Rare earth metals utilization opportunities in the development of Indonesia defense industry technology

N F Jannah*, S Aritonang, S Sunardi, S N Adiprayoga and D D A Rajak
Indonesia Defense University, IPSC Bogor, West Java 16810, Indonesia

*jk.jannah@gmail.com

Abstract. Industrial technology developments that entered the era of 4.0, other than to utilize the development of technology which based on the internet of things, big data, artificial intelligence, cloud, etc., also need to be supported by advanced material technology capabilities, namely rare earth metals. In the defense industry, rare earth metals used in defense and security equipment such as military vehicle coating materials that are able to dodge or absorb waves of enemy radar detection, jet engine components of aircraft fighter, missile weapons systems, electronic components, subsea detectors, satellite devices and material for radar, etc. This research was conducted through literature review and using the SWOT analysis method on the opportunities for the use of rare-earth metals in Indonesia defense industry products. The data used are secondary data, which includes data on the distribution of rare earth metals in Indonesia and the specifications of the use of rare-earth metals in the defense industry. Based on the defense requirements for defense products and the percentage of rare earth metals content in the territory of Indonesia, one of the opportunities for the use of rare-earth metals for defense industry products is in the application of anti-radar layers.

1. Introduction
The defense industry is an industry that utilizes high technology and complex. Not only the operating system but since the stages of designing defense products to become finished products, defense industry products utilize a system that is mutually integrated and holistic. In this era of technological advancement 4.0, defense products are required to fulfill industrial demand in accordance with the requirements required by utilizing advanced technology and supported by the development of advanced materials.

In Indonesia, one of the advanced materials possessed is rare earth metal. Although its availability is not in the form of chunks of elements, it is scattered and bound in other complex compounds such as monazite and tin, where a simple enrichment process is needed to obtain it, but the potential of rare earth metals in Indonesia is worth taking into account. There have been many studies that provide an overview of the distribution of rare earth metals in Indonesia and explain the elemental enrichment processes that can be carried out. It is just that, for utilization in the field of defense is still very minimal. For this reason, this research was conducted based on literature review and secondary data on the number of rare earth metals in Indonesia as well as material requirements from defense products.

1.1. Defense industry
The end of the cold war is the starting point for technological development and the defense industry. It is also the beginning of the start of the competition and global market competitiveness. In the theory of
revolution in military affairs (RMA), it is stated that the development of defense technology and the industry is caused by the presence of factors of liberalization and changing views on future warfare [1]. It is explained that war in the future is no longer a matter of taking up arms but a war that combines hard power and soft power.

So that the defense technology developed is not only combat equipment but a system that is mutually integrated and connected in one control to achieve certain objectives such as ground combat systems, air combat systems, and others.

The defense industry, according to law number 16 of 2012 concerning the defense industry, is a national industry consisting of state-owned and private enterprises which are tasked with fulfilling defense needs by producing defense and security equipment, as well as carrying out maintenance services in meeting strategic interests in defense and security in the Unitary State of the Republic of Indonesia [2]. In its development, the defense industry is targeted to have the ability to design weapons systems and defense equipment in accordance with Indonesia's strategic environment. Also, it is required to be able to realize the design into a prototype which will be developed and capable of producing or manufacturing. Then, it needs to be able to sell its products and compete in the global market, able to offer services related to maintenance, repair, and overhaul (MRO), able to provide spare parts from products manufactured, and be able to play a role in the integrated national and global defense logistics system. The Indonesia defense industry consists of several layers, namely tier 1 which is the main tool industry or lead integrator that produces the main tools for defense systems, tier 2 industries which are the main and strategic component industries as supporting industries, tier 3 industries namely non-tool components or industrial parts main defense system, and tier 4 which is the raw material industry (See Figure 1).

**Figure 1.** Defense industries elements.

### 1.2. Defense requirement: Air, sea, and land

The requirements of defense equipment for air, sea, and land, are based on the development of a generation of war followed by technological developments in defense. At this time, the generation of war has transitioned from the fourth generation to the fifth generation, which has the characteristics of using sophisticated weapons technology and changes in the context of the war. In addition, the fifth generation war, followed by industrial technology 4.0, has entered the realm of cyberspace where there is no longer a boundary between space and time in its implementation. This condition makes changes in the strategic environment and the types of threats that threaten state sovereignty. In addition, consideration of the requirements for air, sea, and land defense technology is also based on geographical structure, strategic environment, capabilities, and threats that always overshadow.

Knowing Indonesia's air defense power, according to AN Pratama in Kompas.com air magazine on October 8, 2018, the Indonesian Air Force has five mainstay aircraft covering the Sukhoi SU-30 used in carrying out attacks on terrain, Sukhoi SU-27, aircraft the T-50 Golden Eagle supersonic trainer, the EMB-314 Super Tucano anti-guerrilla trainer aircraft which serves to support reconnaissance, close air
support, and rebellion crackdowns, as well as lightweight fighter jets for BAE Hawk 209 trainers [3]. Globally, the development of weapons technology in air defense has evolved into stealth technology and unmanned air vehicle (UAV).

The defense condition of Indonesian sea, when compared to the size of Indonesian sea, the number of fleets owned is still not able to secure the entire region. The Indonesian defense industry still opens wide opportunities for shipbuilding companies from abroad such as the Netherlands, Germany and South Korea due to the lack of capability in meeting the demand and technology standards used in the Indonesian fleet. Also, for operational support of the army, Indonesia still relies on Scorpion tanks, which are a lightweight tank class. If seen from the condition of Indonesia's land surface and its geographical conditions, the Indonesian army should be supported by playing battle tanks, assault helicopters, and counterinsurgency aircraft.

The references used in determining the requirements of defense equipment are the provisions of general forces standards, Indonesian military standards that are transmitted by the ministry of defense, global military standards, NATO Agreement (STANAG) standards, etc. What is emphasized in the requirements of air, sea, and land defense equipment is extreme demand in the use of advanced and renewable technology, advanced engineering, and advanced workforce. Also an extensive cooperation with the research community, in this case, is a research and development institution, as well as the role of academics and university. Moreover, the most important thing is to generate leading technologies and competencies of great importance to civil society. Determination of defense product requirements is determined by the Defense Industry Policy Committee, which is based on user needs, namely the navy, air force and army, which are supported by the role of defense technology research and development institutions and academics in universities.

1.3. The technology of industry 4.0
Industrial technology 4.0 is a form of technological transition revolution in stages from the first level to the fourth level. Where each level of revolution has its characteristics. During the 1.0 industrial revolution, the industry utilized steam-powered engine technology as a tool to produce the desired product. In the 2.0 industrial revolution, Humans began to develop industrial technology that utilizes mass production machines by relying on electricity and fuel use. Whereas in the 3.0 industrial revolution, technology began to be developed that utilizes information technology networks and automated machines. Until in industry 4.0, machines that were integrated with the internet were developed. The reasons for the industrial revolution and the increasingly changing use of technology are productivity, efficiency, effectiveness, and competitiveness. Therefore, humans are competing to start developing technologies that can facilitate their activities so they can increase production productivity. The industrial revolution 4.0 with machine technology that is mutually integrated is not just an engineering problem. However, every component involved in compiling the machine becomes an integrated system that takes part in industry 4.0. (See figure 2).

![Figure 2. The industrial revolution [4].](image-url)
Industry 4.0 is a unified system that communicates in real-time without time constraints by utilizing internet technology and cyber-physical systems to optimize the value of each process in the industry [5]. Meanwhile, according to Vasja Roblek et al., industrial technology 4.0 is a consequence of the use of internet technology connectivity to add value to functions and uses in both organizations and social environments [6]. The internet of things became the center of the industrial revolution. Industry 4.0 is related to the internet of things, industrial internet, and smart and cloud-based manufacturing. Also, it was stated that industry 4.0 is a strict limitation on the integration of humans and machinery in manufacturing [7]. The focus of technology development on industry 4.0 is shown in Figure 3.

![Figure 3. The focus of technology development [4].](image)

### 1.4. Rare earth metals

Rare earth metal is an advanced materials group which has characteristics with a nanotechnology-based metamaterial structure to absorb or reflect electromagnetic waves, shape optimization, use in increasing computational power in small devices, and improved surfaces that are useful for coating technology. Some of the benefits contained in the use of rare-earth metals are, among others [8]:

- Rare earth metals used as advanced materials in the development of neo-magnets, namely magnets that have a magnetic field better than ordinary magnets so that the volume and weight of the magnetic mass can be optimized
- Manufacture of high strength low alloy (HSLA) steel, high carbon steel, super-alloy, and stainless steel in the metallurgical industry
- As a catalyst
- In the field of arbitration, earth metals are rarely used as control rods and radiation detector devices

Globally, rare earth metals mining commodity is calculated and relied upon to become a weapon to deal with trade wars like those carried out by China and the United States (US). In 2012, the Chinese government issued a policy to restrict the export of rare earth metals to the United States, which affected various fields such as the economy, politics, and high-tech products. The reasons given by the Chinese government regarding these restrictions are environmental problems and the presumption of rare earth metals as non-renewable natural resources [9]. The export restrictions carried out by China were then responded by the United States not as a significant obstacle because they have taken steps to limit the use of rare-earth metals from China and rearranged industrial supply chain mechanisms in the process of rare earth metal extraction and magnetic production [10]. In addition to China and the United States, there are five other countries which are listed as the most abundant rare earth producing countries in the world, namely Russia, Vietnam, Brazil, India, and Australia with a percentage as in Figure 4 [11].
Figure 4. Countries with the most abundant rare earth content.

Rare earth metals, as the name implies, although it is rare but has a very high utilization value, so it is necessary to conduct a more in-depth study related to its use both for industrial development purposes in general and for the defense industry in particular. In Indonesia, rare earth metals can be found as follower metals in other minerals such as monazite, bauxite, zircon sand, alluvial gold and tin which can be found from large islands in Indonesia. In addition, in the Southeast Asian tin lane, there are world tin resources that pass through the Indonesian territory starting from Karimun Islands, Singkep, to the Bangka Belitung Islands. That are strategic potentials which can make a significant contribution to national development. The presence of rare earth metals in nature is not as a free element but as a complex compound bond. So, for its utilization, it is necessary to do the process of separating the bonds of these complex compounds. For example, in monazite minerals which are often found in Indonesia, they contain thorium in the form of oxides or thorium-phosphate salts [12]. In addition, other elements with relatively high concentrations, such as lanthanum (La) and Cerium (Ce) were found [13].

In the West Kalimantan region, analysis was carried out on a number of zircon sands namely 4,545.16 tons, 24.35 Kg of gold, and 520.07 tons of monazite obtained from a number of hypothetical resources in 402.67 Ha of a research area, giving information that there are 11.9 tons of rare earth metal [14].

2. Methods
This research was conducted by conducting literacy studies of literatures that discussed the use of rare earth metals and technological developments in raising the national defense industry. In general, the use of rare-earth metals used in battery technology. While its use in technology and the defense industry is still not widely discussed. For a discussion of technology and the defense industry that includes the development of industrial technology 4.0 is about the relationship between systems that are interconnected, implement interoperability functions, and are holistic.

In analyzing, the strategic planning evaluation method used is examined from parts of rare earth metal utilization, which include strengths, weaknesses, opportunities, and threats, or better known as SWOT analysis theory. The framework in this study is illustrated in Figure 5. Data analysis was carried out on secondary data from research results that supported each other.
3. Results and discussion

In order to safeguard national sovereignty, the national defense needs to be strengthened and supported by the development and utilization of defense technology through the modernization of defense equipment that utilizes industrial technology development 4.0. The characteristics of defense technology are interoperability, where the whole system must be interconnected and holistic. The entire system, in addition to covering informatics, mechanical, cyber, and other systems, also includes the use of advanced materials. Indonesia is one country that has advanced material resources in the form of rare earth metals. Although its existence is not in the form of chunks and its quantity cannot be compared with China and the United States, but through a systematic, structured and sustainable processing and enrichment process can produce adequate results to support industries in Indonesia, including the defense industry. In law no. 16 of 2012 concerning the defense industry, things that need to be considered in meeting the needs of the national defense industry, namely defense and security equipment needed whether they can be made in Indonesia or must buy from other countries. It also concerns about defense industry involvement from every tier on 1 to 4 and the guarantee of trade returns, local content and/or offsets is at least 85% where the required fulfillment is at the beginning of 35% and a 5% increase every year.

The potential of natural resources in the form of rare earth metals that can be used in fulfilling the needs of raw materials is one of the potentials for technological development that will support the independence of the national defense industry. If based on the availability of rare earth metals in Indonesia, although they are still contained in complex compounds such as monazite, zircon sand, gold, alluvial tin, etc., the potential for their utilization can be described based on an analysis of strengths, weaknesses, opportunities, and threats it has. In addition to utilization in the field of electronic components, rare earth metals have also begun to be developed to become materials that can absorb radar waves. These materials can be used as a coating material in defense vehicles such as submarines, fighter aircraft, medium tanks, frigate ships, missile destroyers, and others. The development of rare earth metal as an anti-radar material in the X-band 8-12 GHz frequency range was carried out by BATAN which developed smart magnet material as a result of processing monazite sand into rare earth metals which were tested on the Patkamla Sadarin Navy Forces on Mutiara beach [15]. Radar wave absorbing material is important in developing defense capabilities as well as applied to Australia's defense capability standards, which conducts research on its application as smart material [16].

The characteristics of a material can absorb electromagnetic waves from the radar in two ways, namely by absorbing through a magnetic field and converting captured waves into heat energy [17]. Wave absorbent material must also have the ability to interact well between the electric field from the emission of radiation and the electrical components of electromagnetic radiation [18], and meet requirements such as layer thickness, mass of material that is light, has excellent durability, and has a frequency absorption range broad [19]. Wave absorbent material works by minimizing the radar cross-section (RCS), which is the object's ability to reflect the radar signal towards the receiver by
performing a comparison between the backscatter per stationary (solid angle unit) of the target against the interrupted energy density [20]. In the field of defense, radar wave absorbent material has a very significant role in the development of stealth technology. These materials have the ability to prevent detection (radar, acoustics, infrared, etc.) by absorbing waves and suppressing the number of waves reflected from the metal structure found in the body of a combat vehicle [21].

Referring to the defense industry owned by developed countries such as the United States, rare earth metal needs in developing full stealth technology are 920 lbs or 418 Kg per 1 unit of F-35 fighter, 2359 Kg for 1 unit of destroyer belonging to the Arleigh United States Navy Burke DDG-51, and 4173 Kg for 1 unit of submarine with fast attack capability SSN-774 [22] (see figure 6). If based on the amount of defense budget held by the ministry of defense each year, it is known that the existing budget is not sufficient to develop rare earth metals as stealth technology in supporting defense forces. Therefore, the use of LTJ can be modified only as a mixture on the paint layer on military vehicles. It will reduce the amount of rare earth metal use and optimize the defense budget. Another solution that can be applied by the ministry of defense is to establish cooperation with local mining industries to enrich the elements so that the LTJ contained as waste material is not wasted.

![Figure 6. Rare earth ingredients.](image)

If Indonesia can develop stealth technology in its defense products without having to depend on imported commodities from abroad, the Indonesian defense industry has been able to eliminate one of the obstacles to its independence, namely the embargo. The threat of an embargo on raw materials for rare earth metals as China did in the United States, not a frightening thing anymore. However, to carry out rare earth metal development in the Indonesian defense industry technology requires excellent and careful management of the availability of natural resources, human resources, and markets. Local mining industries, such as PT. Timah Tbk, as an example, can be developed to become a tier 4 defense industry that supports rare earth metal needs as a result of the enrichment of tin mining waste.

4. Conclusion

Based on the results of observations on the potential use of rare earth metals in the defense industry which is seen from its availability in nature and the amount of material utilized, the following points can be concluded:

- Even though it is not comparable to the amount of rare earth metal possessed by developed countries such as the United States and China, Indonesia has rare earth metal reserves which are sufficient to develop advanced materials in the defense industry.
- One of the opportunities for the use of rare-earth metals in the Indonesian defense industry is the development of stealth technology by utilizing anti-radar paint coatings.
- The potential for rare earth metal raw, material embargoes from abroad can be minimized by developing the 4th tier defense industry in Indonesia. For this reason, it is necessary to hold downstream industries to produce rare earth metals as part of the defense industry in Tier 4, namely raw materials.
Weaknesses of the defense industry in developing rare earth metals in defense technology are caused by resource management that still needs to be improved, and there are limited defense budgets.

Meanwhile, there will be a lot of struggle to build up the industry on tier 4, which concern on raw materials, but it is worth to be developed because the benefit from its developing has a high-tech requirement completion.

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