Critical Minerals and Strategic Sovereignty: Need for a Mineral-wise Strategy for India

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[**Preferred citation:** Chandra, S., Mahajan, L. 2025. *Critical Minerals and Strategic Sovereignty: Need for a Mineral-wise Strategy for India* - Swaniti Global Initiative.]

India, with its growing economic and strategic ambitions, has been steadily strengthening its defence sector, emerging as a key global player in defence manufacturing. India holds the position of the world's second largest arms importer[1], taking decisive steps towards achieving the status of self-reliance, especially in defence production, through initiatives like 'Make in India'. This move has led to a paradigm shift with India now exporting defence equipment to over 85 countries[2]. The defence exports surged from Rs. 686 Crore in 2013-14, to a record high of Rs 23,622 crore in the financial year 2024-25. This marks a growth of Rs 2,539 crore or 12.04 percent over the defence exports figures of 2023-24, which amounted to Rs 21,083 crore[3]. Major defence exports include BrahMos missiles, Akash missile systems, Advanced Towed Artillery Guns (ATAGs), and radars, among others.

This rapid advancement in defence manufacturing generates a need for securing a robust supply chain. A self-reliant defence industry will minimize dependence on imports and ensure that global supply chain disruptions do not obstruct national security. This is where critical minerals come into play, forming the backbone of modern defence technologies. With increasing needs for strategic defence mechanisms, the reliance on these minerals increases, creating supply chain vulnerabilities. However, to understand these technologies, their strategic importance and associated risks, we must first understand what critical minerals are.

What are Critical Minerals

According to the Ministry of Mines[4], "critical minerals" are defined as those minerals which are essential for economic development and national security, the lack of availability of these minerals or even concentration of existence, extraction or processing of these minerals in few geographical locations may lead to supply chain vulnerability and disruption. What makes them 'critical' is their limited concentration[5]. A disruption in the supply of these minerals can significantly impact a country's industrial output, national security, and technological advancement. What minerals are ‘critical’ is highly context- and country-specific, influenced by factors such as a nation’s mineral endowment, the strategic significance of certain minerals to its industrial and economic growth, and assessments of supply risks and market volatility.

Critical minerals are essential components of modern economies, supporting a wide range of high-tech industries such as electronics, telecommunications, renewable energy, and advanced manufacturing. From powering smartphones and electric vehicles to enabling satellite systems and aerospace technology, these minerals support innovation and industrial growth. Their strategic value is especially evident in the defence sector, where countries like India, the United States, and China rely on them for national security. As highlighted by India’s Department of Atomic Energy (IREL)[6], minerals such as titanium, zircon, and monazite are crucial for defence and nuclear applications, including the production of fighter jets, submarines, missile systems, and reactors. Additionally, critical minerals play a key role in driving the global transition to a low-carbon economy. Thus, critical minerals play a vital role in enabling the global transition to a low-carbon economy, powering renewable energy technologies required to meet the ‘Net Zero’ commitments made by a growing number of countries around the world.

Need for a Multi-Mineral Foundation for Strategic Capabilities

India’s ambition to emerge as an Atmanirbhar defence manufacturing hub[7] cannot be delinked from the structural realities of material security. A robust and resilient domestic defence industrial base hinges on secure, long-term access to a range of critical minerals, many of which underpin modern weapons systems, electronics, propulsion platforms, and surveillance technologies.

The Ministry of Mines of the Government of India has identified 30 minerals as critical. For a preliminary analysis we have performed a broad technical mapping exercise. We have mapped 24 of the 30 critical minerals against major defence system applications. Our preliminary analysis has revealed that over two-thirds of them have direct or enabling applications across land, air, naval, and space-based platforms - as can be seen in Tables 1 and 2. This underscores a central insight: critical minerals are not niche materials—they are structural inputs into the entire spectrum of India’s national security architecture.

- **Aerospace and Missile Systems:** India’s modern air platforms—ranging from indigenous Light Combat Aircraft (Tejas) to BrahMos missile systems—depend on high-performance alloys, heat-resistant materials, and compact electronic components. Titanium (Ti) is critical for airframes and high-thrust, lightweight components.[8] Its corrosion resistance makes it indispensable for both fighter jets and naval aircraft. Nickel (Ni) and cobalt (Co) support the creation of superalloys[9] used in turbine blades and exhaust systems operating in extreme heat. Beryllium (Be) and tantalum (Ta) are used in aerospace-grade ceramics[10] and missile control surfaces due to their high stiffness, low density, and electromagnetic properties. The role of Rare Earth Elements (REEs)[11]—specifically neodymium, dysprosium, europium, and yttrium—is central to high-strength permanent magnets found in radar, missile guidance, and jet propulsion systems. These elements are not mere additive enhancements—they are core enablers of system performance, range, stealth, and survivability.

- **Land-Based Combat Systems:** The indigenous push for next-generation armoured vehicles, artillery systems, and advanced infantry equipment further amplifies the demand for niche metallurgical and electronic materials. Tungsten (W) is crucial in armour-piercing kinetic energy rounds and ballistic protection systems.[12] Often referred to as the "tooth of industry"[13], tungsten is prized for its exceptional hardness, high melting point, and strength at elevated temperatures. These properties make it indispensable in the production of hard alloys and high-performance steels used extensively across the defence, aerospace, and information technology sectors. When alloyed with refractory metals such as tantalum, niobium, molybdenum, and rhenium, tungsten forms ultra-high-temperature materials suitable for critical applications in jet engines, missile components, and advanced armour systems. Molybdenum (Mo) and vanadium (V) are alloying agents that add tensile strength and corrosion resistance to artillery barrels.[14] Non-ferrous alloys incorporating molybdenum emerged as essential materials in weapons manufacturing as early as the 20th century, valued for their strength, durability, and resistance to extreme conditions. In contemporary defence and aerospace engineering, high-precision systems demand advanced alloy compositions—featuring molybdenum, tungsten, chromium, and vanadium—for the fabrication of critical components used in warships, rockets, satellites, and other strategic platforms. These alloys provide the mechanical resilience and thermal stability required for next-generation military hardware. The increasing digitization of land warfare demands tellurium (Te), germanium (Ge), and gallium (Ga)[15] for advanced applications. Synthetic graphite[16] plays a critical role in thermoregulation across advanced defence platforms, particularly in high-energy systems such as laser-based weapons and precision sensor arrays. Its exceptional thermal conductivity makes it ideal for dissipating heat from laser diodes, beam control optics, and power electronics, ensuring operational stability during continuous high-power use. In Directed Energy Weapons (DEWs)—such as the Navy's Laser Weapon System (LaWS)—graphite-based components help mitigate thermal distortion, preserving beam coherence and accuracy during extended engagements. As DEWs become integral to next-generation combat systems, graphite's role as a thermal management material is likely to become increasingly strategic.

- **Naval and Submarine Platforms:** India's naval modernization—evident in the commissioning of platforms like the INS Vikrant, Scorpene-class submarines, and a growing suite of indigenously developed sonar, radar, and electronic warfare systems—rests on a foundation of critical mineral-intensive technologies. These systems require a wide array of specialty materials to meet the demands of performance, durability, and strategic autonomy in maritime defence. Zirconium (Zr), for example, is vital to the construction of nuclear propulsion systems due to its low neutron absorption and corrosion resistance, making it a preferred cladding material[17] in naval reactors. Lithium (Li) and cobalt (Co) are central to the development of high-energy-density batteries essential for advanced underwater endurance, particularly in Air-Independent Propulsion (AIP) systems and next-generation electric submarines. These minerals could also be crucial for backup power systems in warships and unmanned underwater vehicles (UUVs). Beyond traditional shipbuilding inputs, modern naval systems rely on integrated electronics and stealth materials[18]—both mineral-intensive domains. Graphite and advanced composites, meanwhile, are used to enhance stealth capabilities[19]. This expanding technological envelope makes it clear that naval superiority is no longer just about shipbuilding—it is now also about securing reliable access to the critical minerals that underpin maritime combat readiness and survivability in complex, high-threat environments.

Table 1: Mapping India's critical minerals against major defence applications (Part I)[20]

Domain	Application	Sb	Be	Bi	Co	Cu	Ga	Ge	Graphite	Hf	In	Li	Mo	Nb	Ni	PGE - Pt, Pd, Rh, Ru, Ir, Os	P
Air	Aircraft (fighter, transport, etc)																
	Helicopter (combat and multi -role)																
	Missiles																
Water	Aircraft and helicopter carrier, amphibious assault ship																

Domain	Application	Sb	Be	Bi	Co	Cu	Ga	Ge	Graphite	Hf	In	Li	Mo	Nb	Ni	PGE - Pt, Pd, Rh, Ru, Ir, Os	P
	Corvettes, offshore patrol vessels and frigates																
	Submarine																
	Torpedoes																
Land	Main battle tank																
	Infantry Fighter vehicle, armored personnel carrier and self-propelled artillery																
	Towed Artillery																
	Ammunition																
	Assault rifle																

Note/Legend:

(yellow)	*Minerals whose use in defence applications hasn't been investigated for the purpose of the blog*
(orange)	*Mineral used for the specific defence application*

Table 2: Mapping India's critical minerals against major defence applications (Part II)[21]

Domain	Application	Potash	REE	Re	Si	Sr	Ta	Te	Sn	Ti	W	V	Zr	Se	Cd
Air	Aircraft (fighter, transport, etc)														
	Helicopter (combat and multi -role)														
	Missiles														
Water	Aircraft and helicopter carrier, amphibious assault ship														
	Corvettes, offshore patrol vessels and frigates														
	Submarine														
	Torpedoes														
Land	Main battle tank														
	Infantry Fighter vehicle, armored personnel carrier and self-propelled artillery														
	Towed Artillery														
	Ammunition														
	Assault rifle														
Note/Legend:															

Domain	Application	Potash	REE	Re	Si	Sr	Ta	Te	Sn	Ti	W	V	Zr	Se	Cd
		Minerals whose use in defence applications hasn't been investigated for the purpose of the blog													
		Mineral used for the specific defence application													

Table 3: Mapping select critical minerals with their top 3 global producers and India's import reliance for each

Some Critical Minerals for India (Ministry of Mines)	Global mine production scenario			India's Import Reliance (most figures are from 2020 data)
	1st	2nd	3rd	
Beryllium (Be)	United States	China	Brazil	100%**
Cobalt (Co)	Democratic Republic of Congo (DRC)	Indonesia	Russia	100%**
Copper (Cu)	Chile	Peru	Democratic Republic of Congo (DRC)	93%****
Gallium (Ga)	China	Russia	Ukraine	100%***
Germanium (Ge)	China	Canada	Finland / Russia / United States	100%**
Graphite	China	Madagascar	Mozambique	60%**
Lithium (Li)	Australia	Chile	China	100%**
Molybdenum (Mo)	China	Chile	Peru	100%***
Nickel (Ni)	Indonesia	Philippines	New Caledonia*	100%**

Some Critical Minerals for India (Ministry of Mines)	Global mine production scenario			India's Import Reliance (most figures are from 2020 data)
	1st	2nd	3rd	
Rare Earth Elements	China	United States	Myanmar	Import reliance percentage could not be found
Tantalum (Ta)	Democratic Republic of Congo (DRC)	Rwanda	Brazil	100%**
Tellurium (Te)	China	Japan	Russia	Import reliance percentage could not be found
Titanium (Ti)	China	Japan	Russia	Import reliance percentage could not be found. India, though, has significant ilmenite & rutile reserves
Tungsten (W)	China	Vietnam	Russia	100%*****
Vanadium (V)	China	Russia	South Africa	100%**
Cadmium (Cd)	China	South Korea	Japan, Canada	~100%****** (India is the largest importer of cadmium in the world with comparatively

Some Critical Minerals for India (Ministry of Mines)	**Global mine production scenario**			**India's Import Reliance (most figures are from 2020 data)**
	1st	**2nd**	**3rd**	
				negligible domestic production)
Note/Legend/Sources:				
	Sourced from USGS Mineral Commodity Summaries 2024			
	Sourced from Indian Minerals Yearbook 2022			
	Sourced from Reuters[22]			
	Sourced from *https://www.crmalliance.eu/germanium*			
*	*Overseas territory of France*			
**	Ministry of Mines, Government of India, 2023. *Critical minerals for India: Report of the Committee on Identification of Critical Minerals*. (online: https://mines.gov.in/admin/download/649d4212cceb01688027666.pdf).			
***	Chadha, R. Sivamani, G. and Bansal, K. (2023). Assessing the Criticality of Minerals for India: 2023 Addendum: Mineral Factsheets (CSEP Working Paper 49). New Delhi: Centre for Social and Economic Progress.			
****	Ganguly, M. Ali, H. (2024). Critical Mineral recycling: India's path to ensuring energy sustainability - The Wire, *The Wire*, 24 December.			
*****	*TUNGSTEN - Indian Minerals Yearbook 2020 (Part- II :Metals and Alloys)*			

Some Critical Minerals for India (Ministry of Mines)	Global mine production scenario			India's Import Reliance (most figures are from 2020 data)
	1st	2nd	3rd	
******	*Cadmium in India Trade | The Observatory of Economic Complexity*, no date. *The Observatory of Economic Complexity*.			

Multidimensional Dependencies and Policy Implications

One of the most crucial insights from our preliminary technical mapping exercise is that no single critical mineral is linked to a single type of application or platform. Instead, minerals such as REEs, titanium, cobalt, nickel, and tungsten emerge as cross-cutting enablers, whose absence would paralyze multiple branches of defence manufacturing. Moreover, several minerals are involved at multiple stages—not just as structural materials, but also in: sensor systems (e.g., gallium, germanium etc), weapon targeting and optics (e.g., REEs etc), power systems (e.g., lithium, vanadium etc), heat shielding and propulsion (e.g., nickel, tantalum etc). This signals what we would like to call a ‘second-order’ risk: supply disruption of a single mineral could cause systemic bottlenecks across multiple weapons systems.

From a policy and strategy perspective, this creates an urgent imperative - that of a **mineral-wise strategy** which can then be integrated into India’s defence R&D and procurement cycles and also be integrated with other crucial sectors. When it comes to the defence sector, the criticality index of each mineral should account not only for current usage, but also for emerging use-cases (e.g., drone warfare, AI warfare etc). The mineral-wise strategy needs to be tied to the national security threats to India in the short, medium and long terms and the opportunities it presents us with.

Strengthening India’s Critical Mineral Strategy

India’s growing reliance on imported critical minerals for its strategic industries—including defence—poses a structural vulnerability. In Table 3, we select 16 of the 24 minerals studied in Tables 1 and 2, and map the top 3 global producers for them along with India’s import reliance percentage. This mapping highlights a stark geopolitical reality: a concentrated global supply chain, often controlled by a handful of countries, places India’s mineral security—and by extension, its national security and strategic autonomy goals—at risk.

India's critical mineral ecosystem, when mapped against global production realities and its own import dependence, reveals a pronounced structural asymmetry. Of the 30 minerals identified as critical by the Ministry of Mines, India has 100% import reliance on at least 10 of them, including:

- Beryllium (United States, China, Brazil)
- Cobalt (Democratic Republic of Congo, Indonesia, Russia)
- Gallium (China, Russia, Ukraine)
- Germanium (China, Canada)
- Molybdenum (China, Chile, Peru)
- Nickel (Indonesia, Philippines, New Caledonia)
- Lithium (Australia, Chile, China)
- Tantalum (Democratic Republic of Congo, Rwanda, Brazil)
- Tungsten (China, Vietnam, Russia)
- Vanadium (China, Russia, South Africa)

This level of external dependency—especially on China for minerals like graphite, gallium, tungsten, vanadium, and REEs—creates a ‘single-point-of-failure’ supply chain risk for multiple critical sectors. It is a strategic vulnerability that is only going to increase further going into the future. China alone dominates the global production of rare earth elements (REEs), graphite, gallium, germanium, tungsten, titanium, vanadium, and cadmium—all of which have critical applications in advanced defence platforms. Similarly, the Democratic Republic of Congo and Russia control a significant share of cobalt and tantalum production. Australia and Chile (part of the ‘Lithium Triangle’) control lithium, central to energy storage and electric propulsion.

In this context, India’s mineral strategy must evolve beyond domestic exploration. It must become a pillar of its broader economic & trade diplomacy, industrial policy, and national security strategy. To correct this asymmetry, India’s critical mineral strategy must be cohesive with a multidimensional architecture. India needs to secure long-term access to critical minerals through strategic partnerships while simultaneously unlocking domestic reserves by investing in exploration, processing infrastructure, and integrated mineral clusters. To reduce external dependencies, it must also scale R&D partnerships in material substitutes and e-waste recycling, supported by global technology collaborations and circular economy initiatives.

Conclusion

India's critical mineral vulnerability is not just a trade issue—it's a strategic sovereignty issue. Global shifts—from energy transition to defence technology development—are already amplifying global demand. There is an urgent need for India to adopt an anticipatory strategy that combines supply-side realism, demand-side prioritization, and long-term resilience planning. Critical minerals must be viewed as "mission enablers"—strategic materials without which self-reliance in defence is unattainable. India's critical mineral strategy must now move beyond identification and enter the realm of execution, institutional convergence, and global positioning. As India aspires to lead in defence, clean tech, and advanced manufacturing, critical minerals will form the material foundation of its strategic sovereignty. **A future-ready policy must start with framing a mineral-wise strategy which combines resource diplomacy, domestic capability building, and scientific leadership and partnerships.**

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References:

1. Peri, D., 2025. *India second-largest arms importer after Ukraine*, *The Hindu*. (online: https://www.thehindu.com/news/national/india-second-largest-arms-importer-after-ukraine/article69313894.ece).
2. *Aatmanirbharta on the rise: Defence exports reach an all-time high of approx. Rs 16,000 crore in Financial Year 2022-23; Over 10-times increase since 2016-17; India exporting to over 85 countries*, no date. (online: https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1912885).
3. Philip, S. A., Philip, S. A., 2025. *India's defence exports grew to Rs 23,622 cr in FY2024-25, with private sector contributing 64%*, *ThePrint*. (online: https://theprint.in/defence/indias-defence-exports-grew-to-rs-23622-cr-in-fy2024-25-with-private-sector-contributing-64/2574207/).
4. Ministry of Mines, Government of India, 2023. *Critical minerals for India: Report of the Committee on Identification of Critical Minerals*. (online: https://mines.gov.in/admin/download/649d4212cceb01688027666.pdf).

5. Ministry of Mines, Government of India, 2023. *Critical minerals for India: Report of the Committee on Identification of Critical Minerals*. (online: https://mines.gov.in/admin/download/649d4212cceb01688027666.pdf).
6. Ministry of Mines, Government of India, 2023. *Critical minerals for India: Report of the Committee on Identification of Critical Minerals*. (online: https://mines.gov.in/admin/download/649d4212cceb01688027666.pdf).
7. Press Information Bureau (PIB), Ministry of Defence, Government of India, 2025. *Atmanirbhar Bharat in Defence*. (online: https://pib.gov.in/FactsheetDetails.aspx?Id=149099®=3&lang=1).
8. *Tejas Light Combat Supersonic Fighter*, 2024. *Airforce Technology*. (online: https://www.airforce-technology.com/projects/tejas/?cf-view).
9. Morad, A., Shash, A., 2014. NICKEL BASE SUPERALLOYS USED FOR AERO ENGINE TURBINE BLADES, *The International Conference on Applied Mechanics and Mechanical Engineering*, 16, 16, 1–22. doi: 10.21608/amme.2014.35549.
10. Pavel, C., Tzimas, E., European Commission, Joint Research Centre, 2016. *Raw materials in the European defence industry*, EUR 27542 EN. Publications Office of the European Union. doi: 10.2790/0444.
11. *Defence and civilian applications of rare earth elements*, 2022. *AIR POWER Journal*. (online: https://capsindia.org/wp-content/uploads/2023/01/APJ-Jul-Sep-2022-Neha-Mishra.pdf).
12. Singh, I., Dabhade, V. V., 2024. Tungsten heavy alloys for kinetic energy penetrators: a review, *Materials Science and Technology*. doi: 10.1177/02670836241260514.
13. *Six strategic metals widely used in the military industry*, no date. Stanford Advanced Materials. (online: https://www.samaterials.com/content/six-strategic-metals-widely-used-in-the-military-industry.html).
14. National Rifle Association, no date. *NRA Family | Gun Science: What's the best metal for gun barrels?*, *NRA Family*. (online: https://www.nrafamily.org/content/gun-science-what-s-the-best-metal-for-gun-barrels/).
15. Carrara, S., Bobba, S., Blagoeva, D., Alves Dias, P., Cavalli, A., Georgitzikis, K., Grohol, M., Itul, A., Kuzov, T., Latunussa, C., Lyons, L., Malano, G., Maury, T., Prior Arce, Á., Somers, J., Telsnig, T., Veeh, C., Wittmer, D., Black, C., Pennington, D., Christou, M., Supply chain analysis and material demand forecast in strategic technologies and sectors in the EU – A foresight study, Publications Office of the European Union, Luxembourg, 2023, doi:10.2760/386650, JRC132889.
16. *Critical Minerals in Defence and National Security | SFA (Oxford)*, no date b. *SFA (Oxford)*. (online: https://www.sfa-oxford.com/knowledge-and-insights/critical-minerals-in-low-carbon-and-future-technologies/critical-minerals-in-defence-and-national-security/).
17. Ministry of Mines, Government of India, 2023. *Critical minerals for India: Report of the Committee on Identification of Critical Minerals*. (online: https://mines.gov.in/admin/download/649d4212cceb01688027666.pdf).

18. *Critical Minerals in Defence and National Security | SFA (Oxford)*, no date d. *SFA (Oxford)*. (online: https://www.sfa-oxford.com/knowledge-and-insights/critical-minerals-in-low-carbon-and-future-technologies/critical-minerals-in-defence-and-national-security/).
19. *Critical Minerals in Defence and National Security | SFA (Oxford)*, no date d. *SFA (Oxford)*. (online: https://www.sfa-oxford.com/knowledge-and-insights/critical-minerals-in-low-carbon-and-future-technologies/critical-minerals-in-defence-and-national-security/).
20. Girardi, B., Patrahau, I., Cisco, G., Rademaker, M., The Hague Centre for Strategic Studies, 2023. *Strategic raw materials for defence*, report. (online: https://hcss.nl/wp-content/uploads/2023/01/Strategic-Raw-Materials-for-Defence-HCSS-2023-V2.pdf).
21. Girardi, B., Patrahau, I., Cisco, G., Rademaker, M., The Hague Centre for Strategic Studies, 2023. *Strategic raw materials for defence*, report. (online: https://hcss.nl/wp-content/uploads/2023/01/Strategic-Raw-Materials-for-Defence-HCSS-2023-V2.pdf).
22. *Reuters*, 2023. What are Gallium and Germanium and which countries are producers?, 7 July. (online: https://www.reuters.com/markets/commodities/where-are-strategic-materials-germanium-gallium-produced-2023-07-04/).