Technology Readiness Level (TRL) of Loitering Munition for Future Modern Warfare in Indonesian

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***Abstract*—** The concept of the Internet of Military Things and the Internet of Battlefield Things is the idea that future military battles will be dominated by Artificial Intelligent & Cyber Warfare these battles will likely take place in urban environments. Looking at the threats and trends in technology development in the future, a weapon that is autonomous and precise is needed. Loitering Munitions, also known as suicide drones, are a type of hybrid weapon system, which can be combined between guided munitions and unmanned combat aerial systems (UCAS) which are one type of Autonomous Weapon. In the development process, the Technology Readiness Level (TRL) of Loitering Munitions in Indonesia is currently very low. This is indicated by the main technology Loitering Munition has not been touched. This study aims to assess readiness in the development of the main technology of Loitering Munition. Technology Readiness Level (TRL) in Loitering Munition's main technology including Guidance & Control and Seeker is still at TRL 2 which is still in the form of concepts and formulas. Warhead technology is still in TRL 3 because Fuze and Explosives still rely on imports from outside, but Case Warhead Indonesia has succeeded in producing it by itself and the Airframe structure is at TRL 7 where both of these technologies can adopt the Small UAV technology which has been developed by the National and Private Defense Industries and the Propulsions system including Battery & Motor is still at TRL 5.

***Keywords*—** Autonomous Weapon, Loitering Munition, Technology Readiness Level (TRL).

I. INTRODUCTION

War arises in rhythm with the emergence of human civilization. Human civilization can evolve by creating and mastering science and technology. Thus, war is carried out according to the human ability in mastering science and technology. The emergence of the Internet of Things (IoT) is one of the developments of human civilization in the field of science and technology today. IoT is driven by two irresistible technology trends namely Machine Intelligent and Networked Communication. Where the technology is more useful and effectively used at this time.

In the military world, it is often known as the Internet of Military Things (IoMT) and the Internet of Battlefield Things (IoBT). The IoMT concept is the idea that future military battles will be dominated by Artificial Intelligence & Cyber Warfare and will likely take place in urban environments. IoMT includes devices that have intelligent physical sensing, learning, and actuation capabilities via virtual or cyber interfaces integrated into the system. IoMT devices such as sensors, vehicles, robots, UAVs, human wearables, biometrics, ammunition, armors, weapons, and other smart technologies.

From the above classification, Loitering Munition is one type of Autonomous Weapon. Loitering Munition also called suicide drone which is a type of hybrid weapon system, which is suitable for combining guided munitions and unmanned combat aerial systems

IoMT and IoBT technologies can be integrated with Autonomous Weapons. An autonomous Weapon is a weapon system that utilizes a series of sensors and computer algorithms to identify and attack targets without manual human control of the system. [1]. according to a book entitled Mapping The Development of Autonomy In Weapon Systems, there are various types of Autonomous Weapons, namely (a) air defense systems; (b) active protection systems; (c) robotic sentry weapons; (d) guided munitions; and (e) loitering weapons [2].

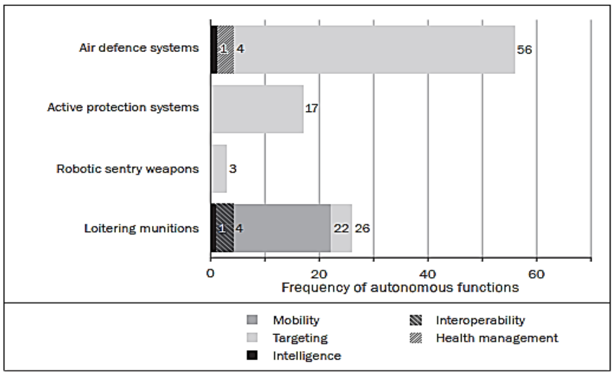

Figure 1. *Autonomy in 'semi-autonomous' and 'autonomous' weapon systems [2]*

(UCAS). Loitering Munitions can roam for a long time to find and attack targets on the ground (see figure 3). The usefulness of Loitering Munition lies in its Operational Function, which is not aimed at a predetermined target but is aimed at the target area (as opposed to the function of a guided weapon) and Loitering Munition is disposable. Where Loitering Munitions can perform offensive and defensive missions that may be deemed dangerous or risky for Unmanned systems, such as suppression of enemy air defenses (SEAD), Artillery Support, and Anti-Access/Area Denial (A2/AD)

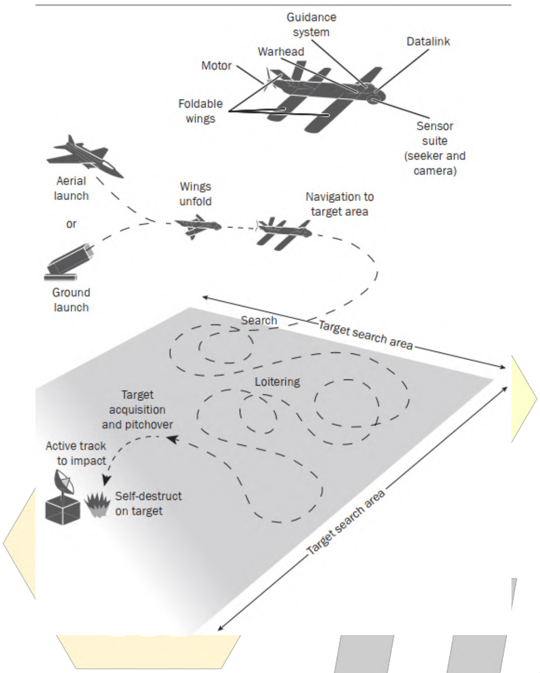

Figure 2. *Loitering Munition [2]*

Loitering Munitions come in many sizes and shapes. The variables that fundamentally differentiate them are as follows [2].

1. Loitering Time. Loitering Munition has varying times of loitering missions. For example, Aerovision's (USA) Switchblade can be loitering for 10 minutes, while IAI's Harpy Next Generation (Harpy NG) (Israel) can loitering for 9 hours.
2. Load/size. The counter-insurgency system is small and has light payloads and short loitering times. Some can be folded and carried in backpacks by troops. The larger system (up to 4 meters) is the size of a missile, with a payload of up to 32 kg. Many are folded into tubes or tubes and launched like missiles.
3. The nature of the man-machine command-and-control relationship. The majority of Loitering weapons are remotely operated, but some systems, especially those used for SEAD, can work in full autonomy once launched.
4. Recoverable. Some systems, especially larger systems, have the potential to have the ability to return to base if they don't find a relevant target or if the mission has to be aborted. However, most of the existing models cannot be recovered. They self-destruct if they don't find a relevant target.

Seeing the threat of Modern War in the future which is very complex and technology trends regarding Autonomous Weapons, Indonesia must prepare a weapon that is Precision and Autonomous, so the development of Loitering Munitions is very necessary to face the threat of modern war in the future. plus, the urban warfare strategy (Urban Warfare) requires precision weapons. In developing the latest technology, it is necessary to analyze the readiness of technology. So in this paper, we will explain the Technology Readiness Level (TRL) in Loitering Munitions. So that this becomes our benchmark in developing Autonomous Weapon Technology, how far are we ready to develop this technology. With the writing, it is hoped that it can be input for government parties through the Ministry of Defense, Users in this case the TNI, the National Defense Industry, and research and development institutions including universities. So that national independence will be created in the acquisition of autonomous weapon technology.

II. METHODOLOGY

The Research Methodology is carried out using a literature study method that aims to formulate concepts and theories as a basis for research. According to Sarwono (2006), a Literature study is a study that studies various reference books and the results of previous similar studies that are useful for obtaining a theoretical basis on the problem to be studied. Meanwhile, according to Nazir (1988) Literature research is a technique of collecting data by reviewing books, literature, notes, and various reports related to the problem to be solved [3]. The Research flow diagram in this research is quoting from the research on Analysis of Missile Technology Acquisition Strategy in Indonesia in the Context of Accelerating National Missile Technology Acquisition [4] which is adapted to this research.

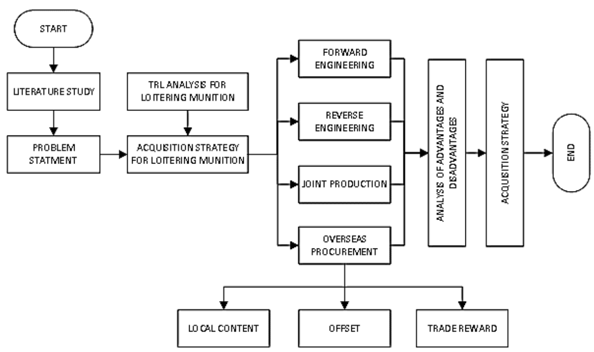

Figure 3. *Research Flow Diagram*
Source: Author 2022

III. RESULT AND DISCUSSION

Technology readiness can be interpreted as how ready technology can be applied based on its intended function. The definition of Technology Readiness shows the existence of a concept about the possibility of differences in whether or not a technology is ready or different levels of technology readiness to be used or utilized based on its function. In general, Technology Readiness Level (TRL) can be interpreted as an indicator that shows how ready technology is to be applied in the real world and adopted by users. Each Technology is evaluated based on the parameters used to assess the level of technology readiness. In the NASA concept, the Technology Readiness Level (TRL) is divided into 9 level categories. TRL 1 is the lowest level and TRL 9 is the highest level. Table 1 below is a summary of the TRL developed by NASA [5].

Table 1. *TRL ratings and metrics for technology assessment adapted from NASA and DOD practices*

Stage of Development	TRL	Description
Basic Technology Research	1. The basic principles are observed and reported	The lowest level of Technology Readiness where at this stage scientific research is initiated and the results are translated into future research and development
Research to Prove Feasibility	2. Concept Formulated	At this stage, after the basic principles have been studied and practical applications can be applied to the initial findings.
	3. Proof of concept.	At this level, generally analytical and laboratory studies are needed to see if a technology is feasible and ready to go further through the development process.
Technology Demonstrate	4. Lab-scale demonstration (low fidelity)	Once proof-of-concept technology is ready, technology advances to the next level. At TRL 4 level, several parts are tested against each other
	5. Lab-scale demonstration (high fidelity)	The basic technology components are realistically integrated with supporting elements so that they can be tested in a simulated environment.
System Development	6. Prototype system designed	The system is integrated with supporting elements, and the model design is created to be tested in a simulated or operational environment.
	7. System prototype tested in an operational environment	The prototype is demonstrated on the planned operational system. This stage also represents a major step from TRL 6 by requiring the demonstration of an actual system prototype in an operational environment
System Launch and Operation	8. Actual system complete	The system is qualified through tests and demonstrations. Technology has been proven to work in its final form and in the conditions expected
	9. The actual system is proven to work	The actual application of the technology in its final form and under mission or market conditions.

The Technology Readiness Level (TRL) of Loitering Munitions in Indonesia is currently very low. This is indicated by the main technology Loitering Munition has not been touched. These key technologies include Guidance System, Warhead, Airframe & Structure, Electric Motor, and Lithium Battery. The Technology Readiness Level (TRL) Loitering Munition parameters can be seen in Table 2 below, where data is obtained from various sources.

Table 2. *Technology Readiness Level (TRL) Loitering Munition*

Technology	TRL Level	Description
Guidance System [4]	2	Formulated Concept
Warhead [6]	3	Prototype Tested
Airframe and Structure [7]	7	Prototype Tested
Electric Motor [8]	5	Prototype
Lithium Battery [9]	5	Prototype

From the table above, it can be seen that the Technology Readiness of the Guidance System is still very low. Currently, the technology is still under research, not in the form of an experiment, and the number of researches is still very small. This makes the readiness of the Guidance System technology still at TRL-2. Warhead's technology is still in TRL 3 because the Fuze technology and Explosive Materials are currently still imported, but Case Warhead Indonesia has succeeded in producing it by themselves. Airframes & Structures. This technology readiness is at level 7 where this technology can be adopted from Small UAV Technology whose development is currently being developed by the National and Private Defense Industries whose prototypes have been tested. While the. Propulsion System Technology consists of Electronic motors and batteries. Technology Readiness is still at the TRL-5 level.

In order to improve technology readiness, a technology acquisition strategy is needed. There are various strategies for mastering technology, such as forward engineering, reverse engineering, joint production and even the use of foreign procurement with local content, offsets and tradeoffs. However, these various strategies have various advantages and disadvantages. Citing research on the Analysis of Missile Technology Acquisition Strategy in Indonesia in the Context of Accelerating National Missile Technology Acquisition [4] The advantages and disadvantages of this strategy can be seen in the table below.

***Table 3.** Advantages and Disadvantages of Technology acquisition strategy*

Strategy Method	Advantages	Disadvantages
Forward Engineering	▪ Able to produce independently ▪ The technology produceds by Indonesian conditions ▪ Not tied to the politics of other countries	▪ Requires a long time and considerable resources ▪ Requires strong basic engineering skills ▪ Expensive investment cost ▪ Not yet available facilities and infrastructure
Reverse Engineering	▪ Able to produce independently ▪ The time required is relatively shorter than forward engineering	▪ Requires a fairly large budget ▪ Not yet available facilities and infrastructure ▪ Often the products made do not meet specifications
Joint Production	▪ Does not require strong basic engineering in mastering technology ▪ Building manufacturing facilities and infrastructure and testing the same technology as the original manufacturer ▪ Produce products of the same quality.	▪ Big challenge in inviting partners ▪ The national missile budget is still small ▪ Not all missile technology from partner countries will be shared with the national defense industry
Overseas Procurement	▪ It's easier than the previous method be cause it doesn't require strong basic engineering and the level of bargaining power in inviting partners is relatively easy ▪ Faster in meeting national missile needs	▪ Vulnerable to State politics ▪ Cause dependency ▪ Need a big budget ▪ The implementation of IDKLO is sometimes not by the core technology needs in the country.

Each technology acquisition strategy has various advantages and disadvantages. However, this technology acquisition strategy is very necessary in order to increase the readiness of technology independence in Loitering Munitions. Loitering Munition technology is very much needed in the face of modern warfare in the future. Where the key to this technology is Precision and Autonomous Weapon. So that the creation of Internet of Military Things (IoMT) and Internet of Battlefield Things (IoBT) technology.

IV. CONCLUSION

The readiness of Loitering Munition Technology is still far from being expected. Where the main technology of Loitering Munition consisting of the Guidance system is still on TRL-2, this indicates that this main technology is still in the process of further research. Warhead technology is in TRL 3 where Indonesia has been able to make warhead cases but for Fuze and Explosive Materials they still rely on imports from outside. Airframe & Structure, where this technology is on the TRL-7 by adopting Small UAV Technology which is widely developed by the National and Private Defense Industries. In addition, further development is needed regarding the Propulsion System consisting of Electric Motor and Battery where the readiness of the two technologies is still in TRL-5. In order to improve the Technology Readiness, a strategy to acquire the technology is needed. There are various strategies in acquiring Loitering Munition technology. Be it, Forward Engineering, Reverse Engineering, Joint Production and Utilization of Foreign Procurement, both the use of Local Content, Offsets and Trade Rewards. In the previous section, the advantages and disadvantages related to the technology acquisition strategy have been explained, but more in-depth analysis is still needed regarding the acquisition strategy in the next research. So that the desired technological readiness is achieved in developing Loitering Munitions to face modern wars in the future.

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