REPORT

Resilient European aerospace & defense supply chains

Addressing critical raw material vulnerabilities

Roland Berger

Management summary

Rising demand from electrification, clean energy, and advanced technologies – combined with underinvestment in global supply chains, overconcentration in sourcing in a handful of countries and increasing geopolitical tensions – has re-elevated raw materials as a strategic priority for aerospace and defense (A&D). In response, the EU and NATO have identified critical materials, including titanium and rare earth elements (REEs), that are essential to production.

These materials underpin virtually all A&D platforms, from structural components to propulsion, batteries, and electronic systems, meaning shortages could directly disrupt production and capability delivery. Structural dependency on upstream extraction and processing – despite domestic resource potential from non-producing countries – creates significant supply chain vulnerabilities, particularly at key chokepoints such as titanium sponge and REE for which processing is dominated by Russia and China.

While mitigation strategies such as scaling domestic production, recycling, and substitution are emerging, each faces technical, economic, and timing constraints that may limit their ability to fully offset projected shortfalls. As a result, the sector is at a strategic inflection point: securing access to critical raw materials requires coordinated government-industry action alongside targeted investments and supply chain partnerships by individual firms.

Our thesis maintains that focusing on each raw material that is necessary for production, and developing targeted plans to secure supply, will be critical in the long-term sustainment of the industry.

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1 Introduction: Why have raw materials become (even more) critical?

Control over raw materials has been a strategic priority for industrial powers throughout modern history. From colonial-era resource extraction to Cold War stockpiling, access to critical inputs has been a foundation of national strength. That imperative faded to some extent in parts of the world during the era of increasing globalization, when supply chains were optimized for cost and efficiency, and raw materials were treated as commodities rather than strategic assets. In recent years, however, a combination of surging demand (driven by clean energy, electrification, digitalization, and adoption of advanced technologies) and underinvestment in extraction and processing has brought geopolitical risks related to raw materials firmly back into focus.

In response, both the European Union and NATO have moved to define and prioritize the materials most critical to industrial and defense resilience. The EU's Critical Raw Materials framework identifies 34 substances that combine high economic importance with high supply risk. NATO has taken a more targeted approach, releasing in 2024 a list of 12 (groups of) defense-critical raw materials that are essential for military readiness and technological edge. These include titanium, rare earth elements and other materials and substances that are difficult to substitute and heavily concentrated in non-allied supply chains. ▶ A

This publication first examines the practical implications of potential shortages in NATO's 12 identified critical raw materials for various aerospace and defense platforms. It then delves into the chokepoints in the supply chains for these materials, exploring specifically titanium and rare earth elements, the potential shortfalls that the aerospace and defense (A&D) sector may face in the next decade, and the implications of these shortfalls. Ultimately, a key question emerges for the sector: should securing critical raw materials be addressed at the European, if not global, level or can individual companies effectively safeguard their specific material needs independently and/or selectively in collaboration with government or other industry players from across the value chain?

"Raw materials are fast becoming a critical risk to aerospace and defense supply chains. Governments and industry must invest now in the partnerships required for sourcing and recycling to ensure continued access for generations to come."

Rachel Hugo, Senior Partner

A **A&D-critical raw materials (CRMs) identified by NATO in the context of the 34 CRMs identified by the European Commission**

HOW TO UNDERSTAND THE 12 A&D-CRITICAL RAW MATERIALS?

118

periodic elements and many substances (combination of elements)

Economic importance for Europe's industry and potential supply disruption risk

34

EU critical raw materials

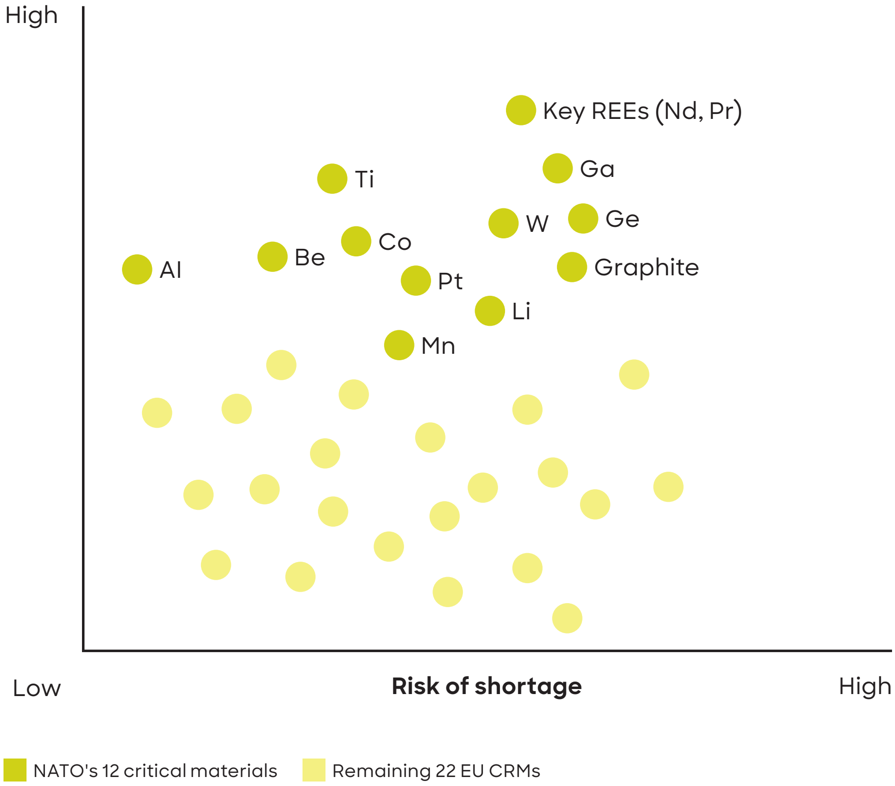
No substitute for A&D platforms and high geopolitical risk

12

critical raw materials

A&D CRITICALITY AND RISK OF SHORTAGE FOR THE 34 EU CRMS

Criticality to the A&D supply chain



Source: European Commission (CRMA 2024); NATO Industrial Advisory Group (NIAG); The International Institute for Strategic Studies; Roland Berger analysis

2 Practical implications of shortages – Which materials impact which components?

The 12 A&D critical raw materials are present in practically all types of air, sea, land, and space platforms to some degree, and in many types of armaments. These materials can be classified into four broad categories. ▶B

BASE MATERIALS

Aluminum (Al) and titanium (Ti):

These are metals that account for a considerable share of the mass of structures and engines of air platforms. Aluminum is mainly used in the fuselage, wing, and empennage of civil and military aircraft, while titanium is a key material for the structure of fighter jets and airliners' pylons, and the main element used in the cold section of aeroengines. A shortage of these materials would significantly impact the ability of OEMs to deliver aircraft.

ADDITIVE MATERIALS

Cobalt (Co), lithium (Li), manganese (Mn), platinum (Pt), tungsten (W), graphite:

These are mainly metals (except graphite) that amount to a small share of the mass of platforms' and armament's structures, engines, and mechanical systems (e.g., alloying elements, coatings) but play a crucial role in enabling platform performance (e.g., high performance of engine by allowing high hot section temperatures in the engine, lightweighting of structures, increased toughness and hardness of armor). Lack of these materials would affect the delivery of aeroengines and armored platforms.

BATTERY MATERIALS

Cobalt (Co), lithium (Li), manganese (Mn), graphite:

These are the main components of batteries that power electric propulsion systems (e.g., for drones), for which their electrochemical properties are leveraged (when used as additive materials, it is their metallurgical and chemical properties that are leveraged). A shortage of these materials would significantly affect deliveries of electrically powered platforms across domains, especially unmanned systems.

INSTRUMENT MATERIALS

Beryllium (Be), gallium (Ga), germanium (Ge), rare earth elements:

These are key enablers for components of electronic instruments (e.g., radars) and electric motors (e.g., permanent magnets). Shortages of these materials would result in delivery delays for primes (Original Equipment Manufacturers) due to constraints in the supply of electronic systems, in particular sensors (e.g., electronic countermeasures) and electrical power and propulsion systems for battery-electric platforms (e.g., unmanned aerial vehicles).

It is important to note that although rare earth elements are presented as an aggregated group, they are a collection of 17 elements typically found in small quantities, which appear in nature combined and which can be difficult to separate. Arguably the most critical of these include neodymium (Nd), praseodymium (Pr), dysprosium (Dy), terbium (Tb), and samarium (Sm), all used in the production of high-strength permanent magnets for diverse applications, and the subject of much investment in sourcing and recycling.

B Presence of the 12 critical raw materials across A&D platforms and main applications within those platforms (examples)

	Mechanical applications			Electronic applications	
Domain	Structures	Additives and alloying elements		Batteries	Instruments and motors
	Al Ti	W Pt Co Li Mn	Graphite	Co Li Mn Graphite	Be Ga Ge REE
Air (e.g., commercial and military aircraft)	Airframe and engine cold section	Engine hot section coating and super alloys	Brake systems	Battery components	Components for sensors, engines (magnets) and optics
Space (e.g., commercial and military satellites)	Overall structure (Al). Ti for specific components (e.g., brackets)	Alloying elements for components	Thermal shield	Battery components	Components for sensors, engines (magnets) and optics
Sea (e.g., dual-use and military vessels, and submarines)	Al for internal structures. Ti for corrosion applications (e.g., pipes)	Engine components	Nuclear reactor parts (neutron moderator)	Battery components	Components for sensors, engines (magnets) and optics
Land (e.g., dual-use and military armored vehicles, including tanks)	Structure mainly made of steel. Al and Ti have limited application (e.g., Ti in Abrams' turbine)	Alloying elements for armor components and coatings		Battery components	Components for sensors, engines (magnets) and optics
Armaments (e.g., missiles)	Missile body and engine cold section	Engine hot section coating and super alloys	Nozzle coatings (for missiles with solid propellant engines)	Battery components	Components for sensors, engines (magnets) and optics

Source: Roland Berger experience

3

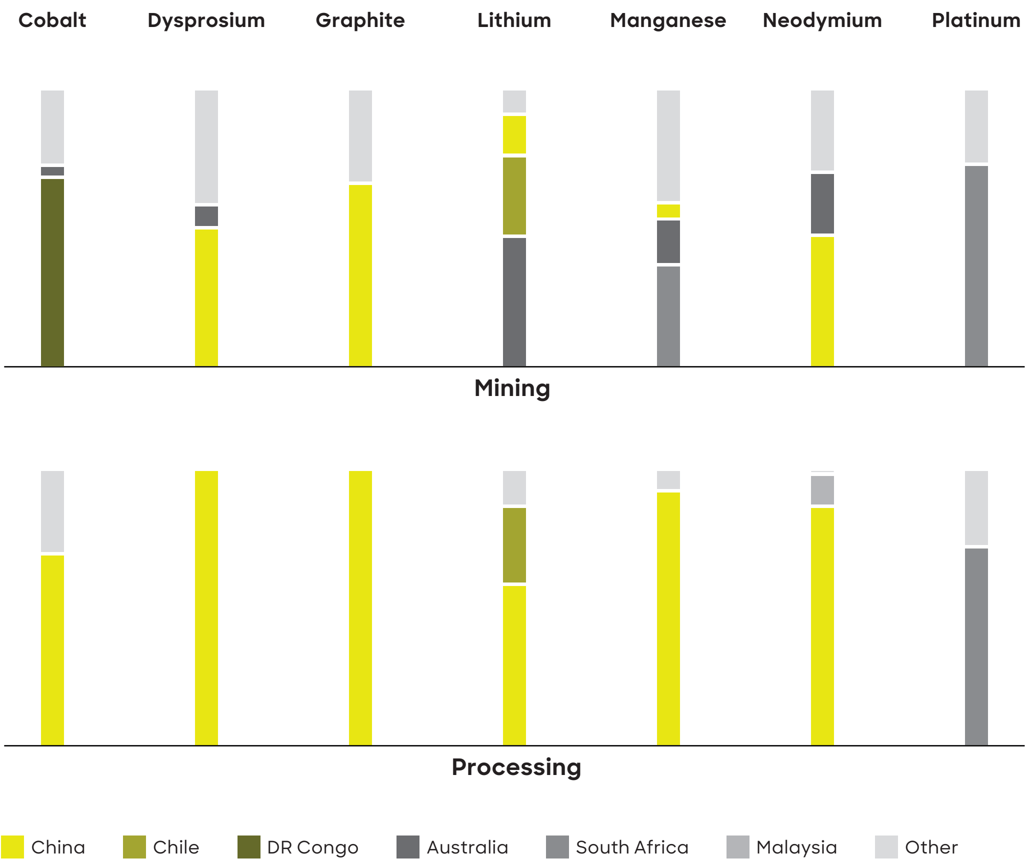
Root causes of potential shortages – What are we missing in Europe and more broadly in the West?

Today, Europe – and more broadly the West – does not control the value chain for most critical raw materials. European and North American activities are normally concentrated in downstream process steps such as the production of final components, while upstream extraction and beneficiation typically happens elsewhere. This imbalance persists despite the presence of untapped material reserves that could be developed with sufficient investment.
▶ C, D

The practical implication is a structural vulnerability: primes (OEMs) may face significant delivery risks if disruptions occur in the early stages of the supply chain, particularly in jurisdictions beyond their control. These upstream dependencies can act as critical chokepoints. To illustrate the potential exposure, we examine two case studies – titanium and rare earth elements (REEs) – to assess the volume of material that could be at risk of shortage.

C Overview of the mining and processing distribution of key critical raw materials by country

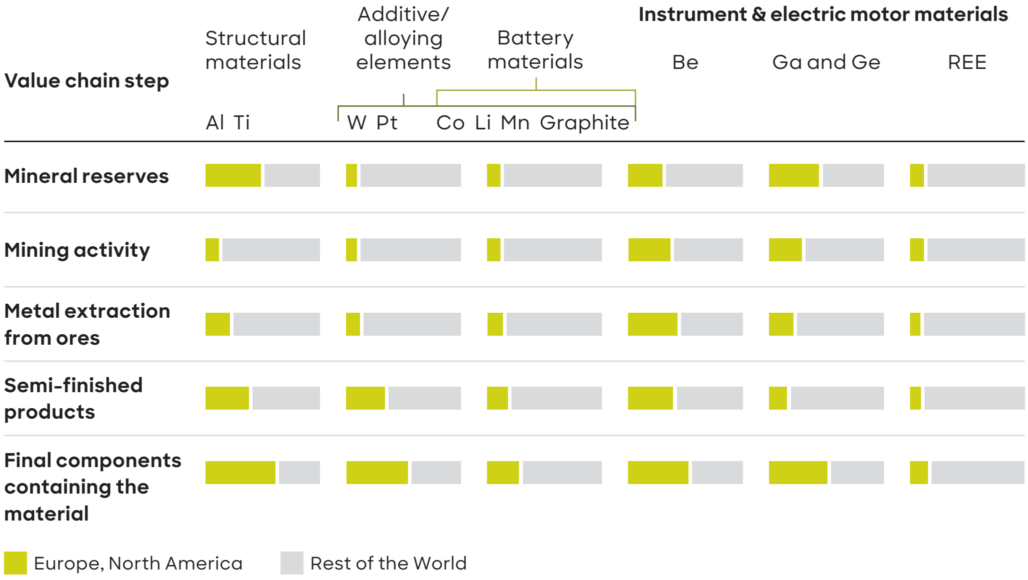
Mine production and processing of critical raw materials by country, 2022 [%][1]



1 Share of total mining and processing

Source: IRENA; Roland Berger

D Value chain coverage of NATO's 12 critical raw materials by Europe and North America, and rest of the world



Source: Roland Berger analysis

3.1/ Titanium: A structural bottleneck from sponge to final component

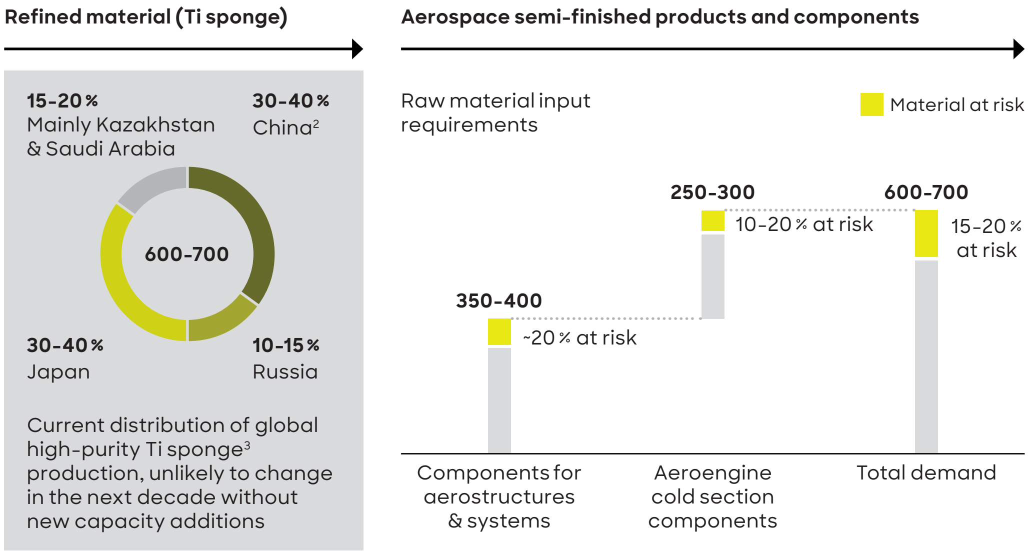
Titanium demand for aerospace and defense is set to grow substantially over the next decade, driven by the ramp-up in civil aircraft production and higher anticipated orders for military platforms amid escalating geopolitical tensions. Our estimates indicate that A&D-related titanium demand could reach roughly 600-700 kilotons over the next ten years, with about 60% attributable to airframe structures and most of the remainder for engines. Against this backdrop of rising demand, titanium supply is exposed to constraints at two distinct levels: at the raw material stage and at the semi-finished/finished product stage.

At the raw material level, the security of high-purity titanium – over 99.5% titanium content with minimal oxygen and iron impurities to guarantee optimal mechanical behavior – is already fragile. Today, roughly half of the world's high-grade titanium sponge originates from China and Russia, creating a concentrated geopolitical risk for Western OEMs. Sanctions, export controls, and transport disruptions linked to Russia's war against Ukraine have already exposed the vulnerability of sponge-dependent supply chains.

At the semi-finished/finished product level, the risk lies in forgings, castings, and machined components, for which the raw material may come from China and Russia, or from less risky sources such as Japan, Kazakhstan, or Saudi Arabia. Before the 2022 war, Western engine and airframe programs were heavily reliant on large Russian forgings, a dependency that has since been reduced but not eliminated; current assessments still point to around a 20% exposure to Russian-origin forged components. Titanium-based forged and cast components for engine cold sections are also at risk, as even though most structural castings are now produced in the West, capacity for such castings is widely expected to plateau at 2027-28 levels, with lead times for forged and machined A&D-grade parts projected to lengthen further under sustained demand. ▶ E

E Overview of titanium demand for A&D

Titanium demand for A&D,[1] cumulative 2026-35 ['000 metric tons] and key supply chain risks



1 Titanium metal and alloy required to produce the finished components mounted on military and civil aircraft (>90% is pure Ti, with the rest being alloying elements); 2 China currently accounts for 65-70% of the global Ti sponge production, with a growing share of its production currently considered high purity; 3 >99.5% Ti and low level of interstitials such as O, N, H, C and Fe

Source: Roland Berger analysis

3.2/ Rare earth elements: Small quantity, outsized impact

Rare earth elements perform a wide range of functions across aerospace and defense (A&D) platforms; however, NdFeB permanent magnets represent one of the most critical and pervasive applications. These magnets are integral to brushless electric motors used in electric and hybrid-electric drones, as well as in motors powering actuator systems in both commercial and military aircraft. ▶ F

In addition, materials such as samarium-cobalt play critical roles in other applications. Quantifying actual REE demand in A&D applications remains inherently difficult due to limited visibility into defense platform production volumes – particularly for military drones – and the confidentiality surrounding equipment bills of materials. While indicative estimates suggest demand over the next decade could reach several kilotons of REE metals, these projections carry a high degree of uncertainty.

At the platform level, individual drones typically contain only tens of grams of REEs, primarily neodymium and praseodymium used in high-performance permanent magnets. However, large-scale deployment of unmanned aerial vehicle (UAV) systems is expected to be a key demand driver. In parallel, civil and military aircraft production continues to expand, with REE content per aircraft reaching tens of kilograms in actuator-related magnet systems. In larger platforms such as submarines and warships, REE content is much higher due to the sheer mass of the systems they carry.

REE supply faces acute risks across the entire value chain, as China controls approximately 90% of global processing, refining, and magnet production capacity. ▶ G

F Overview of rare earth elements

PERIODIC TABLE OF ELEMENTS

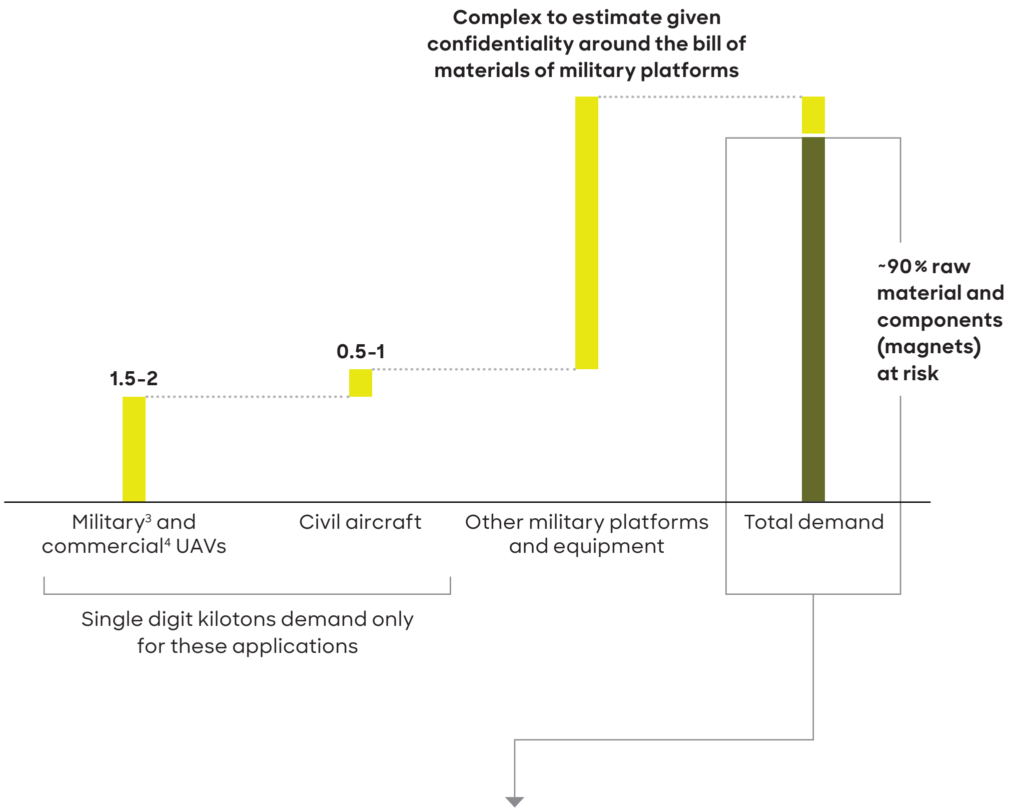
- Light REEs: Lower atomic numbers and larger ionic radii;[1] typically more abundant in nature
- Heavy REEs: Higher atomic numbers and smaller ionic radii;[1,2] typically less abundant in nature
- Other REEs[3]

1 Ionic instead of atomic radius because, in nature, REEs (like most elements) don't exist as neutral atoms, they exist as ions;
2 Yttrium (atomic number 39) is classified as a heavy REE not because of its atomic weight, but because its ionic radius falls right in the middle of the heavy REE range;
3 Scandium is considered a REE because its chemical behavior is similar to that of lanthanides and it tends to occur in the same mineral deposits as the lanthanides

Source: Roland Berger

G Overview of REE metal demand for A&D

REE metal demand for A&D,[1,2] cumulative 2026-35 ['000 metric tons] and key supply chain risks



~90% of the REE magnets value chain is controlled by China

Value chain step	Share controlled by China
Mining and beneficiation	60-70%[5]
Separation of rare earth oxides	~90%
Metallization	~90%
Strip casting/flake casting	~90%
Magnet manufacturing processes	~90%

1 Includes the REE content for A&D platforms, which is mainly concentrated in the NdFeB magnets in brushless electric motors present in electric and hybrid-electric propulsion systems and actuators; 2 Demand for recreational UAVs and ~80% of commercial UAVs are excluded from the analysis given the market dominance of Chinese drones in these segments; 3 Includes demand for NATO and Ukraine electric and hybrid-electric UAVs; 4 Includes demand for non-Chinese electric and hybrid-electric commercial UAVs; 5 Remainder is mainly mined in US, Australia, Myanmar, Thailand, etc.

Source: Roland Berger analysis

4 Mitigation solutions for potential shortages – Are the current efforts enough?

There are three key pathways to mitigate potential shortages of critical A&D materials in the West:

INCREASE OF PRODUCTION CAPACITY

Scale up mining, refining, and processing of raw materials, which requires significant investments and potential re-evaluation of current environmental regulations.

LARGE-SCALE RECYCLING

Recovery of materials from scrapped aircraft, engines, and drones (or other related industry scrap such as clean energy) offers a lower-energy, faster alternative to new mining, creating a reliable domestic stockpile against import risks. This can present difficulties if the recycling process is not mature or if large-scale scrap volumes are not easily accessible.

DEVELOPMENT OF SUBSTITUTES

Advanced alloys, composites, and redesigned components can replace scarce elements in airframes, engines, and actuators. This requires careful consideration in order not to compromise performance, and recertification of components in platforms.

Each material requires a tailored mitigation approach suited to its specific supply risks.

4.1/ Titanium: A potential gap without access to Russia's and China's sponge

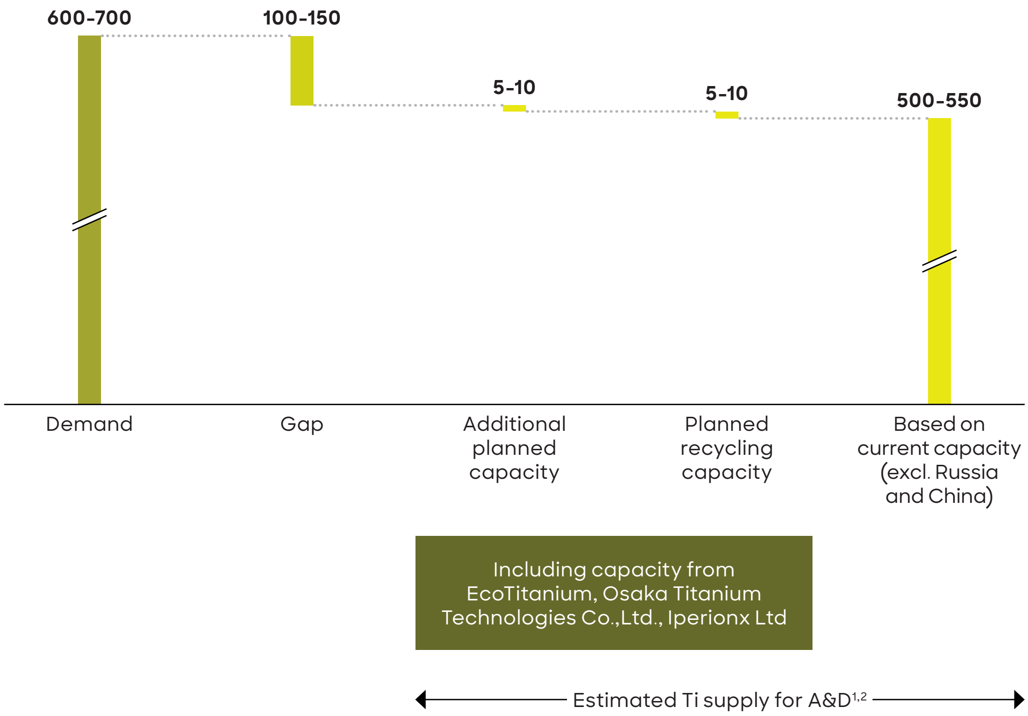
High-purity titanium sponge capacity outside China and Russia is concentrated in Japan, Kazakhstan, and Saudi Arabia, with Japan currently expanding output through Osaka Titanium Technologies. At the same time, several recycling initiatives are advancing scrap recovery. In France, EcoTitanium processes aviation-grade titanium scrap from forging and machining into refined alloys suitable for high-performance applications. In the United States, IperionX converts titanium scrap into high-quality powder and metal meeting aerospace standards.

Despite these efforts, a cumulative supply gap of approximately 100 kilotons could emerge over the coming decade if sponge production and recycling capacity outside China and Russia do not scale more rapidly. Substitution remains largely infeasible, given titanium's unique strength-to-weight ratio and corrosion resistance, which are critical for aerostructures such as engine pylons and cold section engine components. ▶ H

Investment is being made by OEMs and engine manufacturers further back in the value chain, including in casting and forging. Examples are Airbus and Safran's investment in Aubert & Duval, which is active in titanium recycling through EcoTitanium, and Rolls-Royce's expansion of its advanced airfoil casting capacity (focused on nickel superalloys).

H Titanium demand vs. supply for A&D

Cumulative 2026-35 ['000 metric tons]



1 Supply excludes China and Russia; 2 A&D accounts for 60-70% of the global high-purity titanium

Source: Roland Berger analysis

> **"No single organization can solve this alone. Building a resilient raw materials ecosystem requires coordinated investment across OEMs, suppliers, and governments."**
>
> **Adam Healy, Partner**

4.2/ Rare earth elements: Capturing production capacity for A&D

The limited rare earth element production capacity outside China is largely oriented toward neodymium magnets for electric vehicles, consumer goods, and wind turbines.
While substantial REE capacity additions are planned, most output – both existing and incremental – is expected to be absorbed by automotive and industrial motor applications, consumer electronics (e.g., sound and motion components in laptops and smartphones), and energy systems such as direct-drive wind turbines. Furthermore, while such additions are addressing NdPr, there are still gaps in Tb and Dy, dopant materials critical to the functioning of these neodymium magnets.

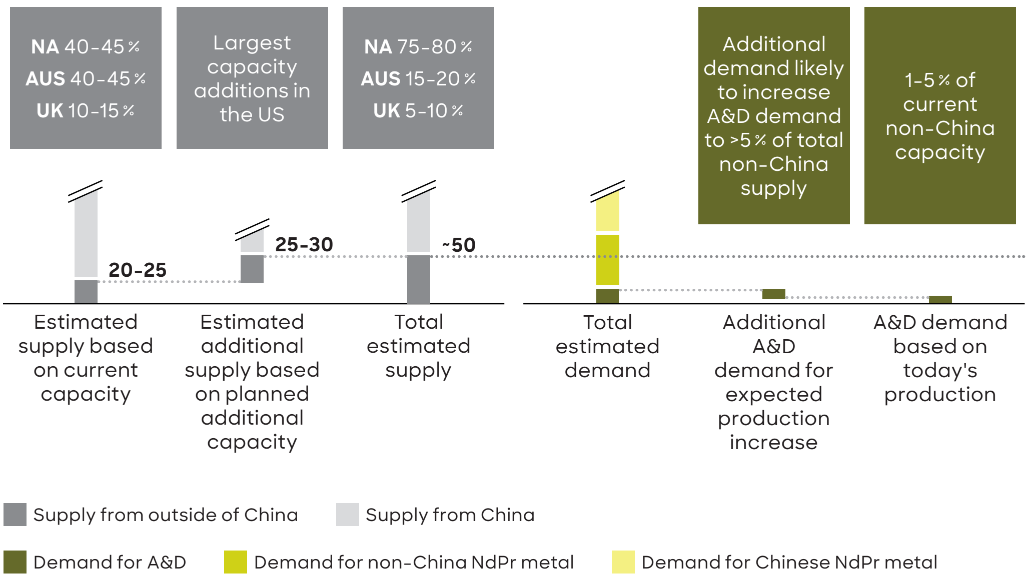
Meanwhile, large-scale REE recycling is unlikely to contribute meaningfully in the short term despite existing pilots and ongoing research, given the limited maturity of recycling technologies and the challenges in aggregating feedstock.

The allocation of REEs to a wide range of sectors that require these materials is likely to persist unless governments secure dedicated volumes for aerospace and defense, or OEMs and their supply chains are willing to pay a premium to guarantee access to the REE metals they require – one example of this in practice is the US DoD's investment in MP Materials, which includes support for expanding its heavy rare earth separation capabilities at its Mountain Pass facility, and an offtake agreement for ten years' worth of magnet production.

If the aerospace and defense sector is unable to secure sufficient REE supply, substitution is a potential option, and manufacturers may need to transition toward magnet-free alternatives (and some have already done so for cost and performance reasons), but in practice this is not possible for some applications. ▶ I

A&D NdPr demand could be served by Western capacity, but it is in competition with larger sectors

Demand vs supply of NdPr metal, cumulative 2026-35 ['000 metric tons]



Source: Roland Berger analysis

5 An uncertain way forward

The industry faces an increasingly uncertain outlook as supply constraints for critical raw materials intensify. Disruptions could become a tangible risk if Europe and the United States lose access to upstream supply from the rest of the world. In some cases, materials could theoretically be designed out; however, this would likely come at a significant cost in terms of performance, qualification timelines, or reliability. More often, companies will need to choose between relying on governments to help unlock supply – through trade policy, diplomacy, and support for domestic investment – or taking a more proactive role in shaping and securing their own supply chains.

There are examples of government and public sector interventions. For example, in rare earth magnets in the US, the DoD recently signed a ten-year agreement with domestic producer MP Materials, setting a USD 110/kg floor for NdPr products and agreeing to buy 100% of magnet output for defense and commercial customers after a new facility is built in that time period. This comes alongside direct funding that JPMorgan and Goldman Sachs have committed to finance this MP Materials' new facility. The European Union has also funded Europe's largest rare earth magnet factory in Estonia, supported by EUR 15 m from the Just Transition Fund, benefiting not only the local region but also wider supply chain resilience. ▶ J

This does not imply that governments should bear the full burden. A more realistic path is a shared approach: companies can help shape a supportive policy environment while also investing selectively in the parts of the value chain most critical to their operations. Apple has also invested USD 500 m in MP Materials in the US, targeting recycling and setting a standard to create a new source for neodymium and praseodymium. Since 2023, there has been more than EUR 60 billion invested via deals and M&A in critical raw materials relevant for aerospace and defense outside China, reflecting growing momentum to strengthen Western supply chains. In the same time period, total public funding committed across Europe and the US has also remained in the tens of billions of dollars, highlighting the relative importance of both streams. However, it is important to note that all of this investment will benefit a range of industries, and only a fraction of the "secured" material output will end up in the A&D sector, which is expected to require investments of billions of dollars to secure the supply for each material.

In this context, companies need a structured way to translate these strategic choices for the key 12 critical A&D raw materials for air, sea, land, and space (highlighted at the front of our report) into concrete investment decisions. RB proposes a simple framework for A&D businesses to guide action:

- Identify the most critical raw materials for the business.
- Determine the available options to secure supply, including strategic partnerships, alternative sourcing, recycling, etc.
- Assess the economic implications of each option.
- Develop implementation plans for the most viable pathways – either individually or collectively in consortia with players in the value chain or with governments and public sector entities.

J Example of public funding initiatives to increase REE production capacity in the US and EU

Project	US project MP Materials	EU project Estonia magnet plant
Project title	DoD–MP Materials rare earth supply chain partnership	Narva rare earth magnet plant
Company leading the project/initiative	MP Materials	Neo Performance Materials
Investor	U.S. Department of Defense	European Union/Government of Estonia under the Just Transition Fund
Amount	USD 400 million equity investment plus a USD 150 million loan	Up to EUR 18.7 million grant
Deal length	10 years	Project grant, not an offtake deal (no fixed timeline stated)
Price support	USD 110/kg floor for NdPr	Not stated
Offtake	100% of magnets from the planned facility for 10 years	Not stated
Strategic purpose	Expand US rare earth processing and magnet manufacturing	Support Europe's first rare earth magnet plant and strengthen supply chains

Source: MP Materials; European Union; Roland Berger analysis

Conclusion

There is a strategic imperative for the aerospace and Defense sector to mitigate potential supply chain disruptions that could affect a wide range of raw materials – including the 12 most defense-critical identified by NATO – on which current platforms depend and whose shortage could severely impact OEMs' ability to deliver.

Given the wide range of applications in which these materials are used, this is not just a risk to aerospace and defense, but the sector must, in collaboration with other industries, be proactive in ensuring the availability of raw materials for critical products. This is needed to reverse long-term underinvestment across much of the West in the upstream stages of these supply chains.

Individual companies should identify the materials most critical to their operations and their potential bottlenecks, and develop risk mitigation strategies for the medium to long term. Although this will require significant time and investment, including in some cases investment in facilities for intensive processing steps, it is essential for the resilience of the sector.

Methodology

The market demand and supply projections for critical materials presented in this report are based on Roland Berger's proprietary aerospace & defense market models. These analyses integrate multiple data inputs, including OEMs' production forecasts and public company announcements such as capacity ramp-up forecasts from producers of raw materials, insights gained from Roland Berger's project experience, and interviews with industry experts.

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