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Security Holism: Strength through Diversification, Upstream and Downstream

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Introduction

My thanks to the Commission, the Commissioners, the Co-chairs and their staff for holding this hearing and for extending the opportunity to testify today.

The US today finds itself in a position of supply chain insecurity decades in the making. For reasons both strategic and serendipitous, and even longer in the making, China finds itself in a position of strength vis-à-vis many of the world's most vital mineral and metal supply chains. These include irreplaceable materials on which the energy and industrial ecosystems of the future are being built, and on which many US national security interests already depend. As evolving global markets increase these commodities' demand, and bilateral tensions risk disruption of their supply, the US must decide: how will it adapt to ensure the country's energy, industrial, economic, and national security?

The future of American economic security hinges on its competitiveness in the emerging industries driving global growth – in many of which China leads the world. Competitiveness is a product of many interrelated variables; the security and cost effectiveness of critical mineral supply chains are among the most fundamental for competitive manufacturing in emerging industries. Meanwhile, critical minerals are also inherently tied to national security interests. As such, Chinese critical mineral export controls pose direct economic and security risks.

Today I examine the strategic logic of China's expanding critical mineral export controls and offer recommendations for effective and sustainable long-term risk mitigation. Chinese export controls are already reshaping global supply chains and the logic of upstream investment, with business-critical implications for American and allied countries' companies across energy, mining, tech, aerospace, and many other industries. Critically, many of the same supply chains of concern for civilian industry are irreplaceable in national security applications, from munitions to remote sensing equipment. Markets alone will not resolve all the simultaneous risks at hand.

Policy discussions of mineral supply chains and export controls are complicated not only by the sheer range of minerals at risk – including 72 that my team actively tracks[a] – but by: each mineral's criticality to myriad, often unrelated downstream interests, both civilian and military; their often unique processing requirements and uneven geological concentrations; and associated market idiosyncrasies that will make it difficult for US supplies to become competitive, absent heavy government involvement. These complications preclude "one-size-fits-all" solutions.

Nonetheless, a coordinated US government response is essential. Many Chinese export control announcements have taken affected entities by surprise, driving supply and price disruptions. Most companies seek to diversify supplies, but they often have few good options

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[a] The US Geological Survey officially recognizes 50 "critical minerals." Trivium tracks these 50 along with all other minerals and materials the EU, Japan, South Korea, China, and other countries designate as "critical" or "strategic."

outside of China. Meanwhile, for most minerals there is no simple, swift, or cost-effective path to onshoring production in time to avoid extreme costs to companies and consumers.

In export controls, China has found a materially impactful means of retaliation against US trade actions, and it still has significant leverage in stock. A sound US response to China's export controls requires integrated understanding of China's advantages and disadvantages, its objectives and the costs of pursuing them, and the US's practical options given its constraints. Together, these considerations make clear that the US requires a coordinated, "big tent" approach to overall supply chain development to compete with China. Joint action with strategic partners would truly and cost-effectively advance US energy, industrial, economic, and national security.

1. Status quo

The big picture

For decades, US producers and consumers alike have reaped the economic benefits of low-cost Chinese upstream production – and the absence of associated negative environment and social impacts – with comparatively little fanfare. The US market decided on its suppliers as expected and, for investors, desired: it optimized investments to maximize profitability. With aggregate advantages in geological resource endowments, decades of industrial policy, and – especially since the 1980s – process innovation, Chinese companies were often the most competitive mineral suppliers. Global supply chains, including the US's, shifted accordingly.

Today, however, the status quo of general Chinese mineral industry dominance poses salient and rapidly escalating supply chain risks. Since mid-2023, the PRC has leveraged US supply chain insecurities to retaliate against US tech controls, tariffs, and related actions that impede Chinese economic interests. Ongoing escalatory trade actions and reactions now pose direct threats to US and allied countries' commercial, industrial, and national security interests. With economic and trade tensions being structural features of the bilateral relation, the associated risks will persist.

The logic of Chinese export controls

Export controls are a key part of China's broader – and increasingly sophisticated – playbook for retaliation against foreign provocations.[1] [b] This playbook also includes reciprocal tariffs, sanctions (e.g., via the Unreliable Entity List), and industrial competitiveness investigations, among other tools. In general, China maintains a defensive posture with respect to trade, responding to foreign threats to its economic and security interests with what it intends to be symbolically and materially tit-for-tat retaliation. For example, in July 2023, it met US-led semiconductor export controls with export controls on minerals used to make semiconductors.

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[b] It is important to note that not all Chinese export controls are retaliatory. Many reflect internationally standard restrictions on hazardous, dual-use, and/or illegal goods. This analysis pertains only to weaponized export controls.

In the case of the recent tariff war, China began by exactly matching US tariffs – symbolically reciprocal. However, because China is a more significant exporter to the US than the US is to China, US tariffs on China have a proportionally greater material impact on Chinese exports than vice versa. So, to make up for the differential in material impacts, China also incorporated other tools – most significantly including the April 4 export restrictions on seven (of seventeen) rare earth elements.[c] This is in line with the expected logic and intended signaling behind China's trade retaliation measures over the past several years.

The next question is why export controls on *critical minerals* have become such a staple of Chinese trade retaliation. In brief, they provide Chinese policymakers a rare degree of asymmetrical leverage: they are highly effective at causing material risks and impacts for the US and other offending actors with comparatively little domestic harm from their implementation.

This is in stark contrast to blanket tariffs, which cause direct, significant economic harm to both sides' consumers and producers alike. Beijing has matched mutually harmful tariffs for direct reciprocation, but otherwise prefers more favorably asymmetric measures. Export controls also contrast with sanctions on US defense contractors, which have limited impact on either country.

Chinese critical mineral export controls are effective leverage for (at least) three key reasons:

1. Geologically, China has a greater volume of commercially viable reserves of more different minerals than the US, which both the central and local governments – and recently, private downstream companies – have spent decades developing
2. Technically, China has significant advantages in both talent development and institutional knowledge, which is especially vital for mineral processing – the key bottleneck for supply chains, more so than raw ore extraction
3. Industrially, Chinese companies enjoy numerous domestic supply chain synergies, upstream and downstream, with many enjoying efficiency gains from vertical integration, further increasing competitiveness

Importantly, critical mineral export controls pose three materially distinct risks to the US:

1. Direct supply disruptions, wherein the US may become unable to obtain non-substitutable inputs to products it manufactures (like American carmakers)
2. Indirect supply disruptions, wherein other countries that produce goods then sold to the US may become unable to obtain non-substitutable inputs to products they manufacture (like Japanese permanent rare earth magnets)
3. Global price shocks, wherein the US may be able to secure both upstream supplies and their key products, but Chinese controls increase global market prices, inhibiting industrial and/or commercial operations (as for standard and legacy semiconductors)

[c] Namely, samarium, gadolinium, terbium, dysprosium, lutetium, scandium, and yttrium. Samarium is a light rare earth; the other six are heavy rare earths.

It is also worth noting the less tangible, but still impactful, effect of sheer uncertainty. Enormous amounts of both government and corporate resources have been diverted to mapping out the potential risks of each control, and potential future controls. Many industries' supply chains are so complex that few companies have complete mappings of who supplies their suppliers (or *their* suppliers); whether a particular controlled compound is critical to their operations; and whether they ultimately obtain applicable compounds from China. Meanwhile, many controlled and at-risk goods used in national security applications are not used in large quantities – theoretically limiting the potential economic impacts of their restriction. But the impact is of course massively amplified by the sensitivity of these applications. Uncertainty and fear remain powerful tools.

Key actions to date

Below are presented key actions – both foreign triggers and Chinese retaliation – in the evolution of China's export control landscape. The timeline makes clear that Beijing's export controls typically follow triggering actions, from tech controls to industry investigations to tariffs. In a few cases, they more generally reflect periods of rising tensions, intended to serve as warning signals to dissuade further action. Also notably, early export controls saw longer delays between trigger and retaliation, as the policy infrastructure and customs enforcement both took time to develop. However, recent controls – likely prepared in advance, ready for appropriate triggers, and streamlined by unified regulations in late 2024 – would come in as little as one to two days.

Timeline: Key waypoints in China's critical mineral export control regime development

Date	Action
August 13, 2018	**The US launches sanctions against Chinese tech firms** The US bans the sale and import of communications equipment made by five Chinese brands, including Huawei and ZTE.[2]
December 1, 2020	**China implements cornerstone Export Control Law** It provides China's first consolidated legal basis for export controls – something Western countries have had in place for decades – to "safeguard national security and interests."[3]
October 7, 2022	**The US restricts China's access to high-end chips** President Biden's "small yard, high fence" strategy extends to both high-end chips and their means of production.[4]
March 31, 2023	**Japan moves to restricts China's access to chip equipment** Japan, a top producer of high-end chips, finalizes strict high-end chip production equipment controls, in line with US policy.[5]
June 30, 2023	**The Netherlands moves to restricts key chip equipment exports** It blocks ASML, maker of the world's top chip manufacturing equipment, from selling to China, in line with US policy.[6]
July 3, 2023	**China imposes gallium and germanium restrictions** The restrictions, which take the form of licensing requirements that give Beijing the ability to deny exports, threaten chip production.[7]

October 4, 2023	**The EU launches electric vehicle (EV) investigation** The investigation targets Chinese EVs, with the expectation – borne out on October 31, 2024 – of additional tariffs.[8]
October 17, 2023	**The US tightens export restrictions on chips, chip-making tech** In a second round of tech controls, the US blocks Nvidia from selling best-in-class advanced AI chips (e.g., the H800) to China.[9]
October 20, 2023	**China imposes graphite export restrictions** The controls, analogous in form to those on gallium and germanium, threaten EV battery and semiconductor production.[10]
December 21, 2023	**China blocks exports of REE processing equipment** To protect domestic industry, Beijing prohibits exports of rare earth element (REE) processing equipment, impeding foreign adoption.[11]
September 15, 2024	**China implements export restrictions on antimony** As a warning sign amid rising tensions, Beijing adds new controls on key antimony products and antimony separation equipment.[12]
October 19, 2024	**China releases Dual-Use Item Export Control Regulations** The regulations, structured similarly to Western models, consolidate prior export controls under a unified dual-use list – and establishes a "Control List" similar to the US Entity List.[13]
December 2, 2024	**The US announces third round of chip export controls** President Biden expands controls on 24 upstream manufacturing tools to inhibit Chinese advanced chip development.[14]
December 3, 2024	**China escalates gallium, germanium, graphite controls to bans** Beijing announces an "in principle" export ban on the three previously restricted minerals, along with "superhard materials."[15]
January 2, 2025	**China unveils draft strategic tech export restriction list update** In a *non*-retaliatory export control update, instead designed to protect future Chinese industrial competitiveness, the draft strategic tech catalog adds select pre-commercial LFP and LFMP batteries.[16]
January 16, 2025	**China warns then President-elect Trump of mineral leverage** The Ministry of Commerce publicly signals it stands ready to implement further mineral export controls to defend its interests.[17]
February 1, 2025	**President Trump adds 10% additional blanket tariffs on China** With respect to China, the tariffs (which separately include add 25% additional tariffs on Canada and Mexico) focus on fentanyl.[18]
February 4, 2025	**China imposes five more dual-use mineral export restrictions** Namely, **tungsten**, **tellurium**, **bismuth**, **molybdenum**, and **indium** – the most cross-cutting controls to date, mirroring US tariffs.[19]
April 2, 2025	**President Trump initiates escalating tariffs** President Trump imposes global tariffs, followed by further tariff increases on China for each round of its reciprocal retaliation.[20]
April 4, 2025	**China imposes export restrictions on seven rare earth elements**

	The specific controls prioritize impacts on defense and aerospace rather than general commercial and industrial interests.[21]
April 9-10, 2025	**China signals accelerated development of export control regime** At its annual export control conference – held six months earlier than last year – the Ministry of Commerce signaled it will expedite the build-out of its still-nascent regulatory framework "in the face of the current complex and challenging international landscape."[22]

Comprehensive policy analysis makes clear that the central government has intended its export controls to serve as defensive, reactionary responses to foreign action, including as signals to warn against further action – though this is not likely the general perception in the US.

Officially, all export controls have non-retaliatory justifications – typically as dual-use controls to prevent use in military applications, though only a moderately sized subset of the specific controls reasonably meet dual-use criteria. That said, officials in Beijing have grown increasingly direct in acknowledging the controls' retaliatory function. Discussing the December 3, 2024 "in principle" bans on gallium, germanium, and graphite exports at a press conference the same day, the Ministry of Commerce (MofCom) stated[23]:

- *"In recent years, the United States has generalized the concept of national security, politicized and weaponized economic, trade and technological issues, abused export control measures, unreasonably restricted the export of relevant products to China, and included a number of Chinese companies in the sanctions list for suppression and containment, seriously undermining international trade rules, seriously damaging the legitimate rights and interests of companies, and seriously undermining the stability of the global industrial chain and supply chain."*

In effect, the rising mutual sense of supply chain insecurity is proving a self-fulfilling prophecy. Now that the current trajectory has been established, though, it will prove difficult to redirect – necessitating a sound long-term risk mitigation strategy.

2. Drivers and trajectory

Origins of China's upstream advantages

China's historical mineral resource investments, dating back to the immediate aftermath of the Chinese Civil War, were anchored in two basic drivers: the central government's efforts to shore up national security and local governments' efforts to drive local economic development. It took decades of winding, often contentious, and even more often wasteful state-led investment to develop China's foundational natural resource extraction capabilities.[d] With few exceptions, coordination was poor, driven and shaped by local interests often in tension with national goals. One consequence was low prices, which incentivized global supply chain migration to China.

But this is not the end of the story. Over the past decade, two new drivers have reshaped and realigned both the political interests and industrial investment in many critical minerals: first, the increased focus on technological upgrading, and second, the emergence of the "new energy" industry. Both support supply chain demand growth, which both the state and private sectors have direct, high-priority interests in meeting. Both have redirected investment toward goods used in higher-value applications. And both are making China more difficult to compete with.

The central government's long-term economic security strategy hinges on moving China up the value chain. That, in turn, requires wholesale industrial upgrading, with specific focuses on "high-end, intelligent, and green" applications.[24] To that end, central authorities are actively pushing for innovation through both supply- and demand-side industrial policies. Among the results has been massive growth in the "new energy" industry, including:

- New energy vehicles (NEVs), e.g., electrics, hybrids, and hydrogen fuel cells vehicles – and now also electric autonomous vehicles and eVTOLS (including "flying cars")
- Renewable energy equipment, e.g., solar cells, wind turbines, and associated systems
- Batteries, both for transportation and energy storage (both closely tied to electrification and renewable energy development)

These industries are now among China's top growth drivers, both domestically and in terms of exports. Local governments have jumped on the chance to ride the wave. Companies – most, and the most competitive of which, are private – have mobilized vast resources to seize market share.

The rapid growth of these industries – supported by concerted central and local policy supports and private investment alike, on both the supply and demand sides – has also massively increased the projected market demand for critical mineral inputs, compared to prior levels required for traditional industries. More chips for intelligent manufacturing, NEVs, and electrified energy systems. More permanent rare earth magnets for motors, including for NEVs

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[d] Based on the unique characteristics of different minerals, regions, and local governments, the historical development paths of China's upstream mineral industries are in many cases highly idiosyncratic. Local governments in regions with limited industrial opportunities often – both in the past and still today – turned to extractive industry, driving expansion efforts that were generally not well coordinated and often frustrated central planning efforts. The buildout was often neither efficient nor, in some cases, even strategic; for example, the rise of township and village enterprises (TVEs) during the Mao era was one of several trends that drove massive overcapacity that ironically undercut strategic industry development. Yet, where the central government attempted to right the ship, it in many cases struggled to enforce its goals, given the local economic and political dependencies that had already formed. It took decades to consolidate many industries, which still struggle from overcapacity. Indeed, such issues still plague the modern steel and rare earth element industries, among others. This is the context in which many Chinese upstream industries evolved – and which Beijing has more recently turned to its advantage.

and wind turbines. More batteries, containing lithium, nickel, cobalt, manganese, and other minerals. And so on.

Today, it is not only the historically large but inefficient, primarily state-led investment that drives China's upstream advantages. Now, ambitious and innovative private companies have also jumped into upstream investment, seeking to secure their own supply chains. Chinese companies have developed significant synergies through vertical integration across high-value production chains, e.g., battery-makers making major lithium investments. The trend has introduced new capital and competitive pressure to make upstream investment more efficient. State investments remain critical, given the decades of prior capital expenditure – and indeed, the state has made it a clear priority to ensure industry has the supplies it needs to grow. But rising mineral demand itself has driven competition between companies and regions, adding profit motives to invest and improve operational efficiency beyond what the central government alone would achieve.

All this is to say, industrial upgrading efforts extend upstream, in mining, as well as downstream, in manufacturing – and the two sides are essential to enabling each other's progress. This is one key lesson for the US: as much as the downstream depends on upstream supply security, an *efficient* buildout of upstream supply chains requires robust downstream demand.

Industrial drivers of national security leverage

The question remains: how does domestic upgrading tie into the emergence of China's export control regime? In brief: it has significantly bolstered China's mineral dominance and the outlook for its persistence – giving China a substantive, durable mode of retaliation beyond the likes of tariffs. The leverage is multiplied by certain compounds' national security applications.

Many of the critical mineral products central to China's industrial and economic upgrading are also critical in national security applications, from munitions to remote sensing equipment. While some dual-use applications are clear-cut – e.g., antimony trisulfide used mainly for munitions – there exist ample gray areas – for example, spheroidized graphite used in batteries, which are predominantly used to power commercial autos, but also military equipment.

To be clear, China has weaponized critical mineral export controls for trade retaliation, targeting many compounds that lack clear dual-use applications. But the strategically targeted controls also cover enough genuine dual-use applications to also create real non-commercial threats.

But weaponization was not a driving, much less a primary, goal behind most mineral investment. The Chinese government would undoubtedly maintain a certain level of production of key minerals for domestic national security purposes, but it would have far less economic ability to maintain its current extreme degrees of overall mineral dominance absent the widespread and growing industrial demand that currently incentives it. By meeting the domestic industrial and commercial demand the state helped spur – driving down costs and thereby maintaining global competitiveness – the government inherently also boosts its leverage vis-à-vis dual-use minerals.

China's contemporary export control regime

Like all major economies, China has legitimate need of a baseline export control regime for the likes of nonproliferation. It arguably went too long with a fragmented system, which until 2020 remained spread across the Customs Law (1987), Foreign Trade Law (1994), and myriad regulations since (including those on exports of arms, nuclear components, and biological items).

Today, China's unified export control regime is built around its cornerstone Export Control Law, which was implemented on December 1, 2020. The landmark legislation provided a unified legal foundation for all Chinese export controls, past and present. Notably, it also laid explicit claim to long-arm jurisdiction authority, which has yet to be meaningfully tested. On October 19, 2024, China released regulations on dual-use item export controls that consolidated prior controls and streamlined the process for implementing new controls, insofar as they are deemed dual-use.

China now maintains two key lists to manage export controls[25]: the set of goods subject to export controls, which include restrictions (requiring export license approvals) and prohibitions, and the Control List for companies specifically barred from importing listed goods (even if the goods are not otherwise prohibited from exports). The latter generally covers entities legitimately involved in military or other sensitive applications; e.g., it includes many foreign defense contractors. However, the weaponization of export controls comes from the former list, with China adding even critical mineral products that are not generally considered to be dual-use to the list.

The regime continues to evolve. China's December 3, 2024 announcement escalating gallium, germanium, and graphite export restrictions to outright bans includes the first explicit invocation of the country's claimed authority to take legal action against "any organization or individual," including foreign entities, for violating Chinese export controls. Two key points remain unclear: the extent to which Beijing is practically *able* to enforce this form of long-arm jurisdiction with respect to any given set of products, and the extent to which Beijing might *attempt* to enforce it.

Strategically, at present, the best outcome for Beijing remains that third countries, fearing retaliation, voluntarily comply with Beijing controls and prohibit through transit, transshipment, through-transportation, and re-export *without* the need for any tangible action by Beijing. This way, China would face no risk of failures that could undermine its position. The worst outcome would be that third parties enable circumvention of Chinese controls and Beijing proves unable to enforce its claimed long-arm jurisdiction. However, given widespread industry and, to our knowledge, foreign government belief in the credibility of the Chinese threat, there is an extremely low chance of the latter case. Many countries are likely to preemptively comply.

Global industry's positioning

Since the initial shock of the gallium and germanium controls in mid-2023, many industry actors have grown proactive in anticipating and preparing for further Chinese export controls. Indeed, not only has the continuation of export controls been anticipatable, but specific targets were anticipated.[26] Some large-scale producers have stockpiled key minerals dominated by Chinese production, and most with significant exposure have actively sought to diversify their sourcing. However, China's advantages in many critical minerals put it a decade or more ahead of most competitors – and even where alternative supplies exist, they may not be available at similar qualities or costs. This is precisely what makes the controls an effective retaliatory tool.

Beyond such high-level information, however, inquiries into the international business community's responses are complicated, A central problem is that, in the current context, most businesses are not in a position to share much information regarding their supply chains. To the extent they *are* at high risk of supply disruptions, they cannot advertise their vulnerabilities, lest competitors seize the advantage and investors flee. To the extent they are *not* at high risk – e.g., companies that have secured stable, cost-effective non-Chinese supplies of Chinese-dominated goods – they cannot risk making themselves a target for other forms of political reprisal.

Overall, though, it is fair to say that, based on the author's engagements with multinational companies – American and otherwise, across the mineral, energy, auto, tech, and aerospace industries, among others – most producers remain very highly concerned about both short-term risks and long-term costs. Moreover, while none are in a position to make such statements directly, there exists a very high degree of doubt that the US is in a position to effectively offset the risks of export controls driven by US-China trade conflicts in the near future.

Strategic trade partners' positioning

US strategic trade partners are likewise in an increasingly difficult position. This is a problem for the US not only diplomatically, but logistically: even in cases where the US has low direct dependencies on specific Chinese mineral imports, it often has high indirect dependencies through trading partners, whose goods may be difficult to substitute. While many key trading partners are politically and economically aligned with the US, there are stark limits to many of their industries' ability to operate without stable flows of minerals extracted and/or processed in China. Most economies are also less diversified than the US and China, meaning they may be unable to manage overt disruptions to critical manufacturing industries – giving China leverage.

The semiconductor, permanent rare earth magnet, and battery industries in Japan and South Korean are important cases. For both countries, these are strategic industries, each with significant Chinese mineral dependencies. In turn, the US is dependent on Japan and South Korea for significant portions of these goods (in different product categories). This means that Japan and South Korea are potential vectors through which China could seek punitive action against the US – where the US would have limited ability to mitigate the impacts, absent de-escalation with China.

Beijing has already engaged with both countries and well understands their positions. In late October and mid November 2024 – just weeks before unveiling its consolidated dual-use export control mechanism, announced in December – China held separate consultations with Japan and South Korea to discuss its evolving export control regime.[27] [28] In both cases, MofCom's readouts sent two clear messages: first, practically, that Beijing is keen to ensure key trading partners fully understand China's export control regime and specific policies; and second, politically, that China will retaliate against provocative actions, presumably such as (in Japan's case) further US-led tech controls. The subtext is, credibly, that China will still make no preemptive or instigative moves, including critical mineral export controls, but will maintain a strong defensive posture.

In short, Beijing has been – and will continue – placing key midstream trading partners in increasingly dire strategic positions vis-à-vis US-China trade and economic conflicts. Where the US has historically relied on economic and trade partners to help enforce its China policies – through diplomacy and pressure alike – China has established a strong capacity to further complicate their alignment and/or compliance with US efforts.

Among the most salient cases today is chip controls: were the US to attempt to align partners on new chip equipment controls today as it did in 2023, it would likely face far greater resistance, given the greater potential costs of Chinese retaliation.[e] There is simply a limit on the degree to which most countries' industries can manage the (highly credible) risk of losing access to critical Chinese supply chains that fuel strategic, high-value industries – including chips, rare earth magnets, batteries, and other energy equipment.

This is all to say that the Chinese threat is credible, well calculated, and essential to factor into broader trade strategy, not only for sake of direct US access to Chinese minerals, but for supplies of the broader array of intermediate goods produced by US allies and partners that depend on Chinese minerals.

Still, it essential to confirm that the Chinese government's demonstrated preference remains, by far, a stable trade status quo that supports both upstream and downstream exports, to the US and elsewhere, as required for its economic upgrading strategy. It still treats export controls as one of relatively few tangible means to defend itself against threats to its economic interests, to the point that it is willing to incur a degree of financial and economic harm to deploy them against material threats – but only where the threat really is material, lest the costs outweigh the benefits.

The upshot is that, with China maintaining a defensive posture, the US is ultimately in a position to decide the extent to which it is willing to accept further supply chain risks in pursuit of its own restrictive trade actions. In the meantime, there is no near-term solution to completely undermine China's leverage over critical minerals. Risk mitigation will necessarily be a long-term project – although it can be made far, far more efficient through strategic partnerships, as discussed next.

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[e] Nor would it necessarily be in the US's near-term economic or industrial interest for them to do so, even if the US saw their compliance as valuable for tactical objectives. So far, the US has weathered Chinese mineral export controls with comparatively few major disruptions precisely because it produces so few of the energy, tech, and other goods that use them. Instead, it largely imports goods containing the affected minerals. If the US's overseas suppliers were to lose access to Chinese minerals, the US would likely face sudden and serious material shortages with little near-term recourse.

3. Securing the future

China's approach

China will continue to deploy export controls – notably on critical minerals, and gradually expanding to other materials and upstream inputs – as long as it feels threatened by foreign trade actions. It remains in a comparatively weak position with respect to tariffs and sanctions, and thereby has relatively few materially impactful alternatives. It could, say, begin to punish larger and larger US companies – but doing so would significantly harm domestic economic interests. Hence, export controls are likely to remain a favored retaliatory mechanism for some time.

Meanwhile, China is not implicitly threatened by foreign minerals competition. Indeed, it continues to partner with and import from many international mineral producers, including US allies and partners. It is chiefly threatened by the weaponization of trade – and acts accordingly.

China's future export control targets will likely depend largely on the action it is retaliating against. Where symbolic reciprocity is possible, it is likely. Where a perceived provocation is more harmful to Chinese interests, China is likely to consider more impactful controls. And in all cases, naturally, risks to specific goods are higher where China has greater market dominance.

The US's approach

Economically, the US is not in a position to develop its own mines for each of the dozens of critical minerals over which China has significant global market influence. It can onshore certain supplies, but onshoring will be woefully insufficient to address the broad, complex set of risks at hand. Economically, free and open trade remains the single best solution for US consumers and producers alike. However, to the extent that bilateral security concerns continue to inhibit stable free trade, the US needs to diversify supplies. It can do so, but it cannot expect to do so alone.

The first challenge is the sheer up-front capital expenditure required. Domestic private sector interest in production development is rising but still very small compared to what is required to substantially offset Chinese supplies of many minerals. Meanwhile, it is structurally limited by the limited demand side in the US. As noted in the above, the US is heavily dependent on imports of intermediate goods as well as upstream supplies; i.e., it does not produce many of the goods that use many critical minerals of concern. US domestic demand is currently too limited to support large-scale production, necessitating revenue from exports. But the US cannot produce at a price point amenable to the global market, given Chinese production costs and overcapacity.

The second challenge is the fact that it takes years to develop a mine – even ignoring the time for permitting, much less financing. No degree of regulatory simplification will make construction alone less than a years-long effort. Key supply risks already exist and will persist in the interim.

The third challenge concerns *processing*. Mine production is only the first step; significant processing is required to make the extracted ores useful. Some minerals are not technically challenging to process, but still require significant knowledge and skilled labor the US does not currently have in any abundance. Other minerals are incredibly complex to process effectively, especially where required in highly purified forms (such as rare earths). Where it does not produce such goods domestically, the US largely relies on upstream processing in China and intermediate good processing in China, Japan, South Korea, and elsewhere.

The fourth challenge concerns a subset of minerals that are not mined, but primarily recovered as byproducts of other industrial activities. For instance: gallium (for which the US is entirely import-dependent) is largely recovered as a byproduct of aluminum production (from alumina); germanium and indium largely from zinc production; tellurium from copper refining; and many platinum groups metals from nickel and copper refining. In some of these cases, the US has capabilities and even some production capacity; these are promising cases for domestic expansion, given significant government subsidization. Some have alternative (if more costly) production methods. Overall, however, there will remain numerous minerals for which US production is not likely to be feasible, absent incredibly high degrees of subsidization – and even then they may not be technically viable, much less useful for mitigating real near-term risks.

But there are solutions – and they necessitate that the US look outward as well as inward.

Recommendations

In the near term, the US should seek to negotiate targeted critical mineral supply chain agreements with key allies and partners, whose existing upstream capabilities can help wean the US from Chinese critical mineral supplies.

The US should onshore where it can and "friendshore" where it must. In the near term, many minerals will fall into the latter category. Even if the US were to seek total mineral independence, its best path forward – by far – would be to build a robust supply chain network with partners who have the necessary resources and expertise. At minimum, the US can secure supply agreements that ensure immediate economic and national security. Beyond that, it could pursue joint investments in new supply lines, domestically or overseas, as geological reserves allow – reducing the burden on US taxpayers while increasing the total benefits for US interests.

In February, the President established the National Energy Dominance Council, which, among other responsibilities, is tasked with "reestablishing American leadership in manufacturing," and to that end, coordinating the use of national resources, including critical minerals. In principle, it should be well positioned to convene interagency planners – drawing on the federal government's vast array of valuable expertise, including at the Department of Energy (including the National Laboratories), the Department of State, and the United States Geological Survey (within the Department of the Interior) – to map out a network of agreements to shore up critical mineral supply chains.

In the medium term, the US should couple upstream investments with reinvigoration of downstream demand development efforts – particularly in fast-growing emerging industries.

The President has already demonstrated support for large-scale government subsidization to support energy, industrial, and broader economic security. In particular, he has authorized use of funds via the Defense Production Act to "[bring] back" the domestic coal industry.

The challenge here is that coal is not a growth industry, domestically or globally, and it will not become one again regardless of the degree of government subsidization; the comparative advantages of alternatives are too great for it to return to competitiveness. As such, the returns on this government subsidization will be low – even, in the medium term, to coal mining communities, compared to other industry opportunities that could be subsidized to support them.

Meanwhile, emerging industries – in most of which China currently leads not only on cost, but in technological innovation – continue to see significant long-term growth outlooks globally. Even amid China's ongoing economic challenges, its companies' leadership in emerging industries is boosting both investment and manufacturing growth, both of which the US is increasingly missing out on. That downstream industry growth, in turn, is proportionally increasing total returns to strategic critical mineral industries further upstream – industries the US would also benefit from developing, for strategic and security purposes, even more so if it requires less extreme degrees of government subsidization than the pursuit of independence would require.

Above all, US policymakers should proceed with three principles in mind:

1. **Industrial, economic, and national security are all best served by the pursuit of leadership in emerging industries.** China's mineral advantages began with historical state-led development, wasteful and inefficient as it was. But its true – and actually replicable – advantage, now and moving forward, is its support for emerging industry leadership. The US cannot fixate on traditional industries whose growth windows are over. It must look to the future to secure new advantages. Else, it will fall further behind.
2. **Holistic economic security requires balanced upstream and downstream investment.** Without the upstream, the downstream suffers from supply chain insecurity; without the latter, the former depends entirely on government subsidization. Together, though, a balanced equation enables significant growth opportunities. China's NEV industry offers an instructive case study. Thanks to concerted supply- and demand-side supports, NEVs now represent *over 50%* of new auto sales in the world's largest auto market. More broadly, NEVs have become the future of the global auto market (regardless of the US trajectory). Currently, Chinese companies (along with Tesla, although it is losing its advantages) are easily the favorites to seize global growth opportunities – even without access to the US market. The other side: this growth has spurred private Chinese investment in lithium extraction and processing – diversifying China's supplies and reducing risks for its NEV industry with less need for further government subsidization.

3. **The US's ability to resist Chinese supply chain and other trade threats is stronger when it convenes partners than when it pursues total independence.** In the case of critical minerals, it has neither the geology, nor the technical capabilities, nor the market incentives to onshore *everything* it needs to diversify away from China. It *does* have a healthy number of critical minerals it could focus on developing domestically – and which partners and allies could also purchase to diversify away from China. And it *does* have trusted, skilled, resource-rich trading partners who could diversify their own risks by jointly investing with and exporting to the US. For example, Australia is well positioned in many resources, and Japan and South Korean have unparalleled processing and intermediate goods production capabilities, particularly for permanent rare earth magnets. Similarly with Canada. Potential partners across Latin America and Southeast Asia – some of which are already engaged with other mineral-producing US partners – also have exceptional capabilities and could be valuable links in a "big tent" critical minerals arrangement.

Overall, the US will be most holistically secure within a network of trusted trade and investment partners, which would amplify available capital, open up more economical investment opportunities, provide for a wider range of comparative advantages, and diversify financial, technical, and other key risks all around. It will be most industrially and economically secure when it is focused on leveraging such partnership for pursuit of global growth industries, advancing American competitiveness.

In the present context, there is no better means than convening strategic partnership to mitigate the risks posed by an evolving US-China economic conflict – or to promote genuine American leadership in such times of trouble.

Appendix A: Chinese critical mineral export controls

Product (English)	Affected HS Codes
Antimony products	
Antimony ore and raw materials, including but not limited to lumps, granules, powders, crystals and other forms	2617101000, 2617109001, 2617109090, 2830902000
Antimony metal and its products, including but not limited to ingots, blocks, beads, granules, powders, etc.	8110101000, 8110102000, 8110200000, 8110900000
Antimony oxide, purity greater than or equal to 99.99%, including but not limited to powder form	2825800010
Trimethylantimony, triethyl antimony and other organic antimony compounds, with purity (inorganic element benchmark) >99.999%	2931900032
Antimony hydride, purity >99.999% (hydride containing antimony diluted in inert gas or hydrogen)	2850009020
Indium antimonide with single crystals with a dislocation density of less than 50 pcs/cm² and polycrystals with purity >99.99999%, including but not limited to ingots (rods), blocks, sheets, sputtering targets, granules, powders, scraps, etc.	2853909031
Gold-antimony smelting and separation technology	N/A
Bismuth products	
6C001.a. Bismuth metal and products not controlled under 1C229, including but not limited to ingots, blocks, beads, granules, powders and other forms	8106101091, 8106101092, 8106101099, 8106109090, 8106901019, 8106901029, 8106901099, 8106909090
6C001.b. Bismuth germanate	2841900041
6C001.c. Triphenylbismuth	2931900032
6C001.d. Tri-p-ethoxyphenyl bismuth	2931900032
6E001 Technology and data for production of 6C001 items (including process specifications, process parameters, processing procedures, etc.)	N/A
Dysprosium products	
1C905.a Dysprosium metal	2805301200
1C905.a (continued) Dysprosium-containing alloys: • Dysprosium ferroalloys • Terbium dysprosium ferroalloys	Not listed
1C905.a (continued) Dysprosium-containing targets: • Dysprosium targets • Terbium dysprosium ferroalloy targets	3824999922, 8486909110
1C905.a (continued) Dysprosium-containing NdFeB permanent magnet materials	Not listed
1C905.b Dysprosium oxide and its mixtures	2846901500, 2846901993, 3824999922

1C905.c Dysprosium-containing compounds and their mixtures	2846902200, 2846902810, 2846903200, 2846903910, 2846904300, 2846904820, 2846909400, 2846909920, 3824999922
Gadolinium products	
1C903.a Gadolinium metal	2805301910
1C903.a (continued) Gadolinium-containing alloys: • Gadolinium-magnesium alloys • Gadolinium aluminum alloys	2805301910
1C903.a (continued) Gadolinium-containing sputtering targets: • Gadolinium sputtering targets • Gadolinium ferroalloy sputtering targets • Gadolinium cobalt alloy sputtering targets	3824999922, 8486909110
1C903.b Gadolinium oxide and its mixtures	2846901930, 2846901993, 3824999922
1C903.c Gadolinium-containing compounds and their mixtures	2846902810, 2846902910, 2846903910, 2846904820, 2846904910, 2846909920, 3824999922
Gallium products	
Gallium metal (elemental)	8112929010, 8112929090, 8112999000
Gallium nitride (including but not limited to wafers, powders, scraps, etc.)	2850001901, 3818009001, 3825690001
Gallium oxide (including but not limited to polycrystalline, monocrystalline, wafer, epitaxial wafer, powder, scrap and other forms)	2825909001, 3818009002, 3825690002
Gallium phosphide (including but not limited to polycrystalline, monocrystalline, wafer, epitaxial wafer, etc.)	2853904030, 3818009003, 3825690003
Gallium arsenide (including but not limited to polycrystalline, monocrystalline, wafer, epitaxial wafer, powder, scrap and other forms)	2853909026, 3818009004, 3825690004
Indium gallium arsenic	2853909028, 3818009005, 3825690005
Gallium selenide (including but not limited to polycrystalline, monocrystalline, wafer, epitaxial wafer, powder, scrap and other forms)	2842909024, 3818009006, 3825690006
Gallium antimonide (including but not limited to polycrystalline, monocrystalline, wafer, epitaxial wafer, powder, scrap, etc.)	2853909029, 3818009007, 3825690007
Germanium products	
Metal germanium (elemental, including but not limited to crystals, powders, scraps, etc.)	8112921010, 8112921090, 8112991000
District melt germanium ingot	8112921090
Zinc germanium phosphate (including but not limited to crystals, powders, scraps, etc.)	2853904040, 3818009008, 3825690008
Germanium epitaxial growth substrate	8112921090
Germanium dioxide	2825600002, 3818009009, 3825690009

Germanium tetrachloride	2827399001, 3818009010, 3825690010
Graphite products	
High-purity (purity >99.9%), high-strength (flexural strength >30Mpa), high-density (density >1.73 g/cm³) artificial graphite materials and their products thereof	3801100030, 3801909010, 6815190020
Natural flake graphite and its products (including spheroidized graphite, expanded graphite, etc.)	2504101000, 2504109100, 3801901000, 3801909010, 3824999940, 6815190020
Indium products	
3C004.a. Indium phosphide	2853904051
3C004.b. Trimethylindium	2931900032
3C004.c. Triethylindium	2931900032
3E004 Technology and data for production of 3C004 items (including process specifications, process parameters, processing procedures, etc.).	N/A
Lutetium products	
1C906.a Lutetium metal	2805301910
1C906.a (continued) Lutetium-ytterbium alloys	Not listed
1C906.a (continued) Lutetium sputtering targets	3824999922, 8486909110
1C906.b Lutetium oxide and its mixtures	2846901800, 2846901993, 3824999922
1C906.c Lutetium-containing compounds and their mixtures	2846902810, 2846902910, 2846903910, 2846904820, 2846904910, 2846909920, 3824999922
Molybdenum products	
1C117.b. Molybdenum powder with: molybdenum content (by weight) greater than or equal to 97%, particle size less than or equal to 50×10^{-6} m (50μm), used in the manufacture of missile parts of molybdenum and alloy grains	8102100001
1E101.b. Technology and data for production of 1C117.b (including process specifications, process parameters, processing procedures, etc.)	N/A
Samarium products	
1C902.a Samarium metal	2805301910
1C902.a (continued) Samarium-containing alloys: • Samarium cobalt alloys • Samarium-iron alloys • Samarium-nickel alloys • Samarium aluminum alloys • Samarium-magnesium alloys	Not listed
1C902.a (continued) Samarium-containing sputtering targets: • Samarium sputtering targets • Samarium cobalt alloy sputtering targets • Samarium-iron alloy sputtering targets	3824999922, 8486909110

1C902.a (continued) Samarium cobalt permanent magnet materials	Not listed
1C902.b Samarium oxide and its mixtures	2846901940, 2846901993, 3824999922
1C902.c Samarium-containing compounds and their mixtures	2846902810, 2846902910, 2846903910, 2846904820, 2846904910, 2846909920, 3824999922
Scandium products	
1C907.a Scandium metal	2805301800
1C907.a (continued) Scandium-containing alloys: • Scandium aluminium alloys • Scandium-magnesium alloys • Scandium-copper alloys	Not listed
1C907.a (continued) Scandium targets	3824999922, 8486909110
1C907.b Scandium oxide and its mixtures	2846901980, 2846901993, 3824999922)
1C907.c Scandium-containing compounds and their mixtures	2846902810, 2846902910, 2846903910, 2846904820, 2846904910, 2846909920, 3824999922
Tellurium products	
6C002.a. Tellurium metal	2804500001
6C002.b. Tellurium compound monocrystalline or polycrystalline products (including substrates or epitaxial wafers) of: 1. Cadmium telluride 2. Zinc cadmium telluride 3. Mercury cadmium telluride	1. 2842902000, 3818009021 2. 2842909025, 3818009021 3. 2852100010, 3818009021
6E002 Technology and data for the production of 6C002 items (including process specifications, process parameters, processing procedures, etc.).	N/A
Terbium products	
1C904.a Terbium metal	2805301300
1C904.a (continued) Terbium-containing alloys: • Terbium cobalt alloys • Terbium cobalt-iron alloys	2805301300
1C904.a (continued) Terbium-containing sputtering targets • Terbium sputtering targets • Terbium cobalt alloy sputtering targets	3824999922, 8486909110
1C904.a (continued) NdFeB permanent magnet materials containing terbium	N/A
1C904.b Terbium oxide and its mixtures	2846901600, 2846901993, 3824999922
1C904.c Terbium-containing compounds and their mixtures	2846902100, 2846902810, 2846903100, 2846903910, 2846904200, 2846904820, 2846909300, 2846909920, 3824999922
Tungsten products	
1C117.d. Tungsten-related materials:	1. 2841801000

1. Ammonium paratungstate 2. Tungsten oxide 3. Tungsten carbide not controlled under 1C226	2. 2825901200, 2825901910, 2825901920 3. 2849902000
1C117.c. Solid tungsten with the following characteristics: 1. Solid tungsten (excluding granules and powders) with any of the following characteristics: a. Tungsten alloy not controlled under 1C226 and 1C241 and tungsten alloy with tungsten content greater than or equal to 97% (by weight) b. Tungsten doped with copper with tungsten content greater than or equal to 80% (by weight) c. Tungsten silver doped with tungsten content greater than or equal to 80% (by weight) (silver content greater than or equal to 2%) 2. Can be machined into any of the following products: a. Cylinders with a diameter greater than or equal to 120 mm and a length greater than or equal to 50 mm b. Pipes with an inner diameter greater than or equal to 65 mm, a wall thickness greater than or equal to 25 mm and a length greater than or equal to 50 mm c. Blocks with dimensions greater than or equal to 120 mm× 120 mm×50 mm	1.a. 8101940001, 8101991001, 8101999001 1.b. 8101940001, 8101991001, 8101999001 1.c. 7106919001, 7106929001 2.a., 2.b., 2.c. N/A
1C004 Tungsten-nickel-iron alloy or tungsten-nickel-copper alloys with all of the following characteristics: • a. Density >17.5 g/cm^3 • b. Elastic limit > 800 MPa • c. Ultimate tensile strength >1270 MPa • d. Elongation >8%	8101940001, 8101991001, 8101999001
1E004 and 1E101.b. Technology and data for the production of 1C004, 1C117.c, and 1C117.d items (including process specifications, process parameters, processing procedures, etc.)	N/A
Superhard materials	
Six-sided top press equipment, with all the following characteristics: specially designed or manufactured X/Y/Z three-axis six-sided synchronous pressurized large hydraulic press, bore size greater than or equal to 500 mm or designed to use pressure greater than or equal to 5 GPA	8479899956
Special key components for six-sided top press, including hinge beam, top hammer, and high-pressure control system with a combined pressure greater than 5 gigapascals	8479909020, 9032899094
Microwave plasma chemical vapor deposition (MPCVD) equipment with all the following characteristics: specially designed or manufactured with a microwave power of 10 kilowatts or more, microwave frequency of 915 MHz or 2450 MHz	8479899957
Diamond window materials, including curved diamond window materials, or planar diamond window materials with all of the following characteristics:	7104911010

• Monocrystalline or polycrystalline with a diameter of 3 inches or more • Visible light transmittance of 65% or above	
Synthetic diamond single crystal or cubic boron nitride single crystal process technology with six-sided top press	Not listed
Technology used to manufacture the six-sided top press equipment listed above	N/A
Yttrium products	
1C908.a Yttrium metal	2805301700
1C908.a (continued) Yttrium-containing alloys: • Yttrium-aluminum alloys • Yttrium-magnesium alloys • Yttrium-nickel alloys • Yttrium-copper alloys • Yttrium-iron alloys	Not listed
1C908.a (continued) Yttrium-containing sputtering targets: • Yttrium targets • Yttrium-aluminum alloy targets • Yttrium-zirconium alloy targets	3824999922, 8486909110
1C908.b Yttrium oxide and its mixtures	2846901100, 2846901993, 3824999922
1C908.c Yttrium-containing compounds and their mixtures	2846902600, 2846902810, 2846903600, 2846903910, 2846904600, 2846904820, 2846909690, 2846909920, 3824999922

Appendix B: Chinese and US strategic/critical minerals

	Chinese Strategic Minerals List[29]	US Critical Minerals List[30]
Aluminum	✓	✓
Antimony	✓	✓
Arsenic		✓
Barite		✓
Beryllium		✓
Bismuth		✓
Cesium		✓
Chromium	✓	✓
Coal	✓ *	
Coalbed methane	✓ *	
Cobalt	✓	✓
Copper	✓	✓ DOE list only
Fluorite/fluorspar	✓	✓
Gallium		✓
Germanium		✓
Graphite	✓ Crystalline	✓
Gold	✓	
Hafnium		✓
Indium		✓
Iridium		✓
Iron	✓	
Lithium	✓	✓
Magnesium		✓
Manganese		✓
Molybdenum	✓	

Natural gas	✓ *	
Nickel	✓	✓
Niobium		✓
Palladium		✓
Petroleum oil	✓ *	
Phosphorus	✓	
Platinum		✓
Potash	✓	
Rare earth elements	✓ All 17	✓ 16, ex promethium
Rhodium		✓
Rubidium		✓
Ruthenium		✓
Shale gas	✓ *	
Tantalum		✓
Tellurium		✓
Tin	✓	✓
Titanium		✓
Tungsten	✓	✓
Uranium	✓ *	
Vanadium		✓
Zinc		✓
Zirconium	✓	✓

** China's strategic minerals list includes fuels, while the US's critical minerals list explicitly excludes fuels.*

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