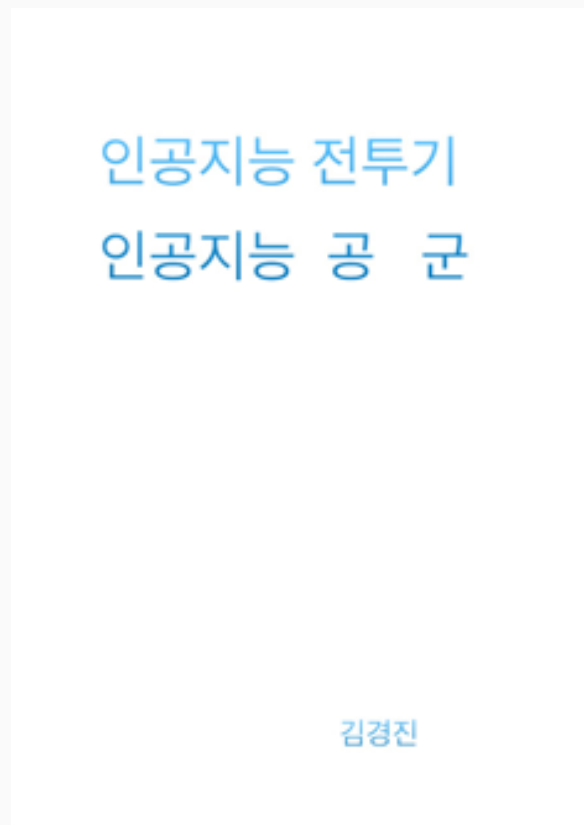


Artificial Intelligence Fighter, Artificial Intelligence Air Force

Table of Contents, Preface, 40 Chapters, Epilogue



Kim Kyung-jin

English PDF edition

Artificial Intelligence Fighter, Artificial Intelligence Air Force

Kim Kyung-jin

Artificial Intelligence Fighter, Artificial Intelligence Air Force is an online AI Library book by Kim Kyung-jin. It covers AI fighters, autonomous air power, unmanned combat aircraft, CCA, MUM-T, sixth-generation fighters and is organized as Table of Contents, Preface, 40 Chapters, Epilogue.

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Preface: Is the Age of Top Gun Over?

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Introduction: Is the era of Top Gun over? May 2, 2024, Edwards Air Force Base, California. The midday sun is scorching in the Mojave Desert. An F-16, decked out in orange and white livery, revs its engines at the end of the runway. The roar of the Pratt & Whitney F100 turbofan engine is the sound that has dominated the American skies for decades. Inside the canopy, in the front seat of the cockpit, sits Secretary of the Air Force Frank Kendall, wearing a flight suit and helmet. This is no ordinary test flight. There is no human pilot at the controls of a fighter jet.

It is an algorithm engraved on a silicon chip, artificial intelligence learned from millions of virtual battles. Secretary Kendall doesn't touch the steering wheel. The same goes for the safety pilot in the back seat. The aircraft leaves the runway and soars into the sky. And soon, another F-16, piloted by a human, appears. The two fighter jets begin to rush towards each other at 900 kilometers per hour. In 1986, the movie Top Gun took theaters around the world by storm. Do you remember the scene where Tom Cruise, wearing sunglasses, grabbed the control stick and competed in the sky with his rival Iceman? Pete Mitchell, call sign Maverick.

He was a reckless pilot who broke the rules, but ultimately won. Human intuition, guts, and above all, the heart behind the steering wheel decided the winner. Fighter pilot was soon another name for a hero. 36 years later, in 2022, the sequel Top Gun: Maverick was released. At the beginning of the film, Maverick, now with all his gray hair, pilots the hypersonic test vehicle Darkstar. However, his project is in danger of being cancelled. What is the reason? This is because the budget goes to the drone program. In the movie, an admiral speaks coldly to Maverick. "The era of pilots like you is over." Maverick retorts.

And the movie moves on to the story of a human pilot completing a mission with his indomitable will. The audience cheered. But reality was already moving in a different direction.

Washington D.C. in August 2020, two years before the film was released. A quiet competition was held at the nearby Johns Hopkins University Applied Physics Laboratory. This is the Alpha Dogfight Trial hosted by DARPA, the Defense Advanced Research Projects Agency under the U.S. Department of Defense. Artificial intelligences developed by eight teams fought each other while driving a virtual F-16 in the simulator. The AI that made it to the finals was an algorithm created by a small startup called Heron Systems. This AI defeated all other AIs in the preliminaries. And then the final opponent appeared. It's human.

Active duty F-16 pilot in the U.S. Air Force, call sign Bangor. He was a veteran with over 2,000 hours of flying experience. In the virtual cockpit, Banger took the controls. Confrontation between AI and humans. The results were shocking. 5 to 0. It was a complete victory for AI. In five engagements, Bangor failed to land a single effective hit on the AI. Instead, they were shot down every time. AI

made judgments at a speed that humans could not handle and maneuvered at angles that humans could not predict. Bangor said after the competition: "Honestly, it was more of awe than surprise." It was in a simulator. virtual reality.

It wasn't real sky. So some said: The actual flight would be different. In the simulation, there is no air resistance, no vibration of the engine, and no pilot's body being crushed by G-force. Reality is always more complicated. Three years later, in September 2023, Edwards Air Force Base again. Researchers from DARPA's Air Combat Evolution (ACE) program parked a modified F-16 called the X-62A VISTA on the runway. The fighter jet was equipped with AI algorithms that fought tens of millions of virtual battles in simulations.

And for the first time in history, a fighter jet controlled by artificial intelligence engaged in an aerial battle with an F-16 driven by a human pilot in the real sky. At 1,900 kilometers per hour, the two aircraft rushed toward each other and approached up to 600 meters away. Nose to nose engagement. It was a real dogfight. Who won? The military has not made an official announcement. They said it was for national security reasons. But that didn't matter. What was important was the fact that the AI could control real fighter jets and conduct dogfights. The wall of simulation has collapsed.

The final line between virtuality and reality has been broken down. And in May 2024, Secretary Kendall personally boarded the fighter jet. The Minister flew for an hour. I experienced rapid maneuvering at a speed of 885 kilometers per hour and 5G acceleration of gravity applied to my body. A dogfight that involves twisting and turning within 300 meters of an F-16 driven by a human pilot.

witnessed. I didn't touch the controls. Secretary Kendall had a smile on his face as he opened the canopy and got off after the flight. he told reporters. "Not having this technology is a security risk. We must have it now." And I added one more thing. When asked whether it would be possible to entrust the decision to fire weapons to AI, the minister nodded. "I saw enough on today's flight. I can trust you." This is the reality we live in. Humanity has sought to conquer the sky for thousands of years. In ancient Greek mythology, Icarus soared into the sky with wings made of wax, but fell because he got too close to the sun.

Thousands of years later, in 1903, the Wright brothers flew 36 meters in 12 seconds from Kitty Hawk Beach. Just 66 years later, in 1969, humans set foot on the moon. On the battlefield, airplanes evolved from reconnaissance vehicles to bombers and then to fighter planes. Biplane pilots in World War I shot each other with pistols. In World War II, Mustangs and Spitfires clashed with Messerschmitts across the skies of Europe. The jet age began in MiG Alley during the Korean War. In Vietnam, an F-4 Phantom pursued an enemy plane and fired a missile. During the Gulf War, the F-117 stealth plane split the night sky of Baghdad.

All of those moments had something in common. There was always a human in the cockpit. There was a person whose heart was pounding, sweating, feeling afraid, and yet he did not let go of the steering wheel. Fighters were an extension of pilots. A fighter plane without a pilot was unimaginable. But now that formula is about to change. Artificial intelligence never gets tired. I know no fear. They

do not lose consciousness even under 9G acceleration of gravity. Performs millions of calculations per second. While human pilots can blink, AI analyzes situations, makes decisions, and executes maneuvers. The U.S.

Air Force is already planning a fleet of more than 1,000 AI unmanned fighter jets. The first Coordinated Combat Aircraft (CCA) is scheduled to enter operational service in 2028. Next to the F-35 stealth aircraft driven by a human pilot, unmanned fighter jets controlled by AI will follow as wingmen. A loyal wingman. That's their name.

It's not just America. China is developing stealth unmanned aerial vehicles such as the GJ-11 Yigeom and Amgeom. Europe is pursuing two sixth-generation fighter projects: GCAP Tempest and FCAS. The Republic of Korea is also planning a next-generation air combat system (NACS) based on the KF-21 Boramae. Japan, Israel and Turkiye follow. A new competition for control of heaven has begun. This book contains that story.

From the time when drones first appeared, how the Predator and Reaper evolved into battlefield assassins, the shock of AI defeating humans 5-0 in the Alphado Gfight, and even the aerial battle between AI and humans that actually took place in the sky. We explain how a technology called reinforcement learning makes fighter planes fly, how the experience gained in simulation is transferred to reality, and how data collected by sensors are fused to find the enemy. Concepts of wingman drones and swarm tactics, sixth-generation fighters, and intelligent formations are also covered. And the inevitable questions.

Can machines decide the life and death of humans? Who should pull the trigger? Who is responsible when AI makes a mistake? Is the era of Top Gun really over? The answer to that question is not simple. Maybe Maverick is right. On the battlefield, human judgment and intuition may still be irreplaceable. But the moment an AI took control of an F-16 in the skies above Edwards Air Force Base and faced off against a human pilot, something changed irrevocably. The question now is not whether AI will replace humans. How will we work together? Who will be the ruler of heaven? Let us now embark together on a journey to find the answer. 2026. 1. 17.

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Chapter 1. Birth of the Unmanned Aircraft: From Target Drones to Reconnaissance Drones

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The birth of unmanned aerial vehicles: From target planes to reconnaissance drones On a deck of the Royal Navy in 1935. Artillerymen look up at the sky. A small radio-controlled biplane is gliding through the clouds. Named DH.82B Queen Bee, this aircraft was born to be hit by artillery shells. It was a target for shooting training. There was no one in the cockpit. Only the hum of engines echoed through the sky, and some compared the sound to the flapping wings of drones. This is how the word 'drone' was born. The history of unmanned aerial vehicles began with sacrifice, not glory. The mission was to get shot down.

In order for anti-aircraft gunners to learn how to aim at moving targets, they needed something real to shoot at, and they couldn't shoot from decoys. So a machine that could fly without a pilot was created. A machine that is okay even if it does not return, a machine that no one will shed tears even if it falls. This was the first identity of the drone. When World War II broke out, the demand for target aircraft increased explosively. In the United States, a man named Reginald Denny began attaching radio control devices to model aircraft and supplying them to the military.

This small aircraft, called Radioplane OQ-2, became America's first mass-produced unmanned aerial vehicle. During the war, over 9,400 OQ-3 models were produced and flew over the skies of the Pacific and Europe. Of course, most of them were shot down during training and ended up in the sea or in the fields. When the war ended and the shadow of the Cold War covered the world, the fate of unmanned aerial vehicles began to change completely. The drone was no longer for training purposes. Finding out what the enemy is doing has become the key to survival.

At that time, reconnaissance planes flying over enemy territory had pilots on board, and if they were shot down, the pilot's life and a huge political crisis followed.

On May 1, 1960, an American U-2 reconnaissance plane was shot down over the Soviet Union. Pilot Gary Powers was captured, and relations between the United States and the Soviet Union became ice cold. This incident raised a question for military strategists around the world. Is there a way to scout enemy territory without a pilot? The answer already existed. All I had to do was turn the target device upside down. All we had to do was make a flying machine come back alive after being shot down. The U.S. Air Force modified a jet-powered target aircraft called the Ryan Firebee for reconnaissance purposes.

Codenamed 'Lightning Bug', these aircraft flew thousands of secret missions during the Vietnam War. They flew over North Vietnam's dense anti-aircraft network, taking pictures, collecting electronic signals, and sometimes acting as decoys to deplete enemy missiles. The Lightning Bug flew along a pre-programmed route. Real-time control was impossible. The captured film could only be developed

after the aircraft returned, and the information was always in the past tense. But just the fact that there was no pilot riding was revolutionary enough.

Even if it was shot down, a diplomatic crisis did not erupt, and it was not dragged into prisoner exchange negotiations. The era in which machines die for us has begun. The real breakthrough occurred in 1982 in the Bekaa Valley in Lebanon. The Israeli Air Force launched small drones 'Scout' and 'Mastiff' to neutralize the Syrian army's air defense network. These small propeller planes were undetectable to radar and, best of all, were capable of transmitting images in real time. Commanders could sit inside the container and watch the battlefield 'live'.

When the enemy's radar was turned on, the waiting fighter immediately launched an anti-radiation missile. 19 Syrian anti-aircraft missile bases were destroyed in just one day. This battle marked a decisive turning point in the history of unmanned aerial vehicles. The machine that started out as a target plane has now become the eyes of the battlefield. I was no longer flying to get hit. We flew to see, to remember and to convey. Shocked by Israel's success, the United States quickly imported the technology, which became the seed that would later lead to the Predator and Reaper. This is how the drone was born.

From bullet canister to battlefield observer. From expendable to strategic asset. From machines where no one cries when shot down, to precision equipment where billions of won disappear into the air when shot down. The simple idea of not having people in the sky began to change the face of war.

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Chapter 2. Predator and Reaper: Drones Evolved into Assassins in the Sky

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Predator and Reaper: Drones evolved into sky assassins 3 a.m., Creech Air Force Base, Nevada. Inside the air-conditioned container, the pilot clutches his joystick. Several monitors are lined up in front of him, and the screen shows an infrared image of a village in Afghanistan on the other side of the world. People appear as white dots. One of them moves. It's a goal. The pilot's finger hovers over the button. "Fire." After 3 seconds, the dot on the screen disappears. The pilot gets off work six hours later and has dinner with his children. This is the new landscape of war created by the MQ-1 Predator.

A war where the distance between seeing and shooting has disappeared. A war in which pilots do not need to be on the battlefield. The Predator was more than just a drone. It was a machine that rewrote the very grammar of war. The Predator's roots begin in the garage of Israeli engineer Abraham Karem. He came to the United States in the 1980s and spent his own money to design a long-endurance UAV called 'Amber'. His philosophy was clear. Drones must stay afloat for a long time and be reliable. Amber's design evolved into the GNAT-750 and the RQ-1 Predator in the mid-1990s. Initially, the Predator was a reconnaissance aircraft.

It served as an eye to monitor the enemy's movements in the Balkan Peninsula conflict. But there was a problem. When a Predator spotted a target, it had to radio in a manned fighter plane, and by the time the fighters arrived, the target was often gone. As long as there was a gap between reconnaissance and strike, the enemy had a chance to escape. On September 11, 2001, the world changed. As the War on Terror began, the need to track down and immediately eliminate Al Qaeda's leadership increased. The U.S. Air Force and CIA experimented with equipping the Predator with Hellfire anti-tank missiles.

It was a surgery to add claws to a reconnaissance plane. A road in Yemen, November 2002. The Predator was tracking a vehicle carrying a high-ranking Al Qaeda official. A button was pressed at CIA headquarters in Langley, Virginia. A signal that traveled thousands of kilometers reached the Predator over Yemen via satellite, and a Hellfire missile was launched from under the wing of the aircraft. The vehicle burst into flames. It was the first 'drone attack' in human history.

The Predator's designation changed from RQ-1 to MQ-1. 'R' stands for Reconnaissance, and 'M' stands for Multi-role. The change in this single letter became the dividing line in the history of war. Drones were no longer passive observers. It has become a predator that hunts itself. The Predator's success spawned a more powerful successor. MQ-9 Reaper. The name itself is 'God of Death'. The Reaper was not simply an improved version of the Predator. Equipped with a turboprop engine, the speed was doubled and the weapon payload increased by 15 times.

It was capable of carrying eight Hellfire missiles, as well as the GBU-12 laser-guided bomb or the GBU-38 Joint Direct Attack Munition (JDAM). It had firepower comparable to that of a fighter jet. The real fear of the Reaper lies in its endurance. Even with a fully loaded weapon, you can stay in the sky for more than 14 hours. It can last up to 27 hours just by filling up the fuel tank. This means giving the enemy no time to rest. Reapers hover over target areas all day, observing the 'Pattern of Life'. Who goes where, who they meet, and when they sleep. Everything is recorded.

And at some point, when the opportunity arises, the missile will fly. The Reaper's eye is the MTS-B (Multi-Spectral Targeting System). Targets are tracked using high-resolution cameras during the day and infrared sensors at night. Synthetic aperture radar (SAR) looks through clouds and smoke to the ground. It can read vehicle license plates and identify human faces. But even the Sky Assassin has his weaknesses. Reaper is slow. The maximum speed is 480 kilometers per hour, but the normal operating speed is 370 kilometers per hour. It's a quarter of the size of a jet fighter. Its wingspan can reach 20 meters, making it easily visible to radar.

They can reign like gods in areas where enemy air defenses are weak, such as Afghanistan, but they are easily shot down against opponents with modern anti-aircraft missiles, such as Russia or China. By 2024, there will be more than 20 MQ-9 Reapers shot down by Houthi rebels in Yemen. A situation where an aircraft costing well over \$30 million per unit falls on an old missile costing hundreds of thousands of dollars. This is the trap of cost asymmetry. It would be difficult for the Reapers to survive in an all-out war between great powers. So the U.S. Air Force is preparing for the next generation.

A new drone that has stealth performance, AI that flies on its own, and can complete missions even when communication is lost. Predator and Reaper built the bridge

These are machines. A stepping stone from the era of remote control to the era of autonomous flight. It may have been the last drone piloted by humans.

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Chapter 3. The Limits of Pilots: The Physical Wall of G-Force and Cognitive Load

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Pilot's Limits: The physical wall of G-forces and cognitive load at 5,000 meters altitude. Inside the F-16 cockpit, the pilot begins a sharp turn. In an instant, your weight increases nine times. Your weight of 80 kilograms changes to 720 kilograms of pressure. Blood begins to drain from my head. The edges of your vision darken. It feels like running through a tunnel. The pilot grits his teeth and gives power to the ship. Hold your breath and tense your muscles. 3 seconds. 5 seconds. 7 seconds. You have to endure it. If you fail to do so, you will lose consciousness and the aircraft will fall to the ground. This is 9G.

9 times the gravity of Earth. This is the limit that modern fighter jets can endure, and this is the limit that humans can endure. And herein lies the irony. It is not the engines, radars, or missiles that limit the performance of the 21st century's most advanced fighter aircraft. This is a human sitting in the cockpit. Fighter airframes can be designed to withstand maneuvers of more than 20G. But as long as there are people in it, 9G is the ceiling. The human heart struggles to pump blood to the brain at 9G. And it often fails.

When blood flow is insufficient, 'greyout' begins, in which vision turns gray, followed by 'blackout', complete darkness. If the condition continues, you will lose consciousness. G-LOC (G-force induced Loss of Consciousness) is the loss of consciousness caused by gravity. If an unconscious pilot lets go of the controls, the aircraft will not be able to fly on its own. Pilots are trained to combat this limitation. Enter the centrifuge and experience artificially created 9G. You wear a G-suit that inflates your stomach and legs. Learn a breathing technique called AGSM (Anti-G Straining Maneuver).

Hold your breath and tense the muscles below your neck to prevent blood from rushing downward. You have to do all this at the same time, chasing enemy planes, checking radar, listening to radio traffic, and firing missiles. But G-forces are only half the problem. The other half is inside the brain. Cognitive Load. Modern air warfare takes place in a storm of information. AESA radar tracks dozens of targets simultaneously. An infrared sensor detects heat sources. Information is exchanged with friendly aircraft via a data link. Electronic Warning Receiver (RWR) notifies enemy radar targeting.

All this information is poured onto the pilot's helmet display and instrument panel. The human brain is not a parallel processing device. You can only focus on one thing at a time. Even though it may seem like you're doing several things 'at the same time', in reality you're just switching quickly. And that transition takes time. 0.1 second, 0.2 second. In air combat, this time can mean the difference between life and death.

The OODA loop, established by Colonel John Boyd, describes the essence of air warfare. Observe, Orient, Decide, Act. Whoever goes through this cycle faster determines victory or defeat. If you judge

0.5 seconds before your opponent and act 0.5 seconds before your opponent, you win. However, humans have physical limitations in terms of reaction time. The time it takes for your eyes to see, your brain to interpret, and your hands to move the control stick. No matter how much you train, you will never be able to completely overcome this limit. Stress makes things worse.

The fear of dying, the anger of losing an ally, and the fatigue of flying all night. These emotions eat away at the brain's processing capacity. There is an expression that says the bucket is full. This is a condition in which the brain can no longer receive information. In this condition, pilots may miss important warning sounds, be fooled by enemy deception, or mistake allies for enemies.

Fifth-generation fighters such as the F-35 seek to reduce this problem with sensor fusion technology. A computer integrates information from radar, infrared and electronic warfare sensors and presents a simplified picture to the pilot.

But battlefield complexity is growing faster than technology. In an environment where swarms of drones fly, hypersonic missiles rain down, and electronic warfare cripples communications, it becomes increasingly difficult for humans to handle it all. Added to this are economic problems. It costs billions of won to train one skilled fighter pilot. Years of training, expensive fuel, sophisticated simulators. If the pilot so created dies due to one mistake, all investment is lost. Pilots are strategic assets in their own right. It cannot be easily replaced. AI, on the other hand, does not know these limitations. I don't feel G-force.

I don't know fatigue. There is no fear. Data from thousands of sensors can be processed in milliseconds. The moment a human recognizes, 'Oh, it's an enemy,' the AI already begins evasive maneuvers and prepares to launch a missile. 15G startup is also easy. No ejection seat, no oxygen mask, no life support required. Ultimately, human limitations prove the need for AI fighters. A physical wall called G-force and a mental wall called cognitive load. These two walls are the result of thousands of years of human evolution, but they are no match for the speed of modern air combat.

It's only a matter of time before the pilot disappears from the cockpit. But pilots are not disappearing completely. The roles just change. From an aviator who directly holds the control stick, to a battlefield manager who commands an AI squadron. From the era of training your fingers to the era of training your brain.

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Chapter 4. Network-Centric Warfare: A Battlefield Connected by Data Links

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Network-centric warfare: Battleground connected by data link at an altitude of 30,000 feet. The sun was sinking below the horizon. The sky outside the cockpit was turning dark blue. Then the radar warning receiver let out a sharp beep sound. It means there is someone. My heart started racing and my palms began to sweat. Where is the red flag? There was nothing on my radar screen. At that moment, a new symbol appeared on the display. It was about 120 kilometers away from me and I had not seen it before. This information was not on my radar. It was a target captured by the E-3 Sentry, an early warning aircraft flying 200 kilometers behind.

The position, speed, and direction of the enemy aircraft picked up by the early warning aircraft's powerful radar were transmitted to my fighter via a data link. I can now see enemies that I could not see before. My eyes were no longer alone. This is the essence of network-centric warfare. In the history of warfare, information has always been as important as weapons. No, maybe it was more important than weapons. Think of a medieval skirmisher. They risked their lives to infiltrate deep into enemy territory to understand the enemy's movements. The informed commander was able to prepare an ambush or secure a route of retreat.

The problem was the speed at which the information was conveyed. By the time the skirmishers rode up and reported, the situation on the battlefield could have already changed. The era of voice walkie-talkies was not much different. During World War II, the Korean War, and the Vietnam War, pilots communicated with each other through radio. "Spotted an enemy flag at 3 o'clock!" These cries came and went. However, this method had fundamental limitations. The first problem was that only one person could speak at a time. If multiple pilots try to report at the same time during a melee, the frequencies get mixed up and nothing is heard.

The second problem was the time it took for it to pass through the human tongue and ears. The few seconds it takes to hear, understand, and act on what the other person said. In the world of supersonic fighter aircraft, seconds can mean the difference between life and death. The 1991 Gulf War showed the world a new paradigm in warfare. U.S. and coalition forces achieved a crushing victory over Iraqi forces. The secret to this victory was not just better fighter planes or more powerful missiles. The real difference was in the way information was shared.

The US military connected all friendly platforms on the battlefield through a tactical data link called 'Link-16'. Fighters, bombers, ships, and ground units are all tied together into one huge network. Let me briefly explain what Link-16 is. While walkie-talkies in the past converted a person's voice into radio waves, a data link is a direct conversation between computers. There is no need for the pilot to verbally explain, "The enemy plane is at 3 o'clock, 80 kilometers away, and 20,000 feet high." The information captured by the radar is converted into a digital signal and transmitted simultaneously to

all allies connected to the network.

Latitude, longitude, altitude, speed, direction, and even identifying information as friend or foe. Information that would take tens of seconds to explain verbally is conveyed in the blink of an eye. The birth of this technology dates back to the 1990s. US Navy Admiral William Owens introduced the concept of “systems of systems” in 1996. The proposal was to integrate sensors, command and control systems, and precision weapons into one. Soon after, Admiral Arthur Severowski coined the term “network-centric warfare.” His core argument was clear. The sharing of information leads to an exponential increase in combat power.

This means that 1+1 can become 10, not 2, and can become 100. Let's look at the technical characteristics of Link-16 a little further. This system uses time division multiple access method. It involves dividing the time into very small chunks and allocating them to each participant. It is similar to a meeting where several people take turns speaking. However, because the order changes hundreds of times per second, it feels like all participants are talking at the same time. It is also resistant to enemy radio interference by using frequency hopping technology.

Because the communication frequency is constantly changing, even if an enemy tries to shoot a jammer, they will not be able to hit it. The moment you feel the effects of network-centric warfare from the cockpit is dramatic. In the past, what my radar showed was everything in the world. It seemed to me that there were no enemies beyond the radar's visible range. But the moment the data link is connected, my field of view expands hundreds of kilometers away. What my fellow fighters saw, what the early warning aircraft saw, what the Aegis ships saw at sea, and even what the radar stations on the ground saw - all integrated into my display.

It's like looking down on the battlefield through God's eyes. This technology also significantly reduces the risk of friendly fire. In a melee situation, it is difficult to distinguish friend from enemy. There are many tragic cases of friendly fire in history. However, as peer identification information is shared in real time through Link-16, this risk has been dramatically reduced. my anger

If the symbol on the face is blue, it is a friend, and if it is red, it is an enemy. Because the computer identifies it, the room for mistakes is reduced. In December 2024, surprising news was delivered. The Norwegian Air Force's F-35 and P-8 maritime patrol aircraft successfully established Link-16 communication via a satellite in space. Until now, Link-16 has only worked for line-of-sight communications, that is, within a distance within which people can see each other. Because the Earth was round, there was no direct communication with allies beyond the horizon. However, this limitation was overcome by using the U.S.

Space Agency's low-orbit satellite constellation as a repeater. Now it is possible to share tactical information in real time with allies on the other side of the world. Let me give you a historical analogy. Think of the longbowmen of medieval England. Although the skill of an individual archer was important, the true power lay in the volley of fire. At the commander's signal, hundreds of archers simultaneously fired arrows. When arrows filled the sky and rained down on the enemy lines, the coordinated power of the group, not the power of individual arrows, dominated the battlefield.

Network-centric warfare is a modern-day salvo.

The coordination of connected forces, not the performance of individual fighters, determines victory or defeat. However, networks are not omnipotent. Data links become targets for enemy electronic warfare attacks. Communication may be lost if the enemy exerts strong radio interference. Additionally, as more information becomes available, the pilot's cognitive load also increases. With dozens of symbols on the screen, you have to make split-second decisions about which are immediate threats and which can be ignored. You can drown in a flood of information. This is where artificial intelligence enters the scene.

AI analyzes and prioritizes massive amounts of data flowing through the network. Threats that need immediate response are raised to the top, and information that can be ignored is filtered out. A division of targets across the squadron may also be proposed. If a network is a neural network, AI is the brain that controls that neural network. AI will become indispensable in the future joint full-domain command and control system. The Republic of Korea Air Force is also joining this trend. By equipping the F-15K and KF-16 with Link-16, the ROK-U.S. joint warfare capability was achieved.

Link-K, a proprietary data link system, is also being developed. The KF-21 Boramae was designed from the beginning with network-centric warfare in mind. In the future, the KF-21 and the unmanned Loyalist Wingman will be connected by a data link to perform cooperative operations.

The beginning of network-centric warfare was not simply the development of communication technology. It was a fundamental shift in the way we view war. From objects to systems, from firepower to information, from platforms to networks. This paradigm shift has set the stage for artificial intelligence fighter jets to be active.

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Chapter 5. The Evolution of Fighter Automation: From Mechanical Controls to Digital FBW

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Evolution of Fighter Automation: From Mechanical Control to Digital FBW, January 20, 1974, Edwards Air Force Base, California, USA. General Dynamics test pilot Phil Osler sat in the cockpit of the new fighter prototype YF-16. That day was the scheduled day for the high-speed glide test. The goal was not to fly, but simply to run down the runway at high speed. As Osler pushed the throttle, the afterburner ignited. The fighter began to accelerate furiously. But something strange happened. While gliding, the aircraft began to shake left and right. Osler tried to balance by moving the control stick.

However, the aircraft's response was different than expected. The shaking got worse, and suddenly a fighter jet jumped off the runway. It was an unintentional takeoff. Osler, an experienced test pilot, made a split-second decision. If you try to land again, a bigger accident could occur. He ascended and flew for six minutes before landing safely. This was the birth moment of the world's first mass-produced fly-by-wire fighter, the F-16. But you might be wondering what the fly-by-wire thing I just mentioned is. To understand this technique, you must first understand traditional flight controls.

Since the Wright brothers achieved the first powered flight in 1903, the way airplanes have been flown hasn't changed much in the decades since. When the pilot pulled the control stick, the movement was transmitted to the wing's control surfaces via steel cables, pulleys, and levers. It's similar to pulling strings to move a puppet in a puppet show. The pilot's arm strength directly moved the plane. This mechanical control was simple and intuitive. The pilot could feel the wind resistance through his fingertips. I flew while feeling the state of the plane with my whole body. But there was a problem.

As airplanes become faster and larger, the force required to fly them also increases exponentially. It has become nearly impossible to move the control surface of a jet fighter that breaks the speed of sound using human muscle power. Hydraulic systems were introduced to solve this problem. The principle is similar to the power steering in a car. When the pilot moves the control stick slightly, the hydraulic pump amplifies the force and moves the control surfaces. Renowned aircraft such as the F-4 Phantom and F-15 Eagle used this method.

Although the pilot's burden was reduced, there was still a mechanical connection between the control stick and the wings. Complex hydraulic piping was heavy, vulnerable to enemy attack, and difficult to maintain.

And there was a more fundamental problem. The point is that mechanical controls cannot handle an unstable airplane. This may sound a little strange. If the plane is unstable, is that a good thing? Actually, that's a good thing for a fighter. A stable airplane has a strong tendency to maintain balance. This is safe, but reduces mobility. This is because they resist sharp changes in direction. On the other

hand, an unstable airplane is like a top, ready to change direction at any time. This is a decisive advantage in air combat. The problem is that human reaction speed cannot control this instability.

An unstable plane loses balance the moment the pilot lets go and is about to crash. To prevent this, the control surface must be finely adjusted dozens of times per second. The human brain and hands cannot move that fast. This is where computers come into play. Fly-by-wire, or FBW for short, breaks the mechanical connection between the control stick and the wings. Instead, it sends electrical signals through wires. When the pilot pulls the control stick, sensors detect the movement and convert it into a digital signal. This signal is sent to the flight control computer.

The computer interprets the pilot's intentions and calculates how much each control surface should be moved, taking into account current flight conditions (speed, altitude, attitude, etc.). Commands are then sent to hydraulic actuators to move the control surfaces. Let me tell you the key differences. In mechanical control, the pilot directly controlled the angle of the control surfaces. In FBW, what the pilot inputs is intent, not angle. If you enter the intention "I want to raise the nose," the computer will calculate the optimal control surface movement to realize that intention under the current situation. NASA's role was critical.

In 1972, NASA's Dryden Research Center removed all mechanical controls from the F-8 Crusader fighter jet and transplanted computers from the Apollo lunar module. It was the world's first digital FBW aircraft experiment. Test pilot Gary Creer took the plane into the air on May 25, 1972, controlled solely by a computer and without mechanical backup. During 210 test flights over 13 years, there was not a single emergency situation due to a computer failure. Digital flight control has proven to be reliable. The F-16 is the first fighter jet to apply this technology to mass production aircraft.

And that's for a fighter plane that was intentionally designed to be unstable. The F-16's center of gravity is located behind its center of lift. This means that the aircraft is constantly trying to raise or lower its nose. A computer compensates for this instability by adjusting the control surfaces thousands of times per second. The pilot feels that this is a stable and responsive airplane. However, this is an aircraft that cannot fly for even a few seconds without a computer.

Another function provided by the F-16's FBW is flight area protection. In fighter jets of the past, it was not uncommon for pilots to make mistakes that exceeded structural limits, resulting in broken wings or stalls (loss of lift) and crashes. The F-16's computer limits the maneuver to what the aircraft can tolerate, no matter how roughly the pilot moves the control stick. It automatically adjusts so that a load exceeding 9G is not applied and the stall angle is not exceeded. Pilots can focus on fighting the enemy. There is no need to fight the plane itself. The early F-16 used analog methods.

The analog method expresses numbers as changes in voltage or current. Digital computers, on the other hand, use binary numbers 0 and 1. Beginning in the late 1980s, the F-16 was upgraded with digital flight control computers. The advantage of digital is that it is programmable. Flight characteristics can be changed with software. Even the same aircraft can now be flown differently through software updates. The FBW revolution has also occurred in civil aviation. The Airbus A320, which entered service in 1988, was the first mass-produced airliner to adopt fully digital FBW. Airbus'

philosophy has been to maximize flight envelope protection.

No matter how hard the pilot pulls on the stick, the plane will not stall. Because your computer won't allow it. Boeing introduced FBW on the 777, but left room for pilots to override computer protections and take manual control. The two companies have different philosophies. Now let's talk about the automatic ground collision avoidance system, Auto-GCAS. This technology is an extension of FBW and an important stepping stone toward AI fighters. One of the greatest risks to fighter pilots is ground impact.

There have been quite a few accidents in which planes plummet to the ground due to loss of situational awareness during dogfights or loss of consciousness during high G maneuvers (known as G-LOC). A good airplane and a skilled pilot disappear in an instant. Auto-GCAS was developed to solve this problem. The system combines a terrain database, GPS, and radar altimeter to predict the current flight path. If it is judged that it will collide with the ground if this continues, it will first warn the pilot. If the pilot does not respond, the computer takes control and raises the aircraft.

The idea is to rotate the wings horizontally and pull them up at 5G. In 2016, the U.S. Air Force released a dramatic video. An F-16 trainee from the Arizona Air National Guard fell into a G-LOC during dogfighting training. He lost consciousness while enduring a load of 8.4G. The fighter jet hurtled toward the ground at more than 700 kilometers per hour with its nose down. Instructor's

An urgent shout rang through the radio. "Two, recover! Two, recover!" But there was no response. At an altitude of 8,700 feet, Auto-GCAS activated. The computer automatically recovered the aircraft, saving the pilot's life. Since fielding in 2014, Auto-GCAS has saved the lives of 12 F-16s and 13 pilots (one was a two-seat aircraft). It is also mounted on the F-35, and there is at least one rescue record on the F-22. This technology is expected to save more than \$3 billion in assets and dozens of lives over 30 years. However, the introduction of Auto-GCAS was not smooth. Technically, it was already completed in the 1990s.

But why did it take more than 20 years to be deployed? This was due to resistance from the pilots. For fighter pilots, the ability to fly an airplane is central to their identity. Their pride lies in the precise handling of aircraft under extreme conditions. Auto-GCAS meant the intrusion of machines into this area. "I'm controlling it and the computer takes my hand away?" Many pilots reacted this way. They felt their skills were being questioned. Lt. Col. Ryan Heflin, DARPA's ACE program manager, likens it to the cavalry of the 1930s. For the cavalymen of the time, horse riding skills were their identity.

Just as they resisted the introduction of mechanized troops, pilots also resisted automation. However, cavalry eventually gave way to tanks. We couldn't go against the flow of technology. Fifth-generation fighter aircraft such as the F-22 and F-35 went beyond FBW and implemented a new level of automation called sensor fusion. In the past, pilots had to look at radar screens, check infrared sensors, listen to radar alert receivers, and integrate all of this information in their heads. The cognitive load was enormous. The fifth-generation fighter's computer takes over this task.

By fusing information from multiple sensors, it provides the pilot with processed information such as “That is an enemy plane, it is optimal to attack with this missile.” As you follow this evolutionary trajectory, AI fighters will naturally appear. From mechanical control to hydraulic control, from analog FBW to digital FBW, from flight area protection to Auto-GCAS, from sensor fusion to AI pilot. Each step has evolved to ease the burden on human pilots. At the end of the spectrum are fully autonomous fighter jets that can fly and fight without humans. Digital FBW is an essential interface for AI to control fighter aircraft.

If the mechanical linkage had remained, the robot arm would have had to physically grab the controls for the AI to control the plane. that

However, FBW allows AI to talk to the flight control computer directly through software code. AI algorithms take over the input that the pilot's hands used to make on the control stick. Think of the Roman gladius sword. The swordsman's skilled hands swung the sword. This is mechanical control. Now a sophisticated device was placed between the sword and the hand. It is a device that reads the swordsman's intention and adjusts the sword to point at the target at the most effective angle. This is FBW. And now the tactical staff was sitting on top of the device. It is the intelligence that determines when, where, and how to attack.

This is an AI fighter. The history of fighter automation is a process of complementing human limitations with machines. And at the end of the process, we are faced with machines that want to rule the sky without humans.

Part 2. AlphaDogfight: The Turing Test of Air Combat

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Chapter 6. DARPA's Challenge: Can AI Defeat a Human Pilot?

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DARPA's challenge: Can it beat human pilots? Somewhere in the Pentagon building, in the fall of 2019, a question was asked: Can machines really beat human fighter pilots in the sky? This question was not just curiosity. This question posed by the U.S. Defense Advanced Research Projects Agency, commonly known as DARPA, was as fundamental a challenge as Alan Turing's question 70 years ago: "Can machines think?" DARPA is a strange organization. On the surface it looks like a bureaucratic government agency, but in reality it's more of a mad scientist's playground. It is here that the Internet was created and GPS was introduced to the world.

It was they who sowed the seeds of stealth fighters. It's not wrong to say that it's the only government agency that bets on the seemingly impossible and says it's okay to fail. This time, they challenged an area dominated by human instinct and intuition: aerial combat. It was the beginning of a program called ACE (Air Combat Evolution) in English. The program manager was Colonel Dan Javorsek. His call sign is 'Animal'. As a former F-16 pilot, he knew the psychology of his fellow pilots better than anyone else. What kind of people are fighter pilots?

These are people who take pride in holding the steering wheel and fighting against their enemies. The idea of entrusting one's life to a machine is almost an insult to them. Colonel Animal decided to break through this resistance head on. He explained the meaning of this challenge with a historical analogy. In 1939, U.S. Army Chief of Staff General George Marshall asked Cavalry Chief John Herr how he would respond to the German blitzkrieg. General Herr's answer was as follows. They said they would put horses on trailers and move to the front lines to save stamina and then overwhelm tanks on the battlefield.

Of course, history did not go as he expected.

The cavalry was gone, and tanks dominated the battlefield. Animal warned. If today's fighter pilots do not want to become the cavalry of the 21st century, they must embrace a new tank called AI. But how can we break the pilots' distrust? It is better to show once than to explain a hundred times. Isn't there an old saying that a hundred words are worth a sight? Animal decided to show AI beating the best human fighters in a one-on-one dogfight. That is the background of the birth of Alpha Dog Fight Trial. Why did it have to be a dogfight, or a close-range dog fight?

Modern air combat is increasingly involving firing missiles from long, invisible distances. This is called BVR, or Beyond Visual Range. But why did they choose a World War II-style close-range dogfight? There was a deep reason for this. First, dogfights are a closed world problem. Like Baduk, the rules are clear, but the number of possible cases is almost infinite. This environment is optimal for AI to develop its skills through reinforcement learning. DARPA saw Dogfight as a gateway to more complex air combat missions. Second, dog fights are an extreme test bed for the OODA loop.

A dogfight is a place where the decision-making process of observing, setting a direction, deciding, and acting takes place in a split second. Here, surpassing humans means proving that AI's computational speed and judgment ability have exceeded human physiological limits. Third, it is also a starting point for building trust. Pilots develop their basic skills through dog fights starting from training camp. If AI surpasses humans in this most basic yet most instinctive area, pilots will have no choice but to acknowledge AI. The Johns Hopkins Applied Physics Laboratory, or APL for short, played a key role in this competition.

They created an AI arena named Colosseum. It is named after the amphitheater where gladiators fought in ancient Rome. This system, which combines open source flight dynamics software JSBSim with middleware, autonomous algorithms, and visualization software developed by APL, can simulate faster than real time.

I was able to turn it. AI agents learned to fight by dying and being reborn tens of millions of times in this virtual sky. DARPA selected eight teams in August 2019. The so-called Elite 8 came from diverse backgrounds. They included defense giants such as Lockheed Martin and Boeing, small AI specialized companies such as Heron Systems and Physics AI, and university research teams such as Georgia Tech Research Institute. Their task was to fully understand the flight dynamics of the F-16 fighter jet, perform basic combat maneuvers to outsmart the opponent, and develop algorithms for shooting down enemies with cannons.

Missiles have been ruled out. It was the most primitive form of fighting, with only the aircraft's maneuverability and machine gun aiming ability determining victory or defeat. The competition took place in three stages. The first trial in November 2019 was an exhibition match. At this time, the AIs could not even fly properly and often fell headlong into the ground. Researchers recalled, "In the beginning, AI didn't even know how to fly an airplane. It was just lucky if it didn't crash." But in just a few months, things changed dramatically.

In the second trial in January 2020, the AIs have already started imitating the basic tactics used by human pilots. As the program was extended due to the COVID-19 pandemic, the 2.5th trial was added virtually in May, and by the finals in August, they began to perform maneuvers that humans could not have imagined.

DARPA Deputy Director David Honey said in his opening remarks at the convention: "When putting together this program, there were important questions that had to be answered: We need to understand whether AI autonomous algorithms can actually operate in the very challenging environment of air-to-air combat." The competition attracted tremendous interest. About 10,000 people from 93 countries registered to watch, and an additional 5,000 wanted to participate. What is unique about Alpha Dog Fight Trial is that it adopts the format of an e-sports competition.

The APL team created a corner called the Control Zone and prepared a commentary area modeled after ESPN's Sports Center. Air combat and autonomy experts discussed the basics of AI and dogfighting, how to train AI and human pilots, and provided educational and interesting analysis and commentary. This approach is

It reflected DARPA's intention to engage the broader public beyond the general defense community. This was not just a skills competition. It was the first official test in the battle for control of the sky, which humanity had monopolized for a long time. Can AI surpass humans in the speed race of the OODA loop? Can machine calculations win in areas where human intuition dominates? In August 2020, the world was waiting for the answer.

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Chapter 7. Heron Systems' Breakthrough: AI Armed with Reinforcement Learning

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Heron Systems' sensation: Lockheed Martin was the strong candidate to win the AI competition armed with reinforcement learning. They created the most powerful fighter planes in existence, such as the F-22 Raptor and F-35 Lightning II, and knew better than anyone else about the physics of fighter aircraft and the doctrine of air combat. Decades of aerodynamics know-how, thousands of engineers, and an astronomical research budget. Anyone could see that they had the advantage. On the other hand, Heron Systems was a small software company with about 30 employees. They had never built or flown a fighter plane.

It seemed odd that this small, Maryland-based company would stand alongside the defense giants. But they had a secret weapon. It was a fanatical obsession and dedication to deep reinforcement learning. The principle of reinforcement learning is simple. You choose an action, see the consequences, receive a reward or penalty, and choose a better action next time. Repeat this at a frantic pace. It's similar to a child learning to walk. Fall, get up, fall again, get up again. But AI is different from a child. You don't get tired, you don't get frustrated, and you can fall and get up a million times a day.

Heron Systems' approach was completely different from that of traditional defense companies. Teams like Lockheed Martin and Aurora have tried to inject the knowledge of fighter pilots into AI. I tried to teach them rules like bite your tail and conserve energy. This is called an expert system. But Heron was different. They didn't teach the AI anything. Instead, they were thrown into a virtual environment and made to repeat the process of killing and killing countless times. Heron's AI agent was called Falco. The name comes from the falcon, a type of falcon.

Falco grew up through self-play, constantly fighting against himself in a virtual space. The process of today's me developing new tactics to overcome yesterday's me, and tomorrow's me breaking them again, was repeated infinitely. According to Ben Bell, a machine learning engineer at Heron, Falco fought billions of dog fights against a league of 102 different AI agents over a total of about five weeks. More than 4 billion simulation steps were performed. Converting this to human flight time, it amounts to over 30 years of accumulated flight experience.

Considering that it is difficult for an actual pilot to fly more than 2,000 to 3,000 hours even if he or she flies a lifetime, this was a triumph of compressed time that transcended the constraints of physical time.

During this process, an interesting phenomenon was discovered. During the initial learning phase, the AI tried to mimic standard maneuvers taught by human instructors. It was a textbook move to manage energy and maintain turn rate. However, as learning continues, AI begins to abandon human

doctrines. Instead, we sought the extreme efficiency allowed within the physics of the simulation engine. The human pilot tries to control the aircraft smoothly so as not to miss the enemy. Heron's AI was different. The aircraft was controlled by constantly modifying the control surface in fine and rough ways. Dozens of corrections per second.

It was a movement impossible by human hands. This creates an incredibly precise shooting angle. Two sophisticated techniques were behind Heron Systems' success. This is reward formation and curriculum learning. Reward shaping is a way to provide more frequent feedback to AI. Rewards are not only given when you shoot down an enemy, but also when you gain an advantageous position or when you get close to the enemy's tail. This will help the AI learn faster in the right direction. Curriculum learning is a method of teaching starting from the easy things.

At first, you'll fight enemies that only fly in straight lines, and then you'll face increasingly smarter enemies. It's like going from elementary school to middle school to high school. Heron combined these two techniques with the Colosseum's self-confrontation system to create a powerful performance. Enemy AI agents developed by APL ranged across a broad spectrum in complexity and capabilities. The simplest zombie simulated a cruise missile with straight, horizontal flight. Rosie, the primary agent, implemented minor time-based altitude and speed changes.

As a script agent, BUD FSM recognized the engagement situation and implemented a predetermined response. Alphamarve0, the highest level reinforcement learning agent, is an agent developed solely through self-confrontation without human input and simulates an expert pilot. On the third day of the competition, as the semifinals and finals progressed, Heron Systems' AI showed off a shocking tactic. It was a frontal attack, a head-on gunshot. This is a tactic where you face the enemy plane head-on, run towards it, and fire your machine cannon. Training regulations prohibit this maneuver for human pilots due to the risk of collision.

Usually do not shoot at angles greater than 135 degrees. There is a high risk of colliding with each other, and fragments of destroyed enemy aircraft may be sucked into my engine.

However, for an AI without fear of death, this was the most likely winning formula. Heron, who met Team Aurora in the semifinals, rushed towards the front of the enemy at breakneck speed as soon as the battle began. Glock, who was in charge of commentary, was astonished. "Heron has no hesitation. As soon as the starting signal is given, he shows his will to live and aims for the bridge of the enemy's nose." Heron's AI put this tactic to good use in the final against Lockheed Martin. Lockheed Martin's AI mirrored human doctrines, attempting to manage energy and dominate positions. It was an elegant and standard move.

But Heron's AI refused such a gentlemanly fight. Like a mad dog, they rushed at each other and preyed on the opponent's weaknesses. The Heron aimed its cannons with incredible precision. The muzzle of the gun stuck to the enemy plane like a magnet. Once I caught a target, I never missed it. In a split second, he dealt a fatal blow to the enemy plane. Even in a situation where the human eye judged that it was impossible to shoot from that angle, in the AI's calculations, the chance of hitting was over 90%. In the end, David defeated Goliath.

Heron Systems defeated Lockheed Martin in the finals with an overwhelming margin of 16 wins and 4 losses to become the champion. A small team of 30 people defeated a slow defense industry dinosaur with tens of thousands of engineers. This was an incident that showed that data learning ability can be more important than domain knowledge. The methodology for training AI was more decisive than the experience of building a fighter jet. Heron Systems' breakthrough was an event that proved that AI can go beyond human imitation and create a new grammar of victory that humans have not discovered through data and simulation.

And now, waiting before them was their final opponent, a human pilot.

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Chapter 8. Human vs. AI, 5-0

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Human vs. AI 5:0 The main event began on the afternoon of August 20, 2020, with the whole world watching the live broadcast on YouTube. The call sign of the pilot who represented the humans was Banger. A graduate of the U.S. Air Force Weapons School, he was a veteran of veterans with over 2,000 hours of F-16 flight time. Washington D.C. He was an active-duty fighter pilot in the Air National Guard, and although his full identity was not disclosed for operational security reasons, he was one of the top pilots in the U.S. Air Force. He was not only good at flying, but was also an instructor who studied and taught numerous tactics.

Banger put on a VR headset and sat in the simulator. The ADT VR system developed by the APL team is designed to provide pilots with information consistent with that provided to AI agents. In addition to traditional heads-up displays, VR headsets present special components to improve situational awareness of threats and relative locations. It was a fair fight. At least in terms of information. Banger watched the AIs play over the past few days and analyzed their patterns. Heron is strong in frontal attacks in the early stages. I will avoid that area and take it to a long game to induce a battle of energy. This was the human strategy.

This was a judgment based on thousands of hours of flying experience. The match lasted a total of 5 rounds. It started with neutral starting conditions at various altitudes. The ACE viewer provided a battle overview, showing the battle space and bangers from the F-16 pilot's perspective. "This is a huge leap forward," commented DARPA's Justin Mock, call sign Glock, as commentator. Round 1 has begun. The two aircraft started out as a neutral merge, crossing each other face to face. Normal human pilots compete in turns to catch each other's tail. As expected, Banger tried to avoid the Heron's direct fight. We lowered our altitude and turned.

But Heron's reaction was much faster than expected. It turned its nose at a speed that was difficult to track with the human eye and dug into the whitebait's blind spot. Immediately after crossing, the human suddenly turned his nose at an unexpected timing to secure the shooting angle. Banger was hit before he could even understand the situation. The first battle quickly ended in Heron's victory.

The commentators stuck their tongues. "The speed of AI response has completely destroyed the OODA loop." While humans observe and judge the situation, AI has already made up its mind and completed its actions. In rounds 2 and 3, Banger changed tactics. We attempted to take advantage of the fact that AI does not rely on vision like humans and has perfect state information. It attempted to deviate from the AI's prediction by making rapid maneuvers. It attempted to disrupt the AI by drastically changing altitude and maneuvering vertically. However, Heron responded as if he knew Banger's movements in advance.

No matter what maneuver the banger made, the nose of the arm responded immediately. It reacted in milliseconds, either diving inside the whitebait's turning radius or firing before the whitebait could even get into position to fire. Heron's autocannon fire hit Banger's fuselage without error. Banger could not hide his embarrassment. "Basic fighter jet maneuvers don't work." In rounds 4 and 5, Banger attempted an extreme low-altitude maneuver. We took the risk of ground collision and tried to lure the AI. We went down to 1,300 feet, about 400 meters. It was an altitude that gave humans the fear of crashing into the ground.

But there was no fear for AI. In the fifth engagement, Banger used aggressive out-of-plane maneuvers to survive the initial engagement and prolong the battle. But Heron did not waver. We coolly maintained our altitude and took advantage of the view of the whitebait from above. They pursued it tenaciously, and eventually caught the tail of the whitebait and shot it down. Final score 5-0. It was a complete defeat for humanity. What was more shocking was the content. Human pilots have never been able to land a single effective hit against AI. All the time had to be spent on evasive maneuvers, but even those were ultimately unsuccessful.

Banger came out of the simulator and was interviewed drenched in sweat. I spoke honestly about my shocking experience. "The standard things you were trained to do as a fighter pilot weren't working." He explained. "We're doing complex physics in a dynamic environment. I'm trying to work out angles, different approach speeds, airspeed differences, etc. to get into a position where I can fire weapons at enemy aircraft."

He was tongue-in-cheek about the Heron's aiming ability. "The Heron's ability to aim was superior to all others." He said that he tried to avoid the AI's fire by maneuvering, but the AI calculated his smallest movements and tenaciously maintained his aim. The ability to adjust at the nanosecond level and leverage complete state information between the two aircraft allowed for very precise control. Banger confessed that he was uncomfortable with the idea of the AI putting his aircraft in a position where it could collide with something else. "The same goes for high side strafing.

AI can exploit that." Aircraft were placed in positions that would be uncomfortable for humans, and shots were fired from angles that humans would not attempt. Colonel Animal analyzed the results. "The AI program's ability to fly accurately gave it the ability to ignore the flight safety rules that human air force pilots are trained for. That ultimately gave it an edge in simulated combat." Humans have rules they follow to stay safe. AI didn't have to follow those rules. The message of this 5-0 result was bigger than technology. The premise that humans are the best in air combat can be broken.

The breakdown comes from a decision-making gap, not an equipment gap. Once it's broken, it's difficult to get it back. Because AI learns tactics, not memorizes them. The reality of the shock felt by the veteran was the limit of cognitive load. Humans consume enormous amounts of mental energy while performing flight control, enemy search, tactical judgment, and communication simultaneously. But AI did all this in parallel and tirelessly. What humans read with intuition, AI reads with probability. And they did so with brutal consistency. The reason Banger was shocked was not because the sense he had spent his entire life learning was useless.

Because that feeling is no longer a decisive advantage. Humans are still superior. But the definition of excellence changes. But Banger did not despair. While acknowledging the capabilities of AI, he left important insights. "This is not the end. If we can get this technology on our side, we will be an unbeatable team on the battlefield." Glock, who was in charge of commentary, had the same thought. "We trust what works." The performance shown by AI was at a level that humans could not imitate. Rather than fearing AI's capabilities, pilots began to think about how reassuring it would be if such an AI were their wingman.

The showdown garnered over 440,000 views and was recognized as a game changer by the aerospace community and the Pentagon. said Dr. Tim Grayson, DARPA Director of Strategic Technologies. "These results show great promise for future airborne combat systems and concepts involving human-machine symbiosis." Alpha Dog Fight Trial rewrote the history of air combat. It has proven that AI is not simply an auxiliary tool, but can be a lethal combatant that surpasses humans. However, at the same time, AI has also revealed the limitations of being strong only under conditions of perfect information and a controlled environment called simulation.

The 5-0 scoreboard wasn't just a number. It was a foreshadowing of times to come and a stern warning message to human pilots. In the future, the value of pilots will shift from who controls better to who supervises and designs better. AI does the maneuvering, and humans design the missions, rules, and responsibilities. This is not a downgrade. It's a shift in roles. Now the challenge was to take this genius in a glass box into the wild and unpredictable real sky. Can what we learn in simulation be reproduced in reality? Can AI beat humans even in a world without perfect information? The journey to find the answer was about to begin.

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Chapter 9. ACE Program and X-62A VISTA: From Simulation to the Real Sky

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ACE Program and X-62A VISTA: From simulation to real skies One day in August 2020, aviation experts around the world were holding their breath in front of their computer screens. I was watching as Heron Systems' artificial intelligence defeated a human veteran pilot 5-0. But the test pilots at Edwards Air Force Base shook their heads. "It's a video game." Their cynicism was valid. The sky in the simulator is always clear. The wind blows according to mathematical formulas, sensors don't lie, and communication links don't break. The most important thing is that even if you make a mistake, you can just hit the reset button.

There, AI fights based on perfect information. You can determine the enemy's location, speed, and direction in milliseconds. But the actual battlefield is different. Noise falls like snow on the sensors, communication is cut off by enemy electronic warfare, and the atmosphere shakes the aircraft. Gravity acceleration, which does not exist in the virtual world, puts pressure on the pilot's neck, and falling does not mean game over, but death. The Defense Advanced Research Projects Agency, commonly known as DARPA, has moved to fill that gap. The ACE program launched in 2019, its full name is the Air Combat Evolution program.

The goals of this program go beyond simply having AI fly an airplane. The goal was to ensure that human pilots would trust the AI and have the ability to fight together as a team. DARPA has identified air combat as a "challenge problem." The calculation was that if trust could be built in air combat, where speed and uncertainty are extreme, other areas would become easier. The ACE program consisted of three phases: The first step was to validate and develop core competencies in a simulation environment over 18 months. The Alpha Dog Fight Trials were part of this phase.

The second step was to translate the algorithm into a small unmanned aerial vehicle by conducting 16 months of unmanned aerial vehicle flight testing.

The third step was testing on a real fighter-scale aircraft. And at the heart of this plan was one unique fighter plane. This is the X-62A VISTA. VISTA stands for Variable In-flight Simulator Test Aircraft. Translated, it means something like a variable flight simulator test aircraft. At first glance, it looks like an ordinary F-16D two-seat fighter. However, the inside of this aircraft is a completely different world. This oddball plane, created through a collaboration between Lockheed Martin's Skunk Works and Carlsplan, can mimic the flight characteristics of aircraft other than the F-16 simply by changing software settings.

If you want the control feel of an F-35, set it that way, and if you want to recreate the movement of an MQ-9 drone, change it that way. Just like a chameleon changes color depending on its surroundings, VISTA was able to change its identity in the sky. DARPA equipped this one-of-a-kind aircraft owned

by the U.S. Air Force Test Pilot School at Edwards Air Force Base with a system called SACS. System for Autonomous Control of Simulation, an autonomous control simulation system. This was an interface that allowed the AI agent to directly access the aircraft's flight control computer to control the control surfaces and engine power.

AI can now directly handle the control surfaces of wings and tails called ailerons, rudders, and elevators, as well as the thrust of jet engines. Of course, safety measures were also needed. It was impossible to hand over control of a fighter jet worth tens of billions of won to a newborn AI. The AI could have bugged and plummeted to the ground, or tried to maneuver beyond the limits of what the aircraft could withstand. For this purpose, a human safety pilot was seated in the back seat. If the AI attempted a dangerous maneuver or went out of control, this pilot could immediately intervene and take back control.

A safety envelope was set in the flight control computer, and software blocked the AI when it attempted to make an unreasonable maneuver exceeding 9G or rush to the ground. In December 2022, a historic flight took place over Edwards Air Force Base in California. From December 1 to 16, the X-62A conducted 12 flights piloted by AI agents. In total, I spent more than 17 hours in the sky. Learned through tens of millions of trials and errors in the simulator.

Those chunks of code controlled the thrust of the actual jet engine, handled the lift, and began to physically fly in the sky. This process was not always smooth. When the AI, which was perfect in the simulation, encountered turbulence in the real sky, it trembled slightly or had a delayed response due to sensor data delay. On some days, the AI was too passive, which was a problem, and on other days, it tried to maneuver beyond the limits of what the aircraft could tolerate, triggering a safety cutoff. However, the true value of testing using VISTA lies in repetition and mastery.

Typically, it takes several months to verify new fighter software. This is because the code needs to be modified, verified on the ground, cleared for flight, and then flown again. However, the ACE team updated the code daily through VISTA. If we discovered an AI error during a morning flight, we modified the coding during lunch, ran the simulation, and applied it immediately to the afternoon flight.

Instructors at the test flight school at Edwards Air Force Base testified that they “witnessed fixes that would previously have taken a year to be resolved in just one day.” Engineers were able to swap out autonomy algorithms on board the X-62A in minutes, and pilots were able to test different teams' AIs every few hours. In September 2023, the day has finally arrived. In the sky above Edwards Air Force Base, an AI-controlled X-62A and a human-controlled F-16 fighter jet engaged in a real-life dogfight. Imagine this. At an altitude of 600 meters, two fighter jets rush toward each other at a relative speed of 1,900 kilometers per hour.

The moment the distance between each other narrows to just 600 meters, the human pilot feels instinctive tension, but the AI calculates the optimal position without hesitation. It started out as a defensive maneuver, but soon developed into an offensive maneuver to chase each other. The climax of the battle was a high-angle nose-to-nose engagement where the two aircraft crossed each other face to face. This was no simple flight following a scripted flight. The two fighter planes

maneuvered furiously, intent on shooting each other down for real.

During the flight, the X-62A had human pilots in the front and rear seats, but they did not touch the controls. They monitor the AI's flight

He only served as a safety officer and prepared for emergencies. AI judged the situation and controlled the aircraft on its own without human intervention. Over the course of 21 test flights, the team modified more than 100,000 lines of flight-related software. The AI flew with greater precision, operated within the limits of safety regulations, and reacted faster thanks to the computer's faster observation-orientation-decision-action loop. While the human pilot attempted to maneuver for a follow-up shot but did not attempt a head-on or opportunistic shot when given the opportunity, the AI fired as quickly as possible.

This ultimately made the difference. The U.S. Air Force did not disclose the specific winner or loser of this confrontation for national security reasons. However, testimonies from those involved in the test suggest that the AI's performance was surprisingly stable. Chief test pilot Bill Gray said, "The X-62A proved that non-deterministic AI can be safely applied to aerospace systems by solving the very complex problem of dogfighting." From a pilot's perspective, this change is palpable. When fighting AI in a simulator, you are left with the feeling that your opponent is trapped within the rules of the game.

But when you move to the X-62A, AI is no longer just pixels and vectors. It's a multi-ton chunk of metal passing by me, and the vortices and angles of closure it creates could cause my aircraft to stall. Speed comes as a shock rather than a number, and G is felt on the neck bone rather than on the screen. Lt. Col. Ryan Heffron, DARPA ACE program manager, emphasized: "In all areas, research progresses only as fast as the tools allow. VISTA's recent upgrades enable rapid integration and safe testing of AI-based autonomy, making it a much more effective testbed.

This brings us at least a year closer to full-scale flight testing of AI-based autonomy." The message from the ACE program and the X-62A VISTA experiment is clear. If Alpha Dog Fight showed possibility, ACE created verifiable reality. The Turing Test of air combat is not just about whether you win or lose, but whether you can conduct the fight while passing real-world safety and reliability standards. The X-62A really steps on that threshold. It was the moment when the genius in the simulator was reborn as a warrior in the real world.

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Chapter 10. Secretary Kendall's Flight: Entrusting Weapon Release to an AI Pilot

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Secretary Kendall's Ride: Letting the AI Pilot Fire the Weapons The moment you sit in the cockpit, all arguments suddenly quiet down. It's easy to talk about autonomy and ethics in a conference room. When you close the canopy and roll out onto the tarmac, the horses gain all their weight again. Because now gravity, not concepts, answers. On May 2, 2024, an elderly man in his 70s stood on the hot runway at Edwards Air Force Base in California. It was Frank Kendall, Secretary of the Air Force. He was not just an administrator.

He served as an army officer during the Cold War and was a technocrat who worked as a defense technical engineer and acquisition specialist his entire life. The reason he came here was not simply to inspect. He decided to risk his life and climb into an AI-controlled fighter jet to determine the fate of his AI unmanned fighter program. The aircraft he boarded was the X-62A VISTA, which had previously undergone numerous tests. Secretary Kendall sat in the front seat, and a safety pilot sat in the back seat in case of an emergency. For this flight, Shield AI installed reinforcement learning-based artificial intelligence on the aircraft.

Shield AI was a company that acquired Heron Systems in 2021. This is Heron Systems, the creator of the AI that defeated the human pilot 5-0 in the 2020 Alpha Dog Fight. The autonomous agent on board was a direct descendant of the then winning AI. The canopy closed and the engine roared to life. Immediately after takeoff, Secretary Kendall had a historic moment. Control authority has been handed over to AI. "I had a button on the control panel and basically started automating it," he later explained.

As we entered the training area over Edwards Air Force Base, we were approached by a manned F-16 fighter jet acting as a virtual enemy aircraft. Secretary Kendall's X-62A immediately entered combat mode. The fight was on, but neither Secretary Kendall nor the safety pilot in the back seat had their hands on the controls or throttles. The aircraft circled violently on its own and maneuvered to catch the enemy plane's tail. The AI performed high mobility up to 5G with Secretary Kendall on board. This is the pressure that increases your body weight five times. 70s

It was quite a burden on the old man's body. Even under that pressure, the AI cool-headedly calculated the enemy's expected path and constantly twisted the aircraft to gain an advantageous position. Lightning maneuvers of more than 885 kilometers per hour followed. The two aircraft raced within about 300 meters, meeting each other almost head-on, twisting and turning to force the other into a vulnerable position. Proximity in heaven is not proximity in human relationships. At 300 meters, two planes are turning nose to nose, waiting for each other to make a mistake. This is a distance where a small error can lead to death.

In this situation, the sensation the passenger feels is not glamor but pressure. The body, not the equipment, is the first to say, "This is real." The AI cleverly made evasive maneuvers whenever the enemy's fire control radar attempted to target it, looking for an opportunity to counterattack. The F-16, piloted by a human pilot, attacked fiercely, but the X-62A's AI did not give up any slack. Rather, the AI gained the upper hand by counterattacking at a timing that was difficult for human pilots to predict. Secretary Kendall's expression was flushed when he returned to the base after an intense flight of about an hour.

He smiled as he climbed out of the cockpit. At a press conference held immediately after the flight, he made a statement that caught the world's attention. "We believe that what we have seen in flight is enough to entrust this still-learning AI with the ability to decide whether to fire weapons in a war." This remark immediately sparked controversy. Arms control experts and humanitarian groups are deeply concerned that AI could one day autonomously drop lethal bombs without additional human consultation.

"There are widespread and serious concerns about leaving life-and-death decisions to sensors and software," the International Committee of the Red Cross warned. But Kendall emphasized that the system will always have human oversight when weapons are used. "Not having it is a security risk. At this point, we have to have it."

From the pilot's perspective, firing a weapon isn't a one-button operation. Launching a weapon is a chain of responsibilities that includes tactics, identification, rules of engagement, friendly forces location, and the aftereffects of the type of ammunition. In dogfights, decisions to fire often have to be made within a second, but the material that goes into that second is messier than you might think. Sensors can be fooled, targets can be deceived, data links can be broken, and humans can misjudge. It's not that AI doesn't make misjudgments, but the types of misjudgments are different.

While humans shake with fatigue and fear, AI can show strange confidence outside of its learning distribution. So, leaving the firing of weapons to AI is not a question of whether the AI is smarter, but a question of whether we can seal that form of misjudgment with some kind of safety device. Kendall's ride demonstration also sent a powerful message to Congress and defense budget officials. The U.S. Air Force determined that the F-35 or next-generation fighter jets, which cost hundreds of billions of won each, could not handle China's volume offensive.

The solution to this is a manned and unmanned complex system that consists of a manned fighter and 3 to 5 AI unmanned fighters. The U.S. Air Force plans to deploy at least 1,000 AI unmanned fighter jets by 2028. An F-35 or a next-generation fighter jet carries several AI drones, leaving dangerous missions to the AI while humans command them from the rear. Kendall added: "This is a transformative moment. The potential of autonomous aerial warfare, imagined for decades, is now a reality.

In the not-too-distant future, there will be two types of Air Forces: those that adopt this technology, and those that do not and are defeated by them." Brett D'Arcy, Senior Vice President of Product at ShieldAI, explained: "We've proven how to get from the lab to a real airplane. We've demonstrated

how to not only get the technology there, but how our people can support the necessary compliance, testing and validation pieces.” According to him, the autonomy on board was not intended for civilian use. It wasn't built to fly from point A to point B. It was built to do something much more sophisticated.

I had to dynamically infer where the enemy was, what the enemy was doing, and how to position my airplane to address both safety and weapons effectiveness. VISTA's military operators say no other country in the world has an AI jet like this. It's a cycle where the software first learns with millions of data points in a simulator, then tests its conclusions during real flights, then feeds that real-world performance data back into the simulator, allowing the AI to learn more. China also has AI, but these tests are conducted outside of simulators.

There is no indication that they have found a way to run it. Like junior officers learning tactics for the first time, some lessons can only be learned in the air, VISTA's test pilots say. Chief test pilot Bill Gray's words sum it up: “It's all guesswork until you actually fly it. And the longer it takes to figure it out, the longer it will be before you have a useful system.” Since VISTA flew its first AI-controlled dogfight in September 2023, it has performed about two dozen similar flights.

But the program is learning so quickly from each engagement that some versions of the AI being tested at VISTA are already beating human pilots in air-to-air combat. The pilots at this base know that in some way they may be training their successors or shaping a future structure that will require fewer pilots. But they also say the U.S. doesn't want to face an adversary with AI-controlled aircraft in the skies if it doesn't have its own fleet. “We have to keep running, and we have to run fast,” Kendall said. To put it bluntly, the real message of this incident is not that AI fires weapons.

The incentive for the system to evolve toward AI firing weapons is too strong. Speed, cost, survivability. The battlefield has become too fast for humans to loop and make decisions every time, and the method of having humans directly control all launches in a combined manned and unmanned formation has limitations in scalability. The realistic picture of the future is usually like this. In peacetime and gray areas, human control is strengthened and AI operates around recommendations and alerts. In high-intensity wartime, humans set policies and red lines in advance, and AI expands its authority to engage under limited conditions.

In the final step, we move from saying that humans always press the button to designing conditions where humans do not have to press the button. What Kendall saw in the cockpit was the first page of that move. People may not be ready to read the page, but heaven is already moving on to the next chapter. In 1947, Chuck Yeager broke the speed of sound in the It was the day when a machine flew into the sky on its own without human help, competed with humans, and received a passing grade from the human leader. Now, the dominion of heaven is no longer solely for humans. The era of algorithmic aces has taken off from the runway.

Part 3. How AI Learns to Fight

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Chapter 11. Tens of Millions of Virtual Deaths

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Tens of millions of virtual deaths at an altitude of 25,000 feet. An F-16 controlled by AI suddenly dives in the virtual sky of the simulator. I turned towards the enemy plane, but lost speed too quickly. The aircraft stalls and plummets straight to the ground. The word “Shot Down” appears on the screen, and the simulation is reset. This AI just died. But a second later, it appears again in the same sky. And then it charges towards the enemy plane again. This time from a slightly different angle and at a slightly different timing. This process repeats millions of times a day.

It takes thousands of flight hours for a human pilot to become a veteran. After graduating from the Air Force Academy, completing basic flight training, receiving fighter jet type conversion training, and being assigned to an actual combat unit and working for several years, you can finally do your part. And the pilot can fly for at most 2,000 to 3,000 hours in his lifetime. This is because there are physical limitations, working period limitations, and above all, life limitations. Once you crash, that's it. But AI has no such limitations. In a virtual space, AI can die at any time and be reborn at any time.

Heron Systems' AI, which won the AlphaDogfight competition hosted by the U.S. Defense Advanced Research Projects Agency (DARPA) in August 2020, has fought approximately 4 billion virtual battles as of the time of the competition. This equates to approximately 31 years of flying experience for a human pilot. Ben Bell, engineer at Heron Systems, said: “Our AI has been trained to fight against 102 different agents, making it strong enough to not break down no matter what it encounters.” The principle of reinforcement learning is surprisingly simple. It's like a baby learning to walk.

No parent teaches a baby to “bend your knees at this angle and shift your center of gravity forward.” The baby just stands up and falls, and then stands up and falls again hundreds of times. Then, at some point, they take a step, and when their parents applaud, they realize, “Ah, this is the right thing to do.” It hurts when you fall, and you get praised when you walk. The same goes for reinforcement learning in AI.

When first thrown into a virtual world, the AI doesn't even know what an airplane is. You have no idea how to move the control stick or when to fire the missile. I just do random things. Turn the control stick to the left, pull the throttle, and press the gun button. Most of them crash or are shot down by the enemy. Whenever that happens, the system gives the AI a negative score. Conversely, if you catch the enemy's tail, succeed in strafing the enemy, or shoot down the enemy, you will receive plus points. AI has only one goal: to increase the sum of these scores as much as possible. The key here is the design of the reward function.

If you simply say “shoot down the enemy,” the AI may learn the kamikaze tactic of rushing around like crazy and then retreating. So engineers have to create very sophisticated compensation systems. You must shoot down the enemy but survive yourself, get extra points if you catch the enemy's tail (6

o'clock position), lose points if you waste energy with excessive maneuvers, and get a big penalty if you enter a civilian area. Lockheed Martin's Alpha Dog Fight team designed this compensation system with advice from a retired F-16 pilot. It's a pilot's decades of experience translated into formulas and weights.

In the Alpha Dog Fight finals, Heron Systems' AI defeated the human pilot "Banger" 5-0. There was one shocking scene. The AI fired an autocannon while facing the human directly. This maneuver is called the "Head-on Gunshot." Human pilots instinctively avoid these maneuvers for fear of collision. It is also prohibited in training regulations. However, through tens of millions of virtual deaths, AI found the answer on its own: "If I fire a precision shot 0.1 seconds before collision, I can shoot down the enemy before I die." This is not a tactic taught by humans. This is the winning equation that AI discovered after infinite trial and error.

This process is called "Curriculum Learning." If you are stuck with a veteran pilot from the beginning, the AI will not learn anything and will just keep dying. So at first you simply learn to maintain level flight. Next, learn how to aim at a stationary target. You develop your skills by meeting increasingly difficult opponents. In the final stage, you fight with yourself or your past self. This is called "Self-Play". The room used by AlphaGo when it conquered Baduk

It's like the law. The me of today destroys the winning strategy that I used yesterday, and the me of tomorrow uses that destruction strategy again, evolving infinitely. Ultimately, reinforcement learning begins with the "freedom to fail." For a real-life pilot, one failure means death. However, AI in the virtual world becomes immortal by dying tens of millions of times. AI condenses the experience that humans accumulate over a generation into a few days. Beings who have been trained in a world where the laws of time are different come down to reality. This is the real reason why Alpha Dog Fight's AI was able to overpower veteran pilots.

AI is not just about fast calculations. This is because through tens of millions of deaths, humans have accumulated an amount of experience that cannot be experienced in a lifetime.

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Chapter 12. Transferring Simulation Experience into Reality

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Transplanting the simulation experience into reality What would happen if the AI that was winning the virtual battle on the monitor screen was placed in the cockpit of a real F-16? Will we be able to rule the sky right away? The answer is "no". The Sky in the Simulation is mathematically perfect. The wind blows as calculated, the air density is uniform, and the engine is always 100 percent efficient. The sensor sends clear data without noise, and there is no delay in communication. But the reality is completely different. Gusty winds blow, clouds obscure the sensors, communication signals are cut off, and the aircraft vibrates inexplicably.

An AI that boasts a 100 percent win rate in simulation may crash on its first flight in real life. This gap is called the "Reality Gap." It is a gap between the virtual world and the real world. The technology that bridges this gap is Sim2Real, or "Simulation to Reality." This is a key challenge in the development of AI fighter jets, and only when this is solved can AI truly fight in the sky. Sim2Real's first strategy is to deliberately mess up the simulation environment.

It's a technique called "Domain Randomization." During training, the wind strength is randomly varied, the aircraft's center of gravity is slightly shaken, and the engine thrust is varied between 80 and 120 percent. Noise is intentionally mixed into sensor data and delay is added to communication. Rather than just training in sunny weather, we inject the simulation into stormy conditions, sensor failures, and engine loss. AI trained in this "messy" environment will perceive the real world as "just another noisy simulation." AI trained only in clean environments is embarrassed in real life.

However, AI trained in all kinds of chaos does not waver even in the face of uncertainty in reality. The second strategy is to continuously feed real-world data into the simulation. This is called a "Digital Twin". We collect real-time flight data from real fighter jets and update the virtual fighter model. The simulation model is constantly modified based on aerodynamic data, engine response speed, and aircraft vibration patterns obtained from actual flight tests. Then the virtual world becomes closer and closer to reality. And then we train the AI again in that sophisticated virtual world.

As this cycle repeats, AI becomes stronger in reality.

The U.S. Air Force is operating an experimental aircraft called the X-62A VISTA to verify this Sim2Real technology. This aircraft, a modified version of the F-16D, is designed so that AI can actually fly the aircraft. AI-controlled flight tests began over Edwards Air Force Base in December 2022. In the first 12 flights, the AI performed both close-quarters combat (dogfight) within cannon fire range and beyond visual range (BVR) scenarios. During more than 17 hours of autonomous flight, the aircraft optimized its performance while complying with real-world airspace restrictions. A historic moment has arrived in 2023.

The X-62A VISTA engaged in an actual air battle with a manned F-16 under AI control. This was the world's first "human vs. AI" real-life dogfight. In May 2024, U.S. Air Force Secretary Frank Kendall personally climbed into the cockpit of the X-62A. The top commander of the U.S. Air Force entrusted himself to a fighter jet piloted by AI. He said this after the flight: "I think we can leave the authority to fire weapons to AI." Of course, safety measures are thoroughly in place. A "Runtime Assurance" system monitors all AI actions in real time.

When the AI gives the command, "Turn right to 5G," the system checks that command every millisecond. If the AI's commands exceed the structural limits of the aircraft or lead to a trajectory that poses a risk of hitting the ground, the system immediately blocks AI's control and restores the aircraft to a safe state. The safety pilot in the back seat can also turn off AI and switch to manual control at any time. In fact, in all of the X-62A's test flights, not once did the safety pilot force the AI to turn off. Another challenge is computing power. The AI in the simulation can freely use the supercomputer resources of a huge server room.

However, space inside a real fighter jet is limited and power is limited. You can't have thousands of GPUs. Therefore, there is a need to lighten huge AI models so that they can fit into small chips. Heron Systems' Alpha Dogfight winning model was designed to be efficient enough to run on a single small Nvidia chip. This has big implications. Powerful yet lightweight AI is a prerequisite for actual deployment. Future AI fighters will know basic combat skills before sortie, but will evolve on the spot by understanding enemy patterns as they fight. This is called "Meta-Learning" or "Online Adaptation".

Rather than using the model learned at the factory, the state of the aircraft in flight

It's about detecting changes or changes in enemy tactics in real time and fine-tuning your neural network. Sim2Real is not just a process of installing software. This is the process where virtual intelligence takes on a physical body and learns the laws of reality. In robotics, this is called "embodiment." For AI to become a true warrior, it must leave the pristine skies of simulation and descend into the harsh skies of reality.

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Chapter 13. Sensor Fusion: Integrating Radar, EO/IR, and ESM Data

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Sensor fusion: Radar·EO/IR·ESM data integration The secret to winning an air battle is simple. Look first, shoot first. However, “seeing” is a more complicated matter than you might think. The human pilot's eyes can only see the sky outside the canopy. This is only effective on a clear day and when there are enemies within visible range. Modern air combat is decided hundreds of kilometers away. Radars detect the enemy, missiles are launched, and the enemy plane is shot down long before the enemy can be seen with the naked eye. This is called “Beyond Visual Range (BVR).” The problem is that no sensor is perfect. Let's take radar as an example.

Radar emits radio waves and detects reflected waves. No matter how far away the enemy is, you can know their location and speed when the radio waves that hit the metal surface bounce back. However, stealth fighters are designed to minimize radar reflection. So it doesn't really go under the radar. Additionally, because radar emits radio waves, it also reveals your location. If the enemy's ESM (electronic warfare support equipment) traces the radio waves back, the hunter may become the hunted. Electro-optical/infrared (EO/IR) sensors see the enemy in a different way.

It detects heat from the enemy aircraft's engines and heat from gas and air friction. It is stealthy as it does not emit radio waves. Even stealth aircraft cannot hide engine heat, so it can be picked up by IR sensors. However, its distance measurement accuracy is lower than that of radar, and it is vulnerable to clouds and bad weather. ESM passively listens to radio waves emitted by enemies. The moment the enemy radar is turned on, the frequency pattern is analyzed to determine the enemy's location and type. But it's no use if the enemy has their radar turned off. Each sensor has both advantages and disadvantages.

Radar knows the distance well but is vulnerable to stealth, IR is good at seeing heat but does not know the distance, and ESM knows the type of enemy but has difficulty in precise aiming. It is nearly impossible for a human pilot to mentally integrate data from all these sensors. You have to look at the radar screen, check the IR image, listen to the RWR (Radar Warning Receiver), and make a decision by combining all that information in a split second. This is the limit of human “cognitive load.” This is where the real power of AI is revealed. “Sensor Fusion”.

AI simultaneously analyzes and integrates data from radar, EO/IR, and ESM to create a complete situational diagram. The radar reports “object 50 kilometers ahead,” and the IR sensor reports “object 48 kilometers ahead.”

When a “circle detection” is reported, the AI determines whether it is the same enemy aircraft or two different objects. It corrects for slight errors in position and speed and combines them into a single “track”. This is called “data association”. The next step is to identify the enemy. It analyzes the radar

frequency pattern collected by the ESM. The first identification is made by saying, "This signal is the radar of a Russian Su-35". The enemy aircraft's speed measured by the radar and The F-35 Lightning II is the culmination of this sensor fusion technology.

The AN/APG-81 AESA radar, AN/AAQ-40 EOTS (Electro-Optical Targeting System), AN/AAQ-37 DAS (Distributed Aperture System), and AN/ASQ-239 electronic warfare equipment are mounted on the aircraft. The 360-degree image is displayed on the helmet display no matter where the pilot looks. When you look back, the AI fuses all of this sensor data into a single, unified picture of the battlefield on the pilot's helmet. What happens when an enemy tries to jam it? The human pilot is confused, but the AI cross-checks the ESM data and the IR image.

If there is no heat signature, the AI determines it is a "decoy" or an "illusion" and erases it from the screen. Even if the enemy tries to fool the IR sensor with flares, it can distinguish between real enemy aircraft and decoys by comparing them with radar data. FCAS and GCAP, a European 6th generation fighter aircraft project, are taking this one step further by sharing sensor information among all manned and unmanned aircraft in the squadron. It aims for "fusion".

The leading drone turns on the radar to detect the enemy (taking the risk of revealing its location), and the manned aircraft behind turns off the radar and receives the information and fires a missile. Although it is not visible to the sensors of the plane, it can target the enemy hidden behind the mountain using the data sent by the friendly drone. In the end, sensor fusion is a technology that clears the fog of war. The most scary thing in war is not the enemy. It is not knowing where the enemy is. Fighting in situations where you don't know what anti-personnel or armed forces are.

If you do this, no matter how good your weapon is, it will be of no use. AI's sensor fusion sheds light on the darkness of that ignorance. It filters out noise from the flood of sensor data, distinguishes between false targets, and provides a single, integrated picture that pilots can trust. This is the real power of 5th and 6th generation fighters. It's not stealth. It's fusion.

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Chapter 14. Target Detection, Tracking, and Identification: ATR and Multi-Target Tracking

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Target detection, tracking, and identification: ATR and multi-target tracking altitude of 25,000 feet. The sky beyond the canopy is bright blue. But beneath that calmness lurks a deadly tension. The radar warning receiver starts beeping. It's a sign that someone is watching me. Six green dots appeared on the cockpit's tactical display. You can't tell if it's an enemy, friend, or just a passing commercial aircraft. My heart is pounding. If one of these six dots is an enemy plane coming to kill me while flying at 1,000 kilometers per hour, I only have a few seconds left.

In the past, fighter pilots had to rely entirely on their eyes and senses for this moment. We called it 'Mk.1 Eyeball'. It means human eyes. Even if the radar detected something, the only way to know exactly what it was was to see it with your own eyes. The problem is that the enemy missile may have already been launched by then. The moment you see it with your own eyes, you die. This is the cruel reality of air combat. This is where ATR comes into play. ATR is short for 'Automatic Target Recognition'.

To put it simply, it is a technology where the machine finds the enemy on its own and tells you "that's an enemy" or "that's an ally." There is no need for people to stare at the radar screen with their eyes wide open. Artificial intelligence sees and judges on your behalf. At the core of the ATR system is a technology called deep learning. Deep learning is a method in which artificial intelligence learns patterns on its own by looking at millions of photos.

Just as a child can look at countless pictures of dogs and suddenly say, "That's a dog!", artificial intelligence also learns the shapes and characteristics of enemy tanks, enemy fighters, and enemy missile launchers. The shape of the turret, the angle of the wings, and the thermal pattern of the exhaust gases. I memorize these things over and over again. Let's take a look at how the ATR performs on the real battlefield. There is a device called Synthetic Aperture Radar (SAR). This radar can capture images of the ground through clouds, at night, and even when it is raining. However, the images sent by SAR are different from the photos we see.

It is a puzzling picture of gray and black mixed together. It would take even a trained analyst hours to decipher the picture. However, artificial intelligence provides an answer in 0.1 seconds. "Lidden in the shadows is a T-72 tank. The turret is rotated 15 degrees and the engine is on." The US Department of Defense's 'Project Maven' showed the world the power of this technology. In the past, analysts had to sift through thousands of hours of video taken by reconnaissance drones.

Yes. If you stare at the screen until your eyes are glued to it, you may lose concentration and miss important things. However, artificial intelligence does not get tired. It analyzes videos 24 hours a day, selects only suspicious scenes, and shows them to people. This allows analysts to focus only on the

decisions that really matter. This is why the F-35 Lightning II is called the 'ruler of the sky.' This fighter has an incredible ability called Sensor Fusion. Artificial intelligence combines all kinds of data coming from radar, infrared cameras, and electronic warfare equipment to create a single picture.

On the pilot's helmet display, enemy flags are displayed in a red box, and the aircraft type and armament status are also kindly written below it. "Su-35, estimated to be equipped with 4 air-to-air missiles." Pilots no longer have to rack their brains trying to decipher radar scopes. But what if the enemy is not just one? This is where multi-target tracking comes into play. This means multi-target tracking. In modern warfare, the enemy does not come alone. Dozens of drones are swarming like bees, and a real fighter is hiding among them. Some are bait, some are real threats.

The human brain has difficulty keeping track of more than three or four objects at a time. When twenty dots appear on the screen, my mind goes blank. While you're trying to decide which one to deal with first, enemy missiles start flying. Artificial intelligence is different. Hundreds of targets can be tracked simultaneously. Assign each target a unique number, calculate its speed and direction, and predict where it will go. It's like a monster with a thousand eyes. In July 2024, the U.S. Air Force launched a project called 'ATA-AI (Advanced Tracking Architecture Using AI)'.

This is a project to develop next-generation target tracking technology with a budget of 99 million dollars, or over 130 billion won in Korean money. This is to deal with threats that are difficult to detect, such as stealth aircraft, hypersonic weapons, and drone swarms. Imagine a drone swarm. Hundreds of small drones swarm like bees. The human eye cannot tell which one is a suicide drone and which one is simply a disruptor. However, artificial intelligence analyzes the flight patterns of each drone. "Numbers 1 through 80 are simple decoys. They have no heat signature and only fly in a straight line.

But numbers 81, 95, and 112 are different. They are doing evasive maneuvers and have infrared signals. These three are the real threat." Artificial intelligence performs this analysis in less than one second.

One of the core algorithms of this technology is the Kalman Filter. It is a mathematical formula developed in the 1960s that is used to predict the next location of a moving object. This is a time-honored technology that was also used in the navigation system of the Apollo spacecraft. Modern artificial intelligence goes one step further. By learning the enemy aircraft's past behavior patterns, it can even predict things like "This pilot likes to turn left" or "This type of aircraft tends to attack while lowering altitude." Lockheed Martin's Skunk Works is developing a missile avoidance system.

When an enemy missile comes in, it instantly knows which member of the squadron is targeting it and calculates the optimal evasive maneuver. In the past, pilots had to look at multiple displays to make decisions. Now, artificial intelligence compiles all that information and tells you, "Turn right to 5G right now!" China is not left behind in this competition. We are integrating a sophisticated electro-optical tracking system into the J-20 fighter jet and developing algorithms to detect US stealth aircraft, the F-22 and F-35. Attempts are also underway to neutralize stealth technology by combining quantum radar and artificial intelligence.

The European FCAS (Future Combat Aviation System) project pursues the concept of 'Combat Cloud'. All aircraft on the battlefield are connected to one huge network, and each person shares what they see in real time. When a drone detects an enemy that a manned fighter cannot see, information is immediately transmitted. It's like hundreds of eyes connected to one brain. Ultimately, the laws of air combat have not changed. Whoever looks first, shoots first, and kills first wins. What has changed is speed. There are biological limits to human judgment speed.

It takes at least a few hundred milliseconds for the eyes to see it, the brain to recognize it, and the hand to move. However, the computational speed of artificial intelligence is in microseconds, not milliseconds. The human said "Huh?" Meanwhile, the artificial intelligence had already identified the target and opened the missile seeker. However, this does not mean that humans are no longer needed. No matter how many targets a machine can detect and classify, the final decision remains with humans. What if artificial intelligence mistakes a civilian airliner for an enemy plane?

We need someone who can say, "No, that's not the enemy." A hunter who wields a powerful hunting dog called artificial intelligence. That is the role of the future fighter pilot.

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Chapter 15. Explainable AI (XAI)

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Explainable AI (XAI) July 3, 1988, Persian Gulf. The tragedy began in the Combat Information Center (CIC) of the U.S. Navy's Aegis cruiser USS Vincennes. An unidentified track appeared on the radar screen. The captain and crew were nervous. This is because military tensions with Iran were extremely high at the time. The computer system classified the track as an Iranian Air Force F-14 fighter jet. The captain ordered the missile launch. But it wasn't an F-14. Iran Air Flight 655 was a commercial airliner. All 290 passengers and crew died.

Later investigation revealed that the computer system displayed incorrect information and, in a state of extreme tension, the crew believed it. Why did this tragedy happen? The system at the time just said, "That's an F-14." They did not explain why they decided it was the F-14, how confident they were, or whether there were any other possibilities. The crew had no way to verify what the machine was saying. This is the 'black box' problem. A black box is a black box that cannot be seen inside. When you put in an input, you get an output, but you don't know what happens in between.

The same goes for modern deep learning artificial intelligence. Millions of parameters are complexly intertwined, and even developers are often unable to explain exactly why a conclusion was reached. For combat pilots, trust means life. If my wingman suddenly breaks out of formation and makes a sharp turn, I will grab the radio and yell. "Why are you doing this!" At that time, if the wingman responds, "We have confirmed a SAM (Surface-to-Air Missile) launch at 3 o'clock! We are evading!", I immediately understand and I also enter evasive maneuvers. Because I explained why. But what if the wingman is an artificial intelligence drone?

The guy suddenly rushes into the middle of the enemy lines. I don't see anything on my radar. I don't know if this is a genius tactic, a system error, or if I've been hacked. At that moment I panic. Incomprehensible behavior is indistinguishable from treason. In 2020, in DARPA's Alpha Dog Fight Trial, Heron Systems' artificial intelligence 'Falco' completely defeated the human pilot 'Banger' 5 to 0. The results were shocking. But it was also strange. Falco performed maneuvers that no human pilot would ever perform. He used the 'head-on' tactic of charging head-on toward the enemy plane and firing the machine cannon dozens of times per second.

I shook the control stick slightly. Banger said after the fight: "That guy's shooting skills are unbelievably accurate, but you can't predict why he's doing that maneuver or what he's going to do next." In a simulation, even if the artificial intelligence does something strange and crashes, you can just press the reset button. But on the actual battlefield? What if an artificial intelligence drone flying next to me suddenly launches a missile toward a civilian village? How do you know if it's hitting an enemy's camouflage point or if it's malfunctioning? XAI (eXplainable AI, explainable artificial intelligence) emerged to solve this problem.

This is a technology that explains “why” artificial intelligence made that decision in words that humans can understand. DARPA has had an XAI program in operation since 2016. Their goals are clear. “Create explainable models while maintaining high performance, and enable humans to understand, appropriately trust, and effectively manage AI partners.” Easier said than done, but difficult to realize. If the existing AI simply said, “This is an enemy tank. 97% probability,” XAI would say: “This is a T-90 tank. The basis for judgment is as follows. First, the shape of the turret is 95% consistent with the T-90’s database.

Second, the engine heat distribution captured by the infrared sensor shows the characteristics of a diesel engine. Third, the formation of the escort vehicles deployed around matches the Russian armored forces doctrine.” Only with this explanation can pilots verify the artificial intelligence’s judgment. If the AI identifies a target for the wrong reason (e.g. because of the shape of a tree’s shadow), the pilot may cancel the attack, saying “That stupid machine was wrong again.” In April 2025, the U.S. Air Force released ‘Doctrinal Document on Artificial Intelligence (AFDN 25-1)’.

The document states that military AI development should use “transparent and explainable algorithms” and conduct “regular audits and evaluations.” Military applications can only be built if data is accessible and understandable. The concept of trust calibration is also important. This means that you should not trust artificial intelligence too much or too little. If you believe too much, the Vincennes tragedy will repeat itself. If you don’t trust it too much, you can turn off or ignore artificial intelligence and not use it. Artificial intelligence must be honest about its level of certainty.

The human response should be different when you say, “This target has a 99% chance of being an enemy,” and when you say, “This target has a 60% chance of being an enemy. Identification is uncertain.”

French defense company Thales has launched the slogan ‘TrUE AI’. The goal is to create artificial intelligence that is transparent, understandable, and ethical. By making the decision-making process of artificial intelligence traceable, they are developing technology that can backtrack the thinking process of artificial intelligence, like analyzing an airplane’s black box when an accident occurs. The MQ-28 Ghost Bat unmanned aerial vehicle, which the Australian Air Force is developing with Boeing, also focuses on this problem.

When a manned fighter pilot entrusts a mission to his wingman, the Ghost Bat, the pilot must be able to see at a glance the status of the unmanned aircraft and whether the commands have been properly understood. We need an interface that turns complex data into intuitive pictures. In May 2024, U.S. Air Force Secretary Frank Kendall personally boarded the X-62A VISTA fighter jet piloted by artificial intelligence. Secretary Kendall was in the backseat while the plane performed dogfighting maneuvers at speeds exceeding 550 miles per hour (approximately 880 kilometers per hour).

After the flight, he said, “I think we can leave the decision to fire weapons to an artificial intelligence.” But this is a trust that only became possible after thousands of hours of simulations and testing, and after artificial intelligence was able to explain why it makes the maneuvers it does. XAI also has limitations. Additional computations are required to generate the description. When fighters have to

make millisecond decisions, they can't afford to waste time creating explanations. Also, explanations that are too complicated will confuse the pilot.

"The curvature of the turret shape is 0.73 and the standard deviation of the heat distribution is 2.4" makes sense only to engineers. The pilot needs to say "That's a tank, shoot!" There is also the threat of adversarial attacks. What if the enemy knows the weaknesses of our artificial intelligence? For example, if we notice that our AI is highly dependent on the turret shape, we can cover the tank with camouflage netting to distort the turret outline. You can also fool artificial intelligence by adding subtle patterns to images that are invisible to the human eye.

If XAI discloses the basis for artificial intelligence's judgments, it could mean informing the enemy of our weaknesses. Ethical issues also remain. Just because artificial intelligence provides explanations does not mean it is exempt from liability. If the artificial intelligence explains that "the target's heat signature pattern matches 94% of an enemy fighter jet," but in reality it was a civilian airliner, who is responsible? Are you a programmer who wrote code? Was it the pilot who pressed the fire button? Or is it the commander who decided to deploy artificial intelligence?

Both the International Committee of the Red Cross (ICRC) and the U.S. Department of Defense identify explainability as a key element in the development and use of autonomous weapons systems. The principle of "Meaningful Human Control" is emphasized. But will humans have time to intervene in the split-second of hypersonic missiles and hundreds of drones? Probably not.

At that time, we may have to delegate authority to artificial intelligence, saying, "You take care of it." So XAI is not just about answering real-time questions like "Explain why now?" Before deploying artificial intelligence, we test it in thousands of scenarios and verify in advance how it makes decisions in certain situations. The goal is to enable artificial intelligence to honestly say, "This situation is beyond the scope of what I have learned. You be the judge, human." As a fighter pilot, I love machines.

When the F-16's engines roar behind me and the fly-by-wire system accurately translates the slightest manipulation at my fingertips, I feel one with the machine. But that's because I understand the machine. Even if the engine sound is slightly strange, you will notice it. If the control's response is different from usual, you will feel it immediately. The same should be true for artificial intelligence. When we understand the thoughts of artificial intelligence and when it can explain its thoughts to us, we become a true 'team'.

At that time, I will be willing to let go of the control stick and take command while looking at the tactical screen displayed by artificial intelligence. Intelligence without explanation is indistinguishable from madness on the battlefield. You need a comrade in arms who can have your back, not a ghost in a black box. XAI is our effort to create those comrades.

Part 4. The Era of Loyal Wingmen

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Chapter 16. Manned-Unmanned Teaming (MUM-T): Human Leaders and AI Partners

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Manned and Unmanned Complex System (MUM-T): Experienced hundreds of sorties from the cockpit of the F-16 Viper with human leader and AI partner. On Wild Weasel missions charging at enemy SAM sites, my radar warning receiver was always beeping like crazy. As the smoke from the infrared missile passed by the canopy, the 9G force of gravity on my body crushed my lungs and narrowed my vision. At that moment I was completely alone. Even if I had a wingman, he was too busy protecting his own life, and in the end, all decisions were in my hands and eyes. But now the war in the sky is taking on a completely different look.

This concept, called MUM-T (Manned-Unmanned Teaming) in the military, is not simply about attaching a drone next to a manned aircraft. This is a revolution that will change the nature of combat. A single manned fighter teams up with multiple AI drones to surround and pressure the enemy like a pack of wolves chasing down their prey. Human pilots are no longer gladiators who fight alone. He becomes a commander in the sky. He is the one who plans tactics, gives orders, and judges whether or not to pull the trigger at critical moments. When the U.S. Army first began developing this concept, many were skeptical.

“How can a robot follow a fighter pilot?” But they were missing the point. The point of MUM-T is not for robots to fight like humans. The idea is to have robots take over jobs that humans don't want to do, or rather, jobs that humans shouldn't do. During the Wild Weasel mission, in order to find the enemy's air defense radar, I had to be caught by the enemy's radar first. The enemy's location was revealed only when he aimed at me, and then I was able to fire the HARM, an anti-radiation missile. To put it simply, I was the bait.

It was crazy rushing into enemy territory shouting “Shoot me!” and I felt like I had to update my will with every sortie. But in the MUM-T environment, there is no need for me to be the bait. The drone instead enters enemy territory, turns on its radar, and draws the enemy's attention. The moment the enemy turns on the shooting radar towards the drone, I detect its location from a safe distance and launch a missile. This is the Force Multiplier effect.

In November 2023, Lockheed Martin's Skunkworks tested this concept in practice. A pilot aboard a jet trainer, the L-39 Albatross, designated targets for two L-29 Delphins converted to unmanned aerial vehicles and gave an attack order. The drones performed their mission as ordered. In May of the same year, Boeing conducted aerial refueling tests with FA-18 Super Hornet and MQ-25 Stingray drones. The manned fighter pilot gave the unmanned aircraft a refueling command, and the drone matched its speed with the manned aircraft and delivered fuel stably. Something even more surprising will happen in 2025. In tests at the U.S.

Air Force Research Laboratory, F-16C and F-15E pilots each controlled two XQ-58A Valkyrie unmanned aerial vehicles simultaneously to conduct dogfight training. The scene where one human pilot commands four drones is a scene that could only be seen in science fiction movies in the past. But now it's a reality. There are several core technologies of MUM-T. AI-based swarm flight technology allows drones to fly in formation on their own. With mission assignment technology, the optimal role is automatically assigned to each drone.

There is command decision support technology that supports pilot decision-making, and there is automatic target identification technology that distinguishes friends from enemies. And data link technology that connects all of this in real time is essential. But there's more to it than technology. It's trust. I have always believed that a wingman who can have my back should be a comrade in arms with whom I have shared a drink and exchanged glances. What if the machine develops a bug and suddenly turns towards me? What if you zone out when you have to shoot an enemy? These concerns are voiced by all air forces considering MUM-T adoption.

Many pilots were shocked when an AI beat a veteran pilot 5-0 in DARPA's Alpha Dogfight competition in 2020. AI did not hesitate even in head-on confrontation situations that humans would instinctively avoid. Because machines are not afraid of death. That's why explainable AI, or XAI (Explainable AI) technology, is important. AI must be able to explain to humans why it made that judgment, so that humans can trust and follow that judgment. If I don't understand why my wingman is going there, I can't have his back. Looking at the situation in Korea, MUM-T is becoming a necessity rather than an option.

A decline in military strength due to low birth rates is an unavoidable reality. It takes billions of won and over a decade to train one skilled pilot. But you can just clone the AI pilot. KF-21 being developed by KAI

The linkage between Boramae and unmanned aerial vehicles is heading down this path. The day the KF-21 teams up with an unmanned aerial vehicle, the skies over the Korean Peninsula will be much more tightly guarded. In the past, medieval knights fought alone. Honor and courage were everything. However, with the advent of the musket, the era of knights came to an end. Now another turning point is approaching. Pilots are no longer the ones holding on to the stick and playing tail with the bandit. He becomes the commander of dozens of drones using a tablet and voice commands.

The romance may be reduced, but your chances of returning home alive will increase. I think that's more important.

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Chapter 17. Skyborg and Valkyrie: Low-Cost Attritable Unmanned Aircraft

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Skyborg and Valkyrie: Low-Cost Expendable Drones Let's be honest. Our fighter pilots are expensive. It's not a joke. The F-16 Viper I drove was expensive, but the F-22 Raptor and F-35 Lightning II that dominate the skies today are truly golden-plated machines. A single F-35 costs between \$80 million and \$100 million. Considering the value of the sensors, stealth coatings, engines, and pilots that go into it, the loss of one fighter jet is a national disaster. Even our enemies know this. So they will fire hundreds of cheap missiles to take out one expensive fighter jet.

The enemy will be smiling while we shoot down hundreds of dollars worth of drones with tens of millions of dollars worth of missiles. This asymmetric cost exchange ratio is not sustainable. This was the problem that plagued the U.S. Air Force. "We are fighting with weapons that are too expensive." The concept that emerged here is Low-Cost Attritable Aircraft. Simply put, the idea is to create "an airplane that won't hurt your stomach even if you lose it." And at the center of this revolution is the Skyborg program and the XQ-58A Valkyrie. First, we need to clear up any misunderstandings. Skyborg is not the name of a specific airplane.

It refers to the AI system developed by the U.S. Air Force, namely the Autonomy Core System. It is the same as the operating system of a smartphone. This AI brain is designed to autonomously fly whatever aircraft it is mounted on. Whether it's Kratos' drone, General Atomics' drone, or even a modified F-16 drone, planting this AI will allow it to fly on its own. The core of Skyborg is its open architecture. In the past, when building an airplane, software and hardware were one body. To upgrade, the plane had to be overhauled. But Sky Borg is different.

Just like installing a new app on your smartphone, new tactics or features can be added simply by updating the software. This means that the enemy missile evasion maneuvers learned today can be deployed to every drone in the world tomorrow morning. The perfect body to contain this Skyborg AI is Kratos' XQ-58A Valkyrie. Valkyrie. She is a demigod female warrior who appears in Norse mythology. The name comes from Valkyria, meaning one who chooses who will die in war. When I first saw this drone, I thought it looked like a sci-fi movie prop.

I thought it was. V-shaped tail wings with a sleek stealth shape. But what's really surprising is the way it takes off. The Valkyrie doesn't fly down the runway. It is launched with a rocket booster from a launch pad mounted on the back of a truck. When to land? Open the parachute and use the airbag to land. Do you know what this means? This means that even if the enemy destroys the runways of our air bases with ballistic missiles, the Valkyrie can be launched from the woods, highways, or behind container boxes at any time. The Achilles heel of the runway has been removed. A further evolution was revealed in April 2025.

Kratos announced a CTOL (Conventional Takeoff and Landing) version with fixed landing gear. This version can take off and land on regular runways and can still be launched with rocket boosters. This maximizes operational flexibility. On January 8, 2026, the U.S. Marine Corps announced that it had selected Northrop Grumman and Kratos to develop the Valkyrie as the first operational CCA. This is the moment when it transitions from an experimental prototype to an actual weapon. The price is amazing. It costs about \$2 million to \$4 million per unit. If you produce more than 100 units per year, it can be done for less than \$2 million.

You can buy 30 to 40 Valkyries with the money you pay for one F-35. According to Kratos officials, the company has the capacity to produce 250,500 Valkyries per year. This is an overwhelming volume strategy. The Valkyrie's performance doesn't match its cheap price. The maximum speed is Mach 0.86 and the range is over 3,000 nautical miles (about 5,500 km). The maximum altitude is 45,000 feet (about 13,700 m). The internal weapons bay has eight hardpoints that can accommodate JDAM bombs or small-diameter guided bombs (SDBs). The 2021 test successfully launched the ALTIUS-600 small drone from its internal weapons bay.

In 2023, an autonomous flight was performed for 3 hours using AI flight software developed by the U.S. Air Force Research Laboratory. Another milestone was reached in July 2025. F-16C and F-15E pilots each controlled two Valkyries simultaneously and performed a dogfight training scenario. This is a close test of the teamwork between humans and machines. What do these low-cost drones do on the battlefield? They escort manned fighter planes as loyal wingmen. But the method is different from the wingman we know.

First, they are sensor extenders. It goes tens of kilometers ahead of manned fighter jets and goes deep into enemy territory. When their sensors detect an enemy, that information is immediately relayed to the manned aircraft behind them. Manned aircraft can remain silent, aim at enemies, and fire missiles without the need to turn on radar. Second, they are weapons trucks. To maintain stealth performance, the F-35 or F-22 only carries missiles in the internal weapons bay. Payload capacity is limited. But what if unmanned aerial vehicles like Valkyrie follow with additional missiles? The problem of lack of firepower is solved immediately.

Third, they are scapegoats. When an enemy surface-to-air missile flies, it hits the missile instead of a manned fighter. Or, in order to confuse the enemy's air defense network, they may intentionally jump into the middle of the enemy's territory and launch an electronic warfare attack to oxidize the enemy. It's a mission that a human pilot would never be able to do, but for Valkyrie, it's the reason for her existence. In the Russian-Ukrainian war, we saw how low-cost drones trampled expensive tanks. The same thing will happen in heaven. The enemy will find himself in a dilemma.

Are you going to shoot down that cheap drone with an expensive anti-aircraft missile? Or will you ignore it and then be attacked? No matter what choice we make, the result will be our victory. Europe is also joining this trend. In 2025, Airbus will partner with Kratos to develop a version of the Valkyrie for the German Air Force. The goal is to electrify by 2029. The plan is to secure a stealth unmanned attack aircraft with a range of over 1,000 km.

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Chapter 18. The CCA Collaborative Combat Aircraft Project: The U.S. Air Force's 1,000-Drone Plan

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CCA Cooperative Fighter Project: 1,000 U.S. Air Force plans for 1,000 unmanned aerial vehicles. It's not just a number. This is a huge gamble and an expression of the U.S. Air Force's firm will to secure future air superiority. When Secretary of the Air Force Frank Kendall personally sat in the cockpit of the X-62A VISTA and flew with an AI pilot, he sent a clear message to the world. "CCA is not science fiction; it is the power of tomorrow." CCA (Collaborative Combat Aircraft) is a project to create a combat squadron that can actually operate by combining both the Skyborg program and the Valkyrie experiment described above. The U.S.

Air Force has put forward a blueprint to assign two CCAs to each of 200 Next-Generation Air Dominance Fighters (NGAD) and 300 F-35s, and operate a total of more than 1,000 AI unmanned fighters. Total inventory could double that number, to 2,000 units. Let's put these numbers into perspective. The 1,000 aircraft is more than the U.S. Air Force's F-22 Raptor, F-15E Strike Eagle, and A-10 Warthog combined. If fielded as planned, the CCA will be one of the most prolific assets in the U.S. Air Force by numbers. The U.S. Air Force plans to spend more than \$8.9 billion on the CCA program from fiscal years 2025 through fiscal 2029.

For fiscal year 2025, approximately \$1.4 billion has been allocated, including \$711.7 million in discretionary funds and \$678 million in mandatory funds. The fiscal year 2026 budget request includes \$111.4 million for research and development and \$15 million for procurement. This is not money for toys. It is an investment that will change the game of future warfare. Why is there such a rush? There is only one answer. It's China. China's anti-access/area denial (A2/AD) strategy focuses on preventing U.S. forces from approaching the Chinese mainland. They have built thousands of long-range missiles and dense air defenses.

The damage that would have to be sustained by breaching this defense wall with the current US Air Force power alone would be too great. Of the total 1,763 F-35As scheduled to be introduced by the U.S. Air Force, only about 400 are currently in stock, and the current purchase rate will not allow the entire planned quantity to be introduced before 2040. If CCA is deployed as planned, it can restore the combat power of the U.S. Air Force, which has weakened over the past 20 years.

On April 24, 2024, the U.S. Air Force eliminated Boeing, Lockheed Martin, and Northrop Grumman from the CCA Increment 1 competition. Instead, what took their place were Anduril, which has Silicon Valley DNA, and General Atomics, a powerhouse in unmanned aerial vehicles. Traditional fighter jet manufacturing companies have been pushed out. What does this mean? This means that the U.S. Air Force will no longer tolerate traditional development methods that are large, expensive, and time-consuming. On March 3, 2025, the U.S. Air Force designated General Atomics' design as YFQ-42A and Anduril's design as YFQ-44A.

In the Pentagon naming convention, Y stands for prototype, F stands for fighter, and Q stands for unmanned. A new category of unmanned fighter jets has been formalized. On August 27, 2025, the YFQ-42A took to the skies for flight testing. David Alexander, President of General Atomics, said, "This is an incredible achievement achieved in just over a year from contract signing to flight." The company applied the AI autonomous flight core technology it has accumulated over five years through the MQ-20 Avenger to the YFQ-42A. On October 31, 2025, Anduril's YFQ-44A also successfully made its first flight. Northrop Grumman didn't give up either.

On December 4, 2025, Project Talon was unveiled in Mojave, California. Learning from the experience of receiving high scores in technical performance but failing in price and productivity in the first stage of the CCA competition, we focused on lowering costs and increasing manufacturing speed. The number of parts was halved and the weight of the aircraft was reduced by approximately 450 kg. On December 22, 2025, the U.S. Air Force officially designated the aircraft YFQ-48A. A third unmanned fighter jet has appeared. CCA's price target is one-third to one-quarter of the price of the F-35, or \$25 to \$30 million per aircraft.

At this price, it should have stealth performance, high mobility, and AI autonomous flight capabilities. Does it seem impossible? But you have to do it. Secretary Kendall asserted, "We cannot win the war with China without CCA." What does it mean tactically for CCA to reach 1,000 units? Let's think about American football. The quarterback (manned fighter) is carrying the ball. Linemen and receivers (CCA) surround him. Some CCAs are jammers. It shoots out powerful electromagnetic waves to neutralize enemy radar. Some CCAs are shooters. Charge towards the enemy plane with a load of air-to-air missiles. Some CCAs are sensors.

Go deep into enemy territory and secretly collect information. Some CCAs are decoys. It lures the enemy's missiles and hits them instead.

Throughout all of this, the human pilot does not move the control stick. All you have to do is give instructions such as "Attack Formation A" or "Switch to Defense Mode" using a tablet or voice command. The autonomous flight AI mounted on CCA takes care of the rest. This grand plan is not just America's alone. The Royal Australian Air Force is developing the MQ-28 Ghost Bat with Boeing. In Europe, France, Germany, and Spain are developing remote carriers through their FCAS programs. India's HAL is developing the CATS Warrior, and Japan also announced the development of an unmanned wingman to be linked with the F-X fighter jet in 2021.

The Netherlands has signed a letter of intent to participate in the US CCA program. In December 2025, the U.S. Air Force signed concept development contracts with nine companies for CCA Phase 2 (Increment 2). Companies that were eliminated in stage 1 can also participate in the competition again. 100 to 150 units can be purchased in the first stage, and up to 2,350 units can be additionally introduced in the second stage. In May 2025, the U.S. Air Force announced Beale Air Force Base, California, as the preferred location for the CCA Aircraft Readiness Unit.

The location where the rapidly deployable CCA power will actually be deployed has been determined. The goal is to secure basic operating capability (IOC) by 2030. Many people ask: "So you don't need

a pilot anymore?” My answer is this. War is ultimately a battle of human will. Machines make calculations, but humans make decisions. It is still up to humans to authorize murder, deal with ethical dilemmas, and exercise intuition amidst unpredictable chaos. The CCA project is not a replacement for pilots. This is an armor that turns the pilot into Superman. I am not alone. I have a legion of 1,000 loyal machines behind me.

They do not complain, they are not afraid, and they are willing to sacrifice only for my victory. We are now at an inflection point in the history of air warfare. The invention of the jet engine, the emergence of missiles, the introduction of stealth technology... and now the era of artificial intelligence wingmen. Those who ride this flow will rule the sky, and those who reject it will be shot down. Enemies, brace yourselves. Now it's not just one wolf coming. A pack of wolves is coming. And those wolves' teeth are made of silicon and gunpowder.

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Chapter 19. General Atomics YFQ-42A and Anduril YFQ-44A Fury

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General Atomics YFQ-42A and Anduril YFQ-44A Fury It was at an airfield in California on August 27, 2025. There was a strange-looking aircraft standing at the end of the runway. There was no cockpit canopy. There were no windows. The aircraft, which looked like a winged dagger, started gliding down the runway with its jet engines roaring. Then it lifted its nose into the sky and took off. YFQ-42A. It was the first flight of the Cooperative Combat Aircraft (CCA) built by General Atomics. I've been at the controls of the F-16 Viper for over 20 years.

When I made a sharp turn over Iraq to avoid enemy anti-aircraft missiles, there was always a human wingman by my side. His breathing could be heard over the radio, and they flew through the sky, risking each other's lives. But now a machine has taken the wingman's place. A fearless partner of steel, without a drop of blood flowing. We need to start by looking at the name YFQ-42A. 'Y' stands for the production representative prototype. It's not a finished product yet. 'F' is Fighter. And 'Q' means uncrewed. This is the first time that the U.S. Air Force has given a 'fighter' designation to an unmanned aerial vehicle.

It's not just an alphabet prank. It is a declaration that unmanned aerial vehicles will be placed at the center of battle. It is a promise to give equal budget priority, operational priority, and development priority to fighter aircraft. You must first know about the company General Atomics. It is called the godfather of the unmanned aerial vehicle world. MQ-1 Predator and MQ-9 Reaper. You've probably heard these names. These are the same drones that delivered death from the sky to terrorists in the skies of the Middle East.

Over the past 30 years, we have delivered more than 1,200 unmanned aerial vehicles, and the flight time is close to 9 million hours. At every moment, somewhere on Earth, more than 50 General Atomics aircraft are flying in the sky. If it's a combat drone made by a company like this, you can have confidence that it will at least 'work properly'. The YFQ-42A evolved from a prototype called the XQ-67A. It was an aircraft that applied the concept of 'Offboard Sensing Station (OBSS)'. This is a project ordered by an Air Force research institute, and the core idea is the concept of 'Genus and Species'.

The idea is to keep the basic framework the same and change the nose, wings, and sensors depending on the mission. In terms of automobiles, sedans and SUVs are made from the same frame. Let me explain why this is important on the battlefield. Imagine you run out of parts at a forward base. If your reconnaissance drone and attack drone use different parts, you should have both in stock. But what if the basic parts are the same? Reduces nightmares for maintenance workers. The sighs of logistics managers

It is reduced by half. Wars are not won with bullets alone. The supply and demand of a single part or screw can determine victory or defeat. Looking at the appearance of the YFQ-42A, it is similar to, but different from, the XQ-67A. There is an air intake at the top of the fuselage, and the elongated body has slender wings. It is equipped with a V-shaped tail rotor and can carry two AIM-120 AMRAAM missiles in its internal weapons bay. To improve stealth performance, serrated edges were applied to the air intakes, a design seen on the B-2 stealth bomber.

David Alexander, President of General Atomics, said: "Thanks to our collaboration with the Air Force, we were able to build and fly the YFQ-42A in just over a year. This is an incredible achievement." The first flight was successful 16 months after signing the contract. Think back to the days when it took 20 years to develop a fighter jet. Consider how long it took for the F-35 to be first conceived and put into production. 16 months is a speed close to a miracle. The core of YFQ-42A's autonomous flight is based on data accumulated over more than five years.

The AI was trained through repeated flight tests using a jet drone called the MQ-20 Avenger owned by General Atomics. This Avenger is an aircraft that no other competitor has. AI grown on millions of hours of flight data. That's the brains of the YFQ-42A. Two months later, on October 31st, it was Halloween evening. Victorville, Southern California. Another monster took to the sky at Southern California Logistics Airport. YFQ-44A. It was a combat drone named 'Fury' created by Anduril Industries. Anduril is a completely different kind of company than General Atomics. Founder Palmer Luckey.

This young man's first creation was not a fighter jet, but a VR headset. Oculus Rift. This is the device that opened up the world of virtual reality. After selling the company to Facebook for billions of dollars, he entered the defense industry. A young man enters a meeting at the Ministry of Defense wearing shorts and slippers. Ethan, who laughs at the rules of existing defense companies. The company he created is Anduril. Fury's history dates back to the late 2010s. There was a small company called Blue Force Technologies. They created a 'virtual aggressor' drone used in US Air Force training.

This is a drone that plays the role of an enemy when our pilots train in air combat. Anduril acquired the company in 2023. And I created Fury.

Jason Levine, Senior Vice President of Air Superiority and Strike at Anduril said: "It took 556 days from blank design to first flight, faster than any major fighter program in recent history." 556 days. It's less than a year and a half. While existing defense companies were handing out design change documents, Enduril was already flying. The core of the Fury isn't the hardware. It's software. There is an operating system called 'Lattice'. It is a platform that connects all sensors and weapons on the battlefield. And AI runs on top of that. Levin explained it this way: "The YFQ-44A was not designed to be a remotely piloted aircraft.

From its first flight, and forevermore, it will fly semi-autonomously. There is no pilot behind the scenes manipulating the stick and throttles." Let me explain what it means. Existing drones are controlled remotely by a pilot on the ground holding the control stick. That's how the MQ-9 Reaper works. But Fury is different. With the push of a button, Fury taxis, takes off, and flies. You enter a mission plan,

and it executes it on its own. Landing is as easy as one button. Humans are 'on the loop', but not 'in the loop'. This means monitoring but not direct control. Let's take a look at Fury's performance. Maximum altitude of 50,000 feet.

Mach 0.95, almost the speed of sound. Up to 9G maneuverability is possible. 9G means pressing with a force equivalent to 9 times your own body weight. This is a load that could cause a human pilot to faint. But it doesn't matter to Fury. Blood doesn't rush to the head, and the vision doesn't go dark. Just maneuver. The engine is a Williams FJ44-4M turbofan. It produces 4,000 pounds of thrust. The maximum takeoff weight is approximately 2,270 kilograms. This is a family of engines used in business jets, and was chosen to ensure performance while lowering costs. Anduril is also obsessed with production speed.

We are building a facility called 'Arsenal-1' in Columbus, Ohio. It is 5 million square feet in size. We are planning to film Fury here. Levin said: "While waiting for Arsenal-1, we more than doubled our manufacturing speed. We made hundreds of adjustments at the design stage to increase productivity." Prototype production is scheduled to begin in the first half of 2026. So what do these two aircraft actually do? First, it acts as a bait. It catches the enemy's radar, attracts their attention, and attracts the enemy's surface-to-air missiles. While the enemy rains down missiles, the manned fighter jet safely escapes.

Second, it serves as a sensor truck. At an angle that a manned fighter cannot see

Find books and share that information through data links. Third, it acts as an armed carrier. Manned fighter jets stay outside the danger zone, while drones move inside and launch missiles. I'll be honest. All of these roles are things pilots don't want to do. Why? Because there is a high probability of dying. It enters the enemy's air defense network first, hits the enemy's missiles on its behalf, and performs dangerous missions on its behalf. This is now done by machines. This is because the human pilot's life is precious. The U.S. Air Force announced that it would deploy more than 1,000 CCAs.

Whether to buy the YFQ-42A, YFQ-44A, or both will be decided in fiscal year 2026. Until then, both aircraft will continue flight testing. Expand the flight envelope and verify system integration at Edwards Air Force Base and Nellis Air Force Base. Let us summarize the meaning of these two gases. The YFQ-42A is an experienced wolf. Based on 30 years of experience, we use reliability and modularity as our weapons. It can be modified depending on the mission and is advantageous for mass production. He is a loyal partner who quietly does what I need. The YFQ-44A Fury is a hungry coyote.

Armed with the speed of Silicon Valley and a software-first philosophy. Autonomy for takeoff and landing with the push of a button. Fast development cycle and low-cost mass production. We have ambitions to break the rules of the existing defense industry. This is what it feels like to look at these two from the cockpit. YFQ-42A is 'the flexible number you need to survive'. YFQ-44A is 'the aggressive companion you need to hit first'. Both assume the doctrine of one human pilot commanding two or three drones. The era of Top Gun is not over. However, Top Gun's wingmen are no longer only human. Pilots are changing from heroes to command nodes.

Victory or defeat will not be determined by a single act of God, but by dozens of reasonable sacrifices. That's uncomfortable? Air combat was originally an uncomfortable game.

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Chapter 20. Shield AI's X-BAT: A Runway-Free Game Changer in Air Combat

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Shield AI's X-BAT: A game changer in air combat without a runway What is a runway to a fighter pilot? It's a lifeline. At the same time, it is also a tomb. Because the enemy knows that. When a war begins, the first place to be bombed is the runway. It's long, flat, and shows up clearly in satellite photos. A few ballistic missiles can turn a runway into a honeycomb. If the runway is destroyed, the fighter plane cannot fly. No matter how expensive the F-22 or F-35 is, if it is tied to the ground, it is just scrap metal. Imagine a war scenario with China.

In the early stages of the war, Andersen Base in Guam, Kadena Base in Okinawa, and Osan Base in Korea were bombarded with ballistic missiles. There are huge potholes on every runway. The maintenance facility is on fire. The fuel tank explodes. Fighters that fail to take off are destroyed on the ground. An air force without a runway is not an air force. There is a company that is trying to turn this nightmare around. This is Shield AI. And the weapon they released is the X-BAT. It was October 21, 2025, in Washington D.C. Shield AI unveiled X-BAT at an event attended by military leaders, government officials, and defense industry figures.

Although it was a scale model, its shape was shocking. An aircraft standing on its tail. A stealth jet that takes off vertically and lands vertically. It is a combat drone that does not require a runway. This is a quote from Brandon Cheng, co-founder and president of Shield AI. "At SHIELD AI, we believe that the greatest victory is no war. To make that belief a reality, we are executing a simple yet ambitious master plan: to prove the value of autonomy, expand across domains, and redefine air power. X-BAT is the next step in that plan. Runway-less air power is the holy grail of deterrence." You must first get to know Brandon Cheng.

I am a former Navy SEAL. This is a warrior who kicked down the door of a dusty building in Afghanistan and wondered, "Why isn't there a smart robot next to me?" This is a company created by someone who knows the smell of blood on the battlefield. The starting point is different from desk-biting engineers. The shape of the X-BAT is bizarre. 'Cranked Kite' shaped wings. It has an overall length of 26 feet (about 8 meters), a wingspan of 39 feet (about 12 meters), and a height of 4.7 feet. It is half the size of the F-35. If you place three of them, they will take up less space than a single existing fighter jet.

How you take off is key. X-BAT stands vertically with its tail on the ground. When the engine catches fire, it soars into the sky like a rocket. Once it reaches a certain altitude, it leans in and switches to level flight. It reminds me of the ancient propeller plane XFY-1 Pogo. This is a method that the U.S. Navy experimented with and abandoned in the 1950s. Human pilots could not land looking backwards. But it doesn't matter to AI. There is no concept of top or bottom. There is only sensor data and vector calculations. The landing is even more impressive. When homing, the X-BAT raises its

nose in a movement similar to a cobra maneuver.

And it comes down from the tail. If you are lighter by consuming fuel and dropping weapons, you can land without afterburner. A recovery mechanism mounted on the trailer catches the aircraft and stops it. The complex guidance algorithm is an extension of proven technology from a small drone called the V-BAT. The engine is GE Aerospace's F110-GE-129. This is the same engine used in the F-15 and F-16. On November 5, 2025, GE Aerospace and Shield AI announced a partnership. This engine is equipped with AVEN (Axisymmetric Vectoring Exhaust Nozzle), an axisymmetric vector exhaust nozzle.

This is a thrust vectoring technology developed in the F-15 ACTIVE program in the late 1990s. The nozzle moves along three axes and changes the direction of thrust. It is the key to enabling both vertical takeoff and landing and high-mobility flight. This is an explanation from Armor Harris, Senior Vice President of Shield AI Aircraft Division. "The It enables projection and simplifies the kill chain." Range of over 2,000 nautical miles. This is much longer than the F-22's 590 nautical miles and the F-35A's 670 nautical miles. Maximum altitude of 50,000 feet. 4G operation possible.

Combining these numbers means that the X-BAT can keep pace with manned fighters. Slower drones fall behind in formation. Only fast drones can fight in the same rhythm. The brain of X-BAT is the Hivemind. This is the AI pilot software that Shield AI is proud of. We have already completed practical testing on a small drone called V-BAT. Since June 2024, more than 130 sorties have been flown in Ukraine. A Russian SA-11 Buk-M1 mobile air defense system was located in an environment rife with GPS jamming, and Ukrainian forces destroyed it with Heimas precision rockets.

Hivemind's true value is revealed in the absence of GPS. In modern warfare, enemies block GPS signals with powerful electronic warfare attacks. Most drones get lost when their GPS is lost. It either spins in place, returns to its programmed homing point, or simply falls. However, the aircraft equipped with the Hive Mind is different. Read the terrain with cameras and sensors. It's like a human pilot looking at a map and deciding, "There's a river there, there's a mountain here, so I'm here now." Even if communication is lost, operations continue. It also has armed capabilities. There are two internal weapon bays.

In the released video, you can see it equipped with the AIM-120 AMRAAM missile and the Navy's new AIM-174B Gunslinger ultra-long-range air-to-air missile. You can also attach larger armaments to external hardpoints. Reconnaissance, electronic warfare, air-to-air, air-to-ground. It is a platform that can fulfill a variety of roles. The price is estimated at around \$27 million per unit. It's a quarter of the size of the F-35. Of course, it is difficult to directly compare it to a full-fledged 5th generation fighter, but if deployed in large quantities, it can secure an economic advantage. Let's take a look at the schedule.

Vertical takeoff and landing testing is scheduled for fall 2026. Full flight testing and operational validation are planned for 2028. ShieldAI said it will announce additional production partners and engine supply partners in the coming weeks. Let us summarize the strategic meaning of X-BAT. Existing fighter jets are tied to runways. If the enemy destroys the runway, it's over. However, the

X-BAT launches from the trailer. You can fly anywhere: a clearing in the forest, a remote island, or the rocking deck of a ship. The enemy can no longer think, 'I only need to hit three air bases.' Potential launch sites expand into the thousands.

The Royal Navy has already expressed interest. In October 2025, the Navy issued a Request for Information (RFI) for 'Project VANQUISH'. This is a technology demonstration project for autonomous drones capable of sea-based takeoff and landing. It is scheduled to be completed by the end of 2026. Of course, there are challenges. Vertical takeoff and landing are structurally complex. A hell of heat, noise and maintenance follows. The vertical thrust design takes up space inside the airframe. A compromise is needed between payload, range, and stealth geometry.

As runway-less operations become possible, safety, maintenance quality, and ammunition handling on the ground become more challenging. This is because aerodrome-level procedures must be implemented outside of the aerodrome.

However, Shield AI believes that the risk can be offset by 'distributed survivability'. Power concentrated in one place is destroyed in one blow. Scattered power does not collapse easily. If dozens of X-BATs are distributed across multiple locations, it will be nearly impossible for the enemy to destroy them all. I am a pilot who stepped out of the F-16 cockpit. We know the importance of runways to our core. When the runway closes, sorties stop. Once the sorties stop, air superiority belongs to someone else. So we shed blood to protect the runway.

However, when a concept like X-BAT becomes a reality, the concept of a 'runway to protect' itself becomes blurred. Even if the enemy rains down missiles, we are already hovering somewhere else and landing somewhere else. General Atomics and Anduril were selected for the first phase of the U.S. Air Force's Coordinated Combat Aircraft (CCA) program. X-BAT couldn't fit in there. But there is step 2. Shield AI said it is already in discussions with customers. It's not just the Air Force. The Army and Navy are also showing interest. Allies such as Australia, the Netherlands and the UK are also taking note. I'll organize it.

The YFQ-42A and YFQ-44A are the first step toward elevating unmanned fighter aircraft to the center of power. X-BAT is an attempt to get the Air Force off the runway. For one, it changes how the squadron is structured. The other changes the way it unfolds. The conclusion is the same. War in the sky is no longer just a pilot's arm strength. It is a battle of networks, autonomy, and deployment capabilities. The X-BAT hasn't flown yet. The one released in October 2025 was a scale model. But that concept alone makes us redraw the map of the battlefield. Imagine the X-BAT rising vertically from the ashes on a day when the runway is on fire.

It is a nightmare for the enemy, but a hope for us. Where there is a runway, there is no need for a runway. That is the future that Shield AI dreams of.

Part 5. The Global Race to Develop AI Fighters When looking at the dark blue sky beyond the canopy at an altitude of 30,000 feet, the pilot feels lonely. At that moment, when your breath heats up inside the oxygen mask and the helmet presses down on your shoulders, you can only trust your own eyes

and trained instincts. For decades, fighter pilots have fought this lonely fight alone. But now a new presence is entering that solitude. A colleague who is neither tired nor fearful, made of silicon and algorithms rather than flesh and blood. The skies around the world have now become a silent battlefield. This competition between the United States, China, and Europe is not just a technology battle. It is a life-and-death gamble to determine who will dominate the air superiority of the next century and who will become the ruler of the skies. Just as the longbow ended the era of the spear and shield, and the machine gun relegated the cavalry charge to history, artificial intelligence is now rewriting the very grammar of aerial combat. This is not a story from the distant future. This is the reality that is happening above our heads right now.

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Chapter 21. United States: DARPA ACE, VENOM, and F-22/F-35 CCA Integration

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United States: DARPA ACE, VENOM, F-22/F-35 CCA integration In the summer of 2020, something unbelievable happened at the 'AlphaDogfight' competition hosted by the US Defense Advanced Research Projects Agency (DARPA). The artificial intelligence agent won 5-0 against a veteran F-16 instructor from the U.S. Air Force Weapons School. Although it was a virtual battle in a simulator, the resulting shock wave was as heavy as a real bomb. Even as the human pilot instinctively begins to take evasive maneuvers due to his survival instinct, the machine has already pulled the trigger. A difference of 0.1 seconds decided the winner. U.S.

Air Force Secretary Frank Kendall spoke bluntly about the results. "If it takes a human a fraction of a second to do something, AI reacts in microseconds. It's orders of magnitude. And that difference in time is what really determines victory or defeat." It was a cold but undeniable reality. But America's ambitions were not satisfied with victory in the simulator. DARPA has begun to take this technology to the real skies through its 'ACE (Air Combat Evolution)' program. A specially modified F-16 named X-62A VISTA served as the stage for the experiment.

VISTA stands for 'Variable Flight Simulator Test Aircraft' and is an aircraft modified to allow an AI agent to take the controls of a real fighter jet.

From December 2022 to September 2023, 21 test flights were conducted over Edwards Air Force Base in California. Over 100,000 lines of flight core software were modified, and the results were historic. In September 2023, the X-62A VISTA engaged in a live dogfight with another human-piloted F-16 under the control of an AI agent. In that dance of death, spinning at 1,200 miles per hour, the two fighters were only 2,000 feet apart. Although a safety pilot was on board the aircraft, they never had to press the emergency switch. The machine fought on its own and made its own decisions.

On May 2, 2024, Secretary Kendall personally climbed into the back seat of the X-62A VISTA. In front of him, an AI piloted the fighter jet. The minister later recalled this experience and described it as "a moment comparable to the Wright brothers' flight in 1903 or Chuck Yeager's breakthrough of the sound barrier in 1947." The owner of the sky has begun to change. The point of the ACE program is not simply to prove that "AI is faster than humans." The real goal is "trust." In a fighter jet flying at 800 miles per hour, the pilot must be able to trust the AI wingman next to him and have his back.

No matter how right AI chooses, if humans do not understand the choice, cooperation is impossible. ACE is an attempt to implement this "explainable AI" in a combat environment. 'Project VENOM' added to this. Venom stands for 'Viper Experimentation and Next-gen Operations Model' and is a project to transform active-duty F-16 fighter jets into 'flying AI laboratories.' The U.S. Air Force is converting six F-16s into AI test platforms to verify autonomous flight technology under conditions

identical to actual combat.

Algorithms that seem perfect in a simulator may perform differently in the face of real-world turbulence, weather changes, and communication delays. Venom is a testing ground to bridge this gap. The destination of all these technologies is CCA (Collaborative Combat Aircraft). The concept is simple. A squadron is formed by attaching one expensive manned stealth fighter, such as the F-22 Raptor or F-35 Lightning II, to two or three AI unmanned fighters that are inexpensive and can be mass-produced. Manned aircraft become 'quarter backs', and unmanned aircraft become 'receivers'.

When it's time to breach enemy air defenses, drones take on the dangerous mission. Become a decoy and consume the enemy's missiles, strike directly, or disrupt the enemy's radar with electronic warfare. Human pilots command from the rear with a view of the entire battlefield.

In April 2024, the U.S. Air Force selected Anduril and General Atomics to develop CCA Phase 1 (Increment 1). In March 2025, these prototypes were given the official names YFQ-44A and YFQ-42A, respectively. 'F' was added. It's an unmanned aerial vehicle, but it's a fighter jet. This alone shows that times have changed. On August 27, 2025, General Atomics' YFQ-42A successfully made its first flight at the California Proving Ground. Just two months later, on October 31, Anduril's YFQ-44A 'Fury' also took to the skies. From contract to first flight took less than two years. Assistant Secretary of the Air Force Troy E.

Maink declared that this achievement "proves that when we remove the barriers and focus on the warfighter, we can deliver warfighting capabilities with speed." The YFQ-42A is an aircraft based on General Atomics' 'Gambit' concept, and is an evolution of the design of the XQ-67A tester. It is equipped with a V-shaped tail, upper engine intake, and internal weapons bay to ensure stealth performance. The three-wheeled landing gear is designed to operate even on unprepared runways. Anduril's YFQ-44A took a different approach. It uses commercial business jet engines and its weapons are mounted on external hardpoints.

It is a choice that prioritizes cost reduction and fast production over stealth performance. Enduril's leadership emphasized, "It is a design that can be produced in a machine shop anywhere in the United States." The price of one CCA is estimated at \$20.5 million to \$27.5 million. It's about a quarter of the price of an F-35. The U.S. Air Force plans to secure 100 to 150 CCAs in Increment 1 and ultimately more than 1,000 CCAs. When the enemy fires a \$100 million missile, the United States throws a \$20 million drone. It's a war of economics. In November 2025, General Atomics made a decisive announcement at the Dubai Air Show.

The F-22 Raptor and MQ-20 Avenger were equipped with L3Harris' Panthera software-defined radio equipment and successfully verified their in-flight data link. This was the moment that proved that the manned and unmanned complex network at the heart of the CCA concept works in the real sky. On January 5, 2026, the U.S. Naval Air Warfare Center released a simulation in which F-35 pilots controlled multiple CCAs using touchscreen tablets. In the Joint Simulated Environment (JSE), F-35 pilots responded to complex threats with advanced communications systems and precision-guided missiles. This is no longer a conceptual study.

This is the stage where you establish actual tactical protocols and procedures.

The U.S. Air Force's vision is clear. The speed of the OODA loop (observation-judgment-decision-action) is taken from the limits of the nervous system of a single human being and expanded to the computational power of the entire squadron. The X-62A VISTA was the experimental blade, and CCA is the factory that mass produces and deploys the blade. The era of viewing a single fighter jet as a 'hero' is coming to an end. Now it's not the hero, it's the orchestra. Conductors are still human. However, machines are faster at reading sheet music and splitting beats. America has already accepted this uncomfortable truth.

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Chapter 22. China: GJ-11 Sharp Sword, Dark Sword, and J-20 Formation Operations

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China: GJ-11 Sharp Sword and Dark Sword, J-20 Squadron Operations Looking east, the red dragon has long since awakened. The People's Liberation Army Air Force of China is no longer an imitator of Western technology. They are forging their own path and, in some ways, eerily ahead of the West. Under the leadership of President Xi Jinping, China has come up with a new concept called 'Intelligentized Warfare'. The ambition is to go beyond mechanization and informatization and preempt the era in which artificial intelligence becomes the brains of war.

On November 11, 2025, to mark the 76th anniversary of the founding of the Chinese Air Force, the People's Liberation Army released a shocking video. The GJ-11 stealth unmanned fighter jet was seen flying in formation with the J-20 'Weilong' stealth fighter and the J-16D electronic fighter jet. In the video, the ground controller reported, "Weilong 01, Xuanlong 08 arrived at location 6," and the J-20 pilot responded, "Weilong 01 received, cooperation establishment with Xuanlong completed." This was the moment when the name 'Xuanlong'—meaning 'mysterious dragon'—was revealed as the new official code name for GJ-11.

The shock waves this video sent were more than just promotional material. China demonstrated to the world that it is actually operating a manned and unmanned combined combat system (MUM-T). The formation of the GJ-11 flying first and approaching the target, followed by the J-20 stealth fighter and the J-16D electronic fighter, showed that China was the first to implement a tactic that even the United States had not yet deployed in practice. GJ-11 'Sharp Sword' is a project that started at Shenyang Aircraft Design Research Institute in 2009, and is currently produced by Hongdu Aerospace Industrial Group.

Its first flight was successful in 2013, and it was first unveiled at the National Day military parade in 2019. This aircraft, which adopts a flying-wing shape, features a stealth design that extremely reduces the radar reflection area. The sleek silhouette with no vertical tail, surfaces covered with radar-absorbing material, and shielded exhaust suppress even infrared signals. GJ-11 reappeared at the military parade marking the 80th anniversary of the victory in the Anti-Japanese War held in Beijing in September 2025. This time there was a noticeable change. The folding wing hinges have been confirmed.

This was designed with carrier-based aircraft operations in mind. This interpretation is also supported by the fact that the insignia of the Chinese Navy's next-generation Type 076 amphibious assault ship 'Sichuan' includes a wing shape similar to that of the GJ-11. GJ-11 does not fight alone. Designed to be a 'loyal wingman' for the J-20. While the J-20 commands from the rear via encrypted datalink, the GJ-11 moves forward to scout, disrupt enemy air defenses, and, if necessary, strike directly. Dangerous missions are taken over by drones, while human pilots see the whole picture from a

relatively safe distance.

Military analyst Song Zhongping (Song Zhongping) analyzed the composition of this squadron, saying, "The squadron consisting of J-20, GJ-11, and J-16D is a perfect structure that combines stealth penetration, electromagnetic interference, and precision strike." The J-20 is responsible for stealth infiltration, the J-16D disrupts enemy radar and communications networks, and the GJ-11 extends the strike range. A 'coordinated combat triad' in which the three aircraft move as one organism is completed. This is why China developed the J-20S, a two-seater version of the J-20.

While the front-seat pilot focuses on flight and air-to-air combat, the rear-seat weapons controller takes on the role of 'drone herder', controlling the GJ-11 formation. It was reported that the J-20S entered operational service in mid-2025. Regardless of whether this is true or not, the direction is clear. A pilot is no longer someone who only holds the stick and the throttle, but becomes an aerial battlefield manager who connects and commands multiple sensors and multiple UAVs. And there is 'Dark Sword (Dark Sword)'. Unlike most UAVs that focus on subsonic reconnaissance or bombing, the Amgeom is designed as a supersonic aerial combat UAV.

The shape with delta wings and canards is designed to maximize maneuverability. Equipped with DSI (Diverterless Supersonic Inlet), supersonic cruising is possible without afterburner, and the maximum speed is estimated to reach Mach 2. A supersonic fighter jet that cannot be ridden by humans. We need to think about what this means. When human pilots exceed 9G, their vision narrows and they lose consciousness. However, Amgeom's AI can push the aircraft to 15G or 20G, which is the limit at which the aircraft cannot be broken. It is a monster that grabs its tail and fires missiles with high maneuverability that humans cannot endure.

If the Dark Sword were to be fielded, the rules of close aerial combat would have to be rewritten. However, cancer screening requires a cautious approach. Official comments have been sparse since it was last unveiled at the 2018 Zhuhai Air Show. Some analysts raise the possibility that Project Amgeom may have been replaced by another program, such as the FH-97A. But whether the dark sword is a present-day force or a concept from the past, China's ambition is clear. "An unmanned fighter jet capable of stealth, high speed, and air-to-air combat." The idea is to force unmanned aerial vehicles to fight for air supremacy that humans used to do.

China's strategy is based on 'Military-Civil Fusion'. The AI capabilities of tech giants like Baidu, Alibaba, and Tencent are flowing into the defense sector. Matters like data privacy and ethical regulation are ignored in favor of the party's goals. Vast amounts of data generated by 1.4 billion people are input into AI learning. While the West talks about "explainability" and "accountability," China focuses only on practicality.

The Chinese military's manned and unmanned complex tactics are not yet complete. Analyst Song Zhongping also admitted, "At present, the cooperative operation of GJ-11 and J-20 is at the training stage." According to a report from the Rand Institute in August 2025, the People's Liberation Army of China has conducted simulations of J-20s or J-16s leading up to 16 drones to attack enemy air defenses, but this is still at the level of theoretical doctrine modeling. The risk of command and control

disruption and weak data links in large-scale operations have not been resolved. But the direction is clear.

China is trying to make up for its qualitative inferiority with quantitative superiority and the ruthlessness of AI. When a U.S. Navy F-35C encounters a J-20 over the South China Sea, the J-20 will not be alone. GJ-11 squadrons connected by invisible data links may surround us like a pack of wolves. This is why we should fear China's AI rise. The dragon's claws come from an unseen source. Behind the mighty tip of the J-20 are hundreds of nameless fangs.

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Chapter 23. Europe: GCAP Tempest and FCAS, Two Sixth-Generation Projects

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Europe: GCAP Tempest and FCAS, two 6th generation projects The skies in Europe have always been complex. Airspace is tight, borders are short, and political memories are long. Nations that have been fighting each other for hundreds of years must now fly in the same formation. So Europe's sixth generation fighter is not just a technical project. The question “Who will be at the helm” comes first on the blueprint. As a result, Europe is now walking down two paths simultaneously. These are the Global Combat Air Program (GCAP) of the UK, Italy and Japan and the Future Combat Air System (FCAS) of France, Germany and Spain.

GCAP's roots are the UK's 'Tempest' project. First unveiled at the 2018 Farnborough Air Show, the Tempest was planned as the successor to the Eurofighter Typhoon. 'Team Tempest', comprised of BAE Systems, Rolls-Royce, Leonardo UK, and MBDA UK, formed a key industrial partnership. The UK has invested more than £2 billion in the project by 2025. In December 2022, a turning point has arrived. The 'Global Combat Aviation Program (GCAP)' was officially launched with the UK, Italy, and Japan agreeing to joint development. It is a combination of Tempest's core technology and Japan's next-generation fighter (F-X) project.

The three countries have set a goal of deploying sixth-generation fighter jets by 2035. GCAP is not simply a project to build 'one airplane'. It is an attempt to build a 'System of Systems'. Centered around a manned fighter, unmanned wingmen, a sensor network, and a combat cloud are connected as one. When a pilot spots an enemy, that information is immediately shared with drones, satellites, and ships. Even before the pilot gives a command, AI suggests the optimal response. In June 2025, GCAP's industrial joint venture 'Edgewing' was officially launched.

BAE Systems, Italy's Leonardo, and Japan Aviation Industry Promotion Corporation (JAIEC) each held a 33.3% stake. The headquarters was located in the UK, and the first CEO was from Italy. Unlike other international aviation projects that have collapsed in disputes over intellectual property rights, export regulations, and manufacturing responsibilities, GCAP has formal agreements in place that enable cross-border work on design and technology. The Tempest technology demonstrator is already in the assembly phase. The first flight is scheduled for 2027.

The simulator flight, which took place at BAE Systems' Wharton facility, exceeded 150 hours, and it is said that core system software was created in days rather than weeks through automatic coding technology. Rolls-Royce is developing an engine demonstrator with Italy's Avio Aero and Japan's IHI.

The requirements for the GCAP fighter jet are ambitious. According to RAF officials, the internal weapons storage capacity is twice that of the F-35A, and the target is a range that allows for a transatlantic flight using only internal fuel. This is not just a “better plane,” it's a “different plane.” On

December 26, 2025, the Japanese Ministry of Defense held the 11th meeting of the GCAP Development Promotion Committee and reaffirmed the 2035 field deployment schedule.

The meeting, chaired by Defense Minister Masahisa Miyazaki, reviewed budget allocations for fiscal year 2026 and the status of development of manned fighter jets and unmanned systems. For Japan, the meaning of GCAP is clear. The goal is to have a stealth fighter designed from the ground up to collaborate with unmanned wingmen, integrate weapons from allies, and maintain independent freedom in sensor and mission software upgrades. On November 25, 2025, ministers from the three countries held a decisive meeting. GCAP has transitioned from a political vision to an actionable program.

Government and industry are aligned behind a clear contract roadmap. There were reports that Canada was considering the GCAP as a follow-up fighter aircraft after the introduction of the F-35A, and Saudi Arabia also expressed its intention to participate. FCAS, on the other hand, is taking a different path. This project, led by France's Dassault, Germany's Airbus, and Spain, is aimed at a huge network rather than a single fighter aircraft, as its name suggests, 'Future Combat Aviation System'. Centered around the next-generation manned fighter (NGF), various unmanned aerial vehicles called 'Remote Carriers' and 'Combat Cloud' are integrated.

But FCAS is plagued by internal conflict. There are constant battles for leadership, intellectual property disputes, and work division issues between Dassault and Airbus. In September 2025, it was reported that Dassault had demanded an 80% share of work on the Next Generation Weapon System (NGWS), which Berlin strongly opposed. In December 2025, Dassault's CEO said he was "not sure if the project could continue." The future of this business, estimated to be worth 100 billion euros, has become uncertain.

German Defense Minister Boris Pistorius said he plans to make a decision by the end of the year, but even a ministerial meeting between France and Germany has not been scheduled. Some German industry figures privately say they would personally like to participate in the Tempest program, given its role in previous European fighter projects such as the Tornado and Typhoon. The possibility that Germany will abandon FCAS and join GCAP cannot be ruled out.

Europe's simultaneous pursuit of two projects is not romantic but an expression of anxiety. If you go all-in on one thing and it collapses politically, the future of air superiority is completely lost. Europe has two engines. However, if the two engines provide thrust in different directions, the fuselage will tear apart. This is why the debate arises: "Can Europe afford two 6th generation programs?" However, we should not underestimate Europe. Europe's strength is not 'integration' but 'experience'.

It has the combat aviation tradition of Rafale and Eurofighter Typhoon, electronic warfare, missiles, aero engines, and actual operational experience. The integrated sensor system being developed by Leonardo processes more than 10,000 times more data than existing radars. BAE Systems has an AI research center with a 90-year history. The GCAP fighter's AI monitors the pilot's vital signs in real time. If you lose consciousness due to high G-force or panic due to excessive information, AI immediately intervenes and takes control of the aircraft. This is not just an autopilot, but a 'virtual

co-pilot' that functions as the pilot's partner.

While the United States and China are already putting AI pilots in the skies and testing drone fleets, Europe is still stuck in the design and negotiation stages. The 2035 target is ambitious, but we may already be a generation behind by then. China's GJ-11 is taking to the skies alongside the J-20, and America's CCA is scheduled for production in 2028. But if GCAP is successful, it will have implications beyond just a new fighter jet. It is proof of a new model of international cooperation that maintains strategic autonomy while sharing sovereignty.

Just as the Tornado and Typhoon protected Europe during the Cold War, GCAP will be able to protect European skies in the mid-21st century. From a cockpit perspective, European pilots don't want fancy brochures. "When will I receive it, how reliable is it, and will the data link survive the first day of war?" Whether GCAP or FCAS, the questions that must ultimately be answered are the same. Stealth is basic, sensor fusion is basic, electronic warfare and cyber survivability are basic. The difference is 'who puts the basics into reality first?' It is a battle for the last pride of the Old Continent.

If Europe survives this race, it will not be a triumph of technological prowess alone. It will be a victory of political will and industrial cooperation. The world has now entered the era of 'algorithm dogfight'. The era in which pilot skills dominated is over, and an era has come where the quality of data and the speed of AI judgment determine victory or defeat. America's Dominant

Japan's technological prowess, China's frightening speed and state-led concentration, and Europe's sophisticated technological alliance. The winner of this three-way battle depends on who puts the smarter AI on top of a more trustworthy network. As a fighter pilot, I still trust human intuition and judgment. However, in order to avoid the missiles flying towards me from the sky and at the same time exploit the enemy's loophole, I absolutely need an AI wingman who can think faster and react faster than me. This is not a matter of choice, but of survival. The ruler of the skies may no longer be the best pilot.

You will be the one with the best algorithm. But it still has to be a human being directing the algorithm. Machines only calculate, they don't fight. War is a clash of wills. AI may be a great hunting dog, but we are the hunters with the guns. The moment we forget that, we will be eaten by machines.

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Chapter 24. South Korea: KF-21 Boramae and the NACS Next-Generation Air Combat System

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South Korea: KF-21 Boramae and NACS Next Generation Air Combat System 1991 Operation Desert Storm. I flew an F-16CG into Iraq's air defenses. The radar warning receiver let out an ear-piercing scream, and the lights on the instrument panel blinked frantically. At that time, I had a wingman next to me. It was a person. No one was sure whether the friend would come back alive. Now, 30 years later, a different type of airplane is warming up its engines on the runway in Sacheon, Gyeongsangnam-do. KF-21 Boramae. It is a supersonic fighter developed independently by Korea.

And soon, there will be machines, not people, sitting next to these fighter jets. Korea's story begins with cursed geopolitics. You can find out by unfolding the map. Giants surrounding a narrow peninsula. China to the west, Russia and North Korea to the north, and Japan to the east. To survive in this narrow land, you needed your own claws. This is not a knife borrowed from someone, but a blade that you forge yourself. In 2001, President Kim Dae-jung made the declaration at the Air Force Academy graduation ceremony. We will produce domestically produced fighter jets by 2015. Many people laughed at the time.

Even the United States has to spend decades and an astronomical amount of money to build a fighter jet, but Korea is doing it? They did not know the desperation of Koreans. July 19, 2022. Boramae cleared the runway at Sacheon Airport and took to the sky for the first time. And in January 2026, 1,600 flight tests were completed without a single accident. At the same time, Türkiye's KAAN, which was developing a fighter aircraft, only made two flights, and India's AMCA has not even flown a prototype yet. Korea did it. The real story of the KF-21 is not the aircraft itself. The future Korea envisions is bigger and scarier. NACS.

Next Air Combat System. The name may be complex, but the core is simple. The idea is to combine human-powered airplanes and AI-controlled drones into one team. KF-21 becomes the brains of this massive system. Pilots become commanders, and drones become loyal hounds. In July 2025, Korea Aerospace Industries (KAI) released a definitive video. A KF-21 flies in formation with four stealth drones. Pilots command drones through helmet displays

Lower it. You scout, you disrupt, you two strike with me. Drones go deep into enemy territory to neutralize air defenses, while manned aircraft launch long-range missiles from a safe distance. It's not just a simulation. This is a technology that is actually being developed. South Korea is developing a stealth drone called Stingray-X1. This drone, which is shaped like a wing without tail fins, is almost undetectable by enemy radar. Flight tests are scheduled to begin at the end of 2025, and a joint flight with the KF-21 is scheduled for early 2026. If all goes according to schedule, operational deployment will be completed by 2030.

There is a reason why Korea is so crazy about AI and drones. Population. The lowest birth rate in the world. The number of young people being sent to the military is decreasing every year. If there is a shortage of people, they must be filled with machines. This is not a matter of choice, but of survival. In June 2025, KAI pulled out another card. K-On Device AI Semiconductor. Even if an enemy disrupts communications, this semiconductor independently detects and determines the threat. Think of it as a tiny pilot inside a silicon chip. No fatigue, no fear.

Even in situations where a human pilot would lose his mind fighting G-forces, this AI coolly performs evasive maneuvers. The KF-21 will evolve into three versions. Block 1 is an early mass production type for air superiority missions. Block 2 is an improved ability that adds ground strike capabilities. And Block 3, aka KF-21EX, is a complete stealth aircraft equipped with an internal weapons bay. Materials that reduce the radar reflection area are applied and the ability to link with unmanned aerial vehicles is completed. The goal is 2039. There is one thing to point out here. Korea is making all of this with its own hands.

When the United States refused to transfer four key technologies, including AESA radar, infrared search and track, electro-optical targeting pod, and radio frequency jammer, Korea chose to develop its own. And I did it. Hanwha Systems created the AESA radar, and LIG Nex1 is responsible for the missile defense system. In May 2024, a live fire of the Me Tier long-range air-to-air missile was successfully conducted. The export outlook is also bright. The price per unit of KF-21 is approximately 80 million dollars. It's half the size of the F-35. Maintenance costs are also cheaper than Western competitors at \$14,000 per hour.

The Philippines, Poland, United Arab Emirates and Saudi Arabia are already showing interest. Indonesia participated as a joint development partner, and the UAE conducted test flights in Sacheon in 2025.

What Korea is selling is not just a fighter jet. It is a platform for future warfare. It is a complete ecosystem that combines fighter jets, unmanned aerial vehicles, AI semiconductors, and data links. Instead of having to buy and assemble parts from multiple countries, you can get them all from one country. This is Korea's competitiveness. Of course, there are challenges. The engine is still produced under license from GE in the United States, F414. Aero engines are the most difficult area in fighter aircraft development. Korea has begun developing its own engine, but there is a long way to go.

The reliability of AI algorithms, communication security between manned aircraft and unmanned aerial vehicles, and verification of autonomous judgment in a real-world environment are also issues that need to be solved. But something is clear. Korea no longer waits for technology from other countries. Boramae is not just a 4.5 generation fighter. It is the center of a huge combat ecosystem called NACS and is a game changer for the Northeast Asian skies in the 2030s. If a conflict occurs with North Korea or China, there will be dozens of AI drones flying behind the KF-21 in the sky, overwhelming the enemy's air defense network.

Like the gladius of ancient Rome or the longbow of the Middle Ages, weapons evolve with the times. KF-21 and NACS are 21st century swords forged on the Korean Peninsula. This is the heavy breathing of a country that has depended on the wings of other countries for over half a century. It is the roar of a beast that seeks to regain sovereignty over the sky.

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Chapter 25. Japan, Israel, and Turkiye: Emerging Powers in Autonomous Unmanned Aircraft

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Japan, Israel, and Turkiye: Emerging powers in autonomous drone development The order of the sky is being reorganized. For a long time, air superiority was the exclusive domain of the United States, Russia, and, more recently, China. They ruled the skies with huge budgets and decades of experience. However, with the invention of a new gunpowder called AI, the rules of the game are changing. Emerging powerhouses with small but sharp blades have emerged. Let's look at Japan first. Don't underestimate this country. They are the country that created Zero Sen during World War II.

Although the wings were broken after the defeat, the potential of aerospace technology still remains. In August 2025, Japan's Ministry of Defense released an important report. The plan is to develop collaborative UAVs that will operate alongside new fighter jets by 2035. Japan, along with the UK and Italy, is building a 6th generation fighter aircraft through the Global Combat Aviation Program (GCAP). But their real ambition lies in AI drones that fly alongside those fighter jets. Japan is an island country. The vast Pacific Ocean must be monitored.

However, the population is decreasing and the number of applicants to the Self-Defense Forces is decreasing. If we can't protect the sky with people, we have to use machines. There is no choice. The Japanese approach is as systematic and sophisticated as their culture. An experimental unmanned aerial vehicle developed by Subaru has been delivered to the Defense Acquisition Program Administration (ATLA). Technology is being tested that would allow a single pilot to remotely control multiple drones simultaneously. A prototype of a human-machine interface system is also being developed. Japan also joined hands with the United States.

Signed a contract with Boeing Japan to conduct simulation research on Royal Wingman drones such as the MQ-28 Ghost Bat. In 2026, the Air Self-Defense Force will observe Ghost Bat flight tests in Australia. Mitsubishi Heavy Industries is also developing two collaborative drone concepts of its own. The GCAP fighter is being designed from the ground up to command a team of unmanned aerial vehicles. Sensor fusion through AI-based battle cloud, 360-degree battlefield awareness through helmet-mounted display. It can carry twice the armament of the F-35A and aims to have a range that can cross the Atlantic Ocean without refueling.

The goal is deployment in 2035.

Japan's strengths lie in sensor and material technology. Their drones are more than just bomb carriers. Equipped with an infrared sensor and high-performance radar, it becomes the eyes in the sky to detect enemy stealth aircraft. Instead of armor, samurai are armed with semiconductors and algorithms. Now let's go to Israel. This small country is the king of drone technology. 1982 Bekaa

Valley air battle. Israel threw a drone as bait to turn on Syria's air defenses. The moment the radar sent out radio waves, an anti-radar missile flew and devastated the area. It was the beginning of modern air defense suppression operations.

For Israel, drones are not the future, but survival. The Heron and Hermes series have been monitoring the skies of the Middle East for decades. The Hermes 900 has an endurance of over 30 hours and reaches altitudes of 30,000 feet. It can carry a payload of 300kg and is equipped with electro-optical/infrared sensors, synthetic aperture radar, and electronic warfare equipment. The militaries of more than 50 countries operate Elbit Systems' unmanned aerial vehicles. But the real scary thing about Israel is their self-destructing drones (Loitering Munitions). See Harop. This thing flies like a missile but hovers over the target area.

When an enemy's radar radio wave is detected, the AI immediately corrects the trajectory and connects it to the radar antenna. What if the enemy turns off the radar? Use the camera to locate and destroy it. The machine finds its prey on its own, without the pilot having to press any buttons. Harop boasts an operational radius of 600 miles and an endurance of 6 hours. It has already been exported to India and Azerbaijan. In 2020, Azerbaijan deployed Harop into combat against Armenia. Israel's self-destructing drones are not simulators, but real-life predators.

In December 2025, the Iron Beam high-energy laser air defense system entered service with the Israel Defense Forces. AI analyzes the trajectory, speed, altitude, and type of the threat in real time and selects the optimal method between laser interception and missile interception. Each laser shot costs only a few dollars in electricity costs. Compare this to the tens of thousands of dollars a single Tamir missile from Iron Dome costs. Israel produces genius hackers and programmers in elite units such as Unit 8200. Their AI algorithms were trained in real-world training grounds: the Gaza Strip and Lebanon.

Technology to recognize the enemy's face, distinguish between civilians and enemies, and accurately penetrate through narrow window gaps. In 2025, Germany purchased Heron drones for almost 1 billion euros. Romania also signed a contract worth \$400 million with Elbit. Europe is quietly relying on Israeli drone technology.

Lastly is Türkiye. This country has changed the landscape of drone warfare. Even 10 years ago, no one would have thought that Türkiye would become an aviation powerhouse. But with the advent of the Bayrak Thar TB2, everything changed. During the Ukraine war, these drones turned Russian tanks into scrap metal. Deadly effect at an affordable price. This is a new grammar of drone warfare. But Türkiye's ambitions did not stop there. On November 29, 2025, history was made. Over Sinop, Black Sea coast. Bayraktar Kızılelma shoots down a jet-powered target drone. By using Gökdoğan beyond-visual-range air-to-air missiles.

This was the world's first incident in which an unmanned fighter jet shot down an aerial target with a BVR missile. Why is this important? For a long time, drones were used only for reconnaissance and ground strike. Fighting other planes in the sky was a man's domain. But Kızılelma broke down that boundary. The drone got into an air battle. During the test, Kızılelma flew in formation with five F-16s of

the Turkish Air Force. The MURAD AESA radar developed by Aselsan detected and tracked the target. The Gokdoan missile manufactured by TÜBİTAK-SAGE hit the target. Platforms, sensors, and weapons are all domestically produced in Türkiye.

This completes the independent kill chain. Kızılelma entered mass production in August 2025. Maximum takeoff weight of 8.5 tons, weapons payload of 1.5 tons. It has a combat radius of 500 nautical miles at altitudes of 25,000 to 30,000 feet. It has a stealth design and aims for supersonic flight. It is scheduled to serve as a loyal wingman along with Türkiye's 5th generation fighter KAAN. On December 31, 2025, a flight test equipped with the KARAT infrared search and track (IRST) system was also successful. It is a passive sensor that tracks targets using infrared light without using radar.

Since it does not emit radio waves to enemies, it does not reveal your location. TAI's ANKA-3 should also be noted. It is a stealth unmanned aerial vehicle in the shape of a flying wing without tail fins. The first flight was performed in December 2023, and the TOLUN guided bomb was launched from the internal weapons bay in January 2025.

The drop test was successful. Internal firing maintains a low radar cross-section until the moment of impact. We plan to expand its air-to-air role by installing Aselsan's MURAD radar. Türkiye has already signed drone export contracts with 37 countries. Pakistan, Azerbaijan, Indonesia, Saudi Arabia and Malaysia are showing interest. MUGEM, under construction by Türkiye, is the world's first dedicated drone aircraft carrier. Kızılelma and TB3 are also scheduled to operate from the TCG Anadolu landing ship. The key to the Türkiye method is quick execution.

Failure is quickly consumed by raising it to the sky before proving perfection with documentation. America's Let's summarize the three countries. Japan is writing new rules in the sky with systems and cooperation, Israel with actual data and algorithms, and Türkiye with mass production and bold implementation. What they had in common was that they were not only looking at the United States. They made their own weapons that were perfect for their battlefield. When I flew the F-16, I wanted my wingman to be human. Humans who can make eye contact, communicate with hand gestures, and share the fear of death.

However, looking at their technology now, my thoughts change. AI drones that do not know fatigue, do not feel fear, and have learned from tens of millions of virtual battles. These may be the true winners of future air battles. The sky is no longer Top Guns' exclusive stage. New warriors armed with chips, sensors, and code are coming. And Japan, Israel and Türkiye are at the forefront of that flow, refining the slings that threaten the giants.

Part 6. Sixth-Generation Fighters and Intelligent Formations

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Chapter 26. Sixth-Generation Fighters: Not a Platform, but a System

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6th generation fighter: a system, not a platform On March 21, 2025, an announcement at the White House in Washington D.C. rewrote the history of air combat. The U.S. Air Force selected Boeing as a key manned fighter contractor for the Next Generation Air Superiority (NGAD) program and gave the fighter the name F-47. At that moment, I heard the sound of an era coming to an end. In those days when we were soaked in adrenaline as we made sharp turns to avoid SA-6 missiles over Iraq, aerial combat was a battle of aircraft versus aircraft. Faster engines, sharper turns, radar that sees further. That was it.

But the 6th generation represented by the F-47 makes a mockery of such simple competition. If you ask the definition of a 6th generation fighter, the answer is simple. It's not an 'airplane'. It is a 'System of Systems'. The U.S. Air Force calls NGAD its "Family of Systems." Here, the manned fighter jet is just the 'Cornerstone' at the center of the family. Surrounding this fighter jet are dozens of Cooperative Fighters (CCA), or unmanned wingmen controlled by AI. Satellites overlook the battlefield, early warning aircraft track enemy movements, and Aegis ships at sea and radars on the ground pour in data.

All these assets are connected like a single neural network. According to the published specifications of the F-47, the combat radius exceeds 1,000 nautical miles (approximately 1,852 kilometers), and the maximum speed is over Mach 2. The operational radius is approximately 25 percent wider than that of the F-22 Raptor. In the vast battlefield called the Pacific, this range is a matter of survival. Relying on tankers exposes vulnerabilities to the enemy. But it's not these numbers that are truly scary. The essence of the F-47 is hidden from view.

Sitting in the cockpit of a 6th generation fighter plane means commanding the battlefield, not just flying the plane. When flying the F-16, I had to look at the radar scope, listen to the RWR (Radar Warning Receiver), listen to my wingman's radio, and put things together in my head. The cognitive load tested the limits of the human brain. If you make a mistake, it means death. But the 6th generation fighter's AI fuses all this data. Thermal images coming down from satellites, information collected by drones on the front lines, detection data from maritime Aegis ships, and patterns of electronic warfare signals. AI is

Match all the pieces to display on the pilot's helmet display: "Enemy plane at 3 o'clock, 120 kilometers, J-20, missile launch with 94 percent hit rate." Stealth technology is also evolving. If the F-22 and F-35 represent '5th generation stealth,' the 6th generation pursues 'Broadband Stealth.' Radar uses a variety of frequencies. X-band, S-band, low-frequency radar. Stealth aircraft of the past were invisible only in certain frequency bands. But the sixth-generation fighter aims to disappear like a shadow across all bands. The flying wing shape without vertical tail fins is confirmed in the already

released concept drawing.

Detection should also be avoided in the infrared spectrum. Heat emissions from the engine must be minimized and thermal management of the airframe surface must be optimized. The engine is also revolutionary. The Adaptive Cycle Engine changes configuration depending on flight conditions. When supersonic combat maneuvers are required, it produces explosive thrust like a turbojet, and when long-distance cruising is required, it maximizes fuel efficiency like a high-bypass turbofan. Pratt & Whitney and GE Aerospace are each developing engines under the Next Generation Adaptive Propulsion (NGAP) program.

These engines enable long-range forays into the Pacific theater. The U.S. Air Force said it plans to acquire at least 185 F-47s. This number is enough to replace the F-22 Raptor fleet one-to-one. But real power isn't measured by these numbers alone. The U.S. Air Force plans to acquire more than 1,000 Coordinated Combat Aircraft (CCA). An F-47 enters the battlefield accompanied by four or five CCAs. The pilot simply gives the command, "Clear out Area A." Then, the AI drones will spread out on their own and ravage the enemy lines. Drones such as General Atomics' YFQ-42A and Anduril's YFQ-44A Fury will take on this role.

China is also not sitting still. In December 2024, China test-flighted two 6th-generation prototypes. These aircraft, called the Chengdu J-36 and Shenyang J-50, are China's answer to America's NGAD. A third tailless stealth aircraft prototype was sighted in August 2025. China is accelerating drone warfare research and training under the direction of President Xi Jinping. Plans are also underway to upgrade the J-20 to a two-seat model so that the pilot sitting in the back seat can take on the role of a combat manager controlling the unmanned aerial vehicles. Europe is also moving.

The UK, Italy and Japan are jointly developing the Tempest under the Global Combat Aviation Program (GCAP). France, Germany, and Spain are pursuing FCAS projects centered on the Next Generation Fighter (NGF). s

Weden also commissioned Saab to study the feasibility of developing a 6th generation fighter in March 2024. The plan is to decide on the successor to the Gripen by 2031. The most fundamental characteristics of the 6th generation fighter aircraft are 'modularity' and 'software focus'. In the past, if you wanted to improve the performance of a fighter jet, you had to ship it to the factory and have it overhauled. However, like a smartphone, the 6th generation combat aircraft integrates new weapons, learns new enemy radar waveforms, and uses new tactics with just a software update.

An aircraft that evolves according to the speed of the battlefield. If the enemy deploys a new air defense system, our fighter jets will also be equipped with countermeasures within a few days. The design that allows switching between manned and unmanned as an option is also a feature of the 6th generation. The same aircraft can carry a pilot or leave it to AI. If it is a dangerous mission that requires entering the middle of the enemy's integrated air defense system, the commander can send the aircraft without a pilot on board. Machines do not suffer G-LOC (gravity-induced loss of consciousness).

It evades missiles with 9G and 10G maneuvers that humans cannot endure, and completes missions without emotional agitation. The conclusion is simple. 6th generation fighters are not 'lone wolves' who fight alone. It is the 'conductor of the orchestra' that connects and directs all assets on the battlefield. Ace pilots of the past were people who were good at turning the control stick. The aces of the future will be those who creatively command this system. In 2029, when the F-47 takes to the skies, the concept of air combat will have completely changed.

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Chapter 27. Swarming: Drone Tactics That Attack Like a Hive

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Swarm: A drone tactic that attacks like a swarm of bees. In the wild, it is not the tiger that takes down the lion. A swarm of thousands of bees. Lions can be killed with guns. But what about a swarm of bees? A few bullets aren't enough. When we destroyed an SA-3 missile site over Iraq, I was alone with one wingman. We trusted each other and entered at a precisely calculated angle. It was a lonely and risky gamble. But the sky of the future is different. Hundreds and thousands of drones move like one giant intelligence, choking the enemy. This is the fear of swarms and drone swarms.

In June 2025, China test-flighted a high-altitude, long-endurance 'drone carrier' called 'Jiu Tian'. With a wingspan of 25 meters, this massive drone can release 100 to 150 small loitering munition drones from two internal hangars in its fuselage. This is a drone factory floating in the sky. As soon as they are released, these drones form swarms and rush towards enemy radar sites, air defense batteries, and communications hubs. It's a nightmare for defenders. The core philosophy of swarm tactics is simple.

"I'll throw more targets at you than you have missiles." Enemy air defense systems, such as the Russian S-400 or the Chinese HQ-9, are powerful. But the number of interceptor missiles they have is limited. Hitting a small drone worth only a few million won with an interceptor missile costing billions of won per shot is an act of economic and tactical suicide. A 2025 report from the U.S. Department of Defense's Center for a New American Security (CNAS) soberly points out this point.

"In a war with China, the People's Liberation Army will likely launch large-scale heterogeneous salvos of missiles and drones, as well as swarms of autonomous drones, against U.S. forces. AI-based combat management and high-power microwave (HPM) weapons will be needed to counter this." Take the US Department of Defense's 'Replicator' initiative. The plan is to deploy thousands of low-cost autonomous unmanned systems on the battlefield by August 2025. \$500 million has been allocated for fiscal year 2024, and additional funding has been requested for fiscal year 2025.

We focus on Autonomous Collaborative Teaming (ACT) and Opportunistic Resilient Network Topology (ORIENT) techniques. This is a declaration of war that will cover the enemy's radar screen in white. In December 2025, the U.S. Central Command (CENTCOM) officially established Task Force Scorpion Strike (TFSS), the Middle East's first dedicated kamikaze drone squadron. And the U.S. Navy successfully launched its Low Cost Unmanned Combat Attack System (LUCAS) from the flight deck of the USS Santa Barbara in the Arabian Gulf. LUCAS is a loitering ammunition reverse engineered from Iran's Shahed-136. Like the multi-million dollar MQ-9 Reaper.

Instead of expensive platforms, the strategy is to deploy large quantities of low-cost drones that can be justified in swarm-based combat where high attrition rates are expected. The US Department of Defense's 'Drone Dominance' program aims to secure 300,000 low-cost drones starting in early 2026.

The goal is to reduce the cost per unit to \$5,000. The roles of swarm drones are divided. Some become decoys. It sends radio signals disguised as fighter jets to fool enemy radars and waste expensive interceptor missiles. A representative example is the American ADM-160 MALD. Some conduct electronic warfare (Jammer).

It jams radio waves that render enemy communication networks and radars unusable. Some function as sensors. Scatter across the battlefield to collect data. Scattered drones become a huge distributed radar that can even detect hidden enemy stealth aircraft. And some are strikers. It is loaded with explosives and crashes directly into the target. In January 2025, the Swedish military unveiled a new drone swarm program developed by Saab. The software allows one soldier to control up to 100 unmanned aerial systems simultaneously. Tested during Arctic Strike exercise in March 2025.

It was planned to demonstrate its ability to adapt to complex environments in reconnaissance, defense and payload delivery missions. China's swarm tactics research is more systematic. The People's Liberation Army is developing three flock warfare approaches: 'Goose Flock Warfare', 'Bee Swarm Warfare', and 'Mothership Warfare'. The wild goose swarm concept involves a swarm of multi-functional drones sequentially performing reconnaissance, electronic warfare, and kinetic strike, with a cumulative effect on the enemy. The swarm concept is that small drones saturate air defense networks, paralyzing their ability to respond.

The mother ship concept is for a large unmanned aerial vehicle to transport multiple small drones to enemy territory and then release them. Jiuten is the embodiment of this concept. In August 2025, the People's Liberation Army tested 'drone swarms and robot wolves' as human-machine cooperative combat teams in an urban warfare confrontation training simulation. And on September 3rd, a number of new unmanned platforms were unveiled at a military parade commemorating the victory in World War II.

One of them is an unnamed fighter-sized drone that is believed to represent the latest development in China's Cooperative Combat Aircraft (CCA), or 'loyal wingman'. The technologies that enable swarming are not romantic. Distributed decision-making (distributed AI), formation geometry without collisions and interference (deconvolution), mission logic maintained even when communications are lost (offline autonomy), position and time synchronization under electronic warfare, sensor fusion that is not fooled by enemy deception.

If any one of these five things fails, the colony becomes a swarm of flies crashing into each other rather than a swarm of bees.

But there are also criticisms. An article published in War on the Rocks in August 2025 sharply points out: "True drone swarms do not exist yet. China's drone light show? Not a swarm. Leader-follower autonomous team? Not a swarm. One person controlling 100 drones? Not a swarm." The real cluster is singular, not plural. A distributed intelligence system that adapts to situations in real time without a central controller, designated leader drone, or even an internet connection. That's a true colony. The U.S. defense industry has yet to provide such a distributed system. Nonetheless, the strategic value of swarms is clear.

The enemy's air defense network has a bottleneck called 'target processing ability'. Radars are limited in the number of targets they can track simultaneously. The channels through which interceptor missiles can engage simultaneously are limited. The chain of command must set priorities, and the moment those decisions falter, the whole thing falters. The swarm rips that bottleneck. The combination of 6th generation fighters and swarms makes a real difference. An F-47 enters the battlefield accompanied by dozens of CCAs. Instead of shooting directly, pilots unleash swarms of these deadly mechanical bees upon the heads of their enemies.

When the drone breaks down the door, the human delivers the final blow from the safety of the back. The romance of war has disappeared. Instead, the efficiency of killing was maximized. Admiral Samuel Paparo, commander of the U.S. Indo-Pacific Command, mentioned the 'Hellscape' strategy in preparation for a Chinese invasion of Taiwan. The idea is to use thousands of aerial and underwater drones as an initial interdiction action, giving time for other warships and fighter jets to arrive in the area.

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Chapter 28. The BVR Revolution: AI That Sees First and Shoots First

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Revolution in Beyond Visual Range (BVR): AI that sees first and shoots first Do you remember the scene in Top Gun where Maverick makes eye contact through the canopy right in front of the enemy plane? Forget it. That has now become history. In May 2025, an event occurred in the sky proving that fact. It was the largest air war between India and Pakistan since World War II. And the battle was not a close-quarters battle (dogfight) in which the two sides bit each other's tail and fired machine guns. The pilots did not see each other.

It was a Beyond Visual Range (BVR) engagement in which long-range missiles were exchanged at a distance of 100 to 150 kilometers. The Chinese-made PL-15 missile mounted on the Pakistan Air Force's J-10C and the European-made Mi Tier missile mounted on the Indian Air Force's Rafale clashed in combat for the first time. The PL-15 is a missile equipped with an Active Electronically Scanned Array (AESA) radar seeker and dual pulse rocket motors, and is said to have a range of 200 to 300 kilometers. Mid-route updates are possible via data link during flight, allowing tracking of even evasive targets.

Meteor maintains kinetic energy over long distances with its adjustable ramjet engine. It is designed to form a 'No-Escape Zone' so that once aimed, it cannot be avoided by maneuver. According to reports, during the encounter, a PL-15 fired by a Pakistani J-10C shot down an Indian Rafale. This battle clearly demonstrates the nature of BVR engagements. Rather than 'seeing' each other, pilots see stochastic shadows created by sensors. Both sides deployed airborne early warning and control systems (AWACS) to exchange real-time targeting data.

The flat terrain of the Punjab Plain and high-altitude AWACS support gave both sides a significant radar horizon advantage. Long-distance engagement was possible without being obscured by terrain. I also did BVR engagement training when flying the F-16. When a dot appeared on the radar, the biggest problem was identifying whether it was friend or foe (IFF). Non-Cooperative Target Identification (NCTR) technology existed, but it was not perfect. We often had to close within visual range, and at that point the advantage would disappear. However, with the intervention of AI, this uncertainty is decreasing.

AI mounted on 6th generation fighter aircraft seeks to solve the 'identification dilemma'. AI instantly detects the subtle tremors of radar reflected waves, infrared waves from engines, and the patterns (fingerprints) of radio waves flowing from electronic warfare equipment.

Analyze. "This is a Sukhoi-57, with two wingmen, and is currently armed with four air-to-air missiles." It takes less than 0.1 second to make this decision. What's even scarier is 'predictive shooting'. When AI outscored human veteran pilots 5-0 in DARPA's AlphaDogfight experiment in 2020, it wasn't just

reaction speed that the AI showed. It was a 'prediction'. Before the human pilot even moves the stick, the AI probabilistically calculates where the human pilot will move and fires the cannon in advance. When this technology is applied to BVR, it becomes terrifying.

Based on the enemy aircraft's current speed, altitude, aircraft type, and past tactical database, the AI predicts, "This enemy aircraft will make a sharp turn to the left in 3 seconds to avoid the missile." And it instructs the missile on the optimal interception path. Rather than blindly chasing after it, guard the corner of the road and then attack. This dramatically increases the effective range of the missile. In 2023, DARPA's Air Combat Evolution (ACE) program tested an AI-controlled dogfight on the X-62A VISTA fighter jet.

In the 12th flight test, the AI agent performed a one-on-one BVR engagement with a simulated enemy and even performed a within visual range (WVR) dogfighting maneuver. The AI flew at 1,200 miles per hour (approximately 1,931 kilometers per hour), matching the speed and agility of human pilots. "We actually pitted the X-62 against a manned F-16," said Lt. Col. Marianne Callen of the U.S. Air Force Flight Test School. They even engaged in head-on combat at a distance of 2,000 feet (approximately 610 meters) and approaching at 1,200 miles per hour. This was the first AI vs. human within visual range engagement in history.

AI has shown its own unique tactics. We used sensor data to make split-second decisions and adjust our tactics. Unlike human pilots, AI was able to quickly process large amounts of data. "The X-62A team demonstrated that cutting-edge machine learning-based autonomy can be safely used for dynamic combat maneuvers," said then-Secretary of the Air Force Frank Kendall. What DARPA and the Air Force are emphasizing is not the dogfight itself. Dogfighting is the most difficult flying style. If we teach AI this, it will become easier to fly other missions autonomously. In BVR engagements, AI's strength is even more overwhelming.

In the race to detect first, fire first, and shoot down first, AI is faster than humans. DARPA's Artificial Intelligence Reinforcements (AIR) program has the explicit goal of tactical autonomy in multi-aircraft BVR air warfare.

BVR becomes even more lethal when networked cooperative engagement (CEC) is added. Picture the situation. I turn off the radar and take a detour to the enemy's flank. My stealth unmanned wingman, far ahead, detects an enemy aircraft. That information is fed into my missile in real time. I fire the missile without even looking at the enemy or turning in their direction. You can also shoot backwards (High Off-Boresight). The launched missile is not guided by your fighter jet, but flies to the enemy based on information sent from a drone or satellite in space ahead.

From the enemy plane pilot's point of view, death suddenly rains down from the sky before the RWR sounds. He is shot down without even having a chance to say, "Where on earth did you shoot from?" This is 'silent assassination'. The U.S. AIM-260 Joint Advanced Tactical Missile (JATM) is being developed to counter the PL-15 threat. Range and performance are classified, but it aims to surpass the PL-15. Russia's KS-172 claims an engagement range of more than 400 kilometers and boasts a speed of more than Mach 5. The European Meteor uses adjustable ramjet propulsion to create an

extended no-avoidance zone. This is a BVR arms race.

Amidst all this technological advancement, there is one thing we must not forget. Who makes the decisions? When the AI says, "An enemy plane is certain, 99% chance of being shot down," who has the authority to pull the trigger? This is why DARPA's ACE program places 'Trust' and 'Human-Machine Collaboration' at its core. No matter how smart the system is, if humans don't trust it, they delay making decisions. Delay means loss in BVR. AI does not replace 'decisions', but sorts the candidates for decisions in real time. "If you fire now, your chance of hitting is 45%. If you get closer for 10 seconds and shoot, it's 85%.

However, if you get closer for 10 seconds, the enemy's chance of a counterattack increases from 20% to 60%." Humans can't do these calculations like they can breathe. AI does. The battlefield ultimately costs you that difference. The conclusion of the BVR revolution is simple and unpleasant. The ace pilots of the future are not the ones with the best flying skills. You will become someone who trusts and knows how to manage the best algorithms. The sky is getting wider, but the window for decisions is getting narrower. Whoever catches the narrow window first wins. The era of Top Gun is over.

The ruler of the skies is no longer the pilot with the best control. Whoever has the smartest algorithms and missiles that fire first from the greatest distance rules the skies.

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Chapter 29. Few Expensive Assets vs. Many Low-Cost Assets: The Strategic Value of Attritable Unmanned Aircraft

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High-priced few vs. low-priced many: The strategic value of expendable drones The moment you enter enemy airspace at an altitude of 30,000 feet, the cockpit is filled with tension. The radar warning receiver emits a sharp beep sound, signaling that an enemy surface-to-air missile has left the runway. My hands are sweating as I hold the F-16's control stick. At that moment, only one thought lingered in the pilot's mind. 'I have to return alive.' Losing both an aircraft worth tens of millions of dollars and a pilot with years of training at the same time would be a military disaster.

When we roamed the skies of Iraq and the Balkans, we were always outnumbered. The enemy's air defenses were dense, and each friendly fighter was as precious as gold. So for us, just coming back from the mission was a victory in itself. But the battlefield of the 21st century is different from then. The enemy no longer struggles to shoot down one of our expensive fighter jets. They fire hundreds of cheap missiles and wait for us to go bankrupt economically. This is the cruel math called 'cost exchange ratio'. The price of one F-35 Lightning II is well over \$100 million.

What if the enemy shoots down this aircraft with a missile worth 2 billion won? Tactically we may have fought well, but strategically the enemy is smiling. It's like capturing the queen in chess with just one pawn. A card was needed to turn this unfavorable mathematical formula on its head. That card is the 'expendable drone'. In English, it is called 'Attritable UAV', and it is necessary to think carefully about the meaning of this word. 'Consumable' does not mean that it is used and thrown away like toilet paper. The goal is to complete the mission and return, but even if it is shot down, the strategic impact is limited.

Like sacrificing a pawn in chess, it means something that is willing to be sacrificed to protect the king or queen. In April 2024, the U.S. Air Force selected Anduril and General Atomics to participate in the next phase of the Cooperative Combat Aircraft (CCA) program. The YFQ-44A Fury and YFQ-42A they are developing are produced at less than one-tenth the cost of the F-35. As of May 2025, these drones have completed ground testing and are scheduled for their first flight. The U.S. Air Force aims for operational deployment by 2029 and plans to invest \$8.9 billion over the next five years. Imagine this.

The F-35 I am on is heading towards enemy territory. But I'm not alone. There are four drones flying in formation in front of me. The moment the enemy's radar turns on, I give a command to UAV No. 1. "Go and jam that radar." Instructions are given to Unmanned Aerial Vehicle No. 2: "Become a decoy and lure the enemy's missiles."

Enemy air defense operators are confused. Five targets suddenly appear on the screen, but you can't tell which is the real threat. While they chase fake targets, expending expensive interceptor missiles, I

command the remaining drones to strike from the safety of the rear. Drones rush towards the enemy's radar station, and I neutralize the enemy's air defenses without lifting a finger. This tactic isn't entirely new. Similar examples can be found in history. On medieval battlefields, knights sat on horses wearing expensive armor. They were nobles, and losing one was like losing a fief.

However, there were many cheap spearmen standing in the front row of the battlefield. While they parried the enemy's arrows, the knight charged at the decisive moment. 6th generation air combat brings this principle back to the digital age. Australia's MQ-28 Ghost Bat is an example of this concept in action. It is 11.7 meters long, carries 500 kilograms of weapons, and flies in formation with the F/A-18 or F-35. As of 2025, more than 100 test flights have been completed, and air-to-air missile launch tests will soon begin. These unmanned aerial vehicles can autonomously conduct reconnaissance, electronic warfare, and even direct combat.

Türkiye's Bayraktar Kızılelma is also noteworthy. It has a speed of Mach 0.9 and is equipped with an internal weapons bay and external hardpoints. It will begin mass production in 2024, and is capable of fully autonomous takeoff and landing under satellite control. At one time, the only drone powers were the United States and Israel, but now many countries around the world are entering the race. China's movements cannot be ignored either. The GJ-11 attack stealth drone acts as a wingman for the J-20 fighter jet and directly challenges the U.S. military's CCA concept.

China is producing low-cost unmanned aerial vehicles based on its huge manufacturing infrastructure. The FH-97A carries eight air-to-air missiles and can take off without a runway thanks to a rocket booster. This breaks down the geographic constraints of the battlefield. The Republic of Korea Air Force is also joining this trend. The KF-21 Boramae two-seat version is being designed so that the rear-seat pilot can serve as a command aircraft to control a squadron of unmanned aerial vehicles. Aiming for the early 2030s, a system is being built where FA-50 light attack aircraft will control multiple expendable unmanned aerial vehicles.

The Stingray-X series of stealth drones being developed by Korean Air will become Korea's 'loyal wingman'. Why is this important? We must deal with North Korea's dense air defenses and massive conventional forces. Responding with only the expensive F-35 is not only inefficient but also dangerous. Early in the war, the enemy's room

The mission to suppress the air net is a gamble that risks the pilot's life. But what if an expendable drone goes in first? Our pilots can operate in a much safer environment. □□□□ □□□□□. Producing 250 to 500 XQ-58A Valkyries per year would bring the price per unit below \$2 million. The choice is between buying two F-35s or 100 Valkyries with the same budget. Two F-35s can only hit two points at the same time. 100 Valkyries can attack 50 locations simultaneously, or 10 units can be concentrated on 10 locations. The true power of swarm tactics lies here.

When dozens of targets appear on an enemy's radar screen, their air defenses are paralyzed. Precious time passes while you decide which one to shoot first. In the chaos, the real predator, the manned fighter, delivers the decisive blow. U.S. Air Force Chief of Staff General Kenneth Wilsbach said: CCA will confuse the enemy and contribute to securing public power. And the 2025 Air Force

report makes it clear: CCA is not a replacement for manned fighters, but a complement to them. Paired with 5th generation fighters, it will be the key to dominating the high-intensity battlefield of the future.

To be honest, as a pilot, it gives me a strange feeling knowing that my wingman is a machine and not a human. However, we must face the harsh reality of the battlefield. Enemy missiles are becoming more sophisticated, and our pilots and expensive fighter jets are limited. The drone does not sleep, is not afraid, and does not worry about its family. Expensive manned fighters become 'quarterbacks' and command the battlefield, while low-cost expendable drones become 'linebackers' and 'receivers' and throw themselves into the game. This is the way to overcome numerical inferiority, destroy the enemy's economy, and ultimately dominate the skies.

The old adage “quantity is its own kind of quality” is gaining new meaning in air combat in the AI era. □□□ □□□ □□ □□ □□□□. However, Top Gun no longer flies alone. He will become the commander of the Iron Legion and rule the skies.

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Chapter 30. Applying Generative AI: Automating Mission Planning, Maintenance, and Intelligence Analysis

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Application of generative AI: Automation of mission planning, maintenance, and information analysis
The movie only shows scenes of pilots making great maneuvers. But in reality, pilot life is 90% paperwork and 10% flying. Each hour of flight requires three or four hours of mission planning, reading thick intelligence reports, and combing through maintenance records. This process is not only tedious but also erodes the human spirit. 3 a.m. Operation briefing room. Coffee is always bitter, and fluorescent lights make people tired.

We plotted enemy air defenses on the map, calculated fuel consumption with a calculator, and drew lines on flight paths with a pen. The SA-6 missile has a range of 25 kilometers, the SA-3 has a range of 30 kilometers, and the early warning radar detection range is 150 kilometers. I had to crumple all these numbers into my head. And this was a single mission. What if it is a complex mission with multiple aircraft collaborating? One day wasn't enough. But generative AI is fundamentally changing this process. In March 2025, the US Defense Innovation Unit (DIU) announced a project called 'Thunderforge'.

This system, developed jointly by Scale AI, Andu Reel, and Microsoft, will first be deployed to the Indo-Pacific Command and European Command. When a commander inputs "Disable enemy air defenses at point A," the AI analyzes thousands of variables and creates dozens of operational scenarios in an instant. In an exercise called DASH-2, human staff created three play plans in 16 minutes, according to U.S. Army Maj. Gen. Robert Claude. On the other hand, AI came up with ten strategy plans in 8 seconds. This is 400 times faster than humans. But there was a catch. Some of the plans created by AI were not realistic.

Details such as which sensors work in what weather are ignored. This is a much more dangerous problem than the 'hallucination' of private chatbots. So what is important is the role of humans. AI creates drafts and presents options. But the final decision still has to be made by humans. A startup called Phyto AI understands this well. Founder Michael Mearn is a former Marine Corps intelligence officer. He experienced firsthand how it took days to put together an operational plan in Afghanistan. A method of assembling maps, tables, and documents using Microsoft Word and PowerPoint.

Pyto AI's system completes the 48-step mission analysis process in just a few minutes. But it doesn't talk like a chat bot. Soldiers use a familiar template structure, and AI agents collaborate to create plans. Once the draft is available, it is reviewed and revised by human planners. Confidence scores are also presented to help you know what information is certain and what information is uncertain. In December 2025, the U.S. Department of Defense took a historic step. Through a website called 'GenAI.mil', generative AI tools were provided to all 3 million military personnel, civil servants, and contractors.

Starting with Google's Mini, several advanced AI models will be added in the future. The U.S. Secretary of Defense declared: "The future of American warfare is here. It's called AI." Emil Michael, Chief Technology Officer at the Ministry of Defense, explained that this AI tool will be used in three areas: The first is routine administrative work. Things like document writing, research, and video analysis. The second is information analysis. We quickly process satellite photos, drone footage, and communications interception data to identify enemy intentions. Third is combat-related features.

Tasks such as logistics planning and combat simulation. The changes in maintenance are quiet but revolutionary. If a fighter jet is on the ground, it's just expensive scrap metal. The key to air power is utilization rate, that is, how often it can be in the sky. In the past, maintenance was done in a 'fix it when it breaks' method. A slightly better method was preventative maintenance, which involved replacing parts every 500 hours. But this is also inefficient. Some engines fail at 700 hours, while others easily last 1,200 hours. In December 2025, Lockheed Martin and Mantech announced an AI-based aircraft maintenance collaboration.

The system collects data in real time from sensors planted throughout the fighter jet. Engine temperature, vibration patterns, hydraulic pressure, fuel consumption rate. A modern military aircraft generates 500 gigabytes of sensor data per flight. It is impossible for humans to analyze all of this. AI finds patterns in data. "The vibration pattern of the No. 3 engine turbine blade is different from usual. There is a 78% chance of failure within 48 hours." This prediction becomes possible. According to Deloitte's 2024 report, AI-based predictive maintenance can reduce unplanned downtime by 50%.

The US Air Force's 'PANDA' system is already monitoring more than 3,000 aircraft. This system, jointly developed by C3 AI and Amazon Web Services, predicts component failures, locates needed parts, and optimizes maintenance schedules. Before the mechanic thinks, "I need a part?" the new part is already at the base.

What's even more surprising is that generative AI learns tens of thousands of pages of technical manuals. When a new mechanic wears augmented reality goggles, AI displays repair procedures on the screen in real time. "Loss this bolt first, then check that wiring." If there's anything you're stuck on, ask verbally. AI instantly finds and summarizes the relevant manual pages. This is like digitizing the know-how of veteran mechanics and passing it on to all mechanics. The role of generative AI in information analysis is even more decisive. The modern battlefield is flooded with information.

Satellite imagery, drone footage, communications interception, and even social media. There is an abundance of data, but the information we really need is buried within it. The director of the National Geospatial-Intelligence Agency (NGA) said AI-generated information was now being circulated "without human hands." AI performs real-time image processing and multi-sensor fusion. The battlefield situation is reconstructed in 3D by integrating images from multiple drones and satellites. "12 new armored vehicles, coordinates X-Y, direction of movement northeast, speed 40 kilometers per hour." This information is relayed to the pilot in real time.

AI can distinguish between toy trucks and real military trucks, and distinguish between decoys and real radar. The war in Ukraine demonstrates the practical use of this technology. Ukrainian drone

developers have equipped small drones with simplified AI algorithms. The drone guides itself the last few hundred meters to the target. At the back, high-capacity AI models analyze massive amounts of data collected from wire sensors. This 'back and forth collaboration' approach is a model the US military is also exploring. Why is this important? While flying the F-16, I had to monitor dozens of systems simultaneously.

Radar, armament, fuel, navigation, communications, threat warning. Your head tracks the enemy plane, your hands are on the controls, and your eyes are scanning the instrument panel. The cognitive load is extreme. Generative AI alleviates this burden. "What is the most threatening target?" "15 kilometers at 5 o'clock." In two words, you'll have the information you need to make your decision. There are also concerns. The problem is that AI can cause hallucinations. You may report an enemy that isn't there, or you may miss an important threat.

One U.S. military reservist said that while using GenAI.mil, he experienced "AI slop," or generic, low-quality output. It contained no doctrinal terms and required a lot of polishing. Another concern is data leakage. Users may input too much context to get a better answer. Tactics, confidentiality, planning details.

So experts emphasize. Thinking about problems and writing documents with a chatbot will not help you win the war. There are no AI systems released publicly that will provide a real military advantage. It has been in development for several years and will be deployed in a much more sophisticated form. South Korea has also begun developing AI for defense generation. Since security-critical military information cannot be passed on to an external server, it is essential to build our own AI model in the defense internal network.

We need a Korean-style defense AI that understands the nuances of the Korean language and our military's unique doctrine and operational environment. We must learn to fight together with the 'Silicon Staff'. It is still up to humans to filter out the hallucinations of their output, assume ethical responsibility, and make the final decision. The efficiencies provided by generative AI across the three pillars of warfare – mission planning, maintenance, and intelligence analysis – will make it an invisible weapon just as powerful as stealth capabilities or advanced weapons. The era of preparing for war with Excel files and PowerPoint is over.

The war of the future will be algorithm versus algorithm. We live in an era where the role of engineers managing AI servers in underground bunkers is becoming as important as the pilots sitting in the cockpit of a fighter jet. That is what 6th generation national defense looks like.

Part 7. Ethics and Law in Algorithmic War

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Chapter 31. The LAWS Debate: Who Pulls the Trigger?

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Autonomous Weapons (LAWS) Debate: Who pulls the trigger? Altitude 30,000 feet, speed Mach 1.2. Outside the canopy it is pitch black, and inside the cockpit the Radar Warning Receiver (RWR) squeaks non-stop. Enemy surface-to-air missile radar bit me. At this moment my finger is on the red button on the control stick. This is the weapon fire button. The cold feel of that gold. My heart is beating like crazy. At this time I ask: Should I pull this trigger? Is the target right? Are there any civilians? Are our troops safe? Hundreds of training sessions and actual battles help me make better decisions. And I decide. firing.

The missile kicks off the rail and flies away. Whatever the outcome, the responsibility is mine. That was the rule I followed for 20 years as a fighter pilot. But now that rule is being shaken. Machines called LAWS (Lethal Autonomous Weapon Systems) have appeared on the battlefield. These machines find their targets, track themselves, and destroy themselves without human commands. You might think of the Terminator in a Hollywood movie, but the reality is quieter and scarier. Look at Israel's Harop drone. This thing roams the sky, and when it detects an enemy's radar signal, it rushes in and self-destructs.

There are reports that Turkey's Kargu-2 drone autonomously tracked and attacked retreating soldiers in the Libyan civil war without human control. This is what happened in 2020. It's already 5 years ago. In 2024, the United Nations General Assembly overwhelmingly adopted a resolution on autonomous weapons of destruction. 166 countries were in favor, and only 3 were against. Belarus, North Korea, Russia. The resolution states that international humanitarian law should apply throughout the entire life cycle of autonomous weapons. In November 2025, 156 countries once again voted in favor of regulating autonomous weapons.

This is proof that the international community is taking this issue seriously. So why is this a problem?

Pulling the trigger is not just a physical act. It's a moral decision. When a medieval knight wielded his sword, he looked his opponent in the eyes. When the opponent surrenders, the sword is raised. The same thing happened when a Roman soldier aimed a gladius. Humans are capable of mercy. I know it's hesitation. Machines don't. When the AI beat the human pilot 5-0 in AlphaDogfight, the AI showed no hesitation. There was no fear, no mercy. There was only a mathematical optimum. The most efficient route to destroy your enemies. What if the other person made a gesture of surrender? The AI wouldn't have noticed.

Unless you have a line in your code that says "recognize surrender gesture". The arguments of those in favor also make sense. They say. "The machine is not tired. It is not afraid. It is not vengeful." This is true. Human soldiers sometimes make terrible mistakes under the stress of war. Sometimes they kill civilians by mistake, or they break the rules of engagement due to emotions. Machines can follow

input rules like a sword. In theory. But war is not a theory. War is chaos. I think about when I was flying over Iraq. There is a man with a gun on the ground. Is he an enemy? Or are you a civilian trying to protect your family?

Or is he a local informant working with our forces? Human pilots see context. Where is the gun pointed, are there children around, is his behavior aggressive or defensive? AI only sees pixels and patterns. We classify the world into 0s and 1s. There is a bigger problem. This means that the threshold for war is lowered. A bloodless war is a sweet temptation for politicians. If you don't have to send a coffin home with a flag, the decision to go to war becomes much easier. If only the broken scrap metal came back, there would be less criticism from the media. States will use force more frequently and more lightly.

An era of endless algorithm disputes may begin. Currently, the international community is in a tense conflict.

On the one hand, there are countries that advocate a complete ban. Countries like Serbia and Kiribati. They say. "Weapons of destruction without human control are an affront to human dignity." On the other hand, there are countries that are already leading the way in this technology, such as the United States, Russia, and Israel. They argue that existing international law is sufficient. It even rejects the phrase "meaningful human control." In 2025, the United Nations Group of Governmental Experts (GGE) created a document called the "Rolling Text." This is a draft set of regulatory elements that can be agreed upon.

This contains important information. Autonomous weapons must be predictable, traceable, and explainable. A human supervisor must be able to interrupt the system at any time. Deployment in areas densely populated with civilians should be avoided. However, there is still a long way to go to reach an agreement. I ask. What are the qualifications of the person pulling the trigger? As a pilot, I believe that qualification comes with responsibility. When I launch a missile, I bear the weight of the consequences. Sleepless nights, nightmares, lifelong memories. That is the cross of the human warrior. The machine doesn't know its weight.

There is nothing called "guilt" in the code. We can borrow efficiency from machines. But you must not sell your soul.

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Chapter 32. Human-in-the-Loop

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Human-in-the-loop cockpit is narrow. If you turn your shoulder, you can almost touch the canopy. However, within this small space, pilots must process hundreds of pieces of information simultaneously. Speed, altitude, fuel, enemy location, friendly location, armament status, communication content. All of this changes by the second. So we need a system. Radars find enemies, computers calculate launch solutions, and warning devices alert you to threats. All this help allows pilots to go beyond human limits. But at the end of it all, it's still a human finger pressing the fire button. This is the essence of "human-in-the-loop".

When you first hear this concept, it seems simple. Even if the machine finds the target, takes aim, and makes all the preparations, the final "fire" command is given by a human. But the reality is much more complicated. There are three steps: The first is human-in-the-loop. Humans directly approve each action. The machine says, "There's a target over there," and the human decides, "Okay, fire." The second is human-on-the-loop. The machine operates on its own, but is monitored by humans. If something looks wrong, a human will step in and stop it. It is a kind of supervisory role. The third is Human-out-of-the-loop.

Humans are completely missing. The machine takes care of everything from start to finish. The problem is that the pace of modern battlefields is too fast. Hypersonic missiles travel at speeds above Mach 5. Hundreds of drones rush in like a swarm of bees. In this situation, would a human have time to press the approve button one by one? The human reaction speed is about 0.2 to 0.3 seconds. Machines make decisions in nanoseconds. Human biological limitations cannot keep up with the speed of machines. The Pentagon is well aware of this problem.

Department of Defense Directive 3000.09 states that autonomous weapons systems must be designed to allow for "an appropriate level of human judgment." The important thing here is not "there needs to be a human in the loop." Official policy avoids this vague language. Instead, it calls for "the exercise of human judgment." It's a subtle but important difference. Here's an interesting fact: The U.S. government opposes the phrase "Meaningful Human Control." There is a reason. This is because this expression is believed to imply an unrealistic level of human supervision.

Existing semi-autonomous precision-guided weapons may also not meet this standard. But many countries and international organizations think differently. In November 2024, the CCW Government Expert Group's "rolling text" included the phrase "contextually appropriate human judgment and control." This recognizes that the level of human control required may vary depending on the situation. Attacks in areas with dense civilian populations will require more stringent human supervision. Interception of anti-ship missiles in the air and seas would allow for relative autonomy. International discussions in 2025 are focused on this issue.

Human Rights Watch warns: “Meaningful human control must be exercised at the very moment an attack occurs. Pre-set parameters alone are not sufficient.” Their logic is this: Compliance with the principle of proportionality requires the weapon user to determine at the moment of the attack whether civilian harm is excessive compared to the military benefit. In a complex and rapidly changing environment. Let's look at the example of Israel. In operations in the Gaza Strip, Israel used AI systems called “Lavender” and “Gospel.” These systems identified Hamas members and generated target lists.

According to the report, the average time it took for a human analyst to approve the AI's recommendation was 20 seconds. 20 seconds. Could humans have properly verified the basis for AI's judgment in this short period of time? This is the “rubber stamp” problem.

Just because humans are in the loop doesn't mean they are automatically in control. Just pressing the formal approval button is not real control. It's just an alibi to avoid responsibility. True human control means the ability to understand AI's judgments, reject them when necessary, and suggest better alternatives. What is the solution? First, we need explainable AI. When AI says, “That's a target,” humans need to be able to understand why it reached that conclusion. “Radar signature pattern matches 93% enemy SAM site. Heat signature matches vehicle engine.

No friendly forces within 10 kilometer radius.” Only with this explanation can humans make judgments. Second, the right to stop must be guaranteed. In any situation, a human should be able to shout “Stop!” And the machine must stop immediately. When communication is lost or data is abnormal, the machine must stop its aggressive behavior and enter safe mode. Third, training is essential. Pilots and commanders must fully understand the capabilities and limitations of AI systems. Under what circumstances can errors occur and what types of deception are you vulnerable to? It is dangerous to just trust the black box.

I call this the “centaur model.” Centaurs in Greek mythology are half-man and half-horse. It combines the power and speed of words with human wisdom. The same should be true for future fighter jets. AI processes thousands of pieces of information and presents options. Humans make decisions based on the big picture. It combines machine efficiency and human judgment. However, the final authority to judge must remain with humans. The moment we hand over the trigger to the machines, we lose our humanity in war. The horrors of war are forgotten, and murder is reduced to simple data processing. It's not a triumph of technology.

It is a defeat of civilization.

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Chapter 33. Who Is Responsible for an AI Mistaken Strike?

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Who is responsible for AI errors? February 25, 1991, at the Dhahran base in Saudi Arabia, where the Gulf War was in full swing. Iraqi Scud missiles have arrived. The Patriot air defense system had to work. But it didn't work. It was a software bug. As the system's clock ran continuously for more than 100 hours, errors accumulated and it was unable to track the missile. The results were disastrous. 28 American soldiers were killed. Who was responsible for this accident? Raytheon, the company that created the Patriot system? Programmers who didn't find the bug? An operational unit that hasn't rebooted its system for over 100 hours?

Or the Department of Defense for not distributing software updates on time? Decades later, this question still has no clear answer. But this wasn't even an autonomous weapon yet. Humans were operating the system. What if autonomous lethal weapons (LAWS) decide to attack civilians? Who should be held responsible for that? This is the “Accountability Gap”. Current international law is designed based on human actions and intentions. Article 25 of the Rome Statute of the International Criminal Court (ICC) provides for individual criminal liability. Article 30 states that “intent and knowledge” are necessary to establish a crime.

But machines cannot have intentions. Algorithms can't go to jail. In December 2024, the ICC issued arrest warrants for Israeli Prime Minister Netanyahu and former Defense Minister Gallant. Among the charges are war crimes: intentional attacks on civilians. Israel has used AI targeting systems extensively in the Gaza Strip. This could be the first time the ICC directly addresses AI-related war crimes. But there are many legal obstacles. The “intent and knowledge” requirements of Article 30 of the Rome Statute are strict. In the 2014 Katanga case, the ICC ruled that *dolus eventualis*, that is, assuming a risk while foreseeing a harmful outcome,

It was confirmed that criminal liability cannot be held. This creates a critical loophole in the operation of autonomous weapons. When someone says “AI did that”, how can you prove their “intention”? Researcher Marta Bo took a deep dive into this issue. She warns that even if the unlawful consequences of deploying autonomous weapons are foreseeable, prosecution may become impossible if there are no identifiable actors with specific intent. The law is not keeping up with technology. So who is responsible? The first suspect is the commander.

In international law, there is a principle called “Command Responsibility.” If a commander knew or should have known of a subordinate's crime but did not prevent it, he or she is held liable. However, applying this principle to AI systems is difficult. Can we say that a commander “should have known” every decision made by a black box algorithm? The second suspect is the developer. Should the programmer who wrote the code be held responsible? However, deep learning-based AI is a black box. Even the developers themselves can't 100% explain why the AI came to that conclusion.

A system that was perfect in millions of simulations can malfunction due to the unpredictable variables of the real battlefield. Is this intentional? Is it negligence? The third suspect is a defense company. Should the companies that manufactured and delivered the weapons be held liable? However, most defense contracts contain indemnification clauses. And defense companies are protected by the state. Current international law makes it very difficult to prosecute companies for war crimes. The fourth suspect... could it be the machine itself? This is impossible. You can't take AI to court.

There is no point in convicting the algorithm "guilty." Ultimately, a situation arises where everyone is involved but no one is directly responsible. The 2024 UN General Assembly Resolution 79/239 is an important development. The resolution confirms that when AI is used in the military domain, international humanitarian law applies throughout its entire life cycle. It also added international criminal law to the applicable legal system. This highlights that personal criminal liability may apply in appropriate cases. There are efforts toward solutions.

First, the "Digital Audit Trail". Like a black box on an airplane, it records every decision made by AI. Why did you identify that target as the enemy at that point? What data was it based on? What alternatives have you considered? This record is required so that accountability can be held after the fact. Second, strengthening national responsibility. The idea is to ensure that the country that operates the AI weapon itself, rather than the individual, is responsible for compensation under international law. If countries are held accountable, governments will be more cautious about introducing AI weapons.

Third, mandatory weapons legal review. Article 36 of Additional Protocol I to the Geneva Conventions requires legal review of new weapons. For AI weapons, this review is even more important. It should be assessed whether the system can comply with the principles of distinction and proportionality of international humanitarian law. 2025, the International Committee of the Red Cross (ICRC) highlighted in its report to the Secretary-General of the United Nations. "It is not the AI systems themselves that must comply with the law, but the humans who use them." AI must remain a tool to aid human decision-making.

It should support humans, not replace them. As a pilot, I am prepared to take responsibility for my actions. If I accidentally attack a civilian, I will carry that burden with me for the rest of my life. You will be judged by a military court. That is the honor of a warrior. But what if I have to go to jail for something my AI wingman did? That's not fair. Conversely, what if no one is responsible for AI's mistakes? That is not justice either. Law is always slower than technology. But without law, only a jungle remains. Laws must exist even in war. This is so that we can remain human and not beasts.

No matter how advanced AI is, it is humans that bleed. The law must be the minimum courtesy to that blood.

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Chapter 34. Hacking and Deception

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Hacking and Deception I remember one night when I was flying in pitch darkness at an altitude of 30,000 feet. The RWR, or Radar Warning Receiver, suddenly started screaming. The enemy's surface-to-air missile radar caught me. There were only two things I could believe in at that moment. The numbers on the dashboard flashed before my eyes, and it was my intuition accumulated from thousands of hours of flight experience. When the numbers lie, your intuition will tell you. When your intuition wavers, numbers set you straight. The balance between these two allowed me to land alive. But AI pilots have no intuition. This is the crux of the problem.

AI sees the world through data. Signals sent by radar, heat sources picked up by infrared sensors, and friendly forces' location information received through data links. All of this is input into the AI's brain as a combination of 0 and 1. If the input value is accurate, AI makes decisions faster and more accurately than humans. But what if the input value is false? AI accepts the lie as truth and runs in the wrong direction at a much faster speed than humans. In ancient Greek mythology, there is a hero named Achilles. He was an invincible warrior. Because his mother made him immortal by dipping him in the River Styx.

But only the heel with which his mother was holding him did not touch the water. In the end, Achilles was hit by an arrow in his heel and fell. The lesson is that even the strongest have weaknesses. The heel of AI pilot is 'data'. If an enemy can manipulate or corrupt this data, the invincible AI warrior will be powerless in an instant. Let me start with the most horrifying threats: hostile attacks, hallucinations with your eyes open. Experts call this an 'Adversarial Attack'. It may sound difficult, but let me explain it to you. When AI recognizes objects, it analyzes the patterns of pixels, or tiny dots that make up the screen.

By looking at millions of photos, it learns, "If this pattern is a tank," or "If that pattern is a truck," it learns. But what happens if an enemy draws very fine patterns on the surface of the tank that are barely noticeable to the human eye? The pattern is a 'customized poison' created by reverse analysis of AI's neural network structure. To the human eye, it still appears to be a tank. However, in the eyes of AI, the tank is recognized as a 'school bus', a 'flock of sheep', or simply a 'rock'.

Imagine this. I give orders to my AI wingman. "Attack enemy tanks in front." But the AI answers. "There are only civilian vehicles ahead." I'm clearly looking at a 60-ton steel monster, but my AI colleague next to me doesn't see it. This is not a malfunction of the machine. The machine is operating normally. However, the enemy has created an illusion in the machine's eyes. A similar thing actually happened at the Chinese People's Liberation Army's training ground in 2024. It was believed that the Blue Team's AI-assisted fire units had accurately hit the Red Team's batteries.

But when the training controller stopped the situation, the truth that emerged was devastating. More than half of BLU's fire force had already been destroyed. The red team commander had placed fake batteries and fake signals at the shooting range. The Blue Team's AI revealed its location by shooting at the ghost. The opposite situation is more dire. What if an enemy projects a special pattern on the roof of a private hospital or school, causing the AI to mistake it for a 'missile launch pad'? Our AI wingman will hit there without hesitation. It's a mistake. Civilians die. And who is responsible for that? This is not just a technical issue.

It is a problem that shakes the very nature of war. Data contamination, poisoning the well There are more insidious attacks. This is an attack that takes place before the war even begins. Experts call this 'Data Poisoning'. It's the same way as secretly poisoning a well. AI grows by eating data. It learns by analyzing millions of simulations, tens of millions of photos, and hundreds of millions of sensor data. But what would happen if an enemy cyber unit secretly infiltrated our training data server and planted a very subtle error?

For example, an enemy could 'train' an AI so that it behaves normally in normal times and then malfunctions only under certain conditions. It only behaves strangely when it detects a red smoke bomb, when it hears radio waves of a certain frequency, or only on a certain date. This is called a 'backdoor'. AI, which normally operates without any problems, suddenly becomes out of control at a critical moment when war breaks out. They mistake their allies for enemies, ignore enemy planes and pass by, or crash completely. This is a digital version of a Trojan horse.

The ancient Greek allies hid their soldiers inside a giant wooden horse and brought them into the city of Troy. The Trojans saw the wooden horse as a trophy and willingly

I accepted it. At night, soldiers came out of the wooden horse and opened the city gates, and Troy was destroyed. If the enemy has hidden a 'horse' in our AI's learning process, we will deploy that AI into the battlefield without knowing it. And at a critical moment, the poison in the wooden horse kicks in. Training military AI requires massive amounts of data, including satellite imagery, reconnaissance images, and open source information. It is nearly impossible to completely verify the purity of all this data. Enemies can distribute large quantities of fake images of military equipment on the Internet.

When our AI learns those images, it will not be able to properly recognize the enemy's real weapon. A strategy that turns our most powerful weapons into scrap metal without ever firing a shot. Spoofing, Whispering a False Reality In the past, electronic warfare was about blinding the enemy's ears with loud noise. The powerful radio interference disrupted the radar screen like a blizzard. But electronic warfare in the AI era is different. It is a hypnotism that whispers 'false reality' to the enemy. Let's take GPS spoofing as an example. GPS calculates your location by receiving signals from satellites.

But what if the enemy sends a fake GPS signal that is stronger than the satellite? AI pilots think they are in a completely different location than they actually are. It flies believing it is 3 kilometers away. They drop bombs thinking they have reached the target, but in reality it is an empty field with nothing in it. Or even worse, a friendly base. GPS spoofing has already become commonplace on the Ukrainian battlefield. Drones lose their location and fly to strange places or crash. As of 2025, the

Russian military is conducting a large-scale GPS jamming operation over Ukraine. Hundreds of drones are affected.

Data link hacking is even scarier. The AI pilot is connected to the friendly command center via a data link. Mission orders, target coordinates, and friendly location information are transmitted through this link. What if an enemy hacks this link and sends fake commands? "Formation, immediately turn 180 degrees and return." This command came through an encrypted channel. The AI turns its nose without question. A human pilot would probably wonder, "It's strange to be ordered to return in this situation." We will request re-confirmation via voice command. However, AI will carry out commands as long as there is no logical contradiction.

Inflexibility is the limitation of machines.

Hacking takes over the digital cockpit We are now sitting in a 'digital cockpit'. Modern fighter jets like the F-35 and F-47 are giant flying computers. Millions of lines of code make the aircraft move. What if an enemy hacker comes through the network and takes control of the AI system? It's like the enemy is riding in my back seat and holding a knife to my throat. There is no such thing as perfect code in the software world. This is why your computer or smartphone is updated frequently. This is to belatedly close security holes that developers did not discover. The same goes for combat prayers.

No matter how thoroughly you inspect, there may be gaps somewhere. If the enemy finds the gap first, the F-47 will become a flying \$100 billion brick or a zombie drone controlled by the enemy. The problem is more serious in the case of drone swarms, or swarms of drones. Hundreds of drones are networked together and move like one giant creature. But that link becomes a weakness. Even just one hack can compromise the entire colony. Just as a virus spreads throughout the body, malicious code spreads across networks. The U.S. Defense Advanced Research Projects Agency (DARPA) is taking this issue seriously.

In 2025, they launched a project called SABER. It is an abbreviation for 'Securing Artificial Intelligence for Battlefield Effective Robustness.' The goal of this project is to assess the vulnerability of AI systems against adversarial attacks, cyberattacks, and electronic warfare attacks and develop defense technologies. DARPA officials warned that there is currently no ecosystem that can systematically assess the security vulnerabilities of AI systems deployed on the battlefield. The breakdown of trust is what I fear most.

As a fighter pilot, my greatest fear is not the enemy. 'It's a situation where I don't trust my airplane.' The moment you suspect that your AI wingman has been hacked or deceived, he or she is no longer a force but a potential threat. When I flew the Wild Weasel mission over Iraq, I trusted both my dashboard and my eyes. If the dashboard showed strange numbers, I checked it with my eyes. If I saw something strange, I checked the dashboard again. These two validated each other. But the AI pilot only knows what the sensors show. Even if the sensor is telling a lie, you can't 'feel' it.

To win the algorithm war, we must secure not only AI's performance but also its 'robustness'. We need AI that is not fooled by the enemy's deception tactics, is unshaken by data contamination, and

can defend itself against hacking attempts. The US Department of Defense operates the 'AI Red Team'. They are a group of experts who ruthlessly attack and hack friendly AI systems to find vulnerabilities. We make AI endure tens of thousands of digital tests before it is deployed in the field. In the end, no matter how advanced technology is, humans must be the last resort.

When the AI says, "This is a truck," the pilot must be able to use his intuition and experience to determine, "No, that's a camouflaged tank." Amid threats of hacking and deception, human intuition is the last safety device that catches AI errors. This is why we cannot completely rely on machines. To survive on the battlefield, you must be able to doubt what you see. AI hasn't learned that suspicion yet. That is the most critical weakness of algorithmic warfare. The ruler of the skies is no longer the fastest. You will be the one who is least deceived.

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Chapter 35. Arms Competition and International Norms: The Dilemma of Export Controls and Technical Standards

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Arms Race and International Norms: Dilemma of Export Controls and Technology Standards In the early morning of July 16, 1945, the first nuclear explosion in history occurred in the desert of New Mexico, USA. Robert Oppenheimer, head of the Manhattan Project, looked at the flash and recalled a passage from a Hindu scripture: "I am now death, the destroyer of worlds." Humanity opened Pandora's box that day. And now, we are opening the second box. It's an AI arms race. Russian President Vladimir Putin said in 2017: "Whoever controls artificial intelligence will rule the world." These are not empty words.

China is making all-out efforts to become the world's No. 1 in AI by 2030. The United States has pledged to field thousands of autonomous weapons systems on the battlefield within 18 to 24 months through its 'Replicator' initiative. This is not just a technology race. It is a war where the survival of the nation depends. The problem is that there are no breaks in this competition. If the United States develops, China must also develop. If China develops, Russia must also develop. "The enemy has an army of robots, so will we be the only humans fighting?" This fear is sweeping the world.

International norms and controls are falling behind, unable to keep up with the pace of technology. Semiconductor War, Oil Embargo of the 21st Century During World War II, the United States banned oil exports to Japan. Without oil, tanks, fighter jets, and warships cannot move. Japan advanced south to secure oil and eventually attacked Pearl Harbor. Oil changed the course of the war. Today's oil is a semiconductor. To train and operate AI, a high-performance GPU, or graphics processing unit, is essential. Chips like NVIDIA's A100 and H100 are no longer just computer parts. It is a strategic material.

Without these chips, large-scale AI models cannot be trained. You can't create two brains for an autonomous drone. The United States is enforcing strong export controls to curb China's military AI capabilities. The semiconductor export regulations to China, which began in 2022, are being strengthened every year. In October 2023, the U.S. Department of Commerce's Bureau of Industry and Security significantly strengthened control of high-performance AI chips. The chip's total computational power, performance density, and data

Control targets are identified based on three criteria: whether they are designed for a specific purpose; The strategy is to physically prevent China from developing advanced military AI. But this is like building a sand castle. Water always finds a way. Several semiconductor companies circumvented regulations by selling low-performance AI chips in the Chinese market. When the United States lowers its acceptance standards, companies design chips with performance just below the standards. The cat-and-mouse battle of regulations and detours continues. There is a bigger problem. Hardware may be held at customs. Because it's a physical object.

But what about software? The algorithm crosses borders on a USB stick or in an encrypted email. It is impossible to completely control open source AI models shared over the Internet. There are reports that Chinese research labs are already using the U.S. open source model to analyze military intelligence. There is an even bigger nightmare: the proliferation of low-cost AI weapons, a poor man's air force. It is not a competition between great powers. Proliferation. In the past, precision-guided weapons and stealth aircraft were the preserve of a few powerful countries.

It required trillions of won in development costs and decades of technology accumulation. However, AI technology has dramatically lowered the barrier to entry. In the war in Ukraine, we saw \$500 commercial drones equipped with simple AI software to destroy multi-million dollar tanks. This is the maximization of asymmetric power. As of 2025, the Russian military is launching large-scale drone attacks on Ukraine. Hundreds of drones fly in one airstrike. Between September 9 and 10, 800 attack drones were deployed. About 20 of them entered Polish airspace, and NATO defenses only shot down four of them.

In the face of large-scale drone attacks, the limitations of traditional air defense systems have been revealed. Now terrorists and criminal organizations have also become dangerous. With just graduate student-level coding skills and a commercially available drone, you can create an autonomous lethal weapon that uses facial recognition technology to assassinate specific people or attack crowds of people. This is the era of 'DIY killer robots'. It is difficult to identify the perpetrator of the attack, and it can cause uncontrollable damage to civilians. As technology becomes more democratized, so too does fear.

Dilemma of international norms: ban or manage?

The international community recognizes this risk. The UN Convention on Certain Conventional Weapons (CCW) has been discussing regulations on autonomous lethal weapons (LAWS) since 2014. However, even after 11 years, an agreement is still far away. In December 2024, the United Nations General Assembly adopted a resolution on autonomous weapons of destruction. 166 countries were in favor, 3 countries (Russia, Belarus, and North Korea) were against it, and 15 countries abstained. The resolution mentioned the possibility of a "dual approach" that would ban some autonomous weapons and regulate others.

UN Secretary-General António Guterres has called for a binding agreement to ban autonomous weapons operating without human control by 2026. But the reality is different. Military powers such as the United States, Russia and Israel oppose a blanket ban. Their logic is this: "AI can strike more accurately than humans and reduce civilian casualties." In fact, if you look closely, it is because they do not want to give up the advanced weapons that are already under development. Human rights groups and some countries claim otherwise. "Machines should not be allowed to decide human life or death." This is ethically sound.

Small island states like Kiribati advocate for a complete ban. The country underwent 33 nuclear tests between 1957 and 1962. I know better than anyone the horrors of new weapons. South Korea is taking a pragmatic stance. We are opposed to a total ban on LAWS, and we must ensure 'Meaningful

Human Control'. In the face of the existential threat of North Korea and the reality of a population cliff, AI weapons are a means of survival that we cannot give up. CCW meetings are run by consensus. Opposition from just one country could derail the proposal. That is why there has been no real progress for over 10 years.

This is why creating norms is so difficult. The war of technical standards, who sets the rules. Along with norms, what is important are technical standards. The future battlefield is a place where all weapons are connected through a network. For the US's JADC2 (Joint Domain Command and Control) or Korea's manned and unmanned complex systems to succeed, a common language and rules are needed for different AI systems to communicate. The question is who sets these standards. America wants the world to follow its standards. NATO members must follow U.S. standards to be compatible with U.S. equipment. NATO in 2025

In announcing the data utilization strategy, interoperability and integration were emphasized. This is not just a technical issue. It's a question of technology dependence. Countries with independent defense production capabilities, such as Europe and Korea, are worried. Following American standards makes joint operations easier. But at the same time, it is dependent on American technology. Israel is building its own AI ecosystem and calling for 'sovereign AI'. The standard dilemma is this. Stronger standards lead to better safety and interoperability.

Instead, the pace of innovation slows, and the country that leads the standards sets the rules. When standards are weak, individual development becomes faster. Instead, communication between allies on the battlefield is not possible. The moment there is no connection, AI becomes an isolated toy rather than a power multiplier. The world is being divided into two blocks by the AI technology barrier. The standards of the United States and its allies, and the standards of China and its allies. Like the Iron Curtain during the Cold War, a digital curtain divides the world.

In front of Pandora's box, we are now in a similar position to the nuclear weapons developers in 1945. The technologies we create can either make the world safer or lead to destruction. The AI arms race is an unavoidable reality. Because our enemies will not stop just because we stop. However, indiscriminate competition leads to mutual destruction. We must compete smartly. First, reliability must be secured. We must be able to control our own AI. Investing in explainable AI (XAI) and security technologies is a necessity, not an option. Like DARPA's SABER program, we need to create a robust AI that is not shaken by enemy attacks.

Second, international cooperation is needed. At the very least, export controls and proliferation prevention systems must be strengthened to prevent lethal AI technology from being passed on to terrorists or rogue states. Although complete control is impossible, you can slow it down. Third, human control must be maintained. We must adhere to the 'Human-in-the-loop' principle, which leaves the authority to pull the trigger to humans, not machines. This is a matter of ethics and at the same time a matter of survival. Weapons that we cannot control will ultimately harm us.

As a fighter pilot, you want better weapons. But you don't want a weapon you can't control. Even in the era of algorithmic warfare, the responsibility and ethics of war must ultimately remain the

responsibility of humans. That's what makes us different from machines. That is the final line we must keep. From the cockpit, international norms feel as light as paper. However, as the paper accumulates, the direction of weapons development and the market changes. In the era of algorithmic warfare, not only missiles but also standards, licenses, and regulations fly in formation. If you don't know that, you'll be late on the battlefield.

If you're late, it's over.

Part 8. Future Outlook and South Korea's Choice

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Chapter 36. The Battlefield Beyond the Atmosphere: Linking Space and Cyber Domains

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The battlefield extends beyond the atmosphere: 30,000 feet of space and cyberspace interconnected altitude. The outside of the canopy changes from dark blue to black. The inside of the oxygen mask becomes damp with your breath, and the vibrations of the engine run up your spine. From this height the world appears calm. But don't be fooled. The real war is now being fought 500 kilometers above your head and within the digital circuits of your avionics. When I was driving the F-16 Wild Weasel and breaking through Iraq's air defenses, the battlefield was all about the sky stretching out before my eyes.

If the enemy radar caught me, a missile would fly, and if I found it first, I would shoot a HARM and destroy the radar dish. It was simple. However, even at this moment, the reality faced by pilots sitting in the cockpit has completely changed. The battlefield extends beyond the atmosphere and infinitely into cyberspace, where there is no physical entity. Space used to be treated as nothing more than a high-end camera that took reconnaissance photos. Now it's the nervous system of the battlefield. The satellites are the eyes, ears, and blood vessels.

The target information I see through the forward viewing display (HUD) is data sent from a low-orbit satellite constellation. Without GPS signals, our vaunted precision-guided bombs (JDAMs) are nothing more than a stupid piece of metal. Communicating with command centers on the other side of the world and identifying the location of enemy air defense networks are all thanks to satellites. The problem is that the enemy knows this. What is the reason why China and Russia are developing anti-satellite missiles and launching killer satellites? The moment the war begins, they will target our eyes and ears first.

Imagine a squadron flying toward an enemy over the Pacific Ocean, when suddenly the navigation screen goes black, communication with friendly forces is lost, and targeting information disappears. It's not just a malfunction. It is a sign that we have been defeated on the cosmic front. Space battles aren't just about blasting satellites with lasers like in the movies. More frequently, and more fatally, strangulation occurs through radio waves. Jamming, spoofing, and link poisoning. The map I believe in and the ecliptic I hear about are slightly off. 200 meters, 500 meters, 1 kilometer.

The moment that error enters the missile guidance, the result is blood and debris. Satellites move quickly, but their orbits are predictable. Anything that is predictable is easy to attack. And cyberspace. This is the fiercest battlefield where no gunshots are heard. If electronic warfare in the past was at the level of mixing noise into the enemy's radar, cyber warfare in the future involves hacking into the enemy's systems and attacking them from within.

It's about to collapse. Imagine this. A squadron of KF-21s enters enemy airspace. The enemy's latest air defense radar is activated. Instead of firing a missile, the KF-21 transmits malware to the enemy radar's network port via a powerful directional data link. This code manipulates the radar's enemy identification algorithm. The enemy's air defense batteries suddenly recognize their own planes as enemy aircraft and begin firing missiles at them. It destroys the enemy's air defense network without using a single bullet.

An adversary can slow down data from sensors, plant fake targets, or mess up priority queues, forcing real threats down the list. What the pilot feels is simple. An alarm sounds but the reason is not explained. A dot appears on the radar screen and then disappears. Link track shakes. Humans hate uncertainty. Uncertainty delays judgment, and delaying judgment leads to death. In October 2024, South Korea established the Strategic Command. It is an organization that oversees the Korean three-axis system consisting of Kill Chain, Korean Missile Defense System, and Mass Punishment and Retaliation.

The Ministry of National Defense announced that it plans to focus on nuclear and conventional weapons integration in the initial phase and later expand the mission to space, cyber, and electromagnetic spectrum operations. The Air Force Space Operations Squadron was promoted from a battalion to a squadron in June 2024, and the goal is to establish a Space Command after 2030. This is not just a reorganization. It is an acknowledgment of the cold reality that in order to protect the sky, we must win even outside the sky. The key to space-cyber interconnection is not to connect more. Connection is a double-edged sword.

What is important is a connection that can be fought even if it is broken, and a connection that extracts the truth even if it is polluted. When space is cut off, airborne platforms must survive with local sensors and short-range links within the formation. Once cyber is compromised, data must prove its origin and authenticity. The standard for future battlefields is resilience. It is not a faster network, but a network that can withstand being hit. Korea's choice is clear. Although Korea has a small territory, it has the advantage of being an IT powerhouse.

It is foolish to compete in physical volume with China or Russia, which have huge territories. Securing an independent communication satellite network is not an option but a necessity. Relying solely on U.S. GPS means limiting wartime operational control. All movements around the Korean Peninsula must be monitored in real time and without interruption through the Korean satellite navigation system and a constellation of micro-reconnaissance satellites. Cyber Command and Air Force operations must be fully integrated.

A fighter pilot pressing a missile launch button must be synchronized with a cyber force's attack breaking through the enemy's firewall. The impact of hardware and the penetration of software move in one rhythm. That is the winning equation for future battlefields.

The atmosphere is now narrow. The outcome of the war will be decided at an altitude of 100 kilometers and in a digital maze of 0s and 1s. If you want to rule the sky, first rule the universe and the network. This is the warning and advice from a 21st century pilot.

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Chapter 37. KF-21EX and AAP Unmanned Aircraft: A Blueprint for Korean MUM-T

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KF-21EX and AAP Unmanned Aerial Vehicles: Blueprint of the Korean MUM-T For a fighter pilot, a wingman is a lifeline. He must be prepared to watch my blind spots, cover me when I attack, and take the missiles for me if necessary. But human wingmen are too valuable to lose. It takes billions of won and years to train one fighter pilot. So we are now turning to mechanical wingmen: manned and unmanned systems (MUM-T). And at the center are Korea's KF-21EX and AAP. The US Air Force's F-22 and NGAD programs are great. But looking at the price tag takes my breath away.

Even the United States is suffering from the astronomical costs, so how can other countries do it? This is where the strategic value of Korea's KF-21 Boramae shines. When I first saw the KF-21, I got the impression that it was a mixture of the agility of the F-16, the solidity of the F-18, and the shape of the F-22. But what really matters is not how you look. This is the possibility of evolution. In May 2025, final assembly of the first KF-21 mass-produced aircraft began. 40 units of Block 1 will be deployed from 2026, and 80 units of Block 2 will be mass-produced from 2027 to 2032. But the real revolution comes later. This is KF-21EX.

This improved performance version, once called Block 3, will evolve into a 5th generation stealth platform with an internal weapons bay. Some changes have been made to the machine gun placement, and an internal weapons bay has been installed in the semi-buried weapon mounting space. It is equipped with four or eight Meteor long-range air-to-air missiles, a compact smart air-to-ground weapon. External target acquisition equipment has also been changed to built-in type to improve stealth performance. However, the KF-21EX's true role is not as a stand-alone fighter. It's a commander. This is where AAP drones come into play.

The multipurpose unmanned aerial vehicles being developed by KAI are loyal royal wingmen. These guys are small, fast, and above all, expendable. It is a small jet unmanned aerial vehicle with a total length of 3.1 meters, a width of 2.2 meters, a weight of 150 kilograms, and a maximum speed of Mach 0.6 to 0.7. This is the key. War is business. You can't send out a \$100 million manned fighter jet to destroy the other side's \$1 million missiles. However, if it's an AAP worth 200 to 300 million won, you can give away as much as you want. Imagine sitting in the cockpit of the KF-21EX.

The radar warning receiver screams that the enemy S-400 anti-aircraft missile radar is searching for me. In the past, I would have immediately taken evasive maneuvers, sprayed chaff and flares, and left the battlefield. The mission is a failure. But now I give orders to my wingman, the AAP squadron.

The AAPs immediately increase their speed and rush towards the enemy lines. They inflate their radar cross-section to fool the enemy into thinking they are KF-21s. Enemy anti-aircraft missile batteries take the bait and launch expensive surface-to-air missiles. One AAP is shot down. It's a

waste, but it's cheap compared to the value of my life or the KF-21. Meanwhile, I take advantage of the opportunity where the enemy's radar location is revealed to take aim with the targeting pod and drop a precision-guided bomb to silence the enemy's air defense network. AAP is not just a bait.

If you attach a reconnaissance sensor, it becomes an eye, if you attach an electronic warfare pod, it becomes a shield, and if you attach a suicide warhead, it becomes a missile itself. You should pay attention to the word adaptive. This means that the drone's mission equipment can be swapped out like Lego blocks. Today you can go out with a reconnaissance module, tomorrow you can go out with an electronic warfare pod, and the day after tomorrow you can go out with a suicide warhead. The flexibility to perform dozens of missions with a single platform is an essential capability for the Korean military, which has limited budget and resources.

KAI unveiled the Next-Generation Air Combat System (NACS) concept at a National Assembly seminar in late 2024. This is a scenario where one KF-21 controls as many as 4 to 16 unmanned aerial vehicles simultaneously. It is the same concept as the US CCA program or Australia's Ghost Bat, but Korea has its own domestic platform called KF-21. Because we have access to the source code, we can modify and optimize the AI algorithms and communication protocols at will. This means you don't have to wait for permission from Lockheed Martin. Let's draw a tactical scenario. A large enemy squadron approaches over the East Sea. We are outnumbered.

In the past, the KF-21 would have had to risk its life in close combat. However, KF-21EX pilots send the AAP formation forward from the safe airspace behind them. The first group is tasked with deception. They lure the enemy's radar by sending out a strong signal as if they were a manned fighter jet. The moment the enemy turns on the radar and wastes missiles to take the bait, your location is revealed. The second group takes advantage of the gap and infiltrates to launch electronic warfare attacks or launch air-to-air missiles. The KF-21EX pilot watches all these situations on the large display in the cockpit and commands the units.

At the critical moment, when it is determined that the enemy's defense line has collapsed, the KF-21EX directly enters at high speed, strikes the enemy's high-value assets, and then exits. The most difficult thing about the Korean MUM-T is not making it fly. Let's fight together. Cooperation begins with links, but it doesn't end with links alone. In an electronic warfare environment, data is cut off and

It becomes soft and distorted. So AAP should have two modes. When Link is alive, humans provide tactical command, and when Link is dead, it acts autonomously based on mission intent. When ordered to locate radar sources in this area, assess the threat level, and maintain survival priority within approved rules, the drone makes detailed maneuvers on its own. Humans become supervisors, not pilots. In Korean Peninsula conditions, density is more of a problem than distance for the Korean MUM-T. Many threats appear simultaneously in a short period of time. So the KF-21EX becomes both an aerial platform and the tactical hub of the squadron.

AAP becomes distributed arms and eyes. What's important is that this team changes the way it fights. In the past, the squadron moved as one mass. Now the squadron spreads out like a cloud,

condensing only when needed. The enemy pours in radar and missiles to hit one point, but the point disappears. Instead, you get multiple dots. Some have expensive pilots on board, while others are cheap but very annoying. The enemy's calculations are messed up. The battlefield is a battle of calculations, and when calculations go wrong, people live. Even industrially, the blueprint is clear.

KF-21EX becomes an upgradeable core node, and AAP becomes an expendable node that can be mass-produced. When high-quality minorities and low-level majorities mix, power explodes. Just as the Roman legion dominated the battlefield by mixing elite legions and auxiliaries, the Korean MUM-T combines elite human platforms and mass unmanned platforms to increase the chances of survival. From the cockpit, this is very realistic. That there is someone who greets me in front of me. It's not technology, it's insurance. Insurance in war is always expensive. Drones are a way to lower those insurance premiums.

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Chapter 38. AI Pilot Technology and LEO Communications Satellites: KAI's NACS Strategy

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AI pilot technology and low-orbit communication satellite: The scariest sound in KAI's NACS strategic fighter is not the missile warning sound. You get used to it. What's scarier is the silence. The silence where the link is cut off, the updates that stop, the battlefield suddenly returns to the 1980s. The goal of a network-centric air combat system such as NACS is to eliminate that silence. It is said that the AI pilot is the brain and the network is the neural network. This is not a romanticism, but a structural truth. There are many companies that make airplanes. But few companies create winning systems.

If you look at the Next-Generation Air Combat System (NACS) strategy presented by KAI, you can see that they have gone beyond the stage of simply selling pieces of metal. They are trying to build a neural network for future air warfare. And the two axes of that neural network are AI pilots and low-orbit communication satellites. First, let's talk about AI Pilot. Many people have a misconception: AI piloting is not a technology that will make human pilots unemployed. Rather, it is a technology that turns human pilots into superhumans.

When flying the F-16, 80 percent of your brain capacity was devoted to the flight itself and operating the systems. I was busy changing radar modes, checking fuel, and tuning communication frequencies. In fact, only about 20% of the brain capacity was available for making important tactical decisions. The AI pilot technology being developed by KAI reverses this ratio. AI handles 90 percent of mechanical tasks such as flight, detection, and system management. As fuel is low, I will set the optimal return route. I suggest evasive maneuver while approaching the missile at 3 o'clock. AI constantly advises and assists.

The core of this technology is not simple automatic flight, but shared situational awareness. AI detects and prioritizes threats that pilots cannot see. Pilots do not need to interpret complex instrument panels, but only need to make the final decision to attack or evade based on the information organized by AI. This significantly speeds up the OODA loop. When the enemy is thinking, we are already shooting. In 2024, KAI tested the performance of basic navigation and obstacle avoidance using a miniature multi-purpose unmanned aerial vehicle.

We plan to demonstrate it with a real aircraft in 2025, and apply AI pilot technology to actual manned fighters and unmanned aircraft for testing in 2027. If all NACS plans according to the roadmap are realized, in future air battles, cheap multi-purpose drones will neutralize enemy air defenses with self-destruction and electronic warfare, and then unmanned fighter jets

will attack the remaining air defenses with air-to-ground weapons, and a manned fighter with a pilot on board will finish the attack. However, no matter how good an AI pilot is, he has limitations on his own. We need data. And we need a lot of data, very quickly. This is where low-orbit communication

satellites come into play. Existing geostationary satellites are too far. It's 35,800 kilometers. There is a delay in the signal coming and going. A 0.5 second delay may be fine when watching YouTube, but it can be fatal when you have to intercept a missile flying at Mach 2.

On the other hand, constellations of low-Earth orbit satellites hovering at altitudes of 300 to 1,500 kilometers have virtually no latency. Radio wave loss and delay are low, making it possible to provide high-speed communication services at the level of a terrestrial network. This is a key element of hyperspace and low-latency 6G communication. In June 2025, KAI signed a 6G low-orbit communication satellite technology development agreement worth approximately KRW 184 billion with the Ministry of Science and ICT, the Korea Aerospace Administration, and the Korea Information and Communication Planning and Evaluation Institute.

By 2030, the entire process from development of the main body of two communication satellites to assembly, testing, and launch will be carried out. This is a project to become self-sufficient in core technologies and secure the ability to enter the global market through the development of the world's first domestic low-orbit satellite communication system based on 3GPP 6G standards. KAI has established a cooperation system with KT and KTSat. We plan to pursue commercialization and global commercialization of the world's first 6G satellite through a strategic cooperation system that integrates space, communications, and services.

KAI's NACS strategy is based on the premise that KF-21, unmanned aerial vehicles, early warning aircraft, and ground control stations are tied together through this low-orbit satellite network. This is hyper-connectivity. Let's say a KF-21 flies over North Korea. The aircraft's own radar is turned off. This is to maintain stealth. However, high-resolution images captured by low-orbit satellites and information detected by early warning devices at the rear are transmitted to the cockpit of the KF-21 in real time. At the same time, KF-21's AI analyzes this information and issues attack orders to drones flying together.

All of this happens in milliseconds. No matter how smart the AI is, if the network dies, it is alone. Sensor data and command data must flow in, and the results must flow out to colleagues. The advantage of low-Earth orbit satellites is simple. If the delay is low and the constellation is tight, even if it is cut off, it can be diverted to another satellite. It is not a structure that relies on one or two geostationary orbits, but a structure that relies on tens or hundreds of distributed nodes. It becomes difficult for an enemy to paralyze the neural network by hitting one point.

In battlefield communications, this is not a luxury, but a survival option.

Of course, low-orbit satellites are not omnipotent. Satellites are also correct. The ground station is also correct. Links are also jammed. So the core of the NACS strategy is not to use low-orbit, but to link multi-layer communication. The idea is to have multiple layers of tactically controllable routes: low earth orbit, ground tactical networks, aerial relays, maritime platforms, even commercial networks if necessary. On top of that, AI evaluates network conditions and redirects traffic. If humans worry about routing during combat, it's already too late.

The network must recover automatically, and automatic recovery is not possible without AI. For NACS to become the center of Air Force power, three things are needed. First, edge AI. Cloud is good, but he dies often on the battlefield. Fighter jets and drones themselves have to do the math. Second, data trust. In a world where cyber is addicted to data, each track and target information must carry with it provenance, time, and reliability. Third, the human interface. Pilots are not geniuses, but workers operating under oxygen and G-limits. When the screen gets complicated, tactics die.

AI should not increase information, but reduce it and provide accurate information. From KAI's perspective, NACS is not a single platform development but an ecosystem design. The KF-21 series becomes the boarding node of the ecosystem, and UAVs such as AAP become the distributed nodes. Low-Earth orbit satellites become the upper-level backbone. And the software that ties these three together, the Tactical OS, is the real weapon. Fighter aircraft become obsolete over time. However, the network and AI tactical logic survives updates. This is where Korea's choices diverge. If you go hardware-centric, you have to create a new aircraft every time.

If you go software-centric, the aircraft is the platform and the power comes from the algorithm. This is the big picture KAI draws. The goal is not to improve the performance of a single fighter plane, but to create an ecosystem that encompasses the entire battlefield. KAI President Kang Gu-young announced that he would build a manned and unmanned complex system based on 6G low-orbit communication satellites and also take on the challenge of commercializing satellite exports.

Based on the satellite package export model linked to aircraft export, we are pursuing strategic cooperation with overseas countries that want to build their own communication networks. Korea has an opportunity. We have the world's best semiconductor technology and communications infrastructure. We have also secured launch vehicle technology to launch a low-orbit satellite. There are many excellent human resources who can create AI algorithms. If all of these elements are melted together in the melting pot called NACS, we will have a unique Korean aerospace power that is different from that of the United States or China.

Of course, there is a long way to go. Challenges include verifying reliable military AI, ensuring the security of satellite communications, and securing computing power inside the aircraft to process this massive data.

It's piled up. But don't forget. The country that produced the F-16 under license developed and launched its own supersonic fighter called the KF-21 in just 30 years. Finally, none of this is possible without political decision. Space and cyber mock military boundaries. If budget, authority, and data are scattered, NACS can only be completed on paper. In the previous chapter, integration is speed, and speed is survival. The ruler of the skies is ultimately the one who sees fastest, produces reliable information fastest, and shoots fastest.

In the future, the engine of that speed will likely not be the pilot's wrist, but the AI and low-Earth orbit link. KAI's NACS strategy is more than just an ambition. It is an inevitable evolution for survival.

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Chapter 39. Defense Industry and Technological Sovereignty: The Next Challenge for K-Defense

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Defense Industry and Technology Sovereignty: K-Defense Industry's Next Challenge The moment I was tracking an enemy plane at an altitude of 30,000 feet, the radar warning receiver rang. The enemy's surface-to-air missile radar began to bite me. At that moment, I sprayed chaff and flares with one finger and activated my electronic warfare equipment. The aircraft responded, and I survived. But what if the chips contained in the electronic warfare equipment are supplied only from overseas? What if the software update rights are in the hands of another country?

In a war situation, saying "Please wait for the parts to arrive" is a death sentence for a pilot. There is a term called technological sovereignty. It may sound difficult, but the meaning is simple. The question is whether my country has the ability to create, repair, and develop the necessary technologies on its own. It's like the difference between a mechanic who knows how to fix a car himself and a driver who has to take it to a repair shop every time. In the world of combat aircraft, this difference can mean life or death. A weapon that requires waiting for permission from others on the battlefield cannot be called a weapon.

When Russia invaded Ukraine in 2022, the world witnessed shocking scenes. Russian military companies, whose imports of cutting-edge semiconductors were blocked by Western sanctions, began using chips from refrigerators and washing machines. It was a scene that showed how important semiconductors are in modern warfare. The amount of data processed by one fighter plane in one sortie is more than the amount processed by the entire Air Force during the Vietnam War. Hypersonic missiles fly by changing their path in milliseconds, or thousandths of a second. It all goes back to semiconductors.

Without semiconductors, modern fighter jets are just lumps of aluminum and titanium. So major countries around the world entered the war to secure semiconductors. The United States has invested \$52 billion through the CHIPS Act, and China is pouring in more than \$150 billion. The European Union has also established a semiconductor plan worth 43 billion euros. In April 2025, the U.S. Department of Defense established a new semiconductor innovation fund worth \$1 billion. This is an expression of our will to complete the military semiconductor supply chain within the United States.

Semiconductors have now become a more important strategic asset than oil. Without oil, a tank stops, but without semiconductors, the brain of a fighter jet stops. Korea's defense industry, K-Defense, is achieving remarkable results. K9 self-propelled howitzers roll across the plains of Poland, K2 tanks are tested in Romania, and FA-50s soar over the skies of the Philippines and Malaysia. In 2023, Korea ranked 9th in global arms exports, and in 2025, exports exceeded \$20 billion. Kim Dong-hyun, general manager of Hanwha Aerospace, said this at the 2025 Global

Business Forum.

I did it. "In the past, independent national defense was a matter of duty and belief. Today, it is a matter of technological competitiveness and industrial leadership." But behind the success lies a challenge. K-Bangsan's strengths were quick delivery, reasonable prices, and reliable quality. It is not as expensive as American products, and it is not as unreliable as Russian products. It has precisely penetrated a gap in the global arms market. But the fight ahead is on a different level. The ability to create hardware alone is not enough.

Self-reliance in these invisible areas, such as software, semiconductors, and artificial intelligence, is the real battleground. Engines are a prime example. It's the heart of a fighter jet. Korea created the KF-21 Boramae brilliantly, but its heart is an engine from the American GE company. If the US stops supplying engines, the KF-21 will not be able to fly. Engine development is difficult. Only a few countries in the world have single crystal alloy technology and precision casting technology that can withstand high temperatures of thousands of degrees Celsius. However, to lead the 6th generation fighter era, we must overcome this wall.

You can't run a marathon with someone else's heart. The K-Chips Act, passed in February 2025, is an important step forward. The tax credit for investment in semiconductor facilities by large companies has increased from 15% to 20%, and for small and medium-sized companies from 25% to 30%. Plans to create a \$471 billion semiconductor supercluster in Gyeonggi Province are also underway. The goal is to produce 7.7 million wafers per month by 2030. Efforts have begun to link private semiconductor capabilities with the defense sector. The electronic warfare library is also key. When enemy radar shines on me, I need to know its language.

Frequency, pulse repetition period, scan pattern. This information is contained in the electronic warfare library. If you don't know this, alarm sounds are just background music from a horror movie. However, this area is prone to external dependence. This is because technology transfer is difficult because it is a confidential field. Korea's experience in independently developing AESA radar is a valuable asset in this regard. When technology transfer was rejected, it was ultimately the right choice to not give up and create it ourselves.

□□□ □□□ □□□ □ □□□□. A fighter jet is made up of thousands and tens of thousands of parts. Radar, mission computer, data link, GPS receiver, display, and even a switch. If one part gets clogged, the whole thing stops. In peacetime, delivery is delayed, but in times of war, flights become impossible. There is a study that analyzed 30 cases of cyber infiltration targeting domestic and foreign defense companies from 2019 to 2023. The results were shocking. Detection capabilities at the end of the supply chain were lacking, and the current legal framework was insufficient to support active defense. Technology transfer is a double-edged sword.

Although it can help you win export contracts, it also comes with risks. If the other country has an industrial base, it can become a competitor with the technology we transfer. There is a case where Türkiye's Alta tank was developed with technology transferred from the K2 platform. Now Altai is K2's competitor. There needs to be a balance of sharing skills but keeping the core. Competition in the

export market is also becoming fiercer. In the old days, performance and price were the competition. Now it's a battle between "alliance politics" and "update rights." Buying countries are asking.

If you buy this fighter jet, what data goes where? □□ □□ □□ □□ □□□. □□ □□□□□□ □□□□□□□□. The defense industry has changed from a business of steel and engines to a business of data and software. Minister of National Defense Lee Sang-myeong said this in October 2025. "To secure K-Defense's global competitiveness, we must present our brand value as a trustworthy security partner." The way the defense industry is developed must also change. The traditional approach was to take a large project for a long time and integrate it at the end. The future is the opposite. Make it small, blow it quickly, break it quickly, and fix it quickly.

The aircraft is bound to be slow for safety and certification reasons, but the software has no reason to be that slow. A structure is needed to separate aircraft certification and tactical software updates. The aircraft is stable and the tactical brain is agile. Technical standards also become weapons. Who sets the interface, who sets the data format, and who sets the communication standards between manned aircraft and unmanned aerial vehicles. Whoever sets the standard becomes the center of the ecosystem. If we don't set a standard, we will always be a subcontractor, fitting parts to someone else's specifications.

If Korea really wants to take the lead, it should say, "We made it happen," but "We let others adopt our standards." □□□ □□□□ □□□ □□□□. Surrounded by great powers, the population is shrinking, and the military is dwindling. The strategy to choose in this situation is the hedgehog strategy. small but deadly thorn

is to have. That thorn is K-Defense, armed with artificial intelligence and cutting-edge technology. As we saw in the war in Ukraine, cheap drones and AI software brought massive tank swarms to a standstill. In the end, technological sovereignty is not a matter of ethics or pride. It's a matter of tactics. We live in an era where opponents attack supply chains, shake satellites, and contaminate data through cyberspace. Power that cannot repair itself and upgrade itself is no different from a model in a glass display case. What survives in the sky is not the gas, but the system.

Taking the system into one's own hands is the essence of K-Defense's next-generation challenge.

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Chapter 40. The Future of Air Combat Written by Humans and AI Together

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The future of air combat between humans and AI When you go above the cloud layer at night, the world is divided into two layers. Above are stars and moonlight, below are clouds like a black sea. Inside the cockpit, the dim glow of the instrument panel fills the air, my hands are on the stick and my feet are on the rudder pedals. This stance has not changed for decades. What has changed is “what I see and believe.” It used to be that my eyes and my radar were all I had on the battlefield. Now, the battlefield organized by artificial intelligence, the targets synthesized by AI, and the risk predictions calculated by AI become my reality.

In August 2020, something historic happened in the finals of DARPA's Alpha Dog Fight Trial. A veteran pilot from the F-16 Weapons School engaged in a simulated dogfight with Heron Systems' artificial intelligence. The result was 5 to 0. It was a complete victory for AI. Many people were shocked. Is the era of Top Gun over? But that day's defeat was not a dirge announcing the end of human pilots. It was a fanfare announcing the opening of a new era. This is an era where humans and machines team up. People ask. Will AI replace pilots? This question is wrong. In air combat, pilots are more than just flight technicians.

The pilot is the last link of responsibility. Who lives and who dies, at what moment you pull the trigger and at what moment you back off. War is a world of consequences, and with consequences comes responsibility. AI makes calculations quickly. However, we are not responsible. When unaccountable calculations dominate the battlefield, it is not a battle but a series of accidents. In July 2025, the U.S. Air Force conducted a historic flight. The Autonomous Cooperation Platform (ACP) flew with a manned fighter jet. Gen.

Ken Wilsbach, commander of Air Combat Command, said: “This test with ACP directly addresses the evolving requirements of modern warfare. We are learning quickly to improve our human-machine team.” An even more groundbreaking test took place in October of the same year. For the first time, American fighter pilots were instructed by AI air combat managers. Starsage, developed by Raft AI, shortens response time and increases accuracy, allowing pilots to make decisions in seconds instead of minutes. In October 2025, Anduril's YFQ-44A successfully made its first flight.

It took off at the touch of a button and performed the entire flight path autonomously. In January 2026, the U.S. Navy flew two BQM-177A unmanned aerial vehicles autonomously using Shield AI's HiveMind software. A virtual F/A-18 served as a squadron leader and instructed unmanned aerial vehicles to perform combat aerial patrol missions. Rear Admiral Rossi said: “Integrating AI-based autonomy into manned and unmanned platforms will be key to developing next-generation air fleet concepts.”

What AI really does in the cockpit isn't fancy conversation. Prioritize in situations where there are many targets. When sensors are telling different stories, it indicates which one is more trustworthy. In the electronic warfare environment, we find patterns that say, "This radar is trying to lure me, not catch me." Humans are weak at this kind of work. We become weaker when we are tired, stressed, and subject to gravitational acceleration. AI is strong there. Tirelessness is a superpower on the battlefield. There is a system called VIPR developed by the Johns Hopkins Applied Physics Laboratory.

It is an abbreviation for Virtual Intelligent Peer-Reasoning Agent. Just think of R2-D2 from Star Wars. A droid that assists the pilot. VIPR serves three roles for the pilot: A situationally aware colleague, a high-performing wingman, and a cognitive support assistant. Computer scientist John Winder explained it this way: "VIPR looks outward to track and anticipate enemy threats. At the same time, it must look inward to understand the human pilot's intentions, goals, and behavior second by second. When a pilot misses something in combat, VIPR notifies them in time to help them survive." However, AI's strengths can also become risks.

Tireless calculations sometimes lead to overconfidence. If the answers provided by AI are too smooth, humans stop thinking for themselves. The moment you stop thinking on the battlefield, death is reserved for you. So, the core of air combat between humans and AI is trust design. Trust is not a feeling. It's a structure. Why did AI make that decision, what data was it based on, how reliable is it, and what are the alternatives? Pilots should know this at a glance. Otherwise, AI becomes just another noise in the cockpit. During combat, people don't read long descriptions.

A few switches, a few beeps, and a few colors can determine life or death. That's why AI interfaces need to be simple. "Recommended Maneuver: Sharp right turn, Reason: SA- 20 estimate, Confidence 0.78, Alternative: Descent and cover terrain." This is the limit. The human brain doesn't read papers in combat. This is why explainable AI (XAI) matters. The AI should say, "Enemy missile is approaching from 3 o'clock, take evasive maneuver." The rationale should be, "This target has a 95% chance of being an enemy command center." That way I can hit the accept button. The squadron of the future will look different from today.

The method of fighting with one human being flying one fighter plane is disappearing. A single human becomes the commander of a squadron with multiple drones. The U.S. Air Force's Cooperative Fighter (CCA) program illustrates this. In 2024, the U.S. Air Force awarded development contracts to five companies. Anduril, Boeing, General Atomics, Lockheed Martin, Northrop Grumman. Among these, Enduril and General Atomics were selected to produce testing machines for stage 1 production. The goal is to secure 1,000 CCAs. The calculation is to attach two unmanned wingmen to each of approximately 500 manned fighters. The U.S.

Air Force plans to spend more than \$8.9 billion on the program from 2025 to 2029.

The drone scouts from the front, disrupts from the side, and replenishes armament from behind. The human role becomes decision-making, not maneuvering. Set tactical objectives, assign mission intent to the drone, and control the rules of engagement. AI can take the reins on behalf of humans, but

more importantly, it will coordinate the actions of swarms of drones. For drones that move like a swarm of bees to fight properly, the swarm must trust each other, share each other's information, and correct each other's mistakes. It is impossible for humans to do this in real time. The AI becomes the squadron's nervous system.

The problem is that the enemies also use AI. The air battle between humans and AI ultimately becomes a battle of algorithm versus algorithm. Deception also becomes more sophisticated. Fake targets, fake propagation, fake link tracks. The enemy sprays data poison that feeds on the AI. Pilots of the future will have to be more skeptical than before. Don't just believe what you see on the screen. It is also dangerous to immediately follow what AI recommends. Paradoxically, pilots in the AI era must train more classic senses. Basic maneuvering, basic situational awareness, basic communications.

When Link dies and the AI becomes confused, what survives is ultimately humans' aviation skills and tactical instincts. As technology advances, fundamentals become more brutally important. How much control will we hand over to AI? There is a concept of meaningful human control. It is a mechanism that seeks to ensure ethical and safe use of autonomous systems. But research shows that there are significant barriers to achieving this in highly autonomous AI systems. Time constraints are the first. In hypersonic combat, AI makes decisions too quickly for humans to intervene.

By the time the human pilot assesses the situation, the battle may already be over. There are also cognitive limitations. Humans can't track and assess dozens of threats simultaneously, but AI can. It would be naive to think that the problem can be solved by pressing the "Human Approve" button. The battlefield is fast, and the accept button becomes a bottle neck. If a human has to press it every time, the drone will slow down. Slow drones are good targets. Conversely, if you leave it to AI, the problem of liability for misrecognition and misfire remains. The future is likely to be phased. Defensive autonomy expands first.

Avoidance maneuvers, threat avoidance, jamming countermeasures, and formation realignment. Aggressive autonomy is more tightly bound by rules and restrictions. This is a form in which AI takes over the fighting body and humans take over the will to fight. The trust between pilots and AI must be redefined. Human pilots must develop appropriately calibrated trust in autonomous systems. Do not over-rely on the system's capabilities and underestimate its potential, and do not use it fully. Mark Brinkley, Director of General Atomics, said: "Pilots need to be able to train like they fight. Simulation

Through training and training, we need to develop a mental model of how autonomous teams work to increase interoperability and effectiveness." Dogfighting between humans and AI is not simply about increasing power. Speed up the war. There is something called an OODA loop. Observation, judgment, decision, action. In battle, the one who rotates this cycle faster than the enemy wins. AI reduces the time to observe and judge to almost zero. Humans focus on making decisions and taking action. Before the enemy even realizes the situation, we will already have our sights set on their neck.

Winning or losing is not determined by a single genius maneuver, but by a continuously updated system. Who learns faster, who adjusts tactics faster, and who blocks vulnerabilities faster. War is

increasingly becoming like software. In a software war, the winner is always the same. One that updates quickly, one that is resilient, and one that is designed so that humans can make good decisions at the last moment. In the cockpit I still hold the stick. But there is an invisible pilot sitting next to me. The pilot has no fatigue, no fear, no pride. Instead, there are errors, deception, and overconfidence.

The aerial battle between humans and AI is an era in which we must fly together with our imperfect companions. The skies of the future will be smarter, but they will also likely be crueler. Who will be the ruler of heaven? The answer is clear. Neither AI nor human. We are humans who are perfectly integrated with AI. You don't have to be afraid of technology. However, we must be wary of losing control of the technology. In the hands of a cook, a knife makes a great meal, but in the hands of a robber, it becomes a weapon. AI also depends on how we use it and how we control it. This is also the path that Korea must take.

Beyond simply developing AI technology, we need to train wise warriors to operate that technology. Only when technology and people, ethics and efficiency are in harmony, will we be able to achieve truly independent national defense and peace. The Top Gun of the future will no longer be a lone wolf. He will become a battlefield commander connected to numerous AI wingmen and digital neural networks. And the sky still belongs to the courageous.

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Epilogue: Who Will Rule the Sky?

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Epilogue: Who will rule the sky? In the summer of 2024, two F-16s faced each other in the sky above Edwards Air Force Base. Two fighter jets rushing toward each other at 900 kilometers per hour. There was no one sitting in the cockpit of one of them. AI was at the controls. A fierce dogfight lasted for an hour. The result may have been foretold. The human pilots were defeated. But does this mean the end? It has been flying for decades. While performing Wild Weasel missions, I jumped into the middle of enemy air defenses and crossed the line between life and death countless times in a cockpit with a radar warning receiver blaring like crazy.

When the G-force pressed down on my body, even at the moment when my vision narrowed and I lost consciousness, my fingers did not let go of the control wheel. human limitations. It definitely exists. Under the pressure of 9G, my heart had to beat at three times its normal speed and I had to strain my stomach with all my might to maintain blood flow to my brain. AI does not know such pain. No fear, no fatigue, no hesitation. It judges and reacts to situations in milliseconds. So is the era of Top Gun really coming to an end? Should human pilots, like Maverick in the movie, become a relic of the past?

Looking back on history, this is not the first time this question has been asked. By 1957, American military leaders had declared that the era of manned fighter aircraft was over. They said that now that the era of missiles has come, pilots are no longer needed. But 70 years later, humans are still sitting in fighter jet cockpits. The Vietnam War upset that prediction. Missiles alone could not dominate a complex battlefield. It required human judgment, intuition, and understanding of the situation. It reminds me of the days when Roman legionaries stood on the battlefield holding gladius swords. That short sword was not just a weapon.

It contained the spirit of a warrior who had to fight while making eye contact with the enemy in close formation. The same was true for medieval longbowmen. The power to pull the bowstring, the eye to read the wind, and the sense to predict the enemy's movements. Weapons have changed, but the role of humans in handling them has not disappeared. The war in the sky will be no different.

What we are witnessing now is not an apocalypse, but an evolution. In 2025, in Sweden, Saab's Gripen E fighter jet was equipped with an AI called 'Centaur' and conducted a test flight with a human pilot. This AI is not intended to replace pilots. It was created to help. It analyzes complex sensor data, organizes threats by priority, and provides pilots with the information they need to make decisions. In other words, AI is a tireless combat assistant. The US Air Force's 'loyal wingman' concept is in the same context. A manned fighter piloted by a human pilot becomes the squadron leader, and drones controlled by AI guard his side.

Just like in an ancient battlefield, a general was surrounded by guards and advanced into the enemy camp. X-BAT, developed by Shield AI, is an unmanned fighter jet that can take off and land vertically without a runway. A range of over 2,000 nautical miles and a flight altitude of over 50,000 feet. The future in which these aircraft operate alongside the F-35 is approaching. Lockheed Martin is working on making the F-35 a 'selectively manned aircraft'. Depending on the situation, the same fighter can be flown by a human pilot or an AI can fly alone.

Dangerous missions are left to AI, and humans step in in situations that require complex judgment. China is not standing still either. Sixth-generation fighter prototypes, believed to be J-36 and J-50, appeared in the sky. Another stealth aircraft was spotted in August 2025. It could be a loyal wingman drone, or a brand new decoy. In Europe, two sixth-generation fighter projects are underway simultaneously: GCAP and FCAS. And then there is South Korea. The KF-21 Boramae is our first domestically produced supersonic fighter jet. Adding to this is the NACS program, which combines AI and unmanned aerial vehicles.

Korea Aerospace Industries is planning a manned and unmanned complex system linked to low-orbit communication satellites. Small countries need to be smarter to survive among great powers. Combining the human brain with the speed of machines. That is our way. If you ask me who will be the ruler of heaven, I will answer: Neither human nor AI. The one who joins the two will rule the sky.

Just as a knight roamed the battlefield as one with his horse, future combat pilots must become one with AI. When a radar alert sounds, an enemy missile flies, or when millisecond decisions are needed, AI analyzes data and presents choices. However, the final decision to pull the trigger and bear the weight of it still rests with humans. Ethical responsibility, legal responsibility, and responsibility in the face of history. That cannot be handed over to a machine. I look up at the sky again today. We don't know whether what will one day fly through that blue sky will be a human, a machine, or a combination of the two.

One thing is certain: Heaven will always belong to the bravest, wisest, and best prepared. It was true on the battlefields of BC, it was true during the biplane days of World War I, and it is true now in the era of the F-22 and F-35. Even in the coming era of AI, that truth will not change. Descendants of fighter pilots, have no fear. Adapt. Evolve. Just as pilots of the past transitioned from propellers to jet engines and from mechanical controls to fly-by-wire, you too must move toward coexistence with AI. That is the way to survive, the way to victory, and the way to become the ruler of heaven. The infinite sky spreads beyond the canopy.

It is an area that still requires human dreams and courage. No matter how advanced AI is, only humans know why they fight and what they protect. Even though the technology of war changes, the nature of war does not change. And at the center of that essence, humans always stand. Who will be the ruler of heaven? The answer ultimately depends on ourselves.

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