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DEVELOPMENT STRATEGIC OF SIMULATOR TECHNOLOGY 4.5 GENERATION FIGHTER AIRCRAFT FOR SUPPORTING NATIONAL DEFENSE SYSTEM

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Abstract

The fighter aircraft project is one of the defense and security equipment (*alpalhankam* or *alat peralatan pertahanan dan keamanan*) priority programs contained in the defense industry roadmap. Indonesia and South Korea undertook a joint development program in developing 4.5 generation fighter aircraft. However, Indonesia experiences several obstacles in the development of fighter aircraft, one of which is the ability of disparity and mastery of fighter technology. One of the critical components used as one of the development programs is simulator technology development. Mastery of simulator technology can improve the ability of Technology Readiness Level (TRL) from technology development fighter aircraft and can cause multiplier effects in other fields. Therefore we need a development strategy that is appropriate for the development of simulator technology. This study aims to analyze and define the benchmark level of performance or from the critical components which will then be used as a reference for the development strategy of the 4.5 generation fighter simulator for joint development projects. The method used in this study is a mixed-method with an approach system engineering uses quality function deployment tools and Critical Technology Element (CTE) technology assessment to identify which CTE then used as a reference strategy for the development of fighter simulator technology. The results of the study show that there are several CTE values along with simulator technology performance scores, among others mission 92.5%, data 83.56%, motion 52.51%, and strategic options that can be used in the technological development of fighter simulator generation 4.5 such as strategic joint development, self-development, and local content/offset.

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INTRODUCTION

The implementation of Indonesian national defense adheres to the Total Defense Strategy (Law No. 3 of 2002) which involves all citizens, territories, and all national resources. Cultivation of *Pancasila* (the official, foundational philosophical theory of Indonesia) noble values must have endeavored from the experience of Pancasila noble values in various fields of life (Asmaroini, 2017). The implementation of the defense function can be carried out properly and effectively in accordance with the values of an independent nation and understand democracy (Kementerian Pertahanan Republik Indonesia, 2015). There is a need for a guideline that can be used as a reference for defense. So, it can be well understood then shown by a pattern of action in realizing the establishment of the Republic of Indonesia based on the *Pancasila* and the 1945 State Constitution of the Republic of Indonesia (*Undang-Undang Dasar 1945*).

The basis for the development of the defense industry is contained in Indonesian Law No. 16 of 2012. This can be used as a basis for developing the self-reliance of the Indonesian defense industry, where the availability and capability of the main components of the weapons system in the defense industry currently cannot meet the needs of the user. This condition caused a dependency on equipment from abroad. Indonesia should enhance its capability and mastery of defense technology through research, design and engineering in a national system, and implementing research. Design and engineering consist of elements of research and design institutions, universities, institutions in the field of defense and security (Government & Private), users, and the industry's main tools, and research. Design and engineering are coordinated by Defence Industry Policy Committee or *Komite Kebijakan Industri Pertahanan* (KKIP).

Law Number 16 of 2012 explains the self-reliance of the defense industry. Self-

reliance of the defense industry is an effort in the development of technology that can be used as a foundation for the sustainability of the defense industry. The law regulates the priority in the use of domestic technology in the fulfillment of technology procurement. To meet this need, a good foundation for self-reliance of the defense industry is needed, not only in technological mastery, but also in a good synergy between stakeholders that consist of various industries, governments, and the user.

Collaboration between industries is one of the important aspects of this process. Therefore, the defense industry is divided into several tiers consisting of Lead Integrators, Component Industries, Supporting Industries, and Materials. Mastery in the self-reliance of the defense industry is related to the ability of a country's technological mastery. This directly impacts national defense. National defense requires the development of advanced technology for enhancing the capabilities of the Defense and Security Agency. One important aspect of strengthening Indonesia's defense posture is to strengthen the main weaponry system or *alat utama sistem persenjataan (alutsista)*. By strengthening *alutsista*, Indonesia can face potential threats that can occur at any time (Muhaimin, 2008).

Defense industry technology mastery strategies are contained in government regulations governing several programs related to technology mastery, one of them is offset and transfer of technology (Republic of Indonesia, 2014). This also relates to the ability of the defense industry, the needs of the defense and security equipment (*alpalhankam* or *alat peralatan pertahanan dan keamanan*), technological capabilities, resources, availability, facilities, technological capabilities, resources, availability, facilities, and others.

There are 7 (seven) national defense and security equipment priority programs to build the self-reliance of the defense industry.

Indonesia and South Korea have collaborated in joint development on the development of fighter aircraft since 2009 in which PT. Dirgantara Indonesia (Persero) played the role of Lead Integrator in the project. Strategic cooperation is one of the strategies used for the development of high-level technology, where its functions include gaining access to resources, knowledge, and capabilities (Haeussler, Patzelt, & Zahra, 2012). For Indonesia, the fighter aircraft project is the first and new project, especially the 4.5 generation fighter aircraft, where this creates a disparity between Indonesia and South Korea because Indonesia is required to be able to balance the technology readiness level with South Korea. If Indonesia cannot solve this problem, it could have an impact on the future development of this project (Salsabiela & Midhio, 2017).

Improvement in technology capability is based on the mastery stage reference called Technology Readiness Level (TRL), definitions, mechanisms, and measurement of TRL, explaining the definition of the stages, and mastery of research and technology (Regulation of the Minister of Research, Technology and Higher Education No. 42 of 2016). Critical Technology Element (CTE) is a technology or component that plays a key role and in technological development. CTE cannot be separated from TRL. TRL is a method for estimating the maturity of a CTE during the technology acquisition process (Technology Readiness Assessment Guide, 2011). The ability to scheduling aspects can have an impact if critical technology cannot function properly (Ender, Mcdermott, & Mavis, 2009).

The problem that often occurs when technology acquisition is processed is a license. Indonesian and South Korean fighter aircraft projects experienced several license constraints. The license cannot be approved by the United States (Salsabiela & Midhio, 2017). The strategy of developing technology has several

important aspects that play a role such as mastery of system integration, weapons capability, avionics, production capability, and material availability to be successful in the acquisition process (FAA, n.d.)

The simulator is one of the technologies used in a variety of flight functions such as design development to flight training for pilots (Shashidhara et al., 2018). The simulator is an important technology and a core component. The simulator plays a role in feedback for engineering and training of pilots, especially fighter pilots. At this time, the device used for the simulation still uses devices originating from abroad. Simulator components provide a simulation in the real world under different conditions and different levels of reality. Currently, there are various software and hardware components contained in simulator technology. Besides that, there are several important requirements in designing a simulator, where specifically the system can be used for various purposes (Ruiz, 2014).

Flight simulators have several qualifications and levels related to their development, including the US Federal Aviation Administration (FAA), Aviation Training Device (ATD), Flight Training Device (FTD), Full flight simulators (FFS), and European Aviation Safety Agency (EASA), etc. The development of the fighter simulator was developed by PT. Dirgantara Indonesia (Persero). The simulator is very dependent on the development of the fighter aircraft as a whole and has a very large linkage. The goal of developing simulator technology as mentioned earlier is related to the self-reliance of the defense industry.

The formulation of the problem in this research is the determination of the development strategy of the 4.5 generation fighter simulator which is one of the important components in development, this relates to the ability of Indonesia, and the disparity of technological readiness with South Korea, especially for the level of Technology Readiness Level (TRL) and

mastery of Critical Technology Element (CTE)

Based on those matters, this study was conducted to analyze and define the benchmark level of performance, from the critical components which will then be used as a reference for the development strategy of the 4.5 generation fighter simulator for joint development projects. Due to disparities in technology, Indonesia currently has various deficiencies particularly concerning technical matters. Those directly related to the mastery of technology included in core technology. The core technology in simulator technology can consist of various technical aspects, both in the aspects of electronics, mechanics, as well as informatics. This is a provisional hypothesis from this study that the focus of technology development strategies and critical technology elements are in these three aspects.

METHODS

The basic research methods used in this study are based on research methods based on quantitative and qualitative research (Cresswell, 2012). The research step is based on identifying research problems, reviewing the literature, determining research objectives, collecting data on analysis, interpreting data, reporting, and evaluating research. The disparity in the mastery of TRL Indonesia and South Korea in developing joint development of the 4.5 generation fighter project is the basis of the problem identification used in this research.

Indonesia as a developer country currently has a technological mastery barrier which is this new technology is being carried out for the first time (Salsabiela & Midhio, 2017). Problem identification is focused on determining strategies based on technology mastery problems, especially CTE from simulator technology. This research can develop into other aspects such as economics and multiplier effects. Determination of aspects of CTE is a basic aspect used in the selection of methods. In this case, a system

engineering approach and design engineering methods are carried out.

Based on this, the method used is the mixed-method approach. The mixed-method is chosen based on the system engineering approach. System engineering provides a design solution and predicts from a technology that will be analyzed (Farnell, Saddington, & Lacey, 2019). The system engineering approach is a quantitative method that requires measurable variable data, output variables, and others. The development of fighter aircraft can also have an impact on the economic field because there is a direct link to economic and another aspect that challenges the development (Salsabiela & Midhio, 2017).

The research instrument is based on a system engineering approach specifically using the quality function development method or QFD method. The instrument used in this study is divided into assessments of aspects of user needed and engineering requirements. For user needed, a broad market research approach by conducting interviews with users and developers of next-generation fighter simulator technology 4.5. Besides, the data is then harmonized with the standard used. Based on the QFD method, the values used as a reference in distributing the questionnaire are listed in Table 1.

Table 1. QFD Values

No	Step	Value	Information
1	Importance Rating	1-5	Least to Most Importance
2	Correlation Matrix	1-3	Low to High Correlation
3	Relation Matrix (Between User Need and Engineering Requirements)	1 3 9	1: Low Relation 3: Medium Relation 9: High Relation

Source: Burge, 2007

In determining the value and data collection in research can use the media of

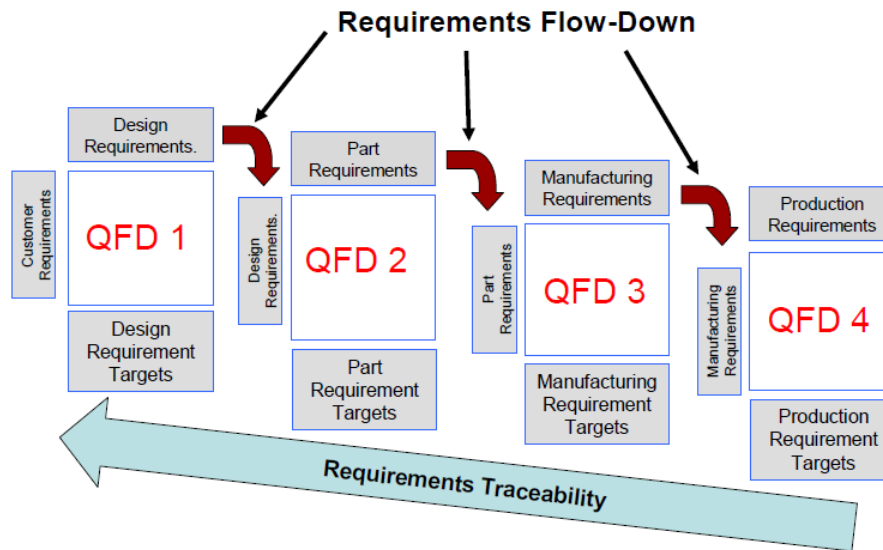


Figure 1. QFD HOQ Steps
Source: Burge, 2007

questionnaire and in-depth interview. The current development also can use web-based data collection (Cresswell, 2012). In this study, reference data are used to determine critical components based on the literature of "Development of a Full Mission Simulator for Pilot Training of Fighter Aircraft" (Shashidhara et al., 2018). The instrument at the qualitative stage is the researcher himself, in this case, a necessity. It because the researcher prioritizes observational findings on events, then interviews conducted by the researcher with the speakers (Cresswell, 2012).

This study uses the quality function development (QFD) method. QFD is used to determine designs based on user needs which are then translated as engineering requirements, the data used in the previous QFD are selected, simplified data, to conclude data collection, and to make data used in QFD becomes relevant. Based on the product design stage using quality function deployment, there are 4 aspects, namely design, parts, manufacturing, and production. Development is based on traceability requirements and flow-down requirements on engineering requirements. The first stage is the design requirements to be part requirements. The second stage is part of the requirements of manufacturing

requirements. The third stage is the manufacturing requirements for production requirements. QFD stages for the House of Quality can be seen in Figure 1.

This research is limited to the development and determination of mastery in strategic development. The QFD is used in the stage of determining user needs and design requirements to performance benchmark values. The QFD stage used is based on the literature "A Functional Approach to Quality Function Deployment" (Burge, 2007). The user needs data are adjusted to the data in the form of standards and definitions of CTE. The other stages include determining the importance rating, engineering data requirements consisting of a list of components that are defined as critical components. In general, the QFD stage can be seen in Figure 2.

The correlation matrix is the stage of determining the correlation value between engineering requirements. In CTE, the value is a correlation matrix which is one of the requirements of the CTE definition. The relationship matrix is the stage of determining the value between the value of importance rating with the engineering requirements. Determining the reference value in comparison with similar

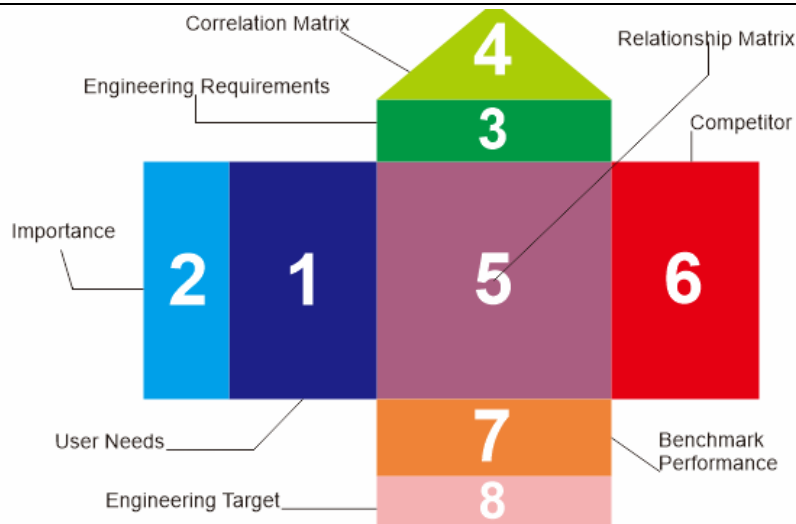


Figure 2. QFD Steps
 Source: Burge, 2007

technology or competitors. The final stage is the benchmark performance and determination of engineering targets.

The research method was carried out using the Quality Function Deployment method with respondents who are the main developers of fighter aircraft simulators. The respondents are experts in the field of simulators, especially in fields related to core technology. The results of this study serve as a reference for determining the strategy used in the mastery of technology. Each level of strategic importance has a different type of strategy based on the level of importance and its current condition. Regarding the selection of sources, resource persons consist of a project engineer team consisting of several engineers from various fields of expertise who become a development team for a fighter aircraft simulator. This can be seen in Table 2.

Table 2. Position of Sources Authority

No	Position
1	Software Simulator Engineer
2	Simulator Engineer
3	Visual Engineer
4	Senior Engineer
5	Software Simulator Engineer

Source: Processed by Authors, 2019

RESULT AND DISCUSSION

Indonesia is still very minimal in terms of defense technology development, PT. Dirgantara Indonesia (Persero) has never developed a fighter aircraft technology. Fighter aircraft development efforts show that Indonesia is currently interested in the role of the global supply chain, which shows that Indonesia is adapting to the globalization of the Defense Industry (Armandha, Datumaya, & Sumari, 2016). The development of fighter aircraft is based on the objectives of fighter aircraft development for Indonesia, including meet the needs of defense equipment based on operational requirements of the user, build self-reliance in the procurement of fighter aircraft, enhance the capabilities of the defense industry, increases the effect of trepidation, and improve the nation's economy through the export of military technology. The strategy to accelerate the mastery of aircraft technology is through the transfer of technology. The transfer of technology program will facilitate Indonesia in producing fighter aircraft and its technology in the future because strengthening the mastery of technology will be able to provide a multiplier effect on the industry (Afiff & Tjarsono, 2016).

Indonesia has not yet achieved self-reliance in the defense industry. The procurement is often based on import mechanisms. The procurement process has several problems in Indonesia, such as technology that is not based on user needs, differences in conditions, geographical location, potential threats, and other than that, the technology often does not fully meet and use the requirements in the form of Operational Requirements and Technical Specifications set by the Indonesian Military (TNI) (Indrawan & Widiyanto, 2016).

Based on the background of this study, the issue related to License and Qualification & Approval is one of the problems that hinder the development of the 4.5 generation fighter project. Several technologies have not been obtained at this time. One of the key technologies in fighter aircraft is a flight simulator. Currently, in Indonesia, there are several private simulator developers in various cities in Indonesia such as Bandung and Surabaya. But in this case, Indonesia still cannot be said independent in its development. It is because Indonesia has not yet mastered software development technology, such as flight control law that is needed in fighter maneuver simulation. Besides that, various components are imported components from abroad. Flight simulators have several types related to their development objectives, including training simulators and engineering simulators. The levels related to development include aviation training devices, flight training devices, and full-flight simulators.

Development of the simulator for fighter generation 4.5 is currently developing for engineering simulators. The simulator aims to simulate a condition that can be used as a reference and review for the design of the overall development of fighter aircraft. Especially for the development of fighter training simulators, at present, the development is very dependent on the development of the fighter aircraft itself. Making fighter simulators expected to be

following the actual conditions of the fighter aircraft. Therefore, the simulator's development can be done when fighter aircraft products already exist. However, the fighter simulator has begun to be prepared in the development phase with an activity called the Training System.

CTE is a technology that is very related or has a high dependence on other technologies to achieve operational requirements, in general, critical technology has a high technological risk in the design and demonstration process. Besides that, critical technology is a new technology and has novelty. CTE can be in the form of software, hardware, data, and more (Department of Defense, 2011).

As a test of the data validity, the critical component criteria in this study cannot only be based on theory but also should be based on the conditions and criteria of the industry related to the development of fighter simulator technology. Therefore, interviews and direct data observations were conducted where it was found that the prerequisites critical technologies include, dependence, new technology or novelty, hard to own or produce, and exclusive or limited components.

The level of technological maturity is described in the early stages of a technology acquisition project, the level of maturity describes the stages that have been mastered today, critical technology elements, systems, or applications, verification of data related to the level of technological maturity can be in the form of documents, research papers, and demonstrations. Based on the results of interviews and questionnaires in PT. Dirgantara Indonesia (Persero), found that the data related to the components of critical technology elements of the 4.5 generation fighter simulator can be seen in Table 2. This is based on the results of benchmark performance among others.

Table 3 shows the aspects that are included in the core components. This core component is a list of components that are listed by experts and developers of

simulator technology.

Table 3. Engineering Requirements

CTE	Elements	Element
1	Mission	NVG, FLIR
2	Data	Database, Data Package, Mapping
3	Software	Algorithm, AI, Mission, etc.
4	Instruments	Avionics Hardware, Control Loading, Electronic
5	Visual & Display	Projector, Multiple Display, Cockpit, etc
6	Computer	Realtime Computer System, Hardware
7	Motion	Actuator, 6 DOF
8	Model	CAD
9	Development Tools	Engine

Source: Processed by Authors, 2019

Benchmark performance shows the reference value in development as a priority number and guides for the development of fighter simulator technology. The initial step is to determine user needs. The references are used based on the operational requirements of the user, which is the Indonesian Airforce (TNI AU). This reference is used as a reference for further development.

PT. Dirgantara Indonesia (Persero) is the developer that defines the CTE criteria. After the CTE criteria are defined, the assessment of the importance of the CTE is carried out. The CTE data and its importance can be seen in Table 4.

Table 4. CTE Importance Rating

Criteria	Interviewees					Mean
	1	2	3	4	5	
Dependent	4	3	5	3	5	4
Novelty	3	3	3	4	4	3.4
Difficult to obtain	2	4	4	3	4	3.4
Exclusive Component	3	4	5	3	4	3.8

Source: PT. Dirgantara Indonesia (Persero), 2019

Value Information:
1: Not important

2: Less important
3: Quite important
4: Important
5: Very Important

The second stage is the determination of the CTE. The determination of the CTE at this stage is based on the engineering requirements of the Quality Function Deployment. CTE can be in the form of software, hardware, design, and theory. The correlation matrix will identify the relationship between CTE. The results of the correlation matrix can be seen in Table 5.

Table 5. Correlation Matrix

	1	2	3	4	5	6	7	8	9
1			3	2	3	3			
2			3	1		3		3	
3				3		3		3	2
4					2	2	2	1	
5						2	2	2	
6							2	3	3
7								1	
8									3
9									

Source: PT. Dirgantara Indonesia (Persero), 2019

Information:

Value 1: Low Correlation
Value 2: Medium Correlation
Value 3: High Correlation

Assessment of the relationship between the CTE criteria and the CTE itself, CTE criteria are based on the user needs stage, while the CTE is based on the engineering requirements stage. The relation matrix assesses the relationship between user needs and engineering requirements. Relation matrix table data as can be seen in Table 6.

At this stage, the data obtained is the result of brainstorming based on group discussions. Some data show overlapping results or data that has some differences. Therefore, the data used is the mean or average data from the resulting value.

Grouping is done to analyze similar components but has different terms according to the perceptions of the related sources. Besides, there are speakers from the same scientific field but provide

different data. Because the construction of this 4.5 generation fighter aircraft simulator is one of the new technologies, and the real form of the aircraft does not yet exist, so the comparative aspect at the comparison stage with QFD competitors can be ignored.

The fourth stage is determining the Benchmark Performance. Benchmark Performance is in the form of calculation results and percentage values. The results of the calculation of Benchmark Performance can be seen in Table 7. Table 7 shows the percentage of importance of each CTE. The value of 100% means that this component is very critical. On the other hand, a value of 0% indicates no level of criticality.

The benchmark performance value is the result of the multiplication between the importance of rating value multiplied by the relation matrix value. The value is then compared with the highest value, then the result is obtained in the form of a percentage of critical level and importance of a component. PT. Dirgantara Indonesia (Persero) in developing the 4.5 generation fighter aircraft implemented a strategy to increase the level of KLO local offset content through several programs, including self-development, joint development, local content & offset, and joint marketing, as can be seen in Table 8. KLO improvement strategy data is secondary data.

Self-development is a technology development strategy by conducting development activities independently, starting from the initial stage of research to the final stage. Self-development is a stage that is not much influenced by outside intervention. In the process of development, self-development requires a capability in the form of technological mastery and the ability of qualified human resources. It requires a big cost until a relatively long time.

Strategic Joint Development is a development strategy by collaborating with other parties in terms of technology development. The competencies that can be

Table 6. Relation Matrix

CTE		A	B	C	D	BP
1	Software	9	1	3	9	83.3
	Display System	3	3	3	3	43.8
	Visual System	3	1	1	1	22.6
	Development Tools	3	1	1	1	22.6
	Mission Avionics	9	3	9	9	111
2	Hardware	3	3	3	3	43.8
	Digital Mapping	3	3	9	9	87
	Database	9	3	9	9	111
	Visual System	9	3	9	9	111
3	Instruments	1	9	9	1	69
	Motion System	1	9	9	1	69
	NVG & FLIR	9	9	9	9	131.4
	Computer Cockpit	3	3	3	3	43.8
4	Display	9	9	3	3	88.2
	Simulation Model	3	3	1	3	37
	Visual & Motion	3	3	3	2	36.2
	Software	9	9	3	3	88.2
	Visual System	9	1	1	1	46.6
5	Control Loading	9	3	3	3	67.8
	Data Package	9	9	9	9	131.4

Source: PT. Dirgantara Indonesia (Persero), 2019

Information
 A: Dependence
 B: Novelty
 C: Difficult to Obtain
 D: Exclusive Component

Table 7. Benchmark Performance

No.	CTE	Rating Score	%
1	Motion	69	52.51
2	Computer	43.8	54.75
3	Mission	121.6	92.54
4	Visual & Display	58.07	44.19
5	Development Tools	22.6	17.19
6	Software	86.0	65.45

7	Data	109.8	83.56
8	Model (CAD)	37	28.15
9	Instruments	60.2	45.81

Source: Processed by Authors, 2019

Table 8. KLO Improvement Strategy

Strategy	Competency
Self-Development	Design, Production, Final Assy & Integration, Testing
Strategic Joint Development (Strategic Partner)	Design, Production, Final Assy & Integration, Testing
Local Content & Offset	Final Assy & Integration, Testing
Joint Marketing/ Under License	Final Assy & Integration, Testing

Source: PT. Dirgantara Indonesia (Persero), 2019

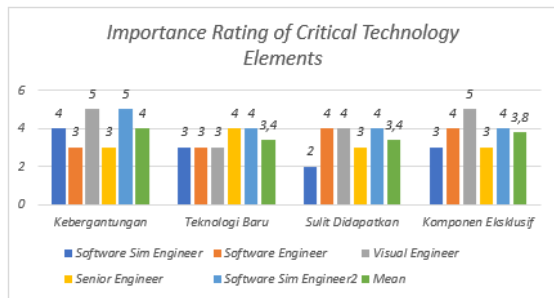


Figure 3. Importance Rating

Source: Processed by Authors, 2019

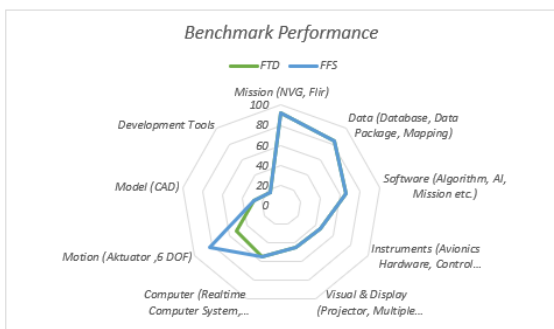


Figure 4. Benchmark Performance

Source: Processed by author, 2019

acquired from this strategy are the same as the competencies obtained from self-development from design to testing. Strategic joint development requires the ability of diplomacy to synergy and support both among related institutions and stakeholders. Local content or offset is a strategy based on the defense equipment procurement program. Technology

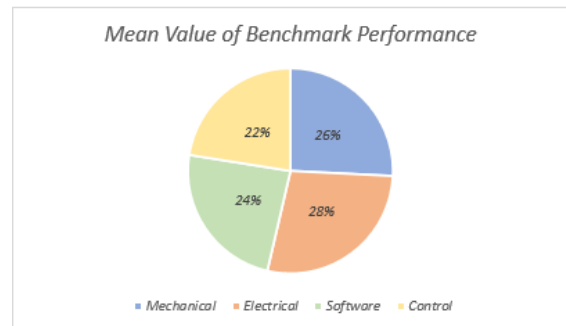


Figure 5. Group Benchmark Performance

Source: Processed by author, 2019

acquisition in this program is based on reverse engineering activities to find out or master technology. Local content or offset has several obstacles in its activities, including related to licensing and qualification & approval. The technology that can be acquired includes final assembly and testing, as well as Joint Marketing & Under Licenses. So, the mastery of the technology obtained is not comprehensive. Based on the analysis of critical components of the simulator technology, it was found that there were 9 (nine) components that were stated as critical components along with their benchmark performance level

CONCLUSIONS, RECOMMENDATION, AND LIMITATION

From the research results, it can be seen that there are similarities related to the provisional hypothesis relating to the technology list including the core technology. This can be a further consideration that the development of current technology must be developed based on the main aspects of the preparation of the technological components to be acquired.

Simulator technology is an integrated system consisting of 4 (four) components in the fields of science, mechanics, electronics, informatics, and control. Components, that are the core components in the development of simulator technology based on research results and based on benchmark performance values, are Mission 92.54%, Data 83.56%, Software

65.45 % &, Instrument 45.81%, Visual & Display 44.19%, and Motion 52.51%. The strategy of mastering the simulator technology is synergized with the strategy of mastering local content offsets in mastering the technology of the 4.5 generation fighter aircraft simulator, including self-development, strategic joint development, local content of offset, and joint marketing. The fulfillment of core components is adjusted according to the criteria of CTE, such as dependency level, new technology, difficulty to own or produce, and exclusive components.

Prioritize the development of simulator technology that has a high level of benchmark performance when the technology acquisition process is carried out because it can significantly increase the TRL level. The technology contained in the industrial revolution 4.0 technology plays an important role. In this regard, the technology that is included in critical technology is part of the latest technology. Therefore, mastery is required to be oriented towards developing technology. The development is focused on strengthening technology in the field of defense technology.

The role of PT. Dirgantara Indonesia (Persero) as the lead integrator is a reference to the development of 9 CTE simulator technology. In this case, the development of 9 (nine) CTE can be carried out by industries that encompass the technology field. There are several other industries such as the main component industry, component industry, and material industry standard. It can be one of the factors that make economic factors develop not only within PT. Dirgantara Indonesia (Persero) but can also cause a multiplier effect for other industries.

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Appendix

Question 1:

Critical technology elements (CTE) criteria

Critical component if a system is highly dependent or its application is a new technology or have novelty. Here are the criteria related to the definition of components that can be said to be critical components, assess the form of a "circle" related to how big the importance of the value in the column provided.

Question 2:

Critical technology element

Define the components included in the critical components of the fighter simulator technology and then determine the value of the relationship between the CTE.

Question 3

Technology Readiness Level Simulator

Please fill in the following fields by circling/crossing out one of the two available answers (Yes / No).

No Question Yes / No

Q9 (TRL 9) Has the technical equipment/process been successfully operated in a fully operational environment? Yes No

Q8 (TRL 8) Has the technical equipment/process been successfully demonstrated in the actual environment? Yes No

Q7 (TRL 7) Has the technical equipment/process been successfully operated in the relevant operational environment? Yes No

Q6 (TRL 6) Has the scale testing of prototype techniques been demonstrated in the relevant environment? Yes No

Q5 (TRL 5) Has bench-scale testing equipment/processes been demonstrated in the relevant environment? Yes No

Q4 (TRL 4) Has laboratory-scale testing been carried out in a simulated environment? Yes No

Q3 (TRL 3) Have the process and concept analyzes been simulated? Yes No

Q2 (TRL 2) Have the process and conceptual design been formulated? Yes No

Q1 (TRL 1) Have the basic principles of the technological process been observed and reported? Yes / No

Question 4:

Relationship Between CTE

Please complete the following table based on the value of the level of relevance between CTE.