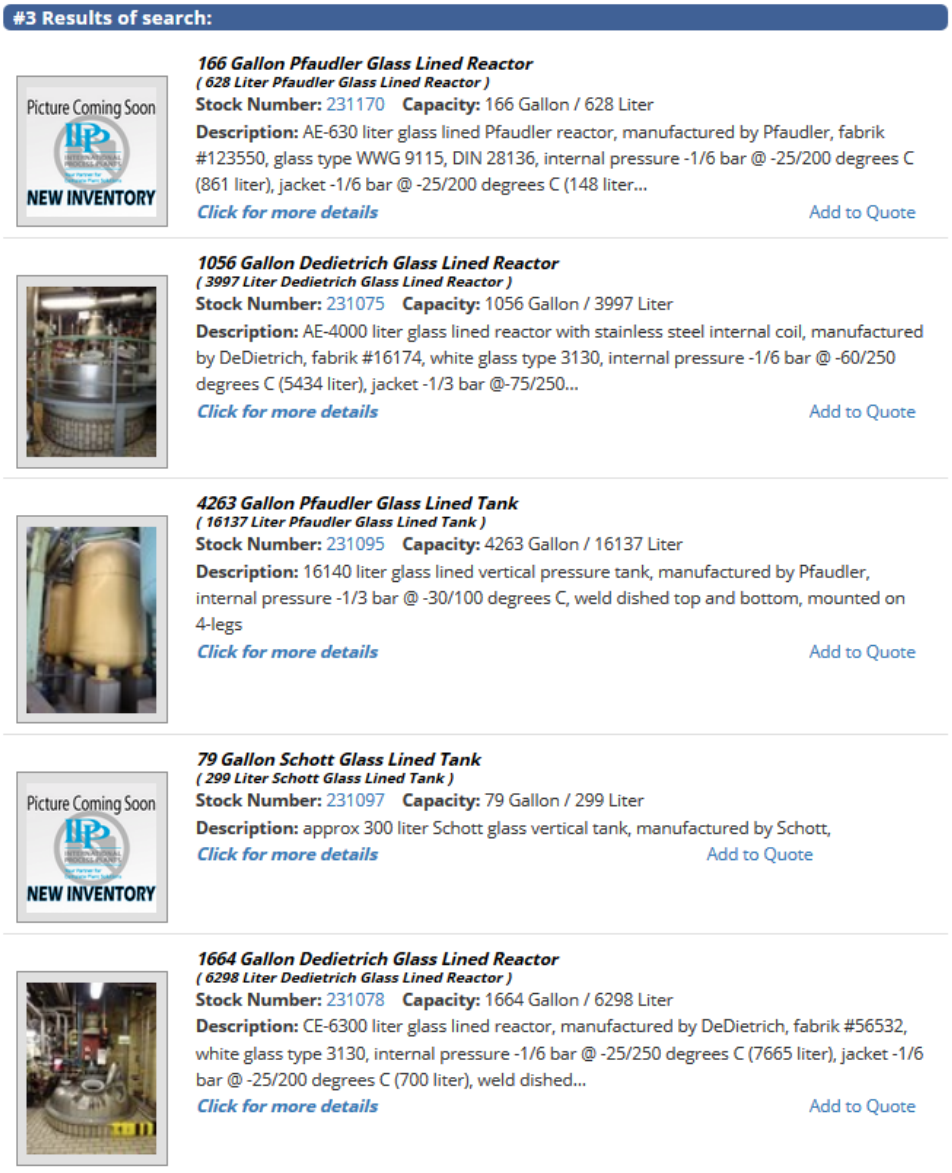

Figure 3 Search Results for Glass-lined Reactors for Sale by International Process Plants ("International Process Plants," 2019)

As mentioned at the beginning of this section, this study makes no effort to determine whether companies responsible for selling used or refurbished listed chemical processing equipment are aware of the export control requirements associated with this equipment. Naturally, only a small fraction of the equipment sold by companies recovering these investments are likely to be listed commodities. However, these companies that infrequently sell refurbished equipment (e.g., reglassed chemical processing equipment) may not be as familiar with export requirements, unlike the OEM that have more experience.

Given the strong secondary market for chemical process equipment and the good possibility that listed commodities may exist in that market, outreach to resellers of used or refurbished chemical process equipment and whole processing plants is advised.

6.1.4 Biological Process Equipment

Finding: Biological process equipment has a high likelihood of reuse and has been seen on the secondary market.

Finding: The DIY Bio community is an area where the secondhand market for biological process equipment is likely to continue growing, and for that reason, more outreach may be necessary.

Commodities addressed in this section include the following:

- 2B352.b-i: Biological process equipment

The project team identified biological process equipment as a high-interest commodity group for the secondary market. Biological process equipment (ECCN 2B352) includes fermenters, centrifugal separators, cross-flow filtration equipment, steam-serializable freeze-drying and spray-drying equipment, protective and containment equipment, aerosol testing chambers, aerosol challenge testing chambers, inhalation chambers, and spraying and fogging systems. P3 and P4 biological containment facilities (2B352.a) are of low interest as none were observed on the secondary market, likely because they are special ordered by a purchaser. With this exception, all of the commodities in ECCN 2B352 are reusable and have a high likelihood of reuse. They are easily identified, have a high frequency on the market, and have been observed for sale on the secondary market.

The researchers, Zilinskas and Mauger, have thoroughly documented the reuse of biological process equipment, and their work supports an important conclusion reached by several researchers: most biological process equipment is cheap, widely used, and easily available secondhand (Shaw, 2016; Raymond A. Zilinskas & Philippe Mauger, 2015). Moreover, it is not uncommon for end users to repurpose or recondition biological process equipment (Raymond A. Zilinskas & Philippe Mauger, 2015). This is particularly true with biotechnology and fermentation industries “where process conditions are generally mild and non-abrasive, and for equipment that has no moving parts” (Council, 2014, p. 9). This means that it is common and cost-effective to remanufacture and resell biological process equipment on the secondary market. In fact, a quick search of LabX, one online facilitator specializing in biological process equipment, yielded results for all of the commodities listed (aside from P3 and P4 biological containment facilities). See Figure 4 for an example of one type of used and potentially listed biological process equipment, a pass-through vacuum steam sterilizer.

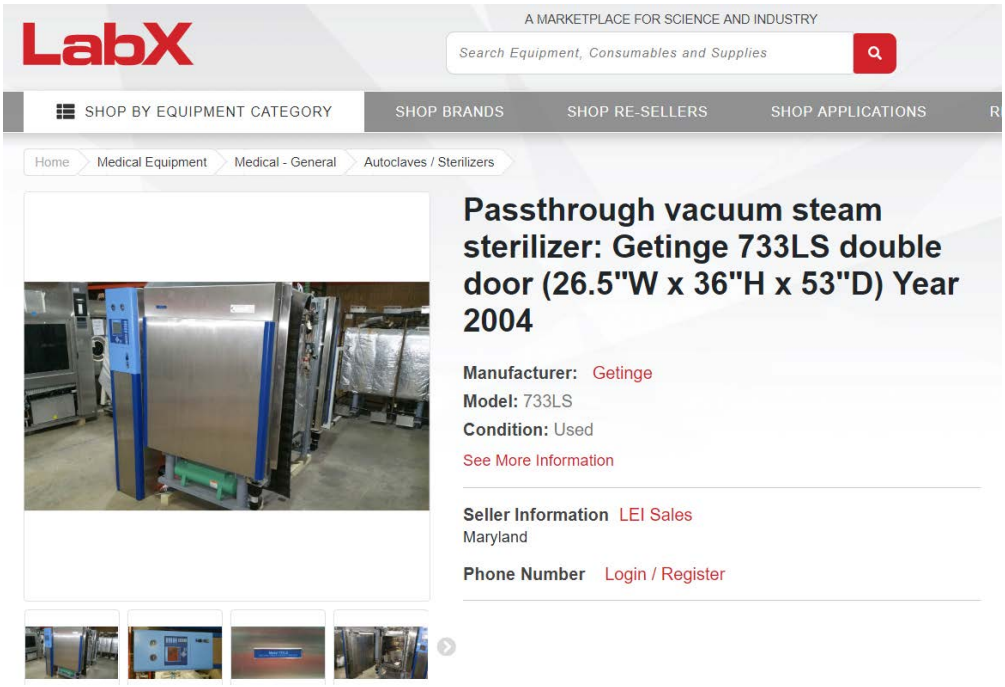

Figure 4 Passthrough Vacuum Steam Sterilizer ("LabX," 2019)

The market for secondhand biological process equipment will continue growing, particularly in light of the recent trend known as the "Maker Movement" or "Do It Yourself (DIY) Bio." New developments in life sciences research launched a paradigm shift regarding where and how such research is performed. Research once conducted by top research institutes and governments can now be conducted at home or in small laboratories by DIY Bio enthusiasts. These small-scale operations do not have support teams to assist them with navigating the legal and regulatory requirements and responsibilities that accompany such research, which presents challenges to enforcement of bio-related laws and regulations. Fortunately, this issue has gained the attention of the U.S. Government, and programs[1] are in place for outreach to the biological research communities, including the DIY community (Wolinsky, 2016). The export control community, from large government outreach programs to industry export control offices, can support this outreach by promoting export control awareness among the new and existing biological research communities.

Similar to chemical process equipment, given the strong secondary market for biological process equipment, the growing DIY Bio movement and the good possibility that listed commodities may exist in that market, outreach to resellers of used or refurbished biological process equipment is advised.

[1] Since 2009, the FBI has made efforts to engage the DIY Bio community, beginning with sponsoring a booth and workshop at the 2009 International Genetic Engineered Machine (iGEM) competition in Cambridge, MA. The engagement has continued since then through sponsorship of several synthetic biology conferences and hosting a number of meetings with the DIY Bio community, including the FBI- sponsored "Bridges" Meeting in San Francisco in 2012.

6.2 Listed Commodities of Medium Interest

Commodities included in this sub-section are generally identified as medium-interest based on the criteria described in section 4.0 *Methodology*. The team identified listed commodities of medium interest based on the following reasons: they are reusable with a high likelihood of reuse, have a high presence on the secondary market, but are inferior to the high interest commodities in several ways:

- **Lower Cost Savings:** The cost difference between new and used is smaller than for high-interest commodities. Instead of saving hundreds of thousands of dollars, buyers would be saving hundreds to thousands of dollars, which might not make the performance degradation worth the price.
- **Remanufacturing or Refurbishment Unlikely:** Compared to high-interest commodities, these commodities are less amenable to remanufacturing or refurbishment. The value is not recouped to the same extent as with high-interest commodities.
- **Medium Frequency on the New Market:** These commodities are relatively less frequent on the new market than the high-interest commodities, indicating they could be less prevalent on the secondary market.

Commodities in the medium-interest category include:

- Toxic gas monitoring systems (2B351)
- Protective and detection equipment (1A004)
- Analog-to-digital converters (3A002)
- Accelerators (3A101)
- Frequency changers (3A225)
- High-voltage and high-power DC power supplies (3A226, 3A227)
- High-speed pulse generators (3A230)

For more detail on these commodities see the “Medium Interest” tab in Appendix A. The research team prioritized in-depth analysis for only the high-interest listed commodities. Future research could provide in-depth analysis on medium- and low-interest listed commodities. .

6.3 Listed Commodities of Low Interest

Commodities discussed in this section are identified as low-interest *Listed Commodities of Interest* based on the criteria described in section 4.0 *Methodology*. The team identified these commodities based on the following reasons: despite being reusable and having some likelihood of reuse, they may either be indistinguishable from the non-listed counterparts or not frequently observed on the secondary market. If these items are seen on the secondary market, they are of interest but the following characteristics could negatively affect their presence:

- **Absence on the New Market:** Commodities that are rare on the new market may be impossible to find on the used market simply due to insufficient supply, or they are so quickly purchased they do not register on any market sites.
- **Specially Designed:** Special order commodities are difficult to sell because they are tailored to the original buyer’s needs and may be difficult to adapt to other applications. Difficulty selling an item may preclude someone from posting it for sale even if they want to resell it. For example, if an

aircraft company special orders a tape laying machine (1B001) to produce composite airframes, it would be unlikely to fit another company's needs.

- **Difficulty Refurbishing:** While returning a commodity to its original state may be technically possible, it is not always easy, particularly for recycled materials. For example, radiation shielding windows (1A227) will stay in a facility until the facility is decommissioned. A radiation shielding window could be decontaminated and reused, but it is unlikely.[1]
- **Traded vs. Sold**: Some commodities are traded, rather than sold, and are therefore difficult to observe on the secondary market. The most important example of this type of commodity is biological materials, which are often shared between researchers. For more information on this phenomenon, see section 6.5.2.1 *Biological Materials and Awareness of Requirements*.

Naturally, the importance of the aforementioned criteria varied between commodity groups. Some commodities in this group were reviewed in greater detail because they were originally thought to be of greater interest; analysis of those commodities is included in Appendix C. For more information on all commodities in this section see Appendix A, tab "Low Interest". Future research could provide in-depth analysis of listed commodities of low interest.

Commodities in the low-interest category include:

- Biological materials
  - Human pathogens, zoonosis, toxins (1C351)
  - Genetic elements, genetically modified organisms (1C353)
  - Plant pathogens (1C354)
- Metals
  - Aluminum alloys (1C002.b.4, 1C202.a)
  - Titanium alloys (1C002.b.3, 1C202.b)
  - Tungsten (1C117.a, 1C226)
  - Hafnium (1C231)
  - Zirconium (1C234)
  - Molybdenum (1C117.b)
  - Depleted uranium (1A290)
- Graphite (1C298)
- Superconducting solenoidal electromagnets (3A001.e.3, 3A201.b)
- Accelerometers (7A001)
- Cameras (6A003)
- Composites production equipment (1B001, 1B101, 1B201)
- Drone production facilities (9B610)

[1] Notably, one of the project SMEs observed the sale of used radiation shielding windows but in a very rare case, when a facility was built and used only lightly before being decommissioned.

- Furnaces (2B105, 2B226, 2B227)
- Gravity meters (1A290, 6A007, 6A107)
- Lasers (6A005, 6A205)
- Radiation-shielded windows (1A227)
- Remote manipulators (2B225)

6.4 Listed Commodities of No Interest

Commodities discussed in this section are generally identified as having little or no interest for the secondary market based on the criteria described in section 4.0 *Methodology*. The project team identified the following commodity characteristics that either exclude reuse entirely or degrade commodity performance, such that it would not be desired for a WMD application. These characteristics are not exhaustive but provide a quick reference for understanding which listed commodities are not relevant for the secondary market.

- **Consumables:** Many listed commodities are used only once, as they will be permanently destroyed following use (e.g., many missile components, detonators) or use will irreversibly degrade the performance (e.g., some filters).
- **Custom Design:** Numerous commodities are judged to not be reusable because they are specialized for the system or application, and therefore they cannot be reused for a new application. Many missile or aerospace components are specifically designed for that model or application and can only be reused in the exact same application.
- **Degraded Performance with Use:** For many listed commodities, performance degrades with use. Reusability depends on the performance of the commodity and, thus, reusability also depends on the extent, duration, and/or conditions of use. For example, many commodities (e.g., switching devices, triggered spark gaps) can only be used a certain number of times before the reliability is compromised. For commodities exposed to extreme conditions (e.g., radiation), their reusability degrades with the severity of the conditions and duration of exposure. For these reasons, some used commodities may not be as common in the secondary market, but further investigation is required to confirm this.

The following information summarizes the results for the commodities listed as little to no interest for the secondary market. A full list of the commodities can be found on the tab titled “No Interest” in Appendix A. The team identified commodities of no interest based on the following reasons:

- **Listed Commodities that are Not Reusable:** Commodities indicated as “Not Reusable” are not reusable as they are either single use or destroyed in use.
- **Listed Commodities with a Low or No Likelihood of Reuse:** Commodities indicated as “Reusable Unlikely” are reusable and the likelihood of reuse is low or nonexistent. From a technical perspective, these commodities are likely to perform at or near the required specifications, but for reasons discussed previously they would not be reused.
- **Listed Commodities that are Difficult to Distinguish from Non-listed Commodities:** Commodities indicated as “Indistinguishable” are reusable but researching them was impeded by difficulty identifying the correct commodity and finding them on the secondary market would be difficult.

- **Listed Commodities Rarely Found on the New Markets:** Commodities indicated as "Rarely New" are reusable and the likelihood of reuse is high, but they are not frequently seen on the new market. In the unlikely event these are seen on the new or secondary market, they would be of interest.

6.5 Cross-Cutting Issues

The project team identified several issues unique to the secondary market which transcend the individual listed commodity discussion. These topics warrant further discussion.

6.5.1 Recycling of Scrap Metals and Other Materials

Finding: With current recycling processes, most metals cannot be recycled and returned to the composition or performance required for listed commodities. However, consumer and economic trends are changing rapidly in this area, along with innovations in recycling technology. Therefore, research should continue on this area.

Finding: Aluminum, titanium, and graphite are the materials most likely to be reused for production of listed commodities.

In general, many materials (especially metals) are reusable and the recycling industry is growing. The United Nations noted that metal reuse (or recycling) needs to dramatically increase to meet the growing demands for critical metals including aluminum, molybdenum, titanium, and tungsten (Graedel et al., 2011). However, three necessary conditions must be met for recycling to be feasible:

1) A supply of material must exist. Many materials dissipate with use and cannot be recycled. For example, the titanium pigment found in many paints cannot be easily recovered. On the other hand, some metals retain their mass while in service, making them good candidates for recycling.

2) The cost of identifying, collecting, processing, and transporting scrap materials must be low enough to provide a profit margin for an entity that would perform those tasks.

3) The quality of recycled materials must be sufficient. In many cases, recycled materials are used in lesser applications because recycling mixed materials dilutes and compromises their composition. This means that some recycled materials may not be ideal for strength-critical areas (e.g., WMD applications), unless it is possible to verify the recycled material's composition. While high-strength metals can be made from scrap, it is only economical when the origin and composition of the metal are known, like with new scrap.

Scrap can be described as either new or old. New scrap is generated during fabrication and manufacturing operations, usually in the form of clippings, stampings, and turnings. These items are usually segregated by material specification and returned to furnace operations where the scrap is matched and melted into a product with the desired composition. The location of new scrap recycling varies: some companies recycle onsite or release it to a contracted recycler, others return it to the source which may be in a foreign country. Old scrap originates when a product of the aforementioned manufacturing process is no longer economical to use (e.g., an old airplane). Unlike new scrap, which is usually recycled directly, old scrap may wait for years until it is recycled and may be mixed with other old scrap materials. As a result, it is more difficult to tell the origin of old scrap and, consequently, more difficult to recycle it to the same standards for composition and strength. The one exception is graphite, for which the recycled properties may be superior to those of its new counterpart, in some cases (Liu, Wang, Dong, & Liang, 2016).

Though recycling of graphite is uncommon, it may be wise to examine innovations and increases in graphite recycling.

Future research should focus on those companies recycling new listed scrap and those which claim to produce listed materials from recycled scrap. Advancements in recycling approaches that make the recycling of old scrap more economical at the quality required for WMD applications should be monitored. For additional discussion of the issues related to the secondary market for recycled metals and graphite, see Appendix C.

6.5.2 Institutional and Regulatory Issues to the Secondary Market

In conducting this analysis, the project team discovered several institutional and regulatory issues relating specifically to the secondary market for some listed commodities. While a thorough analysis of these issues is beyond the scope of this study, an overview of these issues is provided below. These issues may deserve further investigation in a follow-up analysis.

6.5.2.1 Biological Materials and Awareness of Requirements

Finding: Biological materials may be transferred on the secondary market by researchers who are unaware of the export control requirements but may be more aware of safety-related requirements.

The project team identified biological materials as a commodity group of interest for the secondary market. In this context, the term *biological materials* refers to human pathogens, zoonosis, and toxins (1C351), plant pathogens (1C354), and genetic elements and genetically modified organisms (1C353).

SME interviews indicated that the transfer of secondhand biological materials between people is quite common, but the materials are usually shared between people, rather than sold. For instance, a research team will share an attenuated strain of a virus with other researchers (domestically or internationally), once their findings have been published, to allow others to conduct their own study or try to replicate the results. However, SME interviews indicated that many U.S. researchers are more familiar with the Select Agents regulations[1] governing biological materials and research rather than export control regulations. This lack of awareness is important, because the types and quantities under control differ between the regulations. For example, under the select agent requirements, an attenuated strain of a select agent or an inactive form of a select toxin may be excluded from the requirements. However, no such exclusions exist under the EAR: an attenuated strain, if listed on the CCL, might require an export license. As such, a researcher, who is familiar with the select agent requirements may share an attenuated strain of a listed biological material with an international colleague without obtaining an export license, thereby violating the EAR. This topic may warrant further inquiry.

6.5.2.2 Superconducting Solenoidal Electromagnets

Superconducting solenoidal electromagnets (SSEs) (3A001.e.3, 3A201.b) are powerful electromagnets that are often found in Magnetic Resonance Imaging (MRI) machines, mass spectrometers, fusion reactors and particle accelerators. Even though they are reusable, they are not often found alone (i.e.

[1] The Select Agent regulations are provided by 7 C.F.R. Part 331 (Agriculture), 9 C.F.R. Part 121 (Animals and Animal Products) and 42 CFR Part 73 (Public Health). For more information, see: https://www.selectagents.gov/regulations.html

outside of a larger piece of equipment) and have not been observed on the secondary market. For this reason, the likelihood of reusing SSEs is unknown. However, there are two aspects of SSEs that make them interesting to the secondary market. First, SSEs are not listed when incorporated into MRI [1,2] equipment. This is important because MRI equipment can be found in most large hospitals worldwide, meaning that the quantity of SSEs that have been exported is much greater than would be indicated by export license records alone. Secondly, a market for recycling MRI components does exist, meaning that it is likely that used SSEs are being bought and sold (Market, 2018). A future study could investigate whether SSEs could be repurposed for other applications or if they are sufficiently "specially designed" to limit their application to only MRI machines.

7.0 Recommendations

The following section outlines recommendations for incorporating findings of this study into existing activities and avenues for further research to enable companies and the U.S. enforcement community to ensure secondary market compliance with export control regulations.

7.1 Incorporate Findings into Trainings

The findings from this study should be incorporated into existing and new U.S. export control trainings. The U.S. government offers a variety of training opportunities for domestic and foreign entities on export controls. These trainings should include a section on the secondary market and, specifically the high-interest listed commodities found on the secondary market. Additional research on high-interest listed commodities (recommended in section 7.7.2) could improve identification and targeting of these commodities which could enhance training materials.

7.2 Outreach to Companies

The best way to prevent the illegal export of dual-use commodities is through outreach to companies using and selling these commodities to raise their awareness of export control requirements. The project team identified two recommendations:

Outreach efforts should prioritize specialty resellers and remanufacturers focused on any of the high-interest listed commodities. While large eCommerce facilitators such as eBay do undoubtedly facilitate the sale of used listed commodities, outreach to these companies is more challenging for two reasons: 1) they have less legal incentive for compliance, as they have no legal liability, and 2) they typically sell a wider variety of commodities, making it difficult to target outreach and education. Therefore, outreach efforts should prioritize specialty resellers (e.g., LabX) and companies refurbishing specialized equipment (e.g., glass-lining companies) for high-interest listed commodities. Outreach should focus on raising awareness of export control regulations and building relationships in case these specialty resellers receive a suspicious inquiry. Enforcement officials can identify and prioritize

[1] 3A001.e.3 does not control "superconductive" electromagnets or solenoids "specially designed" for MRI medical equipment.

[2] 3A201.b does not control magnets "specially designed" for and exported "as parts of" medical nuclear MRI systems. The phrase "as part of" does not necessarily mean physical part in the same shipment; separate shipments from different sources are allowed, provided the related export documents clearly specify that the shipments are dispatched "as part of" the imaging systems.

companies in their area of responsibility using export data and online research. SMEs might be essential in identifying companies for outreach. Further, government outreach efforts can focus on bringing together companies from similar industries, so that companies with well-established compliance programs can help smaller companies in establishing their compliance programs.

Outreach personnel should encourage companies to track export control information for the listed commodities they use. Companies understand the regulations governing the export of the listed commodities they sell regularly, but they may be less informed about the regulations on the equipment they actually use for manufacturing. Further, outreach efforts usually focus on ensuring companies follow export control regulations for the listed commodities they produce and export. For companies that use listed industrial equipment, outreach should also focus on export control plans for this equipment. This could include recording the ECCN at the time of the original purchase, creating and maintaining a record of each listed commodity they use, and using this information to determine how the listed commodity should be excessed.

7.3 Commodity Tracking or Listing

During this analysis, the project team often encountered difficulty matching secondhand commodities to the control language due to incomplete or confusing commodity descriptions. Similarly, it is often difficult for resellers to properly classify a commodity in relation to the EAR, and it would therefore be helpful to have an easy way to identify listed commodities. Companies can ask the relevant licensing authority[1] for assistance in making a determination, and many companies store this ECCN data in their private databases. Access to such information could greatly improve compliance with export control regulations; however, this information is rarely shared publicly. The U.S. Government should encourage companies to implement the following:

OEMs of listed commodities should include ECCNs in technical specifications. Manufacturers of listed commodities provide the ECCN to a domestic buyer upon request. It should be common practice for manufacturers to include the ECCN down to the subparagraph level (if necessary) in the bill of sales and on the technical specification datasheet (see section 7.5 *Awareness of New Innovations in Materials Recycling*). This would help maintain continuity of knowledge regarding the export control regulations governing that item.

OEMs should maintain a public list of all listed commodities and corresponding ECCNs. It was much easier for the project team to identify used listed commodities with a model number. Dell maintains a reference table of ECCNs, Harmonized Tariff Schedule Numbers, and Commodity Classification Automated Tracking System codes.[2] Companies could consider maintaining a list of all their commodities and the corresponding ECCNs including non-listed commodities.

OEMs should consider adding ECCNs to commodity name plates. In many industries, commodities are affixed with an information plate containing a variety of information including certifications, technical specification, and manufacturer. For example, pressure vessels are affixed with a National Board Number which can be tracked (Council, 2014). However, export control information is rarely attached. If companies included ECCNs on the name plates, resellers and enforcement personnel would have an easier time referencing them.

[1] The licensing authority for dual-use commodities is the U.S. Department of Commerce's Bureau of Industry and Security. For military commodities, the authority is the U.S. Department of State's Directorate of Defense Trade Controls.

[2] https://www.dell.com/learn/us/en/uscorp1/import-export

One of the main arguments for not listing an ECCN is that control lists change over time. This means a commodity meeting control specifications today might be non-listed (EAR99) in a few years as technology and control lists change. Any easy solution could be to list the ECCN and date then a potential seller would know that the commodity was listed at that time. They could then cross reference the CCL from that date with the current version to see if the item meets the current control language. This is only one potential solution; further research and outreach might be necessary to move forward with this idea.

7.4 Guidelines for Rendering Listed Commodities Useless

Regulators should consider providing guidance on best practices, processes, and procedures to help companies excess or dispose of their dual-use commodities securely. No agreed upon definition of, or guidelines exist for, rendering a listed commodity useless. Specific guidelines for rendering military commodities useless do exist, but no guidelines exist for dual-use commodities. The Wassenaar Arrangement documented “Best Practices for Disposal of Surplus/Demilitarised Military Equipment” provides some information on rendering useless, (*Compendium of best practice documents*, 2016) but the document stops short of providing activities or instructions on how to dispose of military equipment. Similarly, U.S regulators have not yet provided any information on disposition of dual-use commodities, which leaves the decision with companies. One SME recounted a story of a rusty magnet being left in a storage container for years, because it was unclear how to excess the listed commodity. Guidance on end-of-life best practices, processes, and procedures from regulators would help companies dispose of their dual-use commodities securely.

7.5 Awareness of New Innovations in Materials Recycling

The export control community should monitor innovations in materials recycling, particularly if these recycling methods can create a recycled materials of a higher quality than new materials. Presently, new scrap is the only material that could be recycled into listed materials. As recycling practices improve, the importance of certain materials for the secondary market should be revisited. For example, several SMEs stated that that powders cannot be reused. However, studies related to additive manufacturing are changing long-held views regarding powder use and recycling (P. Tang et al., 2015; "Recycling Titanium Powder," 2018). Recently, a PhD candidate from the Additive Manufacturing Research Group at McMaster University reported the possibility of reusing aluminum alloy powder without quality degradation (Belforte, 2018). Considering current recycling trends, recycled powders likely would not be the preferred materials for strength-critical applications, but the final results are unclear. Furthermore, additive manufacturing creates far less material waste despite using a more expensive raw material, mainly powder ("How Can Additive Manufacturing Help the Aerospace Sector?," 2019; Markham, 2018).

Another example is carbon fiber, which is currently a single-use commodity. However, scientists and industry are investigating the reuse of carbon fiber due the high amount of new scrap generated during the production process. Like other recycled materials, it is unclear if recycled carbon fiber could meet the performance requirement of new carbon fiber or be economical to recycle. However, the rapidly changing nature of the recycling industry may make it more cost-effective to source listed materials from scrap at the same quality as new materials. As such, trends in recycling should be monitored.

7.6 Understand Industry Compliance and Incentives

A group of industry leaders in the secondary market should be convened to understand how they think about export control regulations and identify incentives that will encourage secondary

market sellers to improve their compliance with export control regulations. Resellers, particularly facilitators, should consider listed commodities as part of their user agreement. For example, eBay prohibits the sale of certain restricted items, which are enforced by monitoring users with a variety of tools including filters (Council, 2014, p. 23). Other companies should be encouraged to institute similar procedures, but no general set of best practices currently exists for these secondary market sellers.

7.7 Future Research

This study provided an initial survey of *Listed Commodities of Interest* to the secondary market. This section provides recommendations for follow-on research aimed to gain a greater depth of knowledge on secondary markets for specific *Listed Commodities of Interest* and assist U.S. enforcement of export control regulations.

7.7.1 Export Data Analysis

To measure and validate the findings in this study, future research is needed to quantitatively analyze trade data for the *Listed Commodities of Interest* to the secondary market. The findings in this preliminary report were based primarily on the experience and opinions of SMEs familiar with the commodities considered. With access to additional trade data, including licensing and export histories, it could be possible to verify the prioritization of commodities and further identify companies who actively export used commodities. For example, accelerometers are very desirable but were difficult to identify in the secondary market. Additional data may be able to provide deeper insight.

Further, such an analysis could help enforcement personnel identify resellers they may wish to engage with. Through research for this paper the project team identified a few methods to more easily identify resellers and used listed commodities. One possibility might be pairing an ECCN with a Harmonized System (HS) Code for used equipment. For example, ECCNs for machine tools (2B001 and 2B201) paired with HS Code 8457.10.0005 for machining centers that are used or rebuilt. Additionally, keywords such as “scrap” and “used” in the commodity description might be helpful as would keywords in company names such as “liquidators,” “recycle,” “scrap,” or “surplus,” which could help identify companies selling used commodities. More research is necessary to refine the approach, these strategies could help enforcement personnel identify resellers they may wish to engage with.

To prioritize engagement related to the secondary market, export trade data could be analyzed to identify partner countries which receive greater quantities of *Listed Commodities of Interest*. Recipient countries of large quantities of U.S.-origin *Listed Commodities of Interest* have the potential for a robust secondary market for these commodities. Foreign companies are required to obtain U.S. export license in order to transfer or re-export a listed commodity to another controlled end user or destination. Export data could allow outreach personnel to prioritize secondary market engagement with partner countries based on their receipt of *Listed Commodities of Interest*. For instance, if a partner country is the largest recipient of U.S. origin machine tools, outreach to that country could help local authorities enforce local and U.S. export control laws on machine tools within their secondary market.

Note: Any research involving export data would need to be conducted at the direction of U.S. enforcement communities. Demonstrating the value of such analysis would be key to gaining their support.

7.7.2 Deep Dives on Listed Commodities of Interest

The *Listed Commodities of Interest,* particularly high-interest commodities identified in section 6.1, should be researched in-depth by small groups of relevant SMEs. A deep-dive analysis of these commodities could highlight the communities that might reuse these commodities and provide better mechanisms for identifying the used commodities including rebuild costs, resale value, and other factors. For example, it could be valuable to understand exactly how difficult it is to refurbish a previously unlisted machine tool and make it meet the control specifications to be listed. These deep dives should be paired with the export data analysis, discussed in section 7.7.1 to provide more precise results. This research could also identify resellers to conduct export control awareness raising and outreach. A deep dive should capture how equipment enters the secondary market, the actors involved, what happens to unsold equipment, and the extent to which a commodity should be rendered useless to become non-listed. With respect to each high-interest listed commodity these deep dives should focus on commodity-specific issues such as:

- **Machine Tools:** The potential to remanufacture previously unlisted machine tools to meet or exceed control criteria.

- **Mass Spectrometers:** Understanding the lifecycle for used mass spectrometers in high-value industries like oil and gas or pharmaceuticals.

- **Chemical and Biological Process Equipment:** Given the potential scope of the secondhand market for chemical and biological process equipment, it will be valuable to understand which listed commodities are most common on the secondary market.

Further, future research could also focus on other *Listed Commodities of Interest*.

- **Recycling of Scrap Metals and Other Materials:** With current recycling processes, most metals cannot be recycled and returned to the composition or performance required for listed commodities. However, consumer and economic trends are changing rapidly in this area, along with innovations in recycling technology. Therefore, research should continue on this area.

- **Superconducting solenoidal electromagnets:** A future study could investigate whether SSEs could be repurposed for other applications or if they are sufficiently “specially designed” to limit their application to only MRI machines.

- **Biological materials:** While not identified as a high-interest listed commodity, a deep dive study on the secondary market for listed biological materials could provide important results, given the preliminary finding that such materials are transferred by researchers who may be unaware of the export control requirements. Such a study could shed light on any gaps between export control and safety-related controls, training, and implementation.

7.7.3 Secondhand Listed Commodities that Would be Used in a WMD Program

To further refine the results of this study, an analysis could be performed to assess the desirability of used, listed commodities for use in a WMD program. This analysis would separate used, listed commodities that are real proliferation threats from those that are simply reusable. This study deliberately avoided analysis of desirability of a listed commodity for a WMD program, because it would have required much greater analysis of the intent of specific actors. Analysis of desirability would have quickly

made this study classified, which was not the objective of this preliminary report. However, follow-up classified analysis of the secondary market for listed commodities could be valuable.

7.7.4 Surplus Market

A similar study, focused on the surplus market for listed commodities, could provide important results on some commodity groups excluded from this analysis. The surplus market was excluded from this research; however, a robust surplus market exists for many listed commodities. Many commodities were excluded from this study because of their single-use nature (e.g., carbon fiber, chemicals, and missile components) but could nonetheless be present on the surplus market and relevant to export controls. Similar to the used market, surplus sellers may not have the requisite knowledge to properly identify and control their items. A study focused on this area of the secondary market could use the methodology and knowledge gained from this research to shed light on additional areas to enhance export control enforcement and outreach.

8.0 Conclusion

Economic and technological trends are changing the way consumers think about used commodities. This study demonstrated that select listed commodities are resold on the secondary market – a concern for implementation of export control regulations. Findings from this study should be incorporated into current training and outreach programs. However, there is still considerable research that needs to be conducted to fully address the concerns of used *Listed Commodities of Interest* being sold through secondary markets. Additional research will yield valuable information to support outreach and enforcement activities and will provide further opportunities to gather data for supporting targeting and risk managements systems. With the incorporation of even some of these recommendations into existing U.S. enforcement activities and further research into the potential risks posed of secondhand dual-use commodities, the U.S. can continue to foster a healthy yet secure secondary market for listed dual-use commodities.

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Appendix A
Commodities of Interest and Results

See accompanying Excel file titled "Appendix A – Commodities of Interest".

Appendix A include 4 tabs: *High Interest*, *Medium Interest*, *Low Interest* and *No Interest*. An "x" in any column indicates that characteristic was not considered in the final determination, usually because the commodity had already been removed from further consideration.

Appendix B
Interview Questions

B.1 Purpose

The purpose of this interview is to gain insight from an SME on the reusability of weapons of mass destruction-related commodities to identify commodities with high probability of reuse or resale and understand the availability of and demand for such commodities in the secondary market. The initial interview will be conducted at an unclassified level. If further discussions are necessary, a follow-up interview will be arranged in the appropriate space.

B.2 Background

Listed commodities are regulated throughout their lifetime, but the continuity of knowledge of controls over those commodities is sometimes lost as items are sold and resold in the secondary market. For example, some dual-use commodities and technologies are removed from service and fall out of control because manufacturers or experts develop or desire newer, faster, more efficient approaches. However, the development of newer and better technologies does not mean "outdated" items have lost their functionality or technical value. For example, though the materials were not obtained on the secondary market, this phenomenon allowed Iraq to pursue its own nuclear ambitions in the 1980s using inefficient enrichment technology, which the international community had deemed obsolete. The technology was not state of the art, but it was effective enough to perform the tasks necessary to achieve their goals. Similar technologies could exist in the rapidly expanding secondary market, but the risks posed thereby are not well understood by the U.S. Government nor have mitigation measures been systematically integrated into U.S. enforcement and multilateral export control programs.

For this study, the secondary market is defined as the post-retail market for selling unwanted goods. These goods can either be unused (e.g., excess), used, or disposed (e.g., scrap). The sellers in this market include original buyers, specialty resellers, and auction houses (brick-and-mortar and online). This definition excludes original manufacturers and distributors, who are expected to have better understanding and awareness of export controls and the commodities they are selling.

B.3 Supply-Related Questions

- Are you aware of situations in which items classified under this ECCN have been reused?
- If not, could you think of any situations in which this commodity might be reused?
- Would a subset be reused?
- Do some lend themselves to be more reuse-friendly than others?
- Is it a single-use item?
- What are the conditions in which the item could not be reused?
- Could this item be refurbished/remanufactured? How difficult or easy would it be? Could it be remanufactured to meet the standards to which it was originally manufactured?
- In which cases could these items be reused or not?

- Does the item expire? What does expiration imply? (e.g., performance, still useful for some [less sensitive] applications)
- Is there a difference in performance between new and used?
- Have you ever seen this type of item resold? In what condition (resell/surplus, used/refurbished)?
- How often are these items resold/reused?
- Who usually resells these items? Source of these items?
- Does the item have good resale value?
- Do some applications of the item result in "single use" vs. reusable items? (e.g., item in a missile is destroyed)
- Is it more likely a used commodity would come from a private company or government (or N/A)?
- How are these items typically removed from service?
- How does this item enter the secondary market? How would this item be sold? (if they have information; otherwise we answer/research)

B.4 Demand-Related Questions

- How motivated would the buyer need to be in order to reuse this item? Stoop to this level?
- Are the niche markets/buyers who would be interested in buying a used item versus a new one?

Appendix C
Analysis of Low-Interest Listed Commodities

C.1 Scrap Metals and Other Materials

As a commodity group, metals (and graphite) were identified as a listed commodity group of interest for the secondary market, given their ease in recycling and high resell value. At initial glance, the project team assessed several metals to be high-interest listed commodities and, consequently, performed analysis on the relevant materials. However, upon further review, the project team learned that recyclers are not generally producing listed materials from recycled scrap, with the exception of new scrap,[1] which is less common and more likely to be performed by companies with more awareness of export control requirements. Therefore, the project team decided to downgrade the materials below to be listed commodities of low interest. However, it should be noted that interest to the secondary market is not uniform across all the metals included in this commodity group, and some metals are certainly of greater (albeit low) interest to the secondary market than others. Moreover, a key finding of this study is that the recycling industry is rapidly innovating; therefore the recycling of these materials could be more relevant to export controls in the future. The following commodities are included within the Metals commodity group, in order of priority for the secondary market:

- Aluminum alloys (1C002.b.4, 1C202.a)
- Titanium alloys (1C002.b.3, 1C202.b)
- Graphite (1C298)
- Tungsten (1C117.a, 1C226)
- Zirconium (1C234)
- Hafnium (1C231)
- Molybdenum (1C117.b)

C.1.1 Aluminum

The project team identified aluminum as one of the higher priority metals within the Metals commodity group for the following reasons: it is highly reusable, distinguishable from other metals, and frequently on the new market. Aluminum is listed largely based on its strength and its shape, which allows it to be used in WMD applications related to uranium enrichment and delivery systems. The uses for non-listed aluminum are far ranging, including aircraft structures, sporting goods, marine vessel applications, and chemical processes in corrosive environments.

The aerospace industry is the main consumer of listed aluminum, with aluminum comprising about 80 percent of an aircraft's unladen weight (Plunkert, 2000). Additionally, in 2017, aluminum recovered from purchased scrap in the United States was about 3.70 million tons, of which about 57 percent came from new scrap and 43 percent from old scrap (Bray, 2018). The project team did not find data to quantify what percentage of new scrap aluminum is controlled for WMD applications. Aluminum scrap must meet both tensile strength requirements and form requirements to be controlled for nonproliferation reasons; however, purchases of listed aluminum that do not meet nonproliferation control specifications may still

[1] See Section 6.5.1 *Recycling of Scrap Metals and Other Materials* for more information on news scrap vs old scrap.

be of interest, given that it may be possible (although difficult) to reform the metal, so that it is still controlled for national security.

C.1.2 Titanium

Relative to the secondary market, titanium is very similar to aluminum. Titanium is highly reusable, distinguishable from other metals, frequently on the new market, and observed on the secondary market. Like aluminum, titanium is also listed based on its strength and shape for similar reasons, related to uranium enrichment and delivery systems. Titanium's commercial uses are also similar to aluminum, including aircraft structures, sporting goods, medical devices, and marine vessel applications.

Titanium is distinct from aluminum in that titanium generates a much higher level of scrap, when compared with aluminum. This characteristic is particularly relevant to aerospace applications, for which 80 percent of the U.S. market in titanium metal was used in 2017 (Bedinger, 2018). The sector has created a term, the "buy-to-fly" ratio, which expresses the relationship between the amount of scrap titanium generated and the amount of titanium actually used in the final part (Michaels, 2008). In other words, with a typical buy-to-fly ratio of 7 to 1, the production of an aircraft part of titanium may generate 7 lbs. of scrap for every 1 lb. pound of product. Given the large amounts of new scrap generated in this manner, this material is being recycled in large quantities. In 2017, 69,600 tons of titanium scrap metal was reused (Bedinger, 2018). Most new scrap is recovered and recycled, either domestically or by foreign entities through the scrap trade (Goonan, 2004). Moreover, the quantity of reused scrap titanium will only increase in the future, as further improvements in titanium scrap recovery systems make scrap a more acceptable source of raw materials for ingot production (Goonan, 2004).

Given these characteristics, the project team concluded further study of titanium may be warranted, as it relates to the secondary market. While large quantities of new scrap titanium are produced each year, the project team was not able to ascertain exactly what is being done with the new scrap titanium and its implications for export controls. If the titanium is being returned to the original manufacturer or being recycled on site, those entities likely are aware of the licensing requirements. However, if the new scrap titanium is being sold to third-party recyclers, recyclers likely will not be familiar with the titanium licensing requirements. Finally, similar to aluminum, listed titanium purchases may still be of interest, even if they only meet national security control specifications and not nonproliferation control specifications.

C.1.3 Graphite

While recycling graphite is not common, future research pay attention to innovations and increases in graphite recycling, particularly as some recent research has indicated that recycled graphite's properties are superior to its new/unused counterpart (Liu et al., 2016; Rothermel et al., 2016). Graphite could become a critical material in the near future for countries such as the United States and members of the European Union that do not produce graphite because of graphite's significance in lithium-ion batteries. A lithium-ion cell contains at least 11 times more graphite than lithium depending on the battery type and application (Dunn, Gaines, Barnes, Sullivan, & Wang, 2012; Moradi & Botte, 2016). Furthermore in 2014, graphite consumption was estimated to reach at least 1.6×10^4 metric tons in the automobile industry alone (Cobb, 2014; Dunn et al., 2012; Gaines & Nelson, 2009).

Despite these trends in demand for graphite, historically, the abundant supply of natural graphite has disincentivized technical innovation in graphite recycling. In fact, the U.S. Geological Survey stated that high-quality graphite recovery is technically feasible but not currently practiced. However, these trends could change if demand continues to rise or if new technology enables better or cheaper graphite

recycling. As an example, researchers in Germany revealed that graphite recycled from spent lithium-ion batteries performed better than new material (Rothermel et al., 2016). In addition, researchers in China demonstrated the feasibility of recycling nuclear graphite, which was superior to the original in density, strength, and thermal conductivity (Liu et al., 2016). The Liu et al. study was conducted on nuclear-grade graphite controls, which under the jurisdiction of the Nuclear Regulatory Authority. However, the same principles could be applied to recycling dual-use graphite meeting the specifications of ECCN 1C298. One company was found to recycle non-contaminated graphite for their own use and resale; they are certified by the International Traffic in Arms Regulations.[1]

C.1.4 Tungsten

Like titanium, tungsten is identified as a commodity of interest for the secondary market because it is recyclable, and its use produces a large amount of scrap. Tungsten is valued for its strength and ability to operate at extremely high temperatures, which is why it is a key addition to several high-strength refractory alloys. Tungsten is listed for its purity and form due to applications similar to aluminum and titanium. Tungsten is another material with a very high buy-to-fly ratio of 7 to 1, resulting in approximately 60 percent of the U.S. tungsten supply being derived from scrap (Shedd, 2011). Alloy industries that produce parts by cast or wrought processes typically generate large quantities of new scrap, and the superalloy industry is one example. However, the scrap tungsten industry in the United States is very consolidated, with only seven companies processing scrap to make tungsten metal powder, tungsten carbide powder, and (or) tungsten chemicals (*Mineral commodity summaries 2019*, 2019). Given this limited number of companies, effective outreach on licensing requirements for tungsten may be easily achievable.

C.1.5 Zirconium and Hafnium

Naturally occurring zirconium ore contains approximately 2 to 7 percent hafnium as a natural constituent. Together, they are not listed, but separately, they are listed. Hafnium content in zirconium alloys varies based on hafnium's market value. Hafnium is increasingly used in commercial space technology (i.e., by SpaceX). The high value of separated hafnium results in the common use of nuclear-grade zirconium in many non-nuclear applications, most notably in the chemical processing industry. In principle, non-nuclear applications of zirconium do not require low hafnium content. Nevertheless, low hafnium zirconium is frequently used in non-nuclear applications due to its availability in standard industrial practices. Thus, zirconium is frequently observed with hafnium values just below or above the amount stipulated in the control language. As a result, zirconium is technically difficult to control as it can require laboratory or sophisticated field equipment to analyze the actual hafnium content, especially in scrap. Meanwhile, hafnium is nearly always listed.

The U.S. Geological Survey states, "[Relative to other materials,] only small amounts of zirconium and hafnium are recycled. Less than 1 percent of discarded zirconium and hafnium metal or alloy is recycled or reused worldwide, and the recycled content of zirconium in products globally is only between 1 and 10 percent; estimates were not available for hafnium" (Graedel and others, 2011). The recycled content includes both new (loss during manufacturing products that is transferred to the scrap market) and old (post-consumer) scrap (Graedel, et al., 2011). Most recycled zirconium is from scrap generated during metal production and fabrication, and hafnium metal recycling is insignificant (Loferski, 2013b). The low proportions of these recycled minerals may reflect the complex materials, such as electronic equipment, in which they are used; the technical difficulty of recycling them; and the small amounts used in these

[1] https://www.weaverind.com/graphite/graphite-industries

products. Also, the long lifetime of some products in which zirconium and hafnium are used make the minerals' return to production very slow (*Critical mineral resources of the United States—Economic and environmental geology and prospects for future supply*, 2017).

One recent study suggests a new method for economically recovering and recycling zirconium from used nuclear fuel cladding (Collins, et al., 2011). Such zirconium is "specially designed" or prepared for use in a reactor and is subject to the export licensing authority of the Nuclear Regulatory Commission (10 CFR part 110). However, zirconium recycling is a major element of U.S. nuclear waste reduction strategy. Removal and recycle of the zirconium cladding would reduce the volume of nuclear waste requiring geological disposal by 50 percent. Oak Ridge National Laboratory confirmed that zirconium can be recovered from zircaloy used nuclear fuel cladding, but there is uncertainty regarding whether this recovered zirconium can be decontaminated enough for reuse in new fuel cladding—a notable research area (Collins, DelCul, Spencer, Brunson, & Hunt, 2015; Del Cul, Collins, Terekhov, & Victor Emmanuel, 2013; Spencer & Bruffey, 2017).

Finally, several of the aforementioned studies were not updated recently and may not accurately capture the current market in the context of industry changes (e.g., the founding of SpaceX), which could drastically change the recycling landscape. While such recyclers are limited, they are recyclers specializing in exotic materials—they know their products and there are fewer companies to consider. An updated U.S. Geological Survey study would be helpful to capture the current zirconium and hafnium markets.

C.1.6 Molybdenum

Molybdenum is a listed commodity of low interest because pure molybdenum recycling rates are negligible. Molybdenum is fully recyclable, but the use of pure molybdenum metal (as listed under this ECCN) is limited. This is because molybdenum is primarily used as an alloy material comprising on average 25 percent of the finished product, which falls outside the control language. Molybdenum is attractive for its strength and stability at high temperatures and corrosion resistance. Eighty percent of the molybdenum is used as a component in the production of steel and superalloys ("Exotech Buys and Sells Molybdenum Scrap," 2018; Graedel et al., 2011). Thus, molybdenum is mostly recycled in the form of steel scrap and is not recovered separately (Polyak, 2018). Presently, no processes exist for recovering and refining secondary molybdenum from its alloys. Still, pure molybdenum metal, when used, is recycled (albeit rarely) (Polyak, 2018). The majority of studies on the use and recycling of molybdenum are dated before 2013. Even with increases in worldwide steel production, increases in pure molybdenum recycling are unlikely. However, current statistics on molybdenum recycling would be helpful.

Pacific Northwest
NATIONAL LABORATORY

www.pnnl.gov

902 Battelle Boulevard
P.O. Box 999
Richland, WA 99352
1-888-375-PNNL (7665)

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