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The Combination of Manned and Unmanned Combat Aircraft (UCAV) as a Collaborative Combat Operations to Strengthen Indonesia's Air Defense System

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Abstract

Airspace violations that occur in Indonesia are a form of threat to state sovereignty, national security, and national safety. The violations are actions taken by foreign military and civilian aircraft that enter the country's territory without permission. Therefore, a strong national air defense system is needed. Ambush fighters with fast reaction capabilities are one of the main elements in a strong national air defense system. The fighter ambush mission can be accompanied by stealth unmanned aircraft technology similar to fighter aircraft, namely Unmanned Combat Aircraft (UCAV), as a Collaborative Combat Aircraft (CCA) mission. This mission collaborates with fighter aircraft and UCAVs to achieve air defense system dominance. In applying the mission, a concept of operation is needed as a guide in carrying out air defense operations. Therefore, this research aims to develop a concept of operations that combines fighter aircraft and UCAVs. The operation concept is developed based on the doctrine of the Air Force and the defense industry, through structured interview methods, forum group discussions, and literature studies. The results showed that collaboration between fighter aircraft and UCAV can fulfill future combat. The proposed operational capability consists of a new generation of unmanned aircraft focusing on collaborative missions and flying alongside 4.5-generation or later manned fighters. The Combat Air Patrol (CAP) concept of operations is one option for collaboration between fighters and UCAVs, with cruise, interception, and air superiority phases. Collaboration is carried out with the division of tasks

between fighters and UCAVs. In conclusion, the concept of operations by combining fighter aircraft and UCAV can be applied in Indonesia's air defense system, to create a strong national defense system.

INTRODUCTION

National defense is one of the government functions organized through the national defense system. The dynamics of technological development and the global, regional, and national strategic environment, can be the basis for creating various types of threats that can have implications for national defense, both physically and non-physically, in the form of military, non-military, and hybrid threats which are real and unreal threats (Sudirin, Darmawan, & Hendra, 2022). The national air defense system is a series of strategies designed to protect the territory from forms of air threats, by detecting, identifying, and destroying or avoiding attacks coming from the air, such as aircraft, missiles, or drones. Indonesia has a National Air Defense System which is an integrated structure to maintain national air defense by involving all elements, which in its implementation uses continuous integrated efforts and actions, both operational and coaching aspects to deal with all forms of potential air threats (Sudirin, Darmawan, & Hendra, 2022).

The military defense is held to prepare for active defensive defense and the preparation of layered defense. The deployment of the Air Force forces is directed to destroy enemy forces and provide an air umbrella to protect Indonesian military forces in the implementation of operations (Ministry of Defense of the Republic of Indonesia, 2015). The government in overcoming the problem of territorial violations has issued Government Regulation No. 4 Year 2018 concerning Security of the Republic of Indonesia's Air Territory (2018) known as the Air Defense Identification Zone (ADIZ).

The development of technology is in line with the dynamics of existing threats. So that it raises potential threats, which can come from external and internal sources. Potential threats originating from external sources are one of them coming from superpowers in the Indo-Pacific region, which needs to be a concern because Indonesia is included in the radius of three capabilities of the United States and China. Indonesia with its new capital city known as IKN (*Ibu Kota Nusantara*) will be vulnerable to aggression from foreign countries because its position is relatively at the forefront of national defense. The position of IKN which historically in the second world war was one of the starting points that experienced Japanese military infiltration. The existence of military power titles from superpowers in the Indo-Pacific is a consideration in terms of potential threats. The national capital region is within the operating radius of strategic bombers, fighter aircraft, and cruise missiles of the United States (hereinafter stated as the U.S.). It is also within the radius of China's ballistic missiles, fighter jets, and bombers. This condition becomes complex if the U.S. military bases spread across the Pacific Ocean and Australia are used as bases for power projection to the north through Indonesian territory (Widjajanto, 2023).

However, Indonesia's ideal air defense system is still difficult to realize, as evidenced by air violations in Indonesian territory by both military and civilian aircraft. Violations committed by military aircraft are air violations that occurred over the waters of Bawean Island, there were five F-18 Hornest of the U.S. Navy aircraft on July 3, 2003, (Widodo, 2019) and the breach of a Singaporean Beechcraft trainer aircraft in October 2014 (Sudirin, Darmawan, & Hendra, 2022). As for civilian aircraft, there were violations

committed by Swearingen SX 300 type aircraft that entered Indonesian airspace without permission in 2014, foreign aircraft that violated Riau airspace on October 31, 2018, and violations by foreign civilian aircraft with registration number G-DVOR type DA62 that violated Indonesian airspace at radar unit 213 Tanjung Pinang, on Friday, May 13, 2022 (Air Force Information Service, 2022). Then throughout 2021, there were 498 cases of violations that occurred in the airspace by military aircraft until May 17, 2018 (Permana, 2022), and throughout 2023 in the period January-June, there were 13 violations in the Flight Information Region (FIR) and one time in Medan Sector 1 Command, with 10 violations by military aircraft and four times by civilian aircraft (Dirgantara & Meiliana, 2023)

In addition to threats originating from external sources, which are indicated by the number of violations that occur, potential threats can also come from internal sources, namely the readiness of existing facilities and infrastructure, the development of the defense industry, and the development of defense technology. In the readiness of facilities and infrastructure, threats can occur in the existence of Indonesian Air Force radar units stationed in various regions, the number of strike fighters, the existence of air bases that are still small, the number of missiles, the number of air defense cannons, the readiness of civil aviation elements and passive air defense that are held (Sudirin, Darmawan, & Hendra, 2022).

Threats that occur both external and internal, it is necessary to develop a concept of national air defense system operations that can support the development of defense technology, thus creating a strong defense ecosystem. This air defense system concept can collaborate Unmanned Combat Aerial Vehicles (UCAV) with fighter aircraft, where this collaboration concept is also being developed by the United States in the 2020s called Collaborative Combat Aircraft (CCA) which is equivalent to Loyal Wingman. This concept deploys UCAVs as Unmanned Aircraft (UCAV) to collaborate with manned fighters, such as the fifth or sixth generation, as a Next Generation Air Dominance (NGAD) program. The concept of Collaborative Combat Aircraft by combining with unmanned aircraft, promises to provide a potentially new combat advantage in future conflicts. It can increase the combat capacity of air forces, which creates a more attrition-tolerant or resilient mix of forces, provides strategic reserves to field commanders for surge operations, as well as enables complex operations that complicate adversary defense challenges (Penney, 2022).

The collaboration of manned and unmanned aircraft in military operations is a form of military air operations system development. Research related to this is still little encountered, but several superpowers have conducted studies on this matter, which are used as a step in projecting military power that depends on the ability of the air force to achieve air superiority conditions with attack and defense missions. One such study was conducted by Gunzinger, Stutzriem, & Sweetman (2024) which describes the need for fighter collaboration for U.S. air warfare and creates innovative concepts of operations to use CCA to disrupt China's advanced IADS and other counter-intervention operations. Other research was also conducted by Sparrow & Henschke (2023) by conducting a miniature battle study by collaborating between manned and unmanned teams, which is a challenge for countries to hone their ability to conduct warfare. Research on the UCAV vehicle used in the CCA system was carried out by NATO through research (Liersch, Cummings, & Schütte, 2022) with the design of the UCAV vehicle applied for the CCA air defense system. Previous research is very important in relation to the current study and as the basis for this study's novelty. Based on previous research, there are important findings that the CCA air defense system is a future defense system that can create an air

combat superiority situation that collaborates with UCAV vehicles equipped with attack missions. In the context of this research, the findings from previous research are very relevant to support the research conducted.

This article will discuss the concept of operations suitable for creating a national air defense system, with collaboration between unmanned and manned aircraft. The operation concept is determined based on the doctrine of the Indonesian Air Force (TNI AU) by combining concepts from the defense industry, by looking at the concept of the Collaborative Combat Aircraft (CCA) air defense system. This study aims to provide an overview of the concept of the latest defense system, by deploying technological capabilities for defense and security purposes. The territory of Indonesia with several potential threats that exist can be guarded with a strong air defense system and to maintain the safety of manned aircraft crews in carrying out combat tasks the role of unmanned aircraft is important. This research was conducted in several stages, namely, the first discussion is an explanation of the national air defense system. The second is Collaborative Combat Aircraft (CCA) as an understanding of the collaborative concept, which is continued with UCAV technology. The third is an explanation of the Air Force defense doctrine as a basis for choosing and determining the concept of operations, and the concept of Collaborative Combat Aircraft (CCA) operations applied in Indonesia later referred to as Indonesian Collaborative Combat Aircraft (CCA).

METHODS

This study uses qualitative methods by taking a descriptive qualitative approach. Qualitative research is an approach to conducting research that is phenomenon-oriented or natural. This research is carried out with procedures that produce descriptive data from the analysis carried out (Abdussamad & Rapanna, 2021). A descriptive qualitative approach is carried out to present a complete picture of a phenomenon or clarify a phenomenon that occurs. Descriptive research also focuses on the problem of how and then explains it by presenting complete facts, and intact (Silalahi, 2009).

The data obtained in qualitative research refers to empirical data in the form of tangible words and not a series of numbers. It also cannot be organized into categories or classification structures (Silalahi, 2009). To obtain data, this research uses literature studies from books, articles, journals, proceedings, online news, and others, which are then compiled to conclude (Hartanto & Dani, 2016). Several articles that discuss the concept of operations and Collaborative Combat Aircraft (CCA) or other related matters are used in conducting literature studies. In addition, to obtain data following the conditions and phenomena in the field, the interview method is used. In this method, a semi-structured interview type is used, which contains predetermined questions following a predetermined sequence of questions, and then information is extracted by asking questions from the results of developing answers to previous questions (Kumar, 2011). The interview stage is divided into four stages: preparation stage, implementation stage, analysis stage, and reporting stage.

The research data analysis process follows the interactive nature between data collection and data analysis, data collection is an integral part of data analysis activities. The data reduction is summarizing the data, and then sorting the data into concept units, certain categories, and certain themes (Miles, Huberman, & Saldana, 2014). In this study, the data used comes from various news sources, academic publications, articles, and the results of conducted interviews. Interviews were conducted on October 30, 2023, with air defense technology experts, 1 expert from the Indonesian Air Force Research and Development Office and 2 experts from the Indonesian Aerospace Industry. Interviews

were conducted with a researcher at the Research and Development Service of the Indonesian Air Force, a stability and control engineer in Indonesian Aerospace, and a design engineer in Indonesian Aerospace.

Information was also gathered from a group discussion forum held in Bandung in November 2023 with 30 participants, on Unmanned Aerial Vehicles at a research reception meeting conducted at the Indonesian Aerospace Industry. The forum was attended by representatives from the Air Force, Indonesian Aerospace, the Defense Industrial Policy Committee, as well as experts and academics.

This research conducts a study by applying existing concepts or developing new ones to create applicable concepts. This concept will support the analysis of results and processes in the discussion. The Collaborative Combat Aircraft (CCA) concept is a concept of cooperation between manned and unmanned combat aircraft. The collaboration concept focuses on the operational mission to be carried out. One of the Collaborative Combat Aircraft (CCA) concepts has been designed by General Atomics called the Gambit Series. Gambit is a series of aircraft that has several types that can be customized for special and challenging missions. The concept consists of four types of unmanned aircraft with missions as sensing, air-to-air strike, tactical, and cruise platforms (General Atomics Aeronautical, 2022). In addition, the CCA concept was proposed by the USAF, which consists of a new generation of fighter aircraft with intelligence, surveillance, and reconnaissance missions accompanied by or carrying weapons (Air Force Technology, 2023). Based on the existing concept, taking into account the scope of operations, this research develops the concept of operations by referring to the air-to-air attack mission profile with survivability and susceptibilities capabilities that allocate one fighter and are accompanied by two unmanned aircraft.

RESULT AND DISCUSSION

The advancement of state-of-the-art air defense systems is leading to the emergence of novel concepts that will necessitate support to maintain air superiority in the forthcoming years. The idea of integrating manned and unmanned aircraft collaboratively can address the requirements to confront the challenges of future conflicts and uphold air superiority in the ensuing decades. The proposed operational capability of the current Collaborative Combat Aircraft (CCA) design involves a novel generation of mission-oriented unmanned aircraft that will operate in conjunction with fourth-and-a-half and subsequent generations of manned fighters. The utilization of sophisticated Artificial Intelligence (AI) driven software is anticipated to augment collaboration and communication capabilities, thereby enhancing the overall effectiveness and performance of manned fighters. The epitome of this transformative era is embodied by the Collaborative Combat Aircraft (CCA), a groundbreaking fighter aircraft that is poised to revolutionize the operational practices of the Air Force and other military branches. A new CCA model, known as Gambit, has been devised by General Atomics Aeronautical Systems, Inc. (GA-ASI) (General Atomics Aeronautical, 2022). This innovative concept comprises a formation of four aircraft, with one aircraft serving as the leader, and each autonomous aircraft assigned various missions and tasks, including Intelligence, Surveillance, and Reconnaissance (ISR), air-to-air missions, and counter operations.

National Air Defense System

The dynamics of technological development and the strategic environment will have implications for the creation of threats, including in airspace which is the domain of

defense in a country. Indonesia's national defense is organized in a universal defense, which is a form of defense developed involving all citizens, territories, national resources, and infrastructure, which is prepared early by the government, and held in a total and integrated, directed, and continuous manner (Ministry of Defense of the Republic of Indonesia, 2015). The air defense system is experiencing the latest developments, one of which is the concept of collaboration between manned and unmanned aircraft. The location of a country's territory will correlate with a country's defense system. Indonesia as an archipelagic country has a sovereign territory of one-third of the land, two-thirds of the sea, and sovereign airspace above the sover. International law recognizes airspace as part of state sovereignty under the 1919 Treaty of Paris and the 1944 Treaty of Chicago. Airspace restrictions expand the state's territory on land and sea. On the other hand, the regulation of state sovereignty in airspace is regulated in Indonesian legislation with Law Number 43 of 2008 concerning State Territory and Law Number 1 of 2009 concerning Aviation. The strategic location of Indonesia's territory will have benefits, but at the same time can pose threats to Indonesia's sovereignty. So it becomes a consequence of Indonesia's ability to build and improve the ability of the national defense system. To maintain state sovereignty over Indonesia's vast airspace, air surveillance is carried out by involving three Air Force division commands, namely:

1. Air Force Division commands I, sector command located in Jakarta for Central Indonesia.
2. Air Force Division commands II, sector command located in Makassar for the Eastern Indonesia region
3. Air Force Division commands III, sector command located in Medan for Western Indonesia.

Each air defense area uses an air defense system arranged in layers with a defense equipment title pattern, consisting of a point air defense area located at an altitude of less than 18 km, a terminal defense area located at an altitude between 18-100 km, and an area defense area, located at an altitude of more than 100 km. Each layer of defense is divided into three layers, namely the first layer with low-speed defense, the second layer with medium range vehicles, and the third layer with high-speed and high-range vehicles, the next layered defense picture is shown in Figure 1.

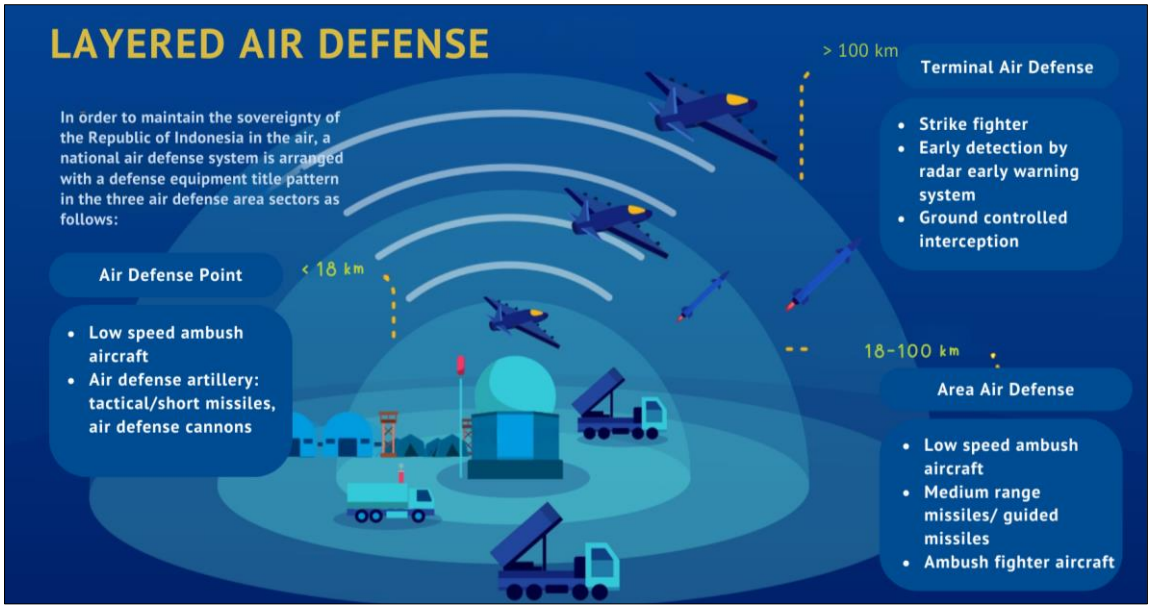

Figure 1. Air Defense System (Siswanto, 2004)

National defense can be used as an effort to uphold state sovereignty, maintain the integrity of the country's territory, and the safety of the entire nation from various threats that exist. Following the 1982 United Nations Convention on the Law of the Sea (UNCLOS), Indonesia has three Indonesian Archipelago Sea Lines (IASL) and several choke points that are strategic for global interests, such as in the Sunda Strait, Lombok Strait, and Makassar Strait (Handini & Risdiarto, 2019). The existence of a defense system in the IASL region and choke points is a strategic agenda, because there are often violations, especially in the airspace, so it requires a strategy for the air defense system. Indonesia's airspace based on the results of the Chicago Convention is the entire airspace above the territory of the state bounded by the Indonesian territorial sea, which is as far as 12 miles from Indonesia's outer baseline. Article 3 (a) and (b) of this convention states that unscheduled international flights from one country are not allowed to cross the territorial boundaries of another country without having a flight permit, this is included in the violation of state borders. Airspace violations, besides being considered a threat to national security, can also influence territorial sovereignty in the national defense system (Ghufron, Herdiansyah, & Nuraeni, 2018).

The concept of air power is the ability to project military power in the air with the power of operating vehicles such as missiles operating above the earth's surface and air vehicles defined as airplanes, helicopters, and unmanned aerial vehicles (Agus, 2017). The development of air defense systems has been efficiently designed to provide strategic warning of potential threats, especially after the start of combat (Gapiński, Krzysztofik, & Koruba, 2018). An efficient air defense system can be an early warning system against enemy attacks from the air, and air defense force (Leedy & Ormrod, 2013). In addition, an effective air defense system can help avoid greater troop losses and deterrence effects. Air defense systems provide five basic needs, namely early warning, tracking, identification, interception, and destruction capabilities (Wulansari & Dermawan, 2011).

The Indonesian Air Force has carried out a title of strength held within the framework of an air defense strategy with the concept of a strategy to provide the effect of deterrence and security of national airspace outside the Indonesian Exclusive Economic Zone (EEZ) region. In its implementation, air defense operations adhere to the title pattern of the Main Weapon System Equipment known as *alutsista* (*alat utama sistem senjata*), namely in area air defense, terminal air defense, and point air defense. The air defense title pattern in the air defense system can have an impact on air defense which is carried out efficiently and successfully to protect national vital objects (Sudirin, Darmawan, & Hendra, 2022). In supporting the National air defense system, Indonesia has several aircraft, including fighter aircraft, transport aircraft, special attack aircraft, training aircraft, reconnaissance and special mission aircraft, helicopters, and combat helicopters (Lestari, 2023).

Activities in its operation include the identification of target reports which include detection or visual identification, correlation identification, and electronic identification, as well as action against the threat of enemy forces. In the application of the CCA concept consisting of manned and unmanned aircraft can be positioned to perform visual identification by deploying fighter aircraft, and electronic identification by emitting a certain code that can be recognized by the air defense system as a friend, so that UCAV as a loyal wingman is not mistargeted in carrying out its operations and correlation detection carried out by fighter aircraft as the center in controlling drones or UCAVs in detecting flying objects and other systems by combining data from both sources to make more informed decisions about the type and intention of the object.

Collaborative Combat Aircraft

The development of cutting-edge air defense systems is giving rise to new concepts that will require assistance to preserve air dominance in the coming decades. The blending of operations between manned and unmanned aircraft will be the space and role in future defense operations. Collaborative concepts that will keep human pilots safe and keep support operators in the loop by adding a lot of autonomy such as artificial intelligence and machine learning, are the future of air operations systems. Air defense systems will be integrated with the new generation by improving their capabilities, one of which has been adopted by the United States and its allies in detecting enemy aircraft (SAE International, 2023).

The Collaborative Combat Aircraft (CCA) program proposed by the United States Air Force (USAF) is a multi-pronged initiative to test, develop, and deploy new autonomous and manned-unmanned aircraft cooperative concepts. CCA focuses on missions on a large scale which is one of the cost-saving and pragmatic solutions to have a resilient air power capacity to respond and counter the development of enemy stealth aircraft. The CCA concept can innovatively utilize cutting-edge disruptive technologies such as autonomy, machine learning, and artificial intelligence (AI) to maximize the performance of current and future combat fleets in agile combat work, as in maximizing safety (Air Force Technology, 2023). CCA is depicted in Figure 3.

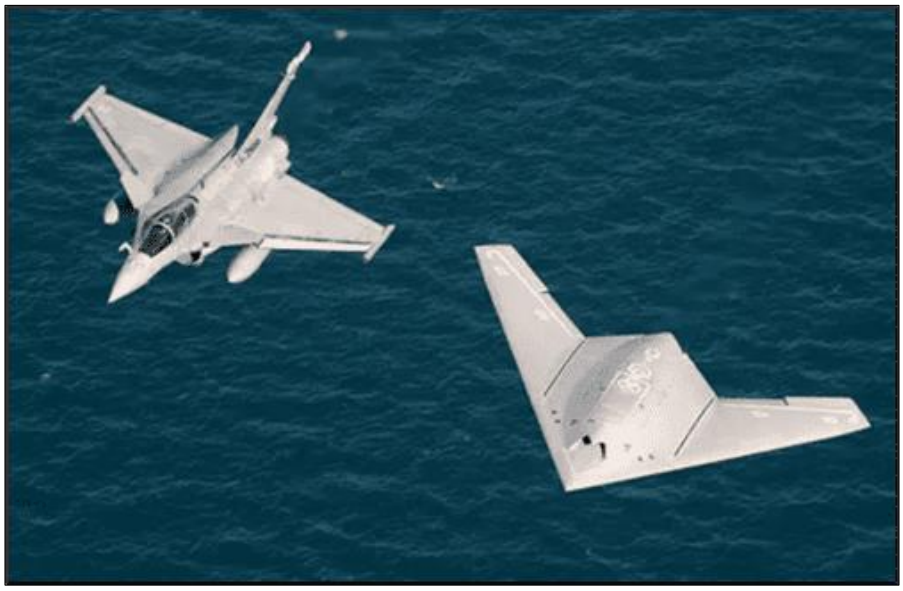

Figure 2. nEUROn and Rafale M on a Joint Flight (Dassault Aviation, n.d)

The ecosystem of surviving peer conflict in a highly contested operational environment will require an air force that has the CCA concept. The CCA concept can help save costs in purchasing and maintaining aircraft. In addition, the CCA concept will minimize the impact of combat risk experienced by fighter pilots. Based on research that has been conducted to make progress in important and fundamental challenges related to the development of CCA, namely, consisting of autonomous flight control dynamics, autonomous flight safety, flight safety, combat space awareness, tactical decision making, and sensing and maneuvering (Penney, 2022). The proposed CCA design and operational capabilities will consist of a new generation of collaboration-focused unmanned aircraft that will fly alongside fifth-generation and newer manned fighters. CCAs will differ in form and function, featuring a mix of sensors, weapons, and tactical systems that can be tailored to the mission as presented in Figure 3 (Tirpak, 2023).

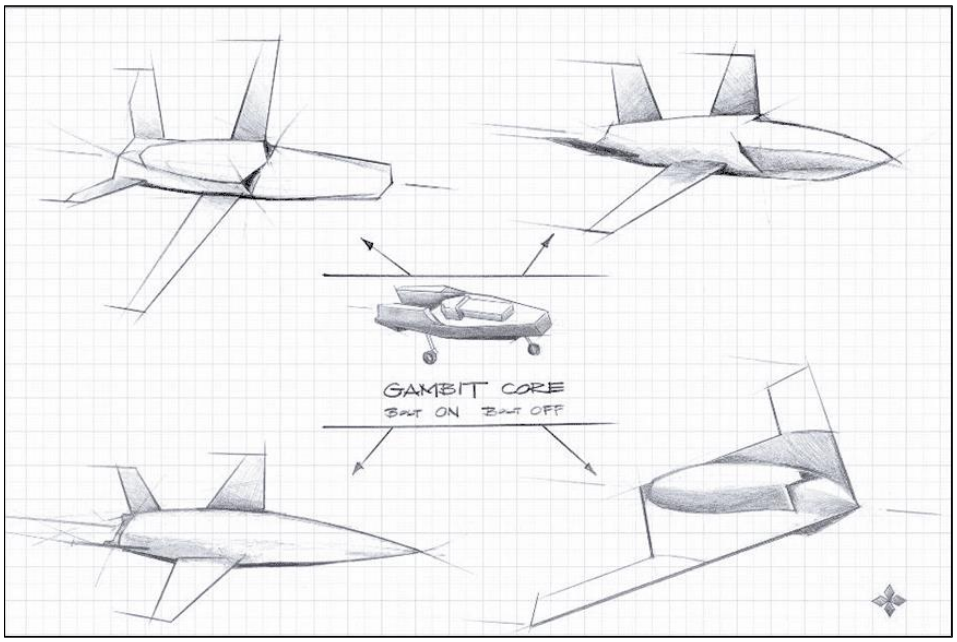

Figure 3. Seri Gambit GA-ASI (General Atomics Aeronautical, 2022)

Figure 4. UCAV Geometric Shape Development UCAV Geometric Shape Development (Coppin, 2014)

The concept of CCA requires mastery of technology, which is a factor in the collaboration system to defend and secure Indonesia's airspace. One such technology is the Unmanned Combat Aerial Vehicle (UCAV). UCAV is an unmanned aircraft vehicle with a special mission, in addition to the Intelligence, Surveillance, and Reconnaissance mission (Utama & Anwar, 2021). The development of UCAVs has had a significant impact on the field of combat (Kong, Zhou, Yang, Zhang, & Zeng, 2020). UCAVs have a high level of efficiency and can perform overload maneuvers that are difficult for manned combat aircraft, so they can be used as one of the main vehicles in future air combat systems (Duan, Wei, & Dong, 2013). In its mission, UCAV must have stealth capabilities which are then referred to as stealth Unmanned Combat Aerial Vehicles. The purpose of this

capability is to be able to survive and avoid the various sensors that exist (Çakin, 2018). The Stealth UCAV is expected to meet various demanding requirements such as lift-to-drag ratio, low Radar Cross Section (RCS), and light structural weight (Tianyuan & Xiongqing, 2009). Technology with stealth geometric shapes is shown in Figure 4.

The concept of CCA in collaborating between manned and unmanned aircraft has a mission as a loyal wingman with a role in air-to-air warfare. The existence of this concept requires an operating concept to create sophisticated capabilities that can be adapted to the future threat ecosystem. Warfighters must be involved in the early stages of developing the CCA concept to shape how autonomous aircraft can operate and interact with humans in the battlespace. Failure to do so risks developing a non-optimal CCA design that has reduced effectiveness on the battlefield.

Indonesia's Collaborative Combat Aircraft Concept of Operations

The operational framework of Indonesia's CCA activities is predicated on the unique geographical characteristics of the Indonesian territory, situated between two continents and two oceans. The strategic positioning of Indonesia holds the potential for bolstering its defense capabilities, aligning with the provisions outlined in Law Number 2 of 2002 concerning National Defense, specifically in Article 3, Paragraph 2, which emphasizes the importance of considering Indonesia's archipelagic geography in national defense planning. Leveraging its advantageous geographical location, Indonesia can enhance its defense readiness to counter a spectrum of potential threats. Collaborative operations, exemplified by the Collaborative Combat Aircraft concept, play a pivotal role in fortifying Indonesia's air defense capabilities. The Indonesian Air Force adheres to the doctrine of the wing of the Indonesian homeland known as "*Swa Bhuwana Paksa*" aimed at safeguarding the security, independence, sovereignty, integrity, and national interests of the Republic of Indonesia through aerial defense measures. Based on an interview conducted with a researcher at the Research and Development Service of the Indonesian Air Force, explained that the Air Force's air operations include various categories, including:

1. Air defense operations. It aims to conduct law enforcement and maintain the security of national jurisdiction airspace in accordance with the provisions of ratified international law.
2. Strategic airstrike operations. It aims to observe, identify, attack, and strategically destroy valuable targets that are centers of gravity to neutralize the enemy's war capabilities and motivation in the war framework.
3. Offensive counter-air operations. These operations aim to destroy or neutralize enemy air power in the context of war to gain air superiority in the area of operations. So that friendly land, sea, and air operations can be carried out without interference and threats from enemy air power.
4. Air support operations. These are operations that include tactical and strategic maneuvers aimed at assisting land, sea and air forces and other relevant agencies in effectively achieving their objectives. These operations play a vital role in maintaining the momentum of an ongoing conflict and ensuring the successful execution of tasks.
5. Information operations. It is a multifaceted approach that integrates intelligence, information technology, communications, electronics, psychology, and data processing capabilities to achieve optimal results. It adheres to a set of principles that include goals, objectives, limitations, functions, and operational forms.

Drawing from various existing theories and considering the geographical context of Indonesia, the concept of Collaborative Combat Aircraft (CCA) operations can be

effectively implemented in the realm of air support operations. The primary objective of such operations is to provide air support, particularly through attack maneuvers aimed at either destroying or neutralizing enemy targets. Furthermore, these operations are designed to enhance the efficiency and effectiveness of air operations and other military endeavors, thereby contributing to the achievement of military objectives. In the Indonesian context, this attack strategy involves a collaborative effort between manned aircraft, such as fourth-and-a-half-generation fighter aircraft, and Unmanned Combat Aerial Vehicles (UCAVs). The collaborative framework within the Indonesian CCA model typically involves the integration of two to four unmanned aircraft with a single manned aircraft serving as the leader. These unmanned aircraft are equipped to fulfill attack and combat roles, incorporating advanced reconnaissance and intelligence technologies.

Unmanned Combat Aerial Vehicles (UCAVs) operate under the guidance of a leader aircraft that is pre-informed of potential threats. Communication protocols between UCAVs and manned fighter aircraft during missions encompass various concepts, including real-time communication. Initially, the manned fighter pilot communicates instructions to the UCAV in real time, directing it to conduct tasks like target detection or specific maneuvers. Once the UCAV reaches the target area, it can transition to autonomous operation, where it independently executes tasks related to maneuvering and combat. Throughout the mission, a data link facilitates information exchange between the UCAV and fighter aircraft, enabling the sharing of target coordinates and reconnaissance findings. The collaboration between UCAVs and fighters is further enhanced by the integration of artificial intelligence (AI) and machine learning technologies, which optimize operational efficiency and effectiveness by aiding in data interpretation, tactical decision-making, and autonomous UCAV control.

The concept of collaboration is defined by applying to Combat Air Patrol (CAP) operations, which is a type of flying mission for combat aircraft. Combat air patrol is an aircraft patrol conducted over a target area, overprotected forces, over a critical area of a combat zone, or over an air defense area, to intercept and destroy enemy aircraft before they reach the target. Combat air patrol applies to operations on land and over water, protecting other aircraft, fixed and mobile locations on land, or ships at sea (Ball, 2003). CAP is included in the Defensive Counter Air (DCA) mission, which is a mission designed to detect, intercept, and destroy or negate enemy forces that try to attack or penetrate the air environment. In the DCA mission, the typical aircraft used is the same as the fighter aircraft in the Offensive Counterair (OCA) mission, which is a mission to achieve the desired level of air supremacy by destroying, damaging, or neutralizing aircraft, missiles, launch platforms, and their supporting structures and systems before and after launch, but as close to the source as possible. The threat from aircraft on DCA missions consists of consistently attacking enemy aircraft. CAP missions consist of aircraft patrols conducted over a specific area to intercept and destroy enemy aircraft or missiles before they reach their target (Ball, 2003).

The ability to loiter for long periods over a patrolled area, using air-to-air refueling, is essential, otherwise, some aircraft will have to return to home stations and bases. It is a specific time-sequence pattern that maintains constant surveillance of the area and allows aircraft that are on station to return to refuel and rest. Specialized versions of CAP are barrier CAP (BARCAP), the establishment of a barrier by a patrol between a possible direction of attack by hostile aircraft and the force assets to be protected, and protected, and (Mikoyan-Gurevich Combat Air Patrol (MIGCAP), a defense patrol conducted between a known concentration of aircraft and a group of non-hostile aircraft on an attack mission (Ball, 2003).

The air superiority mission involves the execution of Combat Air Patrol (CAP) to engage enemy aircraft. This mission is focused on eliminating enemy bombers and fighters to enable friendly forces to carry out operations without interference from hostile air forces. The air superiority super fighter is required to engage enemy fighters with high maneuverability in flight and discharge medium and short-range weapons. This mission holds the highest priority among all flight missions and typically involves air defense or targeting critical objectives. Fighter aircraft equipped with advanced weaponry and sensors are commonly deployed for air superiority missions to safeguard airspace or target high-value assets like enemy air bases or aircraft carriers. The primary objective of a Combat Air Patrol (CAP) mission is to defend airspace against enemy threats, including intercepting and engaging enemy aircraft in aerial combat. CCA Indonesia's CAP operational framework is structured into multiple stages for effective execution, namely:

1. CAP formation. At the CAP formation stage, fighter aircraft and UCAVs will be formed into patrols and operate in protected airspace. Protected airspace in Indonesia is the airspace above Indonesia's territorial area, covering land and territorial sea waters. Based on Law Number 1 of 2009 concerning Aviation, Indonesia's airspace consists of (a) terrestrial airspace, including airspace over the Indonesian mainland; (b) water airspace, covering the airspace above Indonesian waters up to the territorial sea boundary; and (c) airspace over the Indonesian Archipelagic Sea Route (IASL), covering the airspace over the IASL designated by the Indonesian government.
2. CAP Implementation. In the execution phase, the fighter and UCAV patrol the protected airspace. The fighter will use radar to detect and intercept enemy aircraft and the UCAV will fly alongside the fighter during the monitoring mission.
3. CAP Completion. At this stage the Combat aircraft and UCAVs will return to base, having completed the CAP mission.
4. Scenario. The Collaborative Combat Aircraft (CCA) mission scenario was used under air patrol conditions. The air patrol scenario selection is a strategic operation where combat aircraft conduct air monitoring and observation in a specific area, using a variety of equipment and weapons equipped to detect, identify, and respond to air threats that may arise. Optimal combat readiness is supported by a two-drone collaboration mission with effective communication and survivability. The scenario depiction is carried out if there is a threat of aircraft entering Indonesian territory without permission, at the time of patrol, and a situation facing a dog fight. The illustration of this scenario is shown in Figure 5 and the explanation is shown below.
    - Fighter aircraft and UCAVs are flying in airspace controlled by their forces or while executing CAP. The fighter's radar detects an enemy aircraft flying towards the airspace. The fighter and UCAV immediately head towards the enemy aircraft. The fighter uses its radar to identify the enemy aircraft. After identifying the enemy aircraft, the fighter, and UCAV divide the tasks. The fighter will attack the enemy aircraft from the front, while the UCAV will attack the enemy aircraft from behind.
    - Fighter aircraft use their speed and maneuverability to approach enemy aircraft from the front. The Indonesian Combat Drone X (ICD-X) UCAV uses its speed and maneuverability to approach the enemy aircraft from behind. The fighter aircraft attacks the enemy aircraft with the UCAV in the rear position, after the attack, the fighter aircraft and UCAV avoid air-to-air missile attacks from the enemy aircraft or defensive.

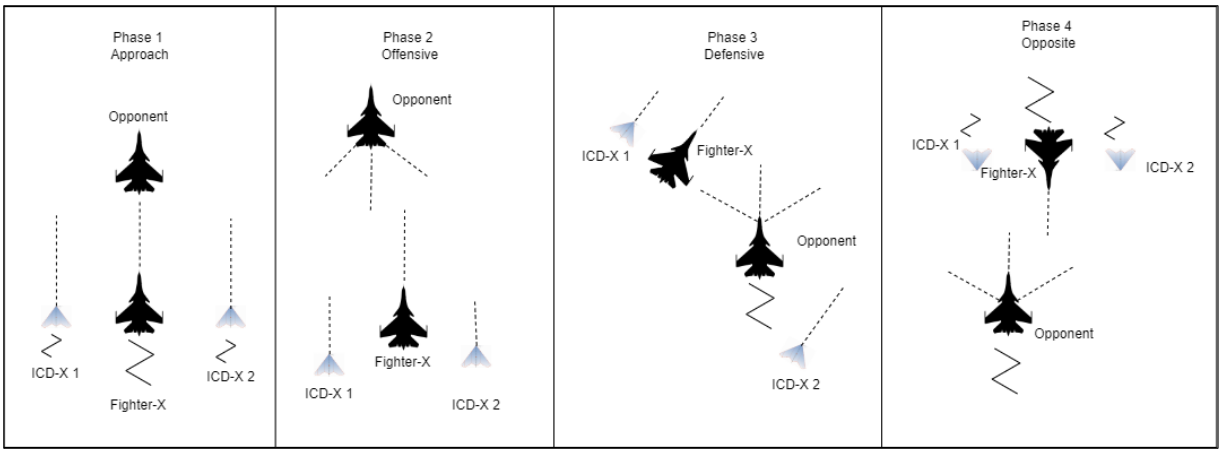

Figure 5. Combat Air Patrol Scenario with UCAV and Typical Fighter Aircraft (Processed by the Author using Corel Draw application, 2023)

Figure 6. Battle Situation Diagram (Processed by the Author using Corel Draw application, 2023)

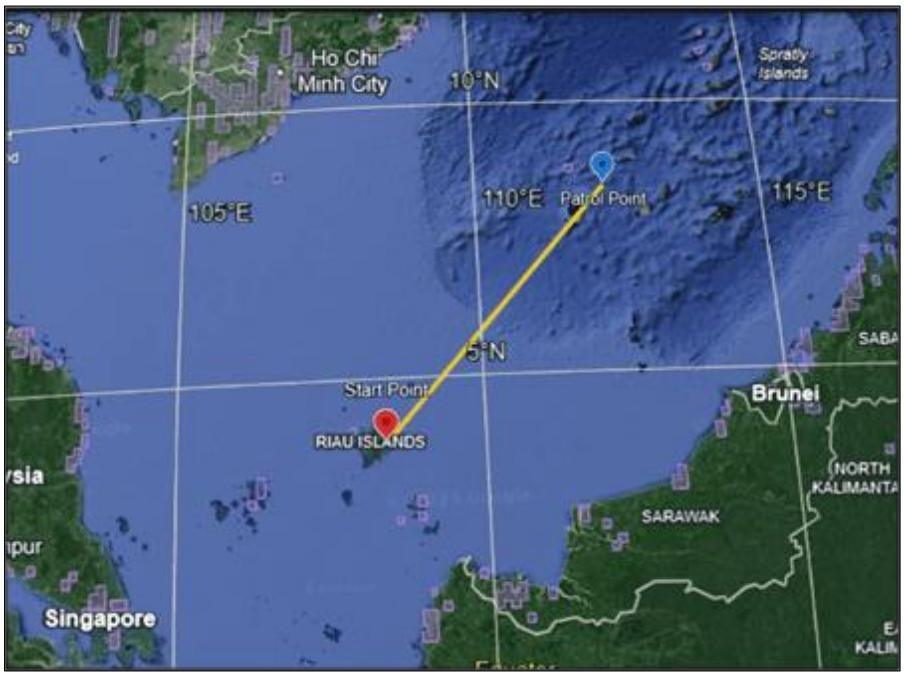

Figure 7. Area Mission CCA Indonesia (Processed by the Author using Google Earth Pro, 2023)

Figure 6 illustrates two conditions if the UCAV is facing an enemy fighter. This illustration was created based on the Collaborative Combat Aircraft (CCA) scenario conditions. The first condition is that the UCAV is behind the enemy aircraft, there will be an advantage for the UCAV to intercept the fighter, but otherwise, if the UCAV faces the enemy fighter, it will be a mutual loss for both of them. So, the UCAV must have objective defense capabilities and high aerodynamic performance. Favorable situations can occur

when UCAVs are on patrol and can be utilized to conduct ambushes. However, on the contrary, during patrol missions, UCAVs and fighter aircraft can experience adverse situations, which trigger the performance of air superiority missions. Both of these situations are part of the Combat Air Patrol concept of operations. The applied Indonesian CAP concept of operations will operate in conflict areas, namely the Natuna Sea. The determination of the operating area is illustrated in Figure 7. Figure 7 depicts the radius and operational path scenario, assuming a combat range of 600 km, equivalent to 1500 km. The mission profile of the implemented Combat Air Patrol (CAP) operation concept aligns with the guidelines outlined in Military Standard (MIL-STD) 3013, a military document issued by the Department of Defense of the United States of America (2003) on February 14, 2003. The CAP mission encompasses four primary objectives.

1. Cruise. This is a mission used as a UCAV patrol that refers to a UCAV with constant speed and altitude. This mission occurs after take-off or climb and before the aircraft performs the next mission that requires maneuvering. This mission has the most efficient speed for that UCAV and flies at the most efficient cruising altitude.
2. Interception. This mission is a radius mission performed to arrive at the battle area as soon as possible and attack enemy air vehicles. In performing this mission, an interception time is defined as the time from engine start to battle initiation at the interception altitude and range. The Interception mission has the most important requirement which is sufficient for the speed capability of the UCAV.
3. Air superiority. This is a mission with the task of achieving air supremacy or at least control of airspace within a limited area and for a limited period. The targets are enemy aircraft operating in the claimed airspace.
4. The UCAV and fighter aircraft will experience several phases in the course of their operations, which are depicted in Figure 8.
   a. Phase A UCAV with fighter aircraft performs warm-up, take-off, and acceleration to climb rate.
   b. Phase B performs the climb phase.
   c. Phase C performs the air patrol phase with the cruise mission.
   d. Phase D performs the descent phase.
   e. Phase E performs the loiter phase.
   f. Phase F performs the combat phase.
   g. Phase G performs the climb phase.
   h. Phase H performs the cruise phase.
   i. Phase I performs the descent phase.
   j. Phase J performs the reserve phase.

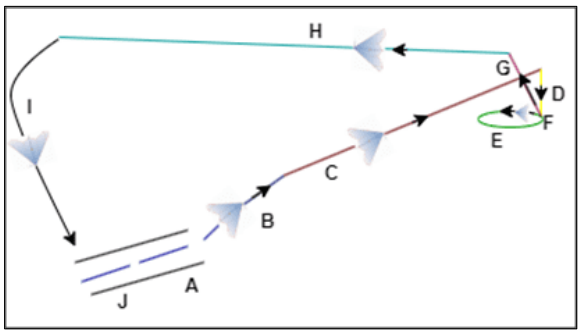

Figure 8. Mission Profile Combat Air Patrol (Department of Defense of the United States of America, 2003)

Government Challenges and Constraints in Realizing the Collaborative Combat Aircraft System for Indonesia

The Collaborative Combat Aircraft (CCA) concept is the latest air combat concept. The superpowers have been assessing this combat concept to achieve the goal of air combat dominance. The U.S., through its Air Force (USAF), has developed an air defense framework incorporating the CCA system. Other countries, including Australia, China, India, Japan, Russia, and the U.K., have also adopted this concept. Some of the concepts that have been developed are using a loyal wingman concept consisting of several types of unmanned vehicles. One potential competitor in the CCA program is Boeing's MQ-28A Ghost Bat UCAV, which made its first flight in February 2021 as part of the Royal Australian Air Force (RAAF) Airpower Teaming System (ATS) program. Kratos Defense & Security Solutions United States has also developed a series of high-performance CCA-type unmanned aircraft, including the Kratos Air Wolf Drone, UTAP-22 Makos, and Kratos XQ-58A, designed for a range of mission capabilities. Similarly, after the successful demonstration of the MQ-20 Avenger's autonomous capabilities, GA-ASI introduced the Gambit autonomous collaborative platform in March 2022. The Gambit family of unmanned combat aircraft includes variants such as Gambit 1-ISR, Gambit 2-Air-to-Air, Gambit 3-High-Fidelity Trainer, and Gambit 4-Combat Recon (US Air Force, 2024). The use of cutting-edge technology is key to the development of this concept. However, in the application process, some challenges and limitations can be faced by the country's government, namely:

1. Unmanned Aerial Vehicles (UCAV) technology used in Collaborative Combat Aircraft (CCA) will become the first challenge for the country's government in developing this concept. Indonesia has yet to reach the Unmanned Aerial Vehicles (UCAV) production technology development independently. This includes expertise in aerospace engineering, avionics, stealth technology, and system integration.
2. Implementation of the Collaborative Combat Aircraft (CCA) concept faced challenges in determining the existing policy and regulatory framework.
3. The strategic alignment of the Collaborative Combat Aircraft (CCA) system with Indonesia's national defense strategy, military doctrine, and geopolitical goals.
4. To build and improve infrastructure facilities to support development, manufacture, testing, and maintenance.
5. Financing capability requires large financial investments in research, development, production, and maintenance.
6. Resource capability of expertise in research, development, production and maintenance.

Overcoming these constraints requires meticulous planning, smart strategic decision-making, and close cooperation between government agencies, defense industry partners, academia, and international stakeholders. This strong collaboration will be key in realizing Indonesia's ambition to have an advanced and effective Collaborative Combat Aircraft (CCA) system. Based on the explanation above, the use of cutting-edge technology is a key thing that can be applied by Indonesia, in creating Collaborative Combat Aircraft. In research conducted by Gunzinger et al. (2024) using the Mitchell Institute's 2023 wargame war scenario is stated that:

1. The Air Force should conduct a tradeoff analysis to determine the optimal CCA in the design of future fighting forces.
2. The Air Force should acquire CCA on a large scale to increase its capacity to project counter-air mass at long ranges into highly contested areas.

3. The Air Force should field CCAs that will reduce the Air Force's reliance on large, fixed air bases in the Pacific
4. The Air Force should seek to increase the lethality of armed CCA over time by developing or adapting munitions to take maximum advantage of CCA payload limitations.
5. Analysis is also needed to determine the capabilities and concepts of operations required to support high-tempo CCA operations in the forward theater.

Indonesia, given its strategic positioning, is well-suited to adopt this approach to attain air superiority utilizing stealth technology. The Indonesian CCA operations, grounded in the Air Force doctrine, present a promising avenue for the development of the Indonesian CCA concept. Leveraging Indonesia's strategic location will be advantageous in the implementation of this concept. Indonesia has the potential to establish air combat superiority through the gradual adoption of Collaborative Combat Aircraft (CCA). This process would commence with the initial stages of research, infrastructure enhancement, and regulatory frameworks.

CONCLUSIONS, RECOMMENDATIONS, AND LIMITATIONS

The evolution of aerial threats has become increasingly intricate due to advancements in technology and the evolving global landscape. The demand for fighter aircraft equipped for combat missions has risen in response to the escalating air threats, necessitating collaboration with Unmanned Aerial Vehicles (UCAVs). This cooperative air defense system is known as Collaborative Combat Aircraft (CCA). The contemporary era has refined the concept of CCA operations to fortify the air defense mechanism, with the collaborative system yielding greater strategic value. The U.S., through its Air Force (USAF), has devised an air defense framework incorporating the CCA system. Other countries, including Australia, China, India, Japan, Russia, and the U.K., have also embraced this concept. Indonesia, given its strategic positioning, is well-suited to adopt this approach to attain air superiority utilizing stealth technology. The Indonesian CCA operations, grounded in the Air Force doctrine, present a promising avenue for the development of the Indonesian CCA concept. Leveraging Indonesia's strategic location will be advantageous in the implementation of this concept. The operational strategy in the region entails air patrols with combat missions, involving a combination of a 4.5-generation fighter aircraft and two UCAVs equipped with stealth technology. This operational concept is poised to deliver significant benefits, particularly within Indonesia's expansive airspace, enabling the successful execution of combat missions and the attainment of air superiority.

Indonesia has the potential to establish air combat superiority through the gradual adoption of Collaborative Combat Aircraft (CCA). This process would commence with the initial stages of research, infrastructure enhancement, and regulatory frameworks. Subsequently, the phased acquisition of CCA, its integration with existing defense systems, and comprehensive personnel training would enable the utilization of CCA for various missions including patrol, intelligence gathering, air attacks, and electronic warfare. Despite Indonesia's robust air power, burgeoning defense industry, and advantageous geographical position, challenges in communication technologies, advanced command strategies, personnel expertise, vehicle design, and cybersecurity need to be effectively managed.

This study can lay the groundwork for the forthcoming implementation of CCA by proposing strategic initiatives such as enhancing data link infrastructure through the establishment of an integrated communication network, developing interoperable data

link technologies, enhancing human resource training, fostering international collaborations, refining pilots' proficiency in CCA air combat tactics, and establishing an integrated command center. Tangible recommendations like fostering partnerships with other nations and investing in communication infrastructure are pivotal in assisting Indonesia attaining air combat supremacy. Furthermore, the successful deployment of a comprehensive CCA, while adhering to international ethical standards and legal frameworks and involving all relevant stakeholders, could be instrumental in realizing Indonesia's air combat dominance.

The collaborative integration of Unmanned Combat Aerial Vehicles (UCAVs) with fighter aircraft represents a novel development pursued by multiple nations through extensive research and analysis. This study aims to elucidate the synergistic relationship between unmanned and manned aircraft to establish aerial combat superiority, with potential applications within Indonesia. The research methodology employed in this study imposes certain constraints on delving deeper into operational concepts associated with combat scenarios, utilizing a quantitative analytical framework. Relying on existing references to explore concepts, including those tailored for the Indonesian Collaborative Combat Aircraft (CCA) initiative, may inadvertently introduce biases. This research evaluates the preparedness of the Indonesian Air Force and defense industry in formulating the CCA operational concept, serving as a preliminary guide for further exploration of critical components such as communication protocols, combat strategies, aerial surveillance techniques, and command structures essential for successful collaborative missions, following the recommendations derived from this study.

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