Added value and possible employment concepts for unmanned collaborative combat aircraft systems in FCAS and equivalent programs

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Table of abbreviations

BMC2	Battle Management Command and Control
CASE	Close Air Support
CCA	Collaborative Combat Aircraft
DCA	Defensive Counterair
DIL	Disconnected, Intermittent, Limited
ELINT	Electronic Intelligence
ESM	Electronic Support Measures
F2T2EA	Find, Fix, Track, Target, Engage, Assess
FCAS	Future Combat Air System
GAASI	General Atomics Aeronautical Systems, Inc.
GCAP	Global Combat Air Program
IMINT	Imagery Intelligence
IOC	Initial Operational Capability
LW	Loyal Wingman
MUM-T	Manned-Unmanned Teaming
NGAD	Next Generation Air Dominance
NGF	Next Generation Fighter
NGWS	New Generation Weapon System
OBSS	Off-Board Sensing System
OCA	Offensive Counterair
OCL	Offensive Counterland
RC	Remote Carrier
SEAD	Suppression of Enemy Air Defenses
UCAV	Unmanned Combat Air Vehicle
USAF	U.S. Air Force
USN	U.S. Navy

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Summary

Most of the major military powers – either alone or in partnership – are designing future air combat systems of systems based on collaborative combat between new-generation manned fighters and unmanned aircraft systems.

The standard-setter in this field is clearly the United States. After years of procrastination, the U.S. Air Force (USAF) and the U.S. Navy (USN) are now focusing on developing a substantial inventory of Collaborative Combat Aircraft (CCA) in the medium term, to increase the depth of their combat aircraft fleet, which they believe has shrunk to a level unable to counter Chinese aggression. The current concept is that of "affordable mass", *i.e.* increased mass at controlled cost. These CCAs will be integrated into the Next Generation Air Dominance (NGAD) systems of systems for both the U.S. Air Force and Navy. The first mission set concerned by this vast collaborative combat architecture is counterair, achieving air superiority (*i.e.* locating and suppressing enemy air defense systems – SEAD), but the USAF envisages "100 roles" for CCAs (interdiction, CAS, communications relay). That said, the debate on the tradeoffs to be found in terms of the cost and operational performance of these systems is still ongoing.

The Americans are currently working on land-based, mostly recoverable aircraft, based on developments such as the Kratos XQ-58, the *Gambit* family from GA-ASI, or Boeing's MQ-28 *Ghost Bat*, although it is not certain that these systems are yet up to the task. Nonetheless, a system of this type will probably form the backbone of the initial CCA increment, translating into the acquisition of at least one thousand units by the U.S. Air Force in the medium term to operate in Manned-Unmanned Teaming (MUM-T) with the F-35 and then the NGAD fighter. While the platform(s) to be used will depend on the level of performance required, it seems certain that these systems will be based on a modular open architecture and on the *Skyborg* artificial intelligence system, development of which is already complete. The Americans are also developing unmanned air-launched vehicles (*e.g.* the Defense Advanced Research Projects Agency's *Longshot* program). Lockheed Martin's designs and the Mitchell Institute's wargames suggest that the U.S. will probably eventually settle on a family of CCAs offering varying levels of performance, some expendable, others recoverable, with a variety of launch solutions, including small numbers of "exquisite" recoverable systems – highly sophisticated unmanned intelligence platforms or Unmanned Combat Air Vehicles (UCAVs). The experts involved in the Mitchell Institute's work on several counterair missions favored the massive

use of expendable CCAs for decoy, ISR, collaborative air combat and communications relay purposes in the initial phase of combat, flying ahead of fifth-generation fighters, before engaging more sophisticated recoverable CCAs once enemy capabilities had been weakened, in order to expand the coverage of the friendly system. They did not use available UCAV solutions.

Many countries are following the American example, albeit with more limited resources:

- ⇒ The UK, with BAE Systems, is developing RC solutions in conjunction with the *Tempest* Global Combat Air Programme (GCAP) – two types of land-based, recoverable RC, light and heavy, offering different levels of sophistication.
- ⇒ Australia is cooperating with Boeing on the MQ-28 *Ghost Bat,* a concept similar to the American CCA. This Australian model is also inspiring the Koreans, who are working on a loyal wingman drone to accompany advanced versions of their KF-21 *Boramea* fighter.
- ⇒ Japan is also developing an RC capable of operating with its future F-X fighter in the 2030s, with support from the U.S.
- ⇒ Among strategic competitors, Russia's situation is the most uncertain. Moscow is working on the development of UCAV-type loyal wingman drones such as the S-70 *Okhotnik* and *Grom*, but Western sanctions and the lack of propulsion solutions have drastically slowed progress on these programs.
- ⇒ China is in a much better position, and is developing, among a wide range of UAVs, a family of collaborative combat systems to operate in MUM-T mode with manned fighters, in particular the J-20: the *Feihung* FH-95 turboprop ISR and electronic warfare drone and FH-97 combat drone, which closely resemble recoverable American CCA designs.
- ⇒ India is also developing its own system of systems, the Combat Air Teaming System (CATS) from Hindustan Aeronautics Limited, comprising the *Tejas* manned fighter as a "mothership" and several RCs, in particular the CATS *Warrior*, quite similar to the MQ-28 and XQ-58, the CATS *Hunter*, a recoverable cruise missile-type RC, and ALFA loitering munitions.
- ⇒ Turkey, which has set up an air power model with extensive reliance on unmanned aircraft, both for its DITB and to compensate for problems on its combat aircraft programs, is also pursuing the development of its own MUM-T RC technology building blocks alongside the future F-X *Kaan* fighter: Bayraktar's supersonic *Kizilelma* UCAV, *Anka-3* stealth drone, *Super Simsek* expendable drones and Turkish Aerospace's Autonomous Wingman Concept.

We note that for most of these air forces, the development of unmanned vehicle technology building blocks and MUM-T systems comes in response to the critical need to compensate for a shortfall in the number of conventional combat aircraft, which can have multiple causes.

What conclusions can be drawn for the Future Combat Air System (FCAS) and its collaborative combat aircraft systems? In many respects, the French case is similar to that of several of these nations. It is true that, considering the tendency set by the multiyear LPM military spending bill, future French air power should benefit from multiple capability advances, including a Next Generation Fighter (NGF), providing all the added value of a new-generation combat aircraft, indispensable in the battlefield of the future. This being said, the first challenge facing the RCs is to correct the lack of depth in air power, which is likely to continue to deteriorate and will become increasingly problematic as more and more nations implement IADS (Integrated Air Defense Systems) upgrades, or as American reassurance becomes increasingly uncertain. The consequences of such a decline are well known: it affects the ability to meet requirements in the various strategic functions; in intervention more specifically, it makes attrition unsustainable, reduces the range of operational options available, and makes it impossible to maintain permanent postures, *e.g.* for dynamic targeting.

Beyond this question of depth, RCs can also qualitatively enhance the capabilities of air combat power: by providing a “stand-in” capability (usable inside the engagement range of enemy systems) they increase the penetrating mass of air power; they enable intelligence and engagement/combat capabilities to be dispersed and disaggregated, making the latter more resilient and improving spatial and temporal coverage. The diversity of launch solutions, which are truly multi-domain, enhances the flexibility and availability of air power.

In many respects, the thinking of Airbus and MBDA on the one hand, and that of American experts (highlighted by the work of the Mitchell Institute mentioned above), on the other, converge towards fairly comparable types of solution, within the framework of an FCAS architecture which is of the same order as that of American NGAD. This applies to the need to reduce “cost per effect” through a mix of attritable systems, whether expendable or recoverable, offering a variety of launch solutions. A number of conditions must be satisfied before these systems can be implemented. These include the definition of tradeoffs between operational performance and cost, the need to develop specific equipment and munitions, the indispensable connectivity architecture and autonomy solutions both for the manned platform whose crew will have to manage these RC missions and, of course, for the vehicles themselves. The autonomy of these vehicles will then have to be governed by very strict rules of engagement. In our view, the actions of these drones can be managed at two levels: at the level of the mission leader, of course, which is what is most often envisioned (hence the notion of the loyal wingman), but also potentially at the level of the Battle Management Command and Control (BMC2) function, which will itself be increasingly distributed. The Americans emphasize that the degree of autonomy to be granted to unmanned aircraft within the context of these rules of engagement, and the level of management of their actions, are variable and interdependent. In particular, they will depend on the operational context, including an electromagnetic environment that can be Disconnected, Intermittent, Limited (DIL) to varying degrees, which affects the functioning of the combat cloud, the connective tissue of the system of systems.

From an operational point of view, these RCs can transform the performance of all missions, including:

- ⇒ for the intelligence function, by providing penetrating sensor networks that considerably extend the coverage of ISR systems;
- ⇒ in the counterair domain, by providing remote decoy, jamming, targeting and engagement capabilities in collaboration with fighter aircraft stationed well away from the front line, enabling on the one hand disorientation and saturation actions required to blind and disintegrate enemy integrated air defense systems (through

SEAD and fighter sweep); and on the other, the creation of dynamic targeting capabilities enabling a sustained SEAD effort for an extended duration in a semi-permissive environment;

⇒ in the offensive counterland (OCL) domain, by increasing the penetrating mass at the start of the campaign and then maintaining coverage of large areas for longer periods of time, enabling the multiplication of interdiction dynamic targeting capabilities, which are also necessary to increase the availability of close air support;

⇒ by providing advanced sensor networks and transmission relays to extend the range and robustness of the Battle Management C2 (BMC2) function.

In conclusion, there is no shortage of potential uses for RCs in future air combat, to recreate the "affordable mass" that the Americans talk about and that Europe sorely needs. Nevertheless, there are a number of challenges to overcome if we are to exploit the full potential of these systems.

It seems to us that we must examine the efficiency of these systems in relation to manned fighters. This efficiency depends on a delicate compromise between, on the one hand, the expendable nature that these machines must retain if they are to be acquired in sufficient numbers, and, on the other hand, performance and reliability thresholds – a compromise that is all the more difficult to find given the need to anticipate, among other things, the confrontation with Integrated Air Defense Systems (IADS) transformed to survive saturation. Secondly, RC employment concepts will have to be based on excellent multi-domain integration to optimize synergies. This raises the question of the C2 agility of the forces implementing these drones, as well as the issue of multinational interoperability between FCAS, NGAD, GCAP and other systems of systems. In terms of technical resources, this presupposes that combat clouds are actually developed as planned. In this respect, while construction of MUM-T will be based in part on existing technologies, *e.g.* in terms of connectivity, it is also based on technological presuppositions that have yet to be demonstrated, notably in the field of artificial intelligence, particularly for manned platforms managing the missions.

These various conditions naturally argue in favor of incremental development, starting as soon as possible, for both RCs and the combat cloud, in order to open avenues leading to concrete solutions to these multiple challenges, as the demonstrations already undertaken or planned fortunately tend to indicate.

Introduction

Unmanned aircraft have been transforming air warfare for at least twenty-five years. They have gone from being the back-up sensors they were for several decades, to the pillars of intelligence functions, to the indispensable sensors and effectors that everyone now recognizes, and which have been used in many different ways in recent wars, from Libya to Ukraine. The years and decades to come promise even more significant transformations in the robotization of air combat.

These transformations are primarily driven by future technological developments, in particular the prospects of artificial intelligence reaching maturity: systems that are no longer simply remotely piloted, but partially autonomous; tactical-level clouds enabling the decentralization to platform level of decision-making capabilities that are currently reserved for remote or even out-of-theatre command posts; collaborative services between mission systems on different platforms, both manned and unmanned; the miniaturization of equipment and weaponry; etc. These technological advances are accompanied by numerous other developments. Firstly, as manned platforms increase in sophistication and operational performance, they are becoming more and more expensive and can no longer be acquired in the same volumes as their predecessors, leading to the inexorable erosion of air force structures. At the same time, the return of high-intensity conventional warfare is synonymous with less permissive environments, all the more so as air defense systems are also undergoing significant improvements.

In view of these developments, most of the air forces of the major powers are designing their future combat capabilities around the notion of families of systems, or even systems of systems, with crewed platforms and unmanned systems operating together, supposedly at lower cost, enabling air forces to engage with less risk and restore depth. The Future Combat Air System (FCAS), which represents the future of French air power, is no exception to this rule of partnership between manned and unmanned elements. The New Generation Weapon System (NGWS) consists of a manned platform, the Next Generation Fighter (NGF), unmanned systems, in this case Remote Carriers (RC), and various weapons with access to the cloud.

This vision of a system based on a partnership between manned aircraft and drones has become so self-evident that its necessity is scarcely questioned. However, many experts still question the lack of detailed visions concerning employment of these systems. This note therefore proposes a reflection on this theme. The first part summarizes the state of the art in terms of the various projects for systems of systems and drones equivalent to the Remote Carriers, starting, of course, with the Americans. The second part is devoted to an analysis of the situation in France. Insofar as this is a note and not a technical-operational study, its analytical granularity is necessarily limited. Readers will therefore be offered a number of milestones, questions and avenues for further exploration.

A few terminological clarifications are in order, as the terms used in the specialist literature can be confusing:

- ⇒ First of all, the term “Remote Carrier” (RC) is often referred to as “remote effector”, but the drones in question are not necessarily effectors (in the sense traditionally attributed to this notion, designating systems directly exerting effects on the adversary or the environment). Even a broader designation such as “sensors and/or remote effectors” does not capture all the possible uses of these systems. We therefore propose the more inclusive term “collaborative combat aircraft systems”. Nevertheless, to avoid overloading the document with abbreviations, we retain the RC abbreviation in the body of the text.
- ⇒ In most of the concepts considered, a distinction is made between “expendable” drones, *i.e.* for single use, like munitions, and “recoverable” drones, *i.e.* reusable for several missions but nonetheless “attritable”, whose potential loss is therefore integrated from the design stage. Definitions may vary, however. Finally, the

concepts envisage a more sophisticated category of drones outside this paradigm, which we will continue to refer to as Unmanned Combat Aerial Vehicles (UCAVs).

⇒ It should be borne in mind that the widely used term "loyal wingman", referring to the addition of one or more drones to a patrol of manned fighters, represents just one of the many uses to be considered for RCs.

⇒ To describe the collaborative action between the components of these air combat systems, including the NGWS, we will use the most widely used American term Manned-Unmanned Teaming (MUM-T). This generic term should not, however, obscure the fact that this collaborative action goes far beyond the relationship between a manned platform and a drone, and can include collaboration between drones, and even between drones and weapons.

Collaborative combat aircraft system projects around the world

1. American collaborative combat aircraft models

In many respects, the system-of-systems logic defined for FCAS echoes the general economics of American Next Generation Air Dominance (NGAD) projects, in which a new generation of manned aircraft will operate in cooperation with drone systems, now called Collaborative Combat Aircraft (CCA), comparable to our Remote Carriers (RC). It should be noted that the Americans have two NGAD and CCA projects: that of the U.S. Air Force, the most hotly debated in the public arena, and that of the U.S. Navy.

1.1. CCAs in the USAF

For the U.S. Air Force, CCAs are now at the core of American air power, of which the USAF is the principal custodian. However, while there has been an abundance of research and experimentation over the years, while the intention to transform this into a medium-term acquisition now seems well established and initial budgets have been released, there are many uncertainties surrounding the implementation of these systems, both operationally and organically.

1.1.1. How the role of drones within a system of systems has evolved

Since the Vietnam War, drone programs have had a convoluted history within the U.S. Air Force. In fact, it was the Israeli Army, not the USAF, that was at the forefront of the development and use of these systems for several decades. It took advances in major technological building blocks, such as satellite communications, GPS and, above all, the rapid increase in surveillance requirements generated by the major irregular wars that followed September 11, 2001, for these remotely piloted systems – in particular the MQ1 *Predator* and MQ9 *Reaper* theater MALE drones – to cross a real "institutionalization threshold" within the USAF (*i.e.*, in short, the capability threshold at which the institution feels it can no longer do without the said system). At the same time, however, the development of the next generation of drones – systems designed for combat in a non-permissive environment, Unmanned Combat Aerial Systems (UCAS) – has once again suffered from a series of delays, due to the lack of a clear vision of requirements. In 2006, for example, the USAF withdrew from the Joint-

UCAS program it was conducting with the X-45, leaving the Navy to continue work alone with its X-47. Of course, the development of numerous classified technologies continued. Witness the RQ-170 and RQ-180 ISR stealth systems.

From the 1990s onwards, faced with the proliferation of long-range ground-to-air capabilities, followed by fifth-generation fighter programs developed by Russia and China, as well as anti-satellite and cyber capabilities – in short, "anti-access and area denial" (A2/AD) capabilities – the U.S. Air Force considered that the superiority of Western power was ultimately compromised. The situation called for better integration of operations in different environments (the Multidomain Operations (MDO) concept), as well as a rethink of the USAF's future force structure and weapons systems. The classified *Air Dominance Initiative Study*, conducted in 2014 by DARPA, estimates that "*[n]o single new technology or platform could deter and defeat the sophisticated and numerous adversary systems under development*"[1]. The *U.S. Air Force Future Operating Concept* (AFFOC), published in 2015, emphasized the need for strong operational agility in future air power. One of the attributes of this agility must be a "*balanced capabilities mix*": "*The future Air Force will retain tailored numbers of high-end assets to operate against adversaries that pose advanced threats [...]. To conduct follow-on sustained operations or a sustained irregular warfare effort in a permissive or semi-permissive environment, AF forces primarily will use lower-cost/lower-capability assets [...]*"[2]. The *Air Superiority 2030 Flight Plan*, developed by a USAF team in 2016, comes to similar conclusions: "*The Air Force's projected force structure in 2030 is not capable of fighting and winning against this array of potential adversary capabilities. Developing and delivering air superiority for the highly contested environment of 2030 requires a multi-domain focus on capabilities and capacity*"[3].

In short, not only did the modernization of capabilities (in the sense of operational performance) need to be actively pursued, but the capacity (in the sense of force volume) anticipated until then was no longer considered sufficient. The 1990s acquisition slowdown, the premature termination of the F-22 and delays to the F-35 have exposed the USAF's force structure to an aging process that new acquisitions cannot compensate for, and thus to a structural reduction in the mass of its engagement/combat function. However, this reality has yet to be translated into concrete new programs, particularly when it comes to defining the specifications of the future combat aircraft that will succeed the F-35. In this respect, the USAF continued to focus on a fairly monolithic Penetrating Counter-Air (PCA) aircraft. In 2019, the Congressional Budget Office (CBO) estimated that the unit acquisition cost of this PCA (assuming a scenario of over 400 acquisitions) would be around $300 million, more than twice the price of an F-35. This cost increase is in line with Augustine's Law[4]. At the end of 2018, aware of this problem, the *U.S. Air Force*, under the leadership of General Goldfein and his head of acquisitions, the "disruptive" Will Roper, definitively steered the design of what was

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[1] Statement Testimony of Mr. Alan R. Shaffer, Principal Deputy, Assistant Secretary of Defense for Defense Research and Engineering before the United States House of Representatives Committee on Armed Services, Subcommittee on Emerging Threats and Capabilities, March 26, 2014, p. 18.

[2] Deborah Lee James, Mark Welsh, *Air Force Future Operating Concept, A View of the Air Force in 2035*, September 2015, p. 10.

[3] Enterprise Capability Collaboration Team, *Air Superiority 2030 Flight Plan*, May 2016, p. 3.

[4] The 16th law of Norman Augustine, ex-CEO of Lockheed Martin, which states that due to the increasing cost of platforms, the Pentagon will only be able to acquire a single aircraft in 2054. Compared with this 1977 estimate, the curve has actually tended to flatten out since then, due to the longer duration of programs.

henceforth to be called the Next Generation Air Dominance (NGAD) program towards a portfolio of systems[5].

In both cases, drones would emerge as a complementary solution to manned fighters. In terms of capability performance, Manned-Unmanned Teaming was seen as a pillar of collaborative combat. AFFOC, for example, envisioned an F-35D operating in cooperation with multi-mission long-range (MMLR) RPASs deployed from the ground, for air superiority and cruise missile defense, with dynamic distribution of drone C2 between fighter aircraft and ground operators depending on the degradation of the electromagnetic environment. Above all, the drone became the solution to the capacity crisis facing the service. In 2016, General Holmes, Deputy Chief of Staff for Strategic Plans and Requirements, joined others in advocating a system of air superiority systems based on missile-armed "Loyal Wingmen"[6]. Dave Deptula's Mitchell Institute, always highly influential, also backed MUM-T in 2017-18: the combat drone employed in this way would enable a return to "digital resilience" in high intensity, preserve the potential of sophisticated manned aircraft from "low-end" missions, and ensure substantial savings in training and maintenance in peacetime[7].

The effort to rationalize the USAF's current capability strategy around seven operational imperatives outlines the approach taken. The fourth of these imperatives, Tactical Air Dominance, sums up the system-of-systems approach: *"The NGAD family-of-systems is, in part, a new crewed platform. It will also include uncrewed air combat aircraft teaming with the crewed platform, the connectivity systems between those platforms, the sensors that support them, the suite of weapons the platforms can carry, and more. This concept includes notionally one or more unmanned combat aircraft operating as a formation controlled by a single, modern, manned aircraft – principally the NGAD manned platform but also the F-35"*[8].

1.1.2. The nature of CCA: the concept of "affordable mass" still under debate

Although drones did not establish themselves as decisive elements of air combat power until the end of the 2010s, and the U.S. Air Force did not go ahead with the X-45 stealth drone program, this did not prevent the service from developing, as early as the end of the 2000s, roadmaps for the development of technological building blocks for all drone families, from nano to large systems (successor to the *Global Hawk*), including small (successor to the *Raven* and *Small Eagle*) and medium systems (successor to the *Reaper*). In fact, the eventual use of these future MQ-Xs in electronic warfare, C2 relay, Suppression of Enemy Air Defenses (SEAD) and Close Air Support (CAS) missions had been on everyone's mind for over twelve years.

Recently, the main concept for combat drones to be used in MUM-T as part of the combat system of systems was renamed CCA. However, there appear to be several other, mostly

[5] Steve Trimble, "The Nearly Decade-long Story That Led To NGAD Flight Demonstrator", *Aviation Week Network*, September 21, 2020. Roper's plan to rapidly develop and successively acquire a series of less expensive fighter types than a long conventional program was nevertheless abandoned.

[6] Matt, "Innovation and Air Dominance: Human-Machine Combat Teaming, A SoS Solution to Air Superiority - Part II", *American Innovation* blog, May 18, 2016.

[7] Lt Gen David Deptula, USAF (Ret.), Douglas Birkey, Maj Gen Lawrence Stutzriem, USAF (Ret.), *Manned-Unmanned Aircraft Teaming: Taking Combat Airpower to the Next Level*, Mitchell Institute for Aerospace Studies, July 10, 2018.

[8] Department of the Air Force, *Operational Imperatives*, 2023.

classified, programs, including the Off-Board Sensing System *(*OBSS), a remote sensor system about which few details have been released.

Following the logic of the balanced capabilities mix, to be able to recreate mass, low cost is inevitably a major criterion for drones within a system of systems. This is logically reflected in the specifications of the corresponding R&D programs. Thus, in 2016, the Air Force Research Laboratory (AFRL) launched a set of technological developments, designated Low Cost Attritable Aircraft Technology (LCAAT), including a Low-Cost Attritable Strike Unmanned Aerial System Demonstration (LCASD), which it contracted with Kratos Defense & Security Solutions, Inc.

The CCA concept did not yet seem to be fully defined in this respect. Until around 2021, the Americans tended to distinguish between the terms "expendable", *i.e.* a consumable vehicle that could only be used for a single mission, and "attritable", recoverable for a series of missions but which you can afford to lose in a non-permissive environment where you would hesitate to risk an "exquisite" platform, the ultimate degree of sophistication and cost. A semantic shift has since taken place, as the notion of "attritable" drone has been replaced by that of "affordable mass". This seems to mark a change in the main parameter, namely the cost of the system, rather than the planned number of missions[9]. However, the notion of affordable mass is itself evolving. At the Air and Space Forces Association's Warfare Symposium in March 2023, General Jobe, Director of Plans and Programs at Air Combat Command (ACC), made it clear that risk-taking was a question of operational C2, not aircraft design. General White, Commander of the Combat Aircraft Program Office, pointed out that if the aircraft does not bring significant capabilities to the fight, its affordability is of little use: "*Affordable mass has to be based on affordability and capability.... We have to start thinking through the lens of lethality for the development*" of these drones[10]. It seems, then, that we are in a phase – fairly common in military institutions – of expanding system specifications. For example, the USAF is beginning to emphasize a larger payload, and therefore greater mass, and in-flight refueling.

Against this backdrop, the House Armed Services Committee initially proposed setting unit acquisition cost limits for these systems in its *National Defense Authorization Act* 2024 (NDAA FY24): $3m for an expendable CCA, $10m for an attritable CCA, $25m for an exquisite vehicle. In this respect, the parliamentarians are quite close to the recommendations made by researchers at the Mitchell Institute, who suggest a scale of options, in particular mission equipment, from $2 million at the expendable extreme to $20 million for a sophisticated system[11]. However, the NDAA for 2024 does not include this proposal. In fact, Air Force Secretary Frank Kendall obviously disagreed. He refers more nebulously to "*one-quarter to one-third the cost of an F-35*", *i.e.* between $20 and $27 million if we refer to the unit cost of the last batch of F-35As, around $82 million. The CCA will also be broken down into at least

[9] Joseph Trevithick, "Here's Why This New Mysterious Air Force Drone Contract Is A Big Deal (Updated)", *The War Zone,* October 27, 2021.

[10] Joseph Trevithick, Tyler Rogoway, "Signs Point To Less Range, Higher Performance For CCA Drones", *The War Zone*, November 28, 2023.

[11] Mark Gunzinger, Lukas Autenried, *Understanding the Promise of Skyborg and Low-Cost Attritable UAVs*, Mitchell Institute for Aerospace Studies, January 2021.

two increments[12]. At the same time, according to General Lawhead, commander of Air Force Futures, "*it's clear that once a CCA reaches the cost of an F-35, it's better to buy an F-35*". The debate on the very nature of the CCA and the tradeoff between capability performance, cost and overall weight therefore does not appear to be over within the USAF. The request for information issued to industry in October is therefore not very precise. The only concrete element is the engine: the Air Force mentions a thrust specification between 3,000 and 8,000lb, which exceeds most of the available offers... The Navy, as we shall see later, is hardly any clearer.

In this context, NDAA FY24, while convinced of the potential contribution of CCAs, deplores that "*neither the Secretary of the Air Force nor the Secretary of the Navy has sufficiently explained to the congressional defense committees: (1) How the Departments can acquire the vehicles affordably in sufficient numbers to execute the concept of operations; or (2) How the program is being defined to apply to challenges in the near-, mid- and long-terms, particularly as it relates to unpiloted CCA capabilities that may be used in either an attritable or expendable mission taskings*"[13]. Congress therefore directed the Air Force and Navy to clarify the concept in a report to be provided in May 2024 and, for the FY25 budget, to provide updatable matrices detailing technological and industrial maturity, cost estimate and key performance parameters.

1.1.3. CCA program highlights

Despite these uncertainties, the CCA program is based on a few well-established elements. Firstly, to reduce costs, the CCAs of the Air Force, Navy and U.S. Marine Corps, which is also interested, will share four elements:

- ⇒ platform architecture;
- ⇒ communication architecture;
- ⇒ control segment;
- ⇒ artificial intelligence architecture for autonomous drone piloting.

The latter will be based on the *Skyborg* Autonomous Core System (ACS), the development of which was one of the USAF's three vanguard projects and is part of the LCAAT. Leidos was selected as the *Skyborg* System Design Agent (SDA), with multiple other contributors, including MIT. *Skyborg* ACS is a "universal" AI engine designed around a modular architecture to accommodate different types of platforms and mission equipment, such as sensors[14]. *Skyborg* is obviously not the only AI development initiative for autonomous systems. DARPA's Air Combat Evolution (ACE), for example, is also said to have fed into *Skyborg*. ACS has been integrated into several systems, including the *Kratos* UTAP-22 and XQ-58, GAASI's MQ-20 *Avenger* and the experimental F-16 X-62 *Vista*. However, according to Heather Penney of the Mitchell Institute, one of the limitations of *Skyborg* is that it does not natively integrate all the

[12] Joseph Trevithick, "CCA Loyal Wingmen Drones To Cost Quarter To Third Of An F-35", *The War Zone*, November 13, 2023.

[13] U.S. House of Representatives, "Sec. 224 - Next Generation Air Dominance family of systems development program accountability matrices", *in National Defense Authorization Act for Fiscal Year 2024 Conference Report to accompany H.R. 2670*, December 2023, p. 2397.

[14] Steve Trimble, "Skyborg Awards Set Stage For Revolution In Manned-Unmanned Teaming", *Aviation Week and Space Technologies*, Special Topic: Autonomous Technologies, February 2020, pp. 5-7.

modalities of MUM-T with a human operator[15]. Nevertheless, it seems that work on Human-System Interface is continuing in this direction. Little has been published about the AI techniques integrated by Leidos. However, in July 2023, the AFRL carried out a three-hour tactical flight on the XQ-58, mentioning on this occasion the machine learning algorithms developed by its Autonomous Air Combat Operations team as part of *Skyborg*, and fed with data from millions of hours of simulation and actual testing with the above drones[16].

The CCA must be based on a modular open architecture, the Modular Open Systems Approach having become a mantra in the development of weapons programs in the USA. That said, the equipment proposed by competitors predates the publication of the Future Airborne Capability Environment (FACE) and Sensor Open Systems Architecture (SOSA) standards. It will be interesting to see whether their future systems will have to comply with these standards.

Like the whole of the U.S. capability strategy vis-à-vis China, the program is marked by a sense of urgency. The initial target was set by Secretary Kendall at 1,000 CCAs, to operate in cooperation with 300 F-35s and 200 NGAD fighters, which are due to start entering service with the USAF in 2030. Initial Operational Capability (IOC) for these CCAs is targeted for 2028. The program is valued at $6 billion. The FY24 NDAA allocates the program $500 million for research, development, testing and evaluation, in particular to set up an operational experimentation unit.

1.1.4. Possible system types

Given these debates, the system that will comprise the CCA is still uncertain. For several years, the XQ-58 *Valkyrie* being developed by Kratos within the LCASD framework has been the "re-ference" experimental drone, to some extent. Given the evolution of the USAF concept mentioned above, it is no longer clear that the very "attritable" *Valkyrie* and its 2,000lb thrust engine meet the requirement.

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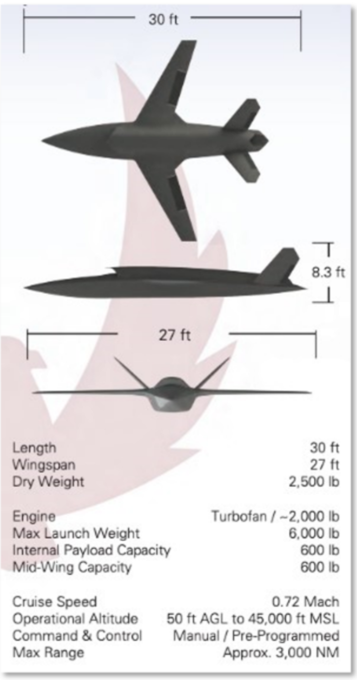
[15] Heather R. Penney, *Five Imperatives for Developing Collaborative Combat Aircraft for Teaming Operations*, Mitchell Institute for Aerospace Studies, Policy Paper, Vol. 38, September 2022, p. 18.

[16] "AFRL - Autonomous Aircraft Experimentation", AFResearchLab, YouTube, July 5, 2023; Air Force Research Laboratory Public Affairs, "AFRL artificial intelligence agents successfully pilot XQ-58A Valkyrie uncrewed jet aircraft", August 2, 2023.

A « reference » model : *Kratos* XQ-58A *Valkyrie*



- **Program origin and timing**
  - Manufacturer: Kratos Defense & Security Solutions, Inc.
  - Developed under the Low-Cost Attritable Strike Unmanned Aerial System (UAS) Demonstration (LCASD) launched in 2016.
  - Demonstrator / Kratos technology testbed in response to USAF LCASD specifications.
  - First flight 2019.
- **Characteristics**
  - Low-cost, low-radar signature reusable combat drone carrying various internal payloads for Of-fensive Counterair missions including SEAD and Defensive Counterair
  - Jet-assisted takeoff (JATO), recoverable by parachute and airbag. Deployable from land and sea-based launchers in container.
  - Range 1,500 nautical miles with 500lb payload.
  - Maximum speed Mach 0.9.
  - Internal weapons bay for two GBU-39 small-diameter bombs (SDBs) or Altius-600 mini-drones.
  - Acquisition cost proposed by Kratos: <$3m up to 99 units, <$2m for more than 100 systems.

Another competitor is the MQ-28 A *Ghost Bat*, developed by Boeing Australia, which offers a propulsion system similar to that of the Kratos. We will come back to this system in the discussion of the Australian RC program in the second section.

The other major competitor is clearly General Atomics Aeronautical Systems, Inc (GA-ASI), which is developing the *Gambit* family: *Gambit 1* for tactical ISR, *Gambit 2* as a remote air-to-air combat effector, *Gambit 3* for MUM-T training and *Gambit 4*, a flying wing for theater ISR. These systems feature 70 % shared components. One of these *Gambits* has been selected for the OBSS program.

Source: https://www.ga-asi.com/leading-the-way-in-autonomous-collaborative-aircraft

These proposed CCA concepts are therefore mainly land-based, recoverable UASs. However, DARPA is continuing to work on air-launched drones. The one most talked about is the X-61 *Gremlins* developed by Dynetics with Kratos. The main program objective was to test in-flight recovery of these tactical drone-sized systems by a C-130. Following a program launch in 2016, several flight tests were performed from 2019 to 2021. The FY24 budget indicates that funding ended in 2022, and it is unclear how the Air Force intends to follow up this program.

In 2021, DARPA launched a new air-launched drone program, the *LongShot.* The concept is that of a loyal wingman for air superiority missions, with the air-to-air missile-armed drone operating in collaboration, possibly well ahead of the NGAD fighter. It is not known whether this is an expendable system, or how it would be recovered. GA-ASI has received a contract for Phase III, starting in 2023, covering prototype production and flight testing ($94 million). The first flight is scheduled for 2024.

Source: https://www.ga.com/ga-asi-poised-to-begin-longshot-flight-testing-phase

1.1.5. Many questions: employment concept? organic management? C2 principles ?

As the concept is still under discussion, many questions remain unanswered. First of all, what exactly will the missions of these CCAs be? The Air Force mentions "numerous variants" and the possibility of entrusting "one hundred roles" to these CCAs. The emphasis is on collaborative air combat, but kinetic and electromagnetic SEAD, interdiction, CAS, communications relay, etc. are clearly also under consideration. General Minihan, who commands the Air Mobility Command, also imagines CCAs as PNT relays or used as forward-deployed effectors, activated on demand.

Bryan Clark, of the Hudson Institute, one of the most imaginative researchers into new modes of action, generally considers that "*[a]gainst a peer competitor, the use of uncrewed systems as extensions of crewed units tends to perpetuate the limitations of crewed systems while failing to take advantage of the ability of uncrewed technologies to improve the force's flexibility and resilience*"[17]. Linking these technologies to those of the Mosaic Warfare concept he actively promotes, he considers that they should be exploited to increase the diversity of American modes of action, multiplying the dilemmas imposed on the adversary, since action will be largely freed from the logistical and organizational constraints inherent in force aggregations composed of manned assets.

Heather R. Penney of the Mitchell Institute raises similar questions about the use of CCAs. For example, should these systems be tethered to a platform, as in the loyal wingman concept, as a remote platform for sensors (which seems to be the role of OBSS) and kinetic and electronic weapons in collaborative combat? Should they, on the contrary, operate more freely, untethered to a given platform, and be managed at the level of a more centralized Air Battle Management function? In her view, this approach allows the use of swarms, offers greater flexibility and, ultimately, imposes richer, more complex modes of action on the adversary. On this point, she fully agrees with Clark. Note that this differentiation more likely concerns the short/medium term, insofar as the pilot of the future NGAD fighter should be able to have battle management authorities delegated to himself, depending on the degree of autonomy of his navigation and attack system, and the capabilities of the combat cloud into which these elements are integrated[18]. Another question posed by Penney: should drone control be "directive" (detailed) or rather "descriptive", according to the principles of mission command? The second solution would obviously be preferable, but it presupposes the most advanced degree of autonomy.

Other questions concern the USAF's organic management of these aircraft. ACC and others often refer to the "replacement" of F-16s and MQ-9s by these CCAs, but does the solution necessarily involve retaining an organization into separate squadrons? In fact, some people seem to envisage the management of CCAs being closer to that of complex munitions, which would imply the distribution of the CCAs within existing fighter squadrons.

1.2. U.S. Navy CCA concepts

The U.S. Navy also intends to deploy CCAs as part of its own carrier-based NGAD. As usual, this special Navy requirement will present its own challenges.

[17] Bryan Clark, Dan Patt, *Unalone and Unafraid: A Plan for Integrating Uncrewed and Other Emerging Technologies into U.S. Military Forces*, Hudson Institute, August 2023, p. 12.

[18] See Philippe Gros, "Le 'cloud tactique', un élément essentiel du système de combat aérien futur", *Notes de la FRS*, n° 08/2019, 20 June 2019.

The first is the reduced mass of carrier-based aviation over the past twenty years – barely fifty combat aircraft, compared with around seventy during the Cold War. This reduction was underlined by the retirement of the KA-6D tanker aircraft, whose buddy refueling role was taken over by the F/A-18E, further draining fighter aircraft resources. It is true, however, that F/A-18 maintenance is simpler than that of the F-14, A-6 or even A-7, probably guaranteeing greater operational availability for the group.

Furthermore, the replacement of the Tomcat, Intruder and Corsair II by the "all-Hornet" fleet has resulted in a significant reduction in the air group's combat radius. Admittedly, this is not really a problem in major air campaigns in semi-permissive environments, with dozens of tankers in operation. But this loss of range becomes a critical challenge in Taiwan intervention scenarios, due to both the extended ranges inherent in the Pacific zone and Beijing's long-range interdiction capabilities, which make it very difficult to deploy such a refueling capability. As a result, the vulnerability of aircraft carriers to Chinese anti-ship missiles (DF-21D/DF-26, DF17, ballistic missiles, YJ-12 bomber-launched cruise missiles, etc.) has sparked a bitter debate within and outside the Navy for over fifteen years. This has resulted in questions as to the employment of the carrier strike group as a first-responder in a conflict of this type, augmented anti-ship capabilities of the surface component operating in autonomous groups (Distributed Lethality concept) and, finally, the Distributed Maritime Operations concept, emphasizing highly dispersed operations by the entire U.S. naval force to maintain, or even reinforce, its degree of lethality, while considerably complicating Chinese targeting.

In this context, the Navy intends to develop its own family of NGAD systems, centered on a future F/A-XX fighter, to replace the F/A-18 E/F in conjunction with the F-35C. The 260-aircraft acquisition target will ultimately be insufficient to go beyond the 16-aircraft squadron planned by the Navy in 2021 for its 2030 Carrier Vessel Wing (CVW), in addition to the 32 to 34 F/A-18/EA-18s[19]. Ultimately, around 2045, the USN intends to achieve 60 % unmanned platforms within this CVW, *i.e.* around 800 CCAs out of the 1,300 aircraft on board, according to *Aviation Week*[20].

When it comes to employment, it seems that the Navy is considering multiple options[21]:

- ⇒ In addition to in-flight refueling, which will be the MQ-25's primary function (see below), the role that has been mentioned for the longest period of time is obviously penetrating ISR.
- ⇒ The EA-18G *Growler*'s loyal wingman function for electronic attack and SEAD is also frequently mentioned.
- ⇒ Like other institutions, the Navy is logically thinking of the CCA as a missile carrier in collaborative combat within the NGAD system. That said, Admiral Harris, Commander Air Division Warfare on the CNO staff, highlights the challenges of using CCAs in air combat.

[19] Thomas Newdick, "Navy's Aviation Boss Lays Out Big Vision For Drone-Packed Carriers of The Future", *The War Zone*, April 1, 2021.

[20] Brian Everstine, "U.S. Navy Wants Its Carrier Air Wing 60% Uncrewed", *Aviation Week Network*, September 19, 2022.

[21] Thomas Newdick, *op. cit.*

⇒ For some years now, the Navy has also been planning a distributed airborne early warning function in which the CCAs would form a network with the E-2D *Advanced Hawkeye*, the air group's critical BMC2 node. As part of the many upgrades the aircraft is receiving, in 2021 the Navy launched the modification of the mission computer to enable MUM-T with drones[22].

Carrier compatibility constraints for these CCAs may mean a smaller, less expensive aircraft than those developed by the USAF. Particularly as the Navy is also considering the possibility of deploying these CCAs on other Air Capable Ships (ACS): amphibious assault ships (LHA), expeditionary sea bases, destroyers, etc.

The MQ-25 *Stingray*, which will be the first operational drone to be integrated into a carrier aviation group, will also serve as an exploratory system for the employment and integration of CCAs. The *Stingray*, which the Navy plans to deploy at a rate of five to eight aircraft per air group starting in 2026, will primarily be a tanker with a secondary mission as an ISR sensor in permissive environments. To further mature the CCA concept, Boeing carried out several virtual MUM-T tests of the MQ-25 in 2022 with F/A-18Es, E-2Ds and P-8A *Poseidon* maritime patrol aircraft, each of which was able to task up to four drones to conduct a surveillance mission. Control was prescriptive, since the P-8 and E-2D only specified the search area and no-fly zones to the drones. The MQ-25's AI engine developed by Aurora Flight Sciences managed the operational constraints on its own, planning its route and conducting its search pattern[23].

As we have seen, maximum interoperability will be sought with the USAF, not just for the CCA, but for the entire NGAD system family. For example, the Navy is talking about the ability to transfer CCA control from one component to another.

1.3. Other points of interest

1.3.1. Lockheed Martin Skunk Works concept

The vision of the CCA unveiled in July 2022 by John Clark, General Manager of Lockheed Martin's Skunk Works (SW), is quite interesting[24]. Clark begins by noting that, in air operations where stealth is paramount, the design of CCAs in terms of speed or radar signature must precisely "match" that of the fighter operating in MUM-T. Like all the players involved in the definition of these systems, SW was confronted with the tradeoff between expendable and recoverable aircraft. Having a drone that matches the fighter in terms of signature implies a more costly design, which must therefore be recoverable. In fact, the company did consider the possibility of recovery by splashdown in water, but this solution seems to have been

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[22] Garrett Reim, "U.S. Navy looks at manned-unmanned teaming role for E-2D Advanced Hawkeye", *Flight Global*, March 19, 2021; Howard Altman, "Keeping The E-2D Advanced Hawkeye On Top Into the 2040s", *The War Zone*, August 5, 2022.

[23] "Boeing Demonstrates Open Autonomy Architecture for Manned-Unmanned Teaming with MQ-25", *EDR Magazine*, September 6, 2022.

[24] Joseph Trevithick, Tyler Rogoway, "Vision For Future Manned-Unmanned Air Combat Laid Out By Skunk Works", *The War Zone*, July 12, 2022; Lockheed Martin, "Introducing the Distributed Team", YouTube, July 12, 2022; John A. Tirpak, "Lockheed Martin's Skunk Works Sees Value in MUT, Autonomous Aircraft", *Air and Space Force Magazine*, July 11, 2022.

abandoned due to the constraints imposed by naval recovery operations. Generally speaking, the cost of the logistical capabilities required to recover the drones must be taken into account as much as the cost of losing them in combat. At the other extreme, Lockheed Martin notes the value of a mass of expendable drones, as they are likely to generate a lot of chaos and confusion with the adversary IADS. Finally, Clark considers that these drones should operate untethered from manned fighters. LM's promotional video presents distributed teaming between the F-35 and a family of four types of drone, in ascending order of sophistication:

- ⇒ the Common Multi-Mission Truck (CMMT), presented as modular and expendable, is used in the LM video as a decoy or jamming platform, but can also be imagined as a loitering munition; these drones are apparently also called *SPEED RACER* (Small Penetrating Expendable Decoy Radically Affordable Compact Extended Range), according to another video[25];
- ⇒ the Tactical Expendable-Combat Air Vehicle (TE-CAV), a UCAV operating as a remote missile carrier, used in the video in collaborative air-to-air combat with the F-35;
- ⇒ an apparently less-deeply penetrating drone, with SATCOM connectivity, but for which the video gives no indication of precise use;
- ⇒ the more sophisticated Next Generation Unmanned Aerial System (NGUAS) as an intelligent, survivable partner; a stealthy flying wing (derived from the RQ-170/*Sea Ghost*) used as an advanced, stand-in ISR platform for targeting.

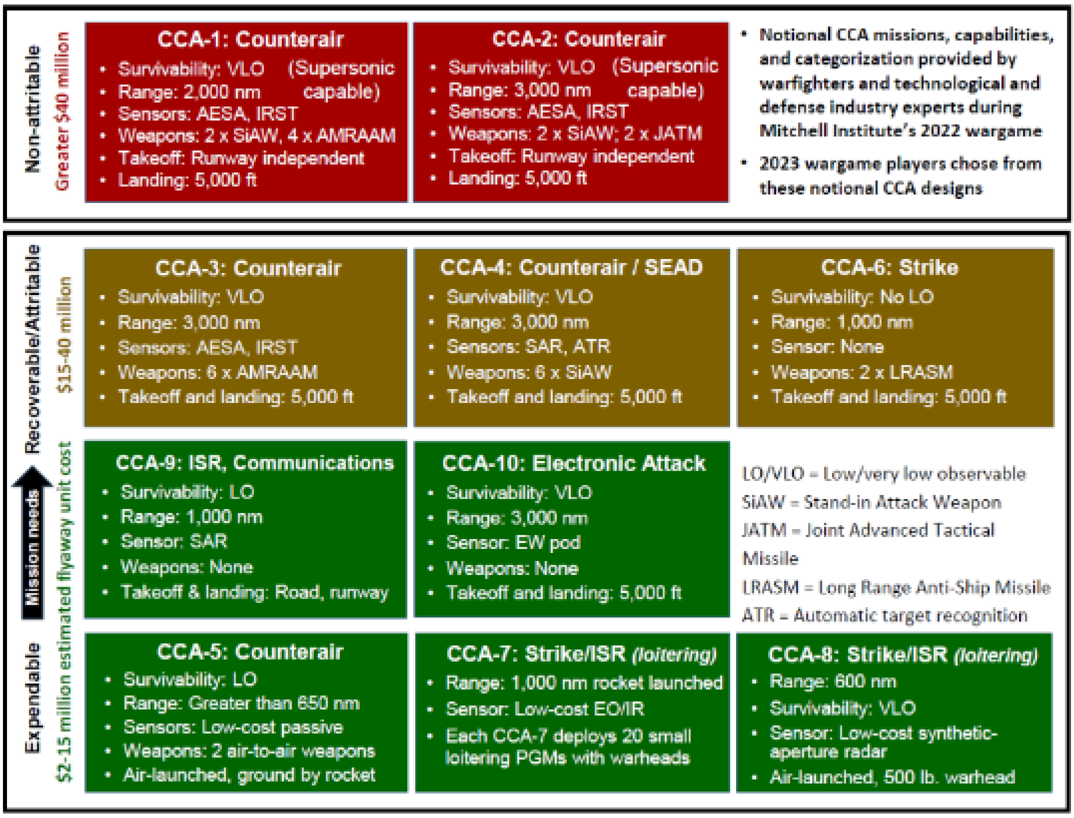
Source: https://www.lockheedmartin.com/en-us/news/features/2022/investing-distributed-teaming.html

1.3.2. Mitchell Institute wargames

The Mitchell Institute has carried out several wargames on the use of CCAs in counter-air missions against China in a projected conflict in the vicinity of Taiwan in 2030. In 2022,

[25] Lockheed Martin, "Investing in Distributed Teaming", September 14, 2022.

warfighters and industry experts developed ten CCA concepts, whose characteristics are summarized in the table below[26].



Source: Col. Mark A. Gunzinger, USAF (Ret.), Maj. Gen. Lawrence A. Stutzriem, USAF (Ret.), Bill Sweetman, *The Need For Collaborative Combat Aircraft For Disruptive Air Warfare*, The Mitchell Institute for Aerospace Studies, Air & Space Forces Association, February 2024, p. 22

In 2023, three teams each worked on a specific counterair mission: SEAD against Chinese naval vessels, fighter sweep against fighter aircraft, and offensive/defensive counterair against Chinese long-range assets targeting American AWACS and tankers. They each determined their mix of manned aircraft (F-22/F-35) and CCAs based on the ten concepts, and played out the confrontation on two time scales of the air campaign: the initial phase of the first two days, followed by a two-week phase of operations.

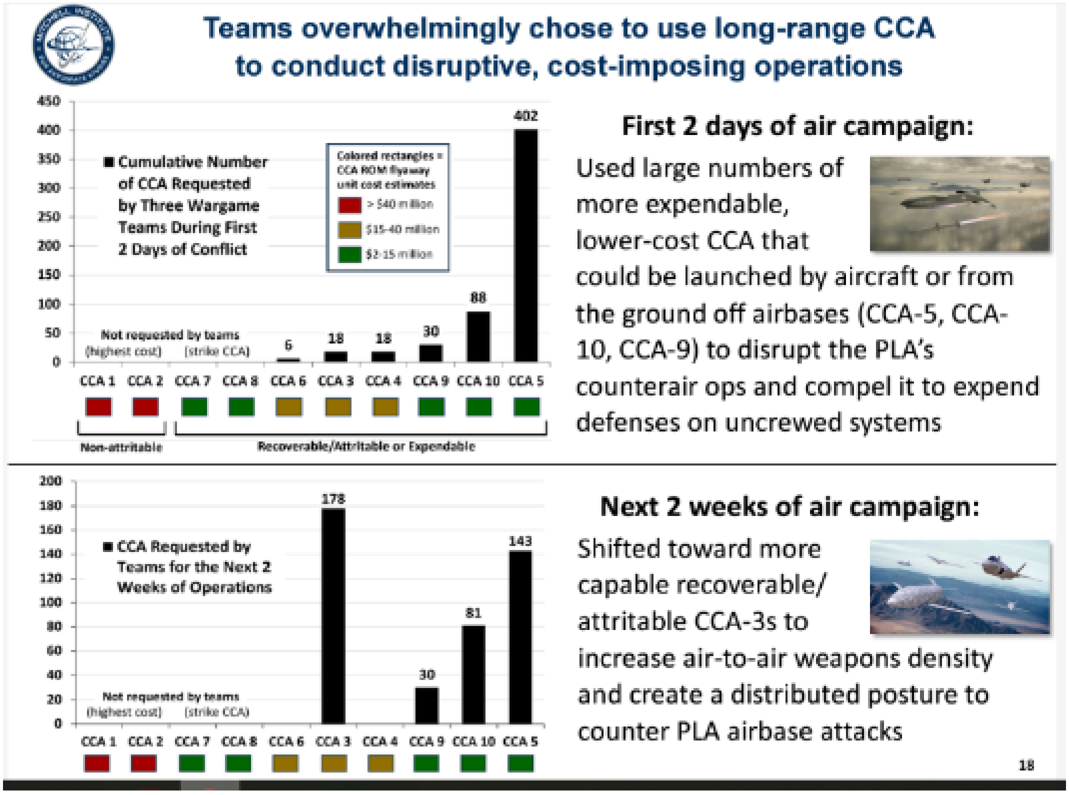
In summary, as the graph below shows, players mainly used:

⇒ for the initial phase, a large number of CCA-5s, *i.e.* expendable drones carrying two air-to-air missiles, and electronic warfare CCA-10s, to create confusion in the Chinese system, as well as a few dozen recoverable CCAs;

⇒ for the two-week phase, not only these expendable drones but also a large number of stealthy recoverable air combat CCA-3s to increase the density of American coverage;

[26] Col. Mark A. Gunzinger, USAF (Ret.), Maj. Gen. Lawrence A. Stutzriem, USAF (Ret.), Bill Sweetman, *The Need For Collaborative Combat Aircraft For Disruptive Air Warfare*, The Mitchell Institute for Aerospace Studies, Air & Space Forces Association, February 2024, p. 22.

⇒ it should be noted that none of the three teams felt it appropriate to use the two types of supersonic, non-attritable UCAV.



Source: Col. Mark A. Gunzinger, USAF (Ret.), Maj. Gen. Lawrence A. Stutzriem, USAF (Ret.), Bill Sweetman, *The Need For Collaborative Combat Aircraft For Disruptive Air Warfare*, The Mitchell Institute for Aerospace Studies, Air & Space Forces Association, February 2024, pp. 36-37

We will carry out a closer examination of their approaches in Part 3, to illustrate the possible uses of RCs in counterair missions.

2. Overview of other collaborative combat aircraft programs

Not surprisingly, American experiments with RCs have had a strong impact on those of allied forces. This is due to the CCA partnership framework initiated by Washington, the characteristics of which were outlined in the previous section. This influence is easily explained:

⇒ by the earlier start of work launched by DARPA and the Armed Services (USAF, USN/USMC). The U.S. therefore has a good decade's experience of the failures, obstacles and progress derived from these tests;

⇒ through conceptual and doctrinal thinking. Admittedly, these are far from complete in the U.S. armed forces, but their content, exchanged in inter-allied circles, necessarily influences the work undertaken by other armed forces who are much less advanced in this field;

⇒ Finally, and this is the main point, CCA manufacturers are American or American-controlled, and therefore form an essential part of the DITB in charge of CCA production – whether Boeing Australia, BAE Systems or Northrop Grumman UK, for example...

As far as countries other than the USA's Western allies are concerned, it is undeniable that the American model of network-centric operations has been duplicated by the Chinese, less happily by the Russians, and is well established in emerging countries such as Turkey. The construction of fifth-generation aircraft is therefore accompanied by the same CCA sub-assemblies, and presents many similarities with the American approach. It should be noted, however, that the real capabilities of these systems are every difficult to assess, given widespread disinformation and propaganda.

This section will give the reader an overview of the state of CCA development in the most advanced air forces.

2.1. *Close allies: direct involvement of the "Anglo-Saxon club" in the development of the American CCA*

The first circle of American allies concerned by loyal wingman programs share the same geostrategic problems in the Indo-Pacific area, and are confronted with the defense challenges posed by China. These include Australia and the UK, who are also members of the AUKUS security partnership, and Japan. South Korea is also involved, but no cooperation plans are currently known.

2.1.1. Australia: Boeing Australia's **Ghost Bat** *program as a joint experimentation pillar with the United States*

The Australian CCA program is a direct spin-off from Boeing's Airpower Teaming System (ATS) project. The parent company has delegated design and manufacture to Boeing Australia, which, in agreement with the Ministry of Defense and the Royal Australian Air Force (RAAF), is co-producing the MQ-28A *Ghost Bat*[27]. The vehicle is a multi-mission combat drone that is *a priori* non-expendable, and operates in remote-controlled or self-piloted mode in danger zones. BAE Systems Australia provides on-board electronics and artificial intelligence software for navigation and information management. Powered by a turbofan engine and with a take-off weight of three tons, it is designed to carry a 500kg payload (modular nose for air combat missions, AESA radar/EW or two Small Diameter Bombs in the internal weapons bay) for a range of 3,700km. It flies at subsonic speeds and its radar signature has been reduced, though it is not stealthy in the strict sense of the word[28]. Ten production models have been ordered by the Australian government for entry into service in late 2025. The *Ghost Bat* will team with the RAAF's F-35A,

[27] See the program presentation on the Boeing website.

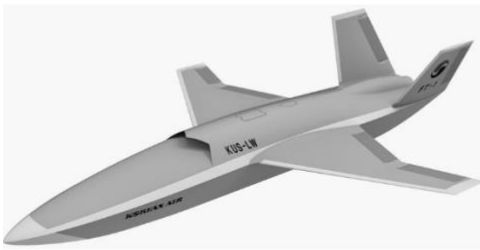
[28] Khaleb Chapman, "What we know so far about Australia's loyal wingman, the MQ-28A Ghost Bat?", *Key Aero*, July 22, 2022.

FA-18/EF and E-7A. The MQ-28A program is one of three American loyal wingman experimental aircraft, along with the Kratos XQ-58A *Valkyrie* and the General Atomics *Avenger.*

2.1.2. Japan: still in the process of defining the sixth-generation twin-role fighter and its loyal wingman

The search for a U.S.-Japan partnership was launched in October 2023, following an initial invitation in December 2020[29]. However, Tokyo is currently engaged in exploring several possibilities for sixth-generation aircraft programs: Japan is cooperating with the UK and Italy on the *Tempest* Global Combat Air Programme (GCAP); in addition to its own weapons aircraft, the F-X or F-3 from Mitsubishi Heavy Industries to replace the current F-2s by the mid-2030s[30]. In this context, the sub-program that could constitute the equivalent of a loyal wingman drone would involve Subaru Corporation (formerly Fuji Heavy Industries), whose TACOM drone shown opposite serves as a technology demonstrator for a consortium including MHI for data links and MUM-T protocols, and the Ministry of Defense's Acquisition, Technology and Logistics Agency for on-board AI software. Three phases are planned up to 2025 for the final testing of a combat aircraft capable of controlling two or three drones, before their integration into a squadron. The results of phase III will then serve as the technological foundation for the development of a more diversified range of drones, or a fully autonomous unmanned combat aircraft, a project that was abandoned several years ago. The aircraft under development is thought to be intended for intelligence and counterair missions[31].

2.1.3. South Korea: contemplating development of a Ghost Bat equivalent



The *Ghost Bat* model seems to have inspired the Korean Ministry of Defense (*Agency for Defense Development* - ADD) to launch its own CCA program. Korean Air and the Korea Institute for Defense Technology Planning and Advancement (KRIT) were contracted in 2022 to study and develop an air-launched UCAV with a reduced radar signature capable of teaming with future advanced versions of the KF-21 *Boramea*[32]. The above artist's view, however, could be misleading. For the time being, the aim is to test the feasibility of the basic building blocks of the CCA (drone stealth technologies, data links with the combat aircraft, on-board AI algorithms, MUM-T interfaces and protocols, etc.). As South Korea is not yet involved in any known international cooperative program, it will be at least another

[29] Micheal Marrow, "Is a US-Aussie-Japanese loyal wingman drone in the cards?", *Breaking Defense Indo-Pacific*, October 27, 2023.

[30] Kris Osborne, "Japan's 6th-Gen Mitsubishi F-X Prototype to Emerge in 2024", Warrior Maven Center for Military Modernization, August 12, 2023.

[31] Albert L, "Japan Commences Development Program For Fighter Loyal Wingmen", *Over Defence*, January 6, 2021.

[32] Greg Waldron, "Korean Air to help develop stealthy loyal wingman UAVs", *Flight Global*, August 16, 2022.

decade before this leads to squadron deployments – if indeed the concept is ultimately adopted.

2.1.4. Europe: British questions about possible loyal wingman configurations

Several years ago, the UK recognized the usefulness of unmanned aircraft as a means of restoring the mass of its shrinking armed forces. In the field of air power, in 2019 the Chief of the Air Staff sketched out his vision of a typical tactical formation in early 2030, made up of two combat aircraft (*Typhoon*, subsequently F-35 and *Tempest*) teaming with a dozen *Mosquito* loyal wingmen and around one hundred *Alvino* swarming drones[33], all receiving intelligence from *Protector* RG MK-1 HALE drones (the British version of General Atomics' future MQ-9B *SkyGuardian*).

Unmanned aerial vehicle experimentation is being carried out by the Defence Science and Technology Laboratory (Dstl) and the RAF Rapid Capabilities Office (RCO), with Squadron 216 as the test unit, as part of an overall program launched in 2015 – the Lightweight Affordable Novel Combat Aircraft (LANCA), itself part of the Tempest Global Combat Air Program (GCAP) (sixth-generation combat aircraft)[34].

Research into a loyal wingman technology demonstrator began in 2019 with the *Mosquito* project; a UCAV to be developed by a consortium led by Spirit AeroSystems Belfast and Northrop Grumman UK. The artist's view opposite shows an aircraft comparable in design to the XQ-58. However, in June 2022, the contract was cancelled by the Ministry of Defence; no model or mock-up was presented[35]. It would appear that other, more advanced technological solutions were proposed by BAE Systems.

The company presented two loyal wingman prototypes in 2022[36]. *Concept 1* (pictured left) is a parachute-recoverable attack drone with a 40kg payload (ISR, GE, or warhead). It would feature a speed of Mach 0.50 and four hours' autonomy at 30,000ft (9,000m), while *Concept 2* (pictured right) is a larger, more sophisticated drone, attritable but recoverable for several hundred missions, carrying a 500kg internal weapons payload (two *METEOR* air-to-air missiles, four *SPEAR-3* air-to-surface, electronic attack). Weighing 3.5t in combat configuration, the aircraft can reach

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33 Harry Lei, "Future Raf will mix crewed fighters, UAVs and swarming drones: CDS", *Air Force Technology*, March 31, 2021.

34 Harry Lye, "Dstl developing unmanned aircraft for the RAF", *Air Force Technology*, July 22, 2019.

35 S. a., "UK walks away from Project Mosquito loyal wingman drone development", *Defense Brief*, June 24, 2022.

36 Craig Hoyle, "BAE Systems unveils new unmanned concepts at RIAT", *Flight Global*, July 16, 2022.

Mach 0.75, with five hours' autonomy at 40,000ft (12,000m). A call for tenders was issued by the Ministry of Defence in 2022 to continue this line of experimentation[37].

These drones are intended to work in groups as the AI algorithms tested in the ALVINA swarm flight experiment mature. The trials, comparable to those undertaken ten years ago by the United States (DARPA's *Gremlins* and CODE programs, the Navy's *Perdix* and LOCUST programs, etc.), aim to control groups of twenty mini-drones carrying seven different types of payload, with gradual improvement of navigation and self-positioning algorithms for agents in the swarm.

While the direction of aerial robotics is not called into question, the UK is focusing on technological building blocks that are simpler and quicker to implement compared with American programs. Experts note two things:

- ⇒ the need to decouple research on the British CCA from the parent GCAP program, whose multinational architecture with Italy, Japan and Sweden is cumbersome to set up[38];
- ⇒ improved conceptual thinking on the respective roles of Remote Carriers capable of operating with on-board sensors and weapons systems in high-threat areas, and therefore implying a degree of costly stealth, and drones more akin to expendable loitering munitions, but with restricted range or insufficient autonomy to engage protected targets without exposing a manned platform.

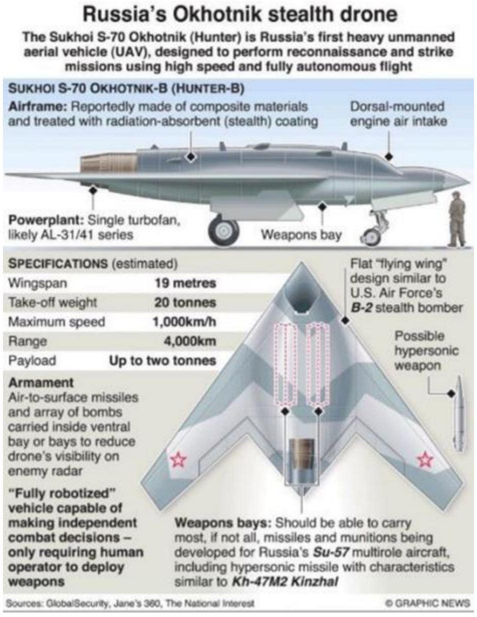
2.2. Contrasts between Russia and China

Developments in aerospace power involving unmanned subsystems are not lost on other non-Western air forces, which are developing their fifth-generation combat aircraft. Russia and China are working to robotize their aircraft, but with results that no one is really in a position to assess.

[37] Tony Osborne, "Memo: Mosquito's End Opens New Chapter for UK loyal wingman Plans", *Aviation Week*, July 17, 2022.

[38] Trevor Taylor, *Gambling Responsibly and the UK Tempest Programme Experiences, Risks and Opportunities?*, Occasional Paper, RUSI, November 2020, 36 p.

2.2.1. Russia: loyal wingman demonstrators slowed down by constraints due to the war in Ukraine and dwindling component supply chains



As regards loyal wingman systems in particular, information has been released on two projects: the *Sukhoi* S-70 *Okhotnik* in versions A and B, and the *Grom* from Kronstadt Group*.* The latter is still only a proposal submitted to the Russian Ministry of Defense.

The *Sukhoi* S-70 *Okhotnik* (infographic opposite[39]), for which studies began in 2011, is presented by the two manufacturers Sukhoi and MiG as a drone to cooperate with Su-57 and future Su-75 multi-role combat aircraft, carrying air-to-ground munitions to neutralize adversary IADS and eliminate high-value targets. Rare flight tests were observed in 2019 and 2023.

The aircraft is said to have on-board AI to manage autonomous navigation tasks and deployment of military payloads. For the moment, it would appear that the current experiment involves a two-seater Su-57 in which the rear crew member remotely monitors the drone. The first examples are due to enter service at the end of 2025.

The second offer comes from Kronstadt Group, with the *Grom,* a static model of which was presented at the end of 2021[40]. According to the manufacturer, this is an autonomous attack drone specialized in IADS neutralization to open up an air corridor ahead of a manned attack formation. It is presented as a payload carrier (transmissions, electronic warfare) and a precision munitions carrier deployed in swarms, with a reduced radar signature. For the time being, this drone, which is self-funded by the manufacturer, has yet to receive a design engineering or production order[41].

Source: Piotr Butowski, "Russia Reveals Loyal Wingman Concept", *Aviation Week*, September 4, 2020

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[39] Source: https://www.pinterest.fr/pin/740068151280402028/

[40] Igor Rozin, "Grom, ce drone russe high-tech qui joue les bombardiers", *Russia Beyond* (French version), September 27, 2021.

[41] Mark Episkopos, "The Grom Drone: Russia's Combat Swarm UAV Platform", *The National Interest*, January 24, 2022.

It is not easy to assess the reality of technological advances in these projects. In a recent study of the DITB's drone manufacturers, several factors seem to be slowing Russian progress on loyal wingmen[42]: firstly, the war in Ukraine has concentrated production on existing models, such as the *Orion* for Kronstadt Group; shortages of electronic components from Western countries, Japan and Israel are slowing production of Russian drones and loitering munitions, and making it very difficult to design and develop new models; finally, the highly centralized and bureaucratized Russian economic system limits adaptability on the part of the Russian DITB. Everything will therefore depend on the real priorities accorded to the modernization of the Russian armed forces at the end of the engagement. However, on June 21, 2023, Russia released an official "strategic" document aimed at developing the DITB, infrastructure and personnel training for unmanned aviation[43]. The aim is the creation of an ecosystem conducive to stimulating demand and diversifying national civil and military production within ten years. The strategy is complemented by a governmental "national project" to achieve the various objectives through each of the ministries and state agencies concerned. There is a clear priority here, but it will be several years before the first results can be seen.

2.2.2. China: RCs play key role in ISR and long-range targeting architectures against U.S. forces

China is the world's leading manufacturer of civil and military drones, with a DITB estimated at 70,000 companies working for 22 groups present on international markets, including DJI, on the various product and component segments involved in drone manufacture, software, batteries, etc.[44] China's armed forces therefore see robotics as an essential element of power to counter the U.S. model of joint force network-centric operations, which they are trying to replicate[45]. The robotic mass must be able to provide transoceanic reach for ISR and targeting architectures to counter U.S. expeditionary forces far from China's shores. In this respect, the drones that have been officially presented appear to be exact replicas of their alter egos from across the Pacific.

Feihong's FH-97 is a UCAV being developed to fly alongside the J-20 *Mighty Dragon* multi-role combat aircraft, whose weapons payload is deemed insufficient by the PLAAF. The model presented in 2022 shows a drone with a design comparable to the MQ-58A. It is shown with a payload of up to eight air-to-air missiles on a sweep mission, or FH-101 loitering munitions. EW and long-range communication management modules are also reportedly available. The FH-97A is said to be able to coordinate the action of several drones under remote control from a two-seater J-20

[42] Pavel Luzin, *Russian military drones. Past, present and future of the UAV industry*, Foreign Policy Research Institute, Eurasia Program, November 2023, 31 p.

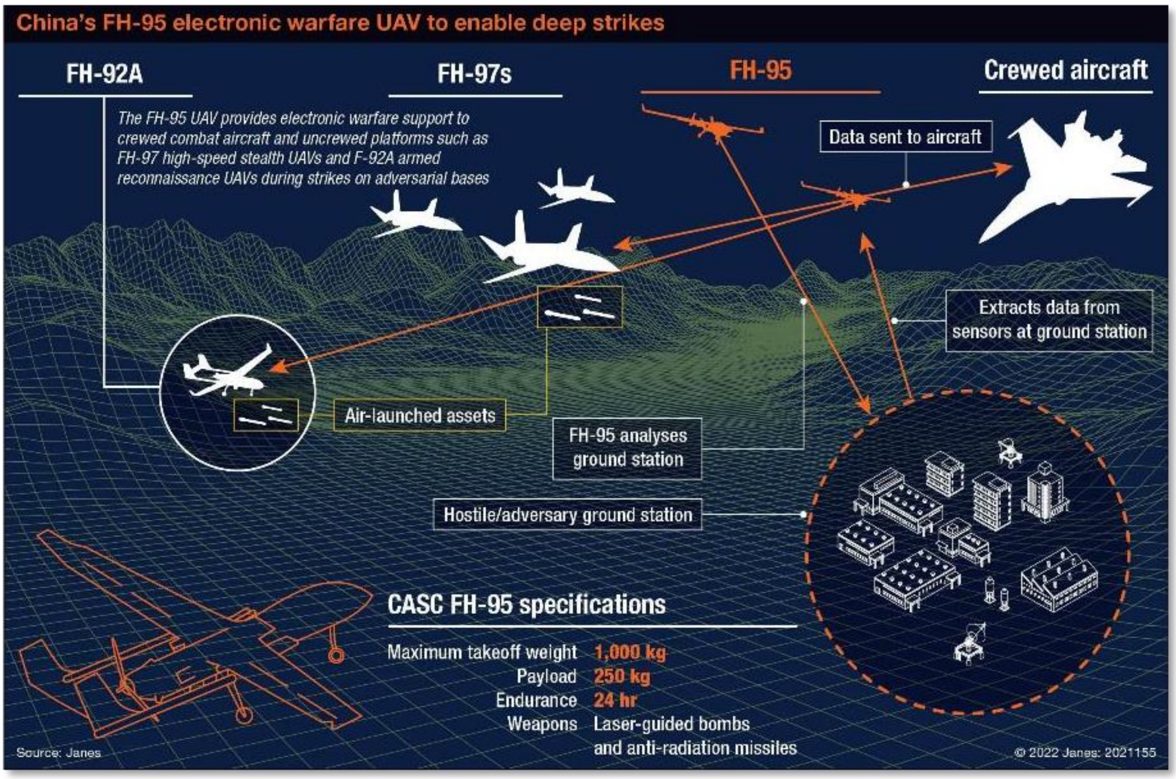
[43] Government of Russia, "Government approved the Strategy for development of unmanned aviation until 2030", June 28, 2023.

[44] Chang Che, "All the drone companies in China - a guide to the 22 top players in the Chinese UAV industry", *The China Project*, Taiwan, June 18, 2021.

[45] Loro Horta, "China's Drone Mania", *Strategic Brief*, n° 38, IRSEM, May 3, 2022.

(coordination of the FH-95 EW drone and FH-92A)[46]. It can be launched from land or from a naval platform.

Electronic warfare is a priority sector. Drones are thought to work in synchronized groups. Feihong also produces the FH-95, for SIGINT, RADINT and jamming missions. This is a Class III drone (1t takeoff weight) with a 250kg payload and claimed endurance of 24 hours at 13,000m. The FH-95 collects data after activation of adversary systems by the FH-97 and transmits the data to fighter aircraft and UCAVs. It can be used for localized jamming ahead of an attack on hardened targets, as shown in the diagram below.



Source: Akhil Kadidal, Akshara Parakala, "China's electronic warfare UAV completes performance test", *Jane's*, August 2, 2022

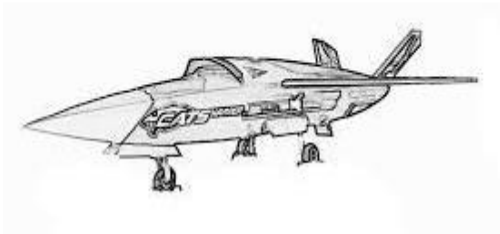
2.3. *New members of the club: India and Turkey*

2.3.1. India and the catch-up effect against Chinese and Pakistani systems

India's geostrategic position is bounded by Pakistan and China, whose air/sea deployments in the Indian Ocean are perceived as a threat. India's air power must therefore address the issue of the region's reinforced IADS capabilities to ensure conventional and nuclear penetration missions, while controlling its maritime communication routes with its naval aviation. The government and its military staffs are therefore investing in the technological building blocks seen in the USA and its close allies (drones, loitering munitions, AI for swarm formations and High Altitude Pseudo-Satellites (HAPS) for regional ISR coverage). A complete family of

[46] Liu Xuanzun, Cao Siqi, Fan Wei, "Exclusive: China's new loyal wingman drone to greatly change air combat: designer", *Global Times*, November 7, 2002.

systems of systems, known as the Combat Air Teaming System (CATS), is currently being developed to support the future long-range strike force provided by the *Rafale* and *Tejas* MK1[47]. A consortium comprising Hindustan Aeronautics Limited (HAL), National Aerospace Laboratories (NAL), Defence Research and Development Organisation (DRDO) and Newspace Research & Technologies is responsible for experimentation and production.



The loyal wingman component is based on the CATS *Warrior* UCAV, launched in 2018 to operate alongside the *Tejas* combat aircraft. Prototypes are due to be ready in 2024-2025. The drone is powered by twin turbofan engines and features a reduced radar signature. It is designed to carry out reconnaissance, electronic warfare and autonomous air-to-air and air-to-ground combat missions. It can carry a 250kg payload for a total weight of 1.5t. It has a maximum speed of Mach 0.7 over a distance of 800km, or 80 minutes' endurance. *Warrior* is designed to be a Remote Carrier. As such, it can be launched from a cargo plane or bomber, and then remotely controlled by an advanced controller on *Tejas*. It carries 24 ALFA-S loitering munitions (opposite). The ALFA-S features a shape recognition algorithm for targeting, and can fly over a zone for up to 100km to search for targets. Other munitions such as anti-runway bombs are being tested[48]. *Warriors* will be launched in groups also containing cruise missiles; CATS *Hunters*, equipped with a TERCOM guidance system and GPS, can carry a 250kg warhead over a range of 300 km[49].

Internal debates within the Indian defense establishment on the evolution of air power (Center for Air Power Studies - CAPS) indicate the imperative need to integrate new robotic capabilities, including tests on swarms of unmanned aircraft[50]. Despite the doubts expressed by Air Chief Marchal Vivek R. Chaudari, current Chief of the Air Staff, about the relevance of using drones, including loyal wingmen, in areas exposed to hardened IADS due to their high vulnerability[51], the choice has nevertheless been made to prioritize development and rapid entry into service in order to compensate for budget cuts reducing international acquisitions of next generation combat aircraft by 50 %[52]. The Indian Air Force, therefore, seems to consider the addition of these capabilities, at the very least, as a further layer to its deterrent posture by adding additional mass to its manned squadrons.

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[47] Pradip R. Sagar, "IAF | A force to rule the skies", *India Today*, November 3, 2023.

[48] Air Marshal Anil Chopra, "Unmanned Wingman Plan India", *Indian Defence Review*, Vol. 37/2, April-June 2022.

[49] Ronak Kunde, "CATS Hunter, India's low-observable ALCM getting further refined", *Indian Defence Research Wing*, May 31, 2023.

[50] Air Marshal Anil Chopra, "Drone swarms are both asset and threat. Is India ready?", *First Post*, August 18, 2023.

[51] Ronak Kunde, "Indian Air Force Sets Sights on Stealthy UCAVs and loyal wingman in Large Numbers", *Indian Defence Research Wing*, September 5, 2023.

[52] S. a., "L'Inde veut réduire de moitié ses acquisitions de nouveaux avions de chasse d'origine étrangère", *Le Journal de l'aviation*, June 3, 2022.

2.3.2. Turkey: expanding its competence through the development of a loyal wingman program

With the success of its TB2s on the marketplace, following demonstrations of their operational effectiveness in Syria, Libya and Azerbaijan, Ankara has established itself as one of the most credible players in the design and operation of aerial drones. It is no surprise, then, that the Turkish DITB should continue to move upmarket with the Kizilelma program from Baykar. This aircraft is presented as a prototype supersonic UCAV, ultimately capable of being progressively configured as a loyal wingman pending future progress with on-board AI software and MUM-T links and protocols. The announced technical specifications include a 6t takeoff weight with a 1.5t military payload. It is said to have five hours' endurance over a range of around 1,000km with a service ceiling of 11,000m. Its current speed is Mach 0.6, but this is set to increase as a new engine matures. It will accompany the F-16C/D already in service[53] and the future fifth-generation aircraft (*Milli Muharip Uçak* - MMU)[54], for which Turkey is seeking partners as part of the FT-X *Kaan* program: Ukraine for engines, Pakistan for internal system design and architecture, and Azerbaijan for financing. A navalized TB3 version is being developed for integration into the naval drone fleets designed for the two *Anadolu*-class aircraft carriers. The first units are scheduled to enter service in 2024.

It should be noted that Turkish Aerospace Industries (TAI), which is leading the MMU, is also working on a technology demonstrator, the *Anka-3* MIUS, an unmanned design in flying wing configuration for testing navigation algorithms and links with the combat aircraft. For the moment, it does not appear to be a fully-fledged loyal wingman prototype. Time will tell[55].

That said, TAI is also developing its MUM-T concept, the *Otonom Kol Uçucusu* (OKU, *i.e. Autonomous Wingman Concept*), centered on the FT-X Kaan and capable of eventually aggregating the *Anka-3* as well as the *Super Simsek*[56] family of drones, derived from a target aircraft (as Kratos has done) for the multiple missions traditionally considered: air-to-air, SEAD, air-to-ground strike, electronic warfare, etc.[57]

For the Turkish Air Force, the arrival of RCs is seen as an alternative means of increasing the firepower and maneuvering capabilities of its F-16s, which will form the core of the attack fleet pending the entry into service of the MMU or its replacement[58]. It should be recalled that, in the current state of technological development of the Turkish DITB, whose opportunities for cooperation with the West have been significantly reduced by U.S. sanctions,

[53] S.a., "Turkish 'loyal wingman' Emerges For Taxi Tests", *Defense Bridge*, November 22, 2022.

[54] John Lake, "Turkey Unveils Stealth Fighter and Combat UAV", *Aviation International News*, March 2023.

[55] Taifun Ozberk, "Turkish firm unveils Anka-3 combat drone ahead of maiden flight", *Defense News*, March 23, 2023.

[56] "TUSAŞ Prepares Turkish loyal wingman: OKU", *TurDef*, August 7, 2023.

[57] "Yüksek hızlı hedef uçak Şimşek'in yeni versiyonu 'Süper Şimşek' geliyor", *Defense Here*, April 26, 2023.

[58] Arda Mevlutoglu, "Turkey's Kizilelma Armed Drone and Beyond", *Politics Today*, May 17, 2022.

and whose expertise in system-of-systems technology blocks has therefore been severely curtailed, F-16s that are providing protection for Ankara's reconnaissance drone flights in exposed areas: an ironic twist![59]

This brief overview of the programs being pursued by the world's leading air forces confirms that "robotic" evolution is a widely shared trend, with reflections underway on the role of loyal wingmen in composite air task forces including combat aircraft, drones, cruise missiles and loitering munitions. What is the situation in France?

[59] S.a., "Role Reversal For F-16 Fighter Jets As Turkey Mulls Using Frontline Attack Warplanes As 'Bodyguards'", *The Eurasian Times*, September 7, 2021.

Analysis of the situation in France

With the FCAS program, France and its partners are also committed to developing combat air power based on an MUM-T system of systems, involving unmanned collaborative combat aircraft. However, the operational added value of the latter needs to be assessed in greater detail. To do this, we need to characterize the strategic and operational problem that the implementation of these RC systems is intended to address, or help to address. We will begin by adopting a *reductio ad absurdum* argument, empirically identifying what air power might look like if the French multiyear military spending bill (LPM) were applied in full, and if the targets put forward for the 2030s were met, without the presence of collaborative combat aircraft. We will then look at the contributions of these RC systems, and explore a few examples of RC concepts and the employment of these systems in the various missions of our future air power.

1. Problem analysis: a future air power without remote carriers

1.1. Review of plausible frameworks for future air power engagement

In considering the contribution of these drones, we need to keep a number of parameters in mind. First, there are the generic missions to be carried out by the air force. The first group comprises the six strategic defense functions to which French air power must globally contribute: knowledge/anticipation through its intelligence capabilities, deterrence through the strategic air forces, prevention through its capabilities deployed in presence and sovereignty functions, protection through the permanent air safety posture (PPS-A) with a secondary influence through deployments, and finally intervention. The second group comprises the tactical missions to be carried out by C2, ISR, engagement/combat, mobility and support capabilities. Here, we refer to the American[60] and NATO[61] doctrines:

- ⇒ *Defensive Counterair* (DCA): neutralization of adversary offensive air power by active and passive air and missile defense;
- ⇒ *Offensive Counterair* (OCA): attack operations (targeting ground-based elements of the enemy's air power, such as airfields, C2 centers, etc.), suppression of enemy air defenses (SEAD) and fighter sweep/escort;

[60] Air Force Doctrine Publication 3-01, *Counterair Operations*, June 15, 2023, pp. 4-7.

[61] NATO Standardization Office (NSO), NATO Standard AJP3-.3, *Allied Joint Doctrine For Air And Space Operations*, Edition B Version 1, April 2016, pp. 1-8, 1-11.

- ⇒ *Air Power Contribution to Counterland Operations* (APCLO) or *countersurface*: interdiction and close air support;
- ⇒ *Air Power Contribution to Countermaritime Operations* (APCMO): anti-ship and anti-submarine warfare.

It should also be noted that the effects to be achieved may be kinetic or non-kinetic (in the cyber domain, in the electromagnetic domain and in the field of influence). The diversity of operating modes in intervention is also a parameter of the problem. These may take the form of attacks or semi-permanent tactical modes, particularly for air cover in DCA and dynamic targeting.

A second category of parameters to be taken into account clearly includes:

- ⇒ the threat: the level of performance of adversary air and missile defense capabilities; their possible integration into an integrated air defense system; the scale of OCL or OCS operations to be carried out in support of land and sea components;
- ⇒ partners and allies: in particular, the presence or absence of American forces in intervention and those of European partners willing to use force;
- ⇒ characteristics of the operational environment, in particular the distances to be covered, constraints on the use of force, etc.

1.2. The source of motivation for RCs: the diminishing depth of French air power

Europe's air powers face critical mass (or depth) challenges, as do the Turkish and Indian air forces, and even more so the U.S. Air Force and U.S. Navy, which aim to counter Chinese forces. Despite differences in scale and pedigree, the problems are relatively the same.

1.2.1. The French LPM multiyear defense spending bill promises significant improvements in air power capabilities...

Within the framework of this LPM and what is planned for the beginning of the 2030s, air power should benefit from several notable improvements. At least four of these are relevant to our subject:

- ⇒ **Engagement/combat performance**: a significant increase in the operational efficiency of the engagement/combat function, primarily due to *Rafale* upgrades. The F4 and above all F5 standards should bring major improvements to mission equipment (RBE radar, OSF, *Talios* pod, etc.), the aircraft's navigation and attack system, and connectivity, with a new high-speed tactical data link enabling multi-platform collaborative combat, all of which constitute key elements of a first iteration of the future combat cloud. Beyond that, the Next Generation Fighter (NGF) should deliver the breakthroughs expected of any fifth/sixth-generation aircraft (stealth, information fusion, etc.). The NGF will be essential not only for the airborne component of the nuclear deterrent, but also for national air power in the high-intensity battlefield of the future. There are, however, many questions to be answered: what volume of mission equipment will be funded, what priority will be given to the new data link, etc.?

⇒ **ISR capabilities**: replacement of the *Gabriel* SIGINT platform by the *Archangel*, arrival of the *Eurodrone* and a small number of ALSR light surveillance aircraft;

⇒ **Through-life support (MCO)**: the 40 % increase in appropriations earmarked for through-life support – in comparison with the 2019-2024 LPM – should enable the French Air and Space Force (ASF) to further improve the satisfactory availability rates that the verticalization of MCO has already achieved, and which the ASF also expects to see as a result of multiple other measures (information systems, 3D printing, changes in regulations, etc.)[62];

⇒ **Increased ammunition stocks**. Another factor is the effort being made to equip these aircraft with bombs and complex munitions, such as air-to-air missiles and cruise missiles. That said, will the increase in volume planned by the LPM cover the capacity to carry out a high-intensity air operation?

1.2.2. ...but does not resolve the mass deficit of this component, which is set to increase

In 1994, French fighter aircraft numbered over 500, compared with 253 in 2021[63]. By the end of the decade, the engagement/combat function should theoretically number 225 fighters, including 185 for the ASF and 40 for the Navy. The target of an "*all-Rafale*" fleet for the ASF has slipped from 2030 to 2035, but this latter date may itself be difficult to achieve, given the delays in acquisition tranches, offsets for aircraft transfers to allies, etc. It is therefore increasingly likely that, at best, we will see a fleet of around 200 fighters in a dozen years' time. Furthermore, while the LPM refers to a buildup of the munitions inventory, it says nothing about the volume of mission equipment, deemed woefully inadequate to equip the entire fleet for such high levels of demand.

In all probability, the decline will be even greater in the NGF era. The development of the demonstrator alone between now and 2025-2026 will cost €4 billion, compared with the €14 billion for the complete development of the *Rafale* calculated in 2005 (including inflation). The total cost of the *Rafale* program was estimated at €46.4 billion in 2014 (€55 billion in 2023), for a target of 286 aircraft, with a unit production cost of €69 to €79 million depending on the version[64]. The cost of the NGF will certainly be much higher, even if it does not reach the $300m of the U.S. PCA. According to the Senate, current cost estimates for the FCAS as a whole range from €50 to €80 billion. In this context, maintaining a combat aircraft fleet of around 200 aircraft after 2040 could prove impossible.

Airborne ISR sensors, too, will not be much more numerous in twelve years' time. The *Archange* should replace the *Gabriel,* but the ASF will have to make do with its three ALSRs.

[62] Romain Guillot, "MCO aéronautique : la verticalisation des contrats commence à tenir ses promesses", *Journal de l'aviation*, January 13, 2022.

[63] "6.3 Armée de l'Air et de l'Espace (chiffres au 1er juillet 2021)" *in* MINARM, *Les chiffres clés de la défense, 2021*, December 2021, p. 24.

[64] IV. Engagement et combat, Projet de loi de finances pour 2014 : Défense : équipement des forces et excellence technologique des industries de défense, Rapports législatifs, Avis n° 158 (2013-2014), tome VIII, submitted on November 21, 2013.

The replacement of the *Reaper* by the *Eurodrone* will not result in an increase in the number of systems. True, combat aircraft will have greater ISR capabilities, but there will necessarily be competition with the priorities of engagement/combat missions.

1.2.3. Mass attrition imposes constraints on the ability to perform six strategic functions...

Let us take a look at the impact of this dwindling mass on the air component's capabilities. Insofar as the LPM does not change much in terms of force structure, these shortcomings have been well known for years. In terms of strategic functions as a whole, the shortfall in ISR sensor mass limits the ability to simultaneously perform knowledge/anticipation and ISR support functions as part of a major intervention. Similarly, the effector mass shortfall will accentuate the inability, already present for over a decade, to concurrently equip the air component of deterrence, the PPS-A, continued presence deployments, the major engagement hypothesis (MEH) and, at the same time, force generation and operational readiness. This is all the truer given that, in many cases, this is not a zero-sum game, and there is no direct relationship between the resources allocated to these different functions: strategic contexts justifying an MEH, such as the risk of confrontation with Russia within NATO, may necessitate reinforcing deterrence and PPS-A levels at the same time. Even if we assume that availability rates will remain at satisfactory levels, *e.g.* close to 60 %, by considerably reducing operational readiness activities, and assuming that there are no further external operations at that time, an operational contract for 45 aircraft to cover an MEH does not seem feasible with a 200-220 aircraft component.

1.2.4. ...and on the ability to conduct a high-intensity air campaign

This structural lack of depth of the manned component would not be critical if all our interventions were part of coalitions led and mainly armed by the Americans. In that case, the main challenge would be more closely linked with France's political position within the coalition than with the fate of the coalition's weapons. However, American leadership and even participation in our engagements has gone from being a comfortable presupposition to an increasingly worrying variable, given Washington's focus on China and the domestic political situation in the U.S. This mass deficit becomes even more problematic if we consider, for example, a NATO engagement involving only European countries against a Russian adversary whose forces have been restored after the long war in Ukraine. Such a situation is plausible in the next decade. The deficit becomes absolutely critical (and even insurmountable) if we consider this time a limited coalition, again without the United States, with a small number of European partners facing a regional adversary in the arc of crisis. The allied air component would then number no more than fifty to one hundred combat aircraft, given the reductions also underway in several other air forces of potentially interventionist countries. For example, the Royal Air Force is already at an all-time low of 160 fighters, and is unlikely to rise beyond 200 again, given the withdrawal of the oldest *Typhoons* and the acquisition of F-35Bs, which will probably not exceed 70 aircraft; the Royal Danish Air Force (RDAF) will go from 44 F-16s to 27 F-35s.

However, given the proliferation of capabilities under way, it is perfectly conceivable that within twenty years we could find ourselves facing an adversary equipped with an air force of several dozen generation 4 or 4.5 aircraft, a genuine IADS integrating several dozen surveillance radars, long/medium/short-range batteries, and electronic warfare capabilities more sophisticated than simple power jamming and more easily reconfigurable. In addition, these IADSs should logically evolve over the coming decades towards greater tactical flexibility (learning from operational feedback from Yugoslavia and Ukraine) and towards detection or even detection/engagement architectures that are more distributed than they are today, and therefore more resilient to SEAD. Furthermore, it is also conceivable that this adversary will deploy deep fire capabilities based on hybrid kill chains combining commercial sensors, drones, commercial satellite communications, drone-munitions, etc., offering OCA and interdiction capabilities at least against fixed sites (including airbases).

In concrete terms, lack of depth will first of all make attrition unacceptable. The rapid loss of a fraction of the air component would most likely lead to severe restrictions on its employment in order to preserve it, which would considerably limit the effects it could achieve, or even exclude any prospect of establishing air superiority. The lack of depth will also limit the component's operational effectiveness. Combined with the challenges posed by long range and the bottleneck of in-flight refueling resources, it limits the volume of air power that can be deployed in theater at any given moment which will have a four-fold impact:

- ⇒ dilemmas concerning the apportionment of resources according to ISR/ DCA/OCA/OCL mission;
- ⇒ limits to situational awareness, which determines all other operations;
- ⇒ near-impossibility of keeping complex fleets in flight, except within a very limited space-time framework, for dynamic targeting;
- ⇒ finally, in terms of engagement, collaborative combat combinations that are much less difficult for the enemy to deal with.

Admittedly, the operational efficiency gains expected from *Rafale* F5s and, later, NGFs used in conjunction with allied F-35s, may guarantee superiority in terms of engagement and a better ability to penetrate enemy defenses. That said, the volume of the penetrating mass will remain small, exposing it automatically to the attrition constraints mentioned above. More specifically, it will be difficult for a reduced component to saturate an enemy IADS, as described above, and then carry out dynamic targeting against a large number of relocatable targets, thereby reducing the prospects of performing SEAD, *a fortiori* interdiction effects and/or availability for close air support.

2. The potential contribution of RCs

There are two options for correcting the general lack of depth (increased supplies of munitions notwithstanding): reinforcing the manned aircraft fleet with a category of less sophisticated, low-cost aircraft, or massive use of drones. These two options are not entirely mutually exclusive. The first is beyond the scope of this note. Suffice to say that, on the one hand, it would represent a new HR challenge, and, on the other, it does not solve the problem of penetrating mass.

In our view, the most important contribution of collaborative combat drones to the FCAS – their *raison d'être* – lies in their ability to correct this mass deficit, as we have seen with the American debate on "affordable mass". In addition, RCs are also likely to bring new capabilities which, while not revolutionary, could significantly transform air power.

2.1. The essential prerequisite: drones must be attritable, whether recoverable or expendable

For RC systems to be able to help reduce the lack of depth, their cost must be sufficiently controlled to allow significant acquisition volumes... while remaining capable of carrying out the required missions. Hence the requirement that the overwhelming majority of these systems be attritable, which is obvious for expendable drones, but must also be a feature of recoverable drones. Inventories must be able to absorb a much higher percentage of losses than that for manned aircraft. Ultimately, these RC systems must reduce the "cost per effect" of air power operations. The kill chain leading to target neutralization must be less costly than using only the manned component and its munitions.

Cost-controlled drones offer another possible advantage in terms of mass: their duration over the course of a confrontation. One of the biases of Western thinking over the last thirty years has been to envisage conventional confrontations lasting only a few weeks or months. However, as the war in Ukraine has once again shown, it is necessary to think in terms of conventional conflicts lasting a year or more, particularly if the balance of capabilities is relatively even. This is a parameter that the Americans are already considering with apprehension in the naval sector, with respect to China. As far as air power is concerned, it is conceivable that at least some RCs could be produced much more quickly than manned fighters, and that any rampup in production could be accommodated within the timeframe of such a conflict. Like certain munitions, this rampup would then provide the real margin for regenerating the potential of air combat power. This capability, combined with MUM-T modes that preserve the potential of fighters in theater (with "quarterback" aircraft at standoff distance, for example), could enhance the ability of air power to sustain a long-term engagement.

2.2. Airbus and MBDA projects and positions

With this prerequisite in mind, it would be appropriate at this point to take a look at the projects of Airbus and MBDA, the two manufacturers responsible, along with SATNUS, for the development of RCs in the FCAS program.

Airbus[65] is responsible for the "heavy" and "recoverable" RC segment. It is studying the contribution of RCs on the basis of several parameters:

- ⇒ tactical effectiveness;
- ⇒ as mentioned above, cost relative to the desired effect, thus efficiency in relation to fighter aircraft, cost being, therefore, an operational criterion;

[65] Interview and discussion with an Airbus Defence & Space operational consultant.

⇒ operational readiness;

⇒ interoperability of the RCs with other FCAS components.

The company also considers that these recoverable RCs should be attritable as a general rule. Recoverable aircraft options under consideration range from low-cost support RCs to sophisticated UCAVs. It also sees legacy wide-body aircraft and fighters as drone launch platforms of interest for multiplying deployment capabilities, and is therefore continuing to study them. Range is a major question mark. Airbus is not yet eliminating any options, including, for example, the possibility of recoverable air-launched RCs. Last but not least, in 2021, Airbus successfully carried out trials of an RC surrogate with the Luftwaffe as part of *Timber Express 20 and 21.* The drone was tested with an EW payload as part of Cooperative ESM Operations (CESMO), and controlled through L16 via a Curtiss-Wright tactical data link translation gateway[66].

MBDA[67], meanwhile, is working on expendable RCs that can be deployed from airborne and surface platforms. Data released at the Paris Air Show highlight the conceptual work and development of an Expendable Remote Carrier (ERC) demonstrator, with a first flight targeted for 2029. MBDA is studying the use of the modular-payload ERC for multiple missions: the most frequently mentioned is saturation decoy during SEAD, but the drone could also be employed in ISR, targeting, sensor grid and electronic attack missions, as well as in support for air-to-air actions (sensor deployment, decoy and harassment), support for deep strike missions as part of effector swarms and, ultimately, kinetic strikes. The ERC, which would have a reduced radar signature, would weigh around 400kg and offer an endurance of one hour. It would have subsonic speed and high maneuverability, enabling it to replicate the behavior of a fighter, and would be equipped with a data link. The approach is clearly multi-domain, since MBDA is studying deployment not only from a fighter or a recoverable RC combat drone, but also from a land vehicle, a surface ship or even a submarine.

Both companies thus seem to be following exactly the same logic as the CCA solutions prioritized by the Mitchell Institute's experts.

2.3. Contributions to the operational effectiveness of air power

While augmenting the depth of air power is at the heart of drone design in future air combat systems, the RCs are also likely to add significant value to combat power capabilities, as envisioned by manufacturers and the Mitchell Institute's wargames, among others.

First and foremost, drones are tools for limiting pilot exposure. In doing so, even more than the depth of the entire air component, RCs will increase the "penetrating mass" already mentioned above, thus enabling them to operate within the range of adversary weapons. This "stand-in" capability will bring a greater number of targets within the range of short- and medium-range munitions, which are themselves less costly and have larger inventories than

[66] Curtiss-Wright, "Curtiss-Wright Successfully Demonstrates TCG-HUNTR Tactical Data Link (TDL) Hub and Network Translator During Timber Express 2020", July 28, 2020; Lt. Col. Volker Schaaf, IDL, "Timber Express — Digitization for the Tactical Advantage", *IDLSoc Newsletter*, August 2021, pp. 2-3.

[67] Interviews with an operational consultant and an engineer from MBDA.

stand-off missiles and long-range air-to-air missiles. In the electronic warfare sector, stand-in action also improves the signal-to-noise ratio for jamming.

Secondly, through their profusion, the RCs will make it possible to disperse and disaggregate intelligence and engagement/combat capabilities, *i.e.* to distribute capabilities that were previously provided in a more centralized manner by a limited number of manned platforms. There are multiple implications:

- ⇒ Firstly, disaggregation will multiply the number of elements for the adversary to detect, identify, target and hit. In short, it can considerably complicate his situational awareness and plan of engagement. In so doing, this significantly enhances the resilience of the capability;
- ⇒ Looked at from the other side, it will offer air component commanders a wider range of modes of action to structure their maneuvers. It may, for example, enable better application of parallel warfare options, *i.e.* the ability to deal simultaneously with several different target systems or target categories. It will also provide greater opportunities for deception maneuvers to disorientate the adversary command;
- ⇒ RC systems will significantly increase the areas covered by airborne systems, both in terms of ISR detection coverage and the volume of targets that can be processed at any given time. This type of coverage is absolutely essential in dynamic targeting, for example;
- ⇒ This diversity of action mode options will be reflected at the subtactical, mission level. For example, by dispersing effector nodes, RCs substantially increase the possibility of saturating the various enemy defense systems.

In addition, the disaggregation of capabilities should also be reflected in the diversity of ways in which these RCs can be deployed, depending on their type: potentially from airborne platforms (fighters, wide-body aircraft, other RCs or more conventional drone systems), naval platforms, land-based platforms, including rocket launchers, launch ramps deployed on austere bases, and so on. Of course, not all of these options will be adopted. Nevertheless, there are several possible implications of this diversity:

- ⇒ It will increase the flexibility of the deployment posture, and therefore the availability of air power. For example, we could envisage pre-positioning RCs at several forward operating bases, as the Americans do, which would limit the logistical constraints of projection;
- ⇒ It is liable to increase the flexibility and resilience of our air power. The pre-positioning of drones could, for example, be based on the American concept, adopted by NATO, of Agile Combat Employment, *i.e.* the dynamic deployment/re-deployment of aircraft from one airfield to another, a dispersion designed to complicate enemy targeting.

We'll take a closer look at these multiple elements in the various air power missions below.

2.4. Additional conditions

The implementation of these collaborative combat aircraft and MUM-T concepts is subject to a number of conditions.

First and foremost, guaranteeing the "expendable" nature of RCs while retaining the operational capabilities needed to accomplish the required missions obviously calls for delicate compromises on drone characteristics. Some of these obviously concern mission equipment (for example, the sophistication of sensors and communication systems). Others relate to aircraft design, and may prove more difficult to achieve. For example, an expendable drone used as a decoy replicating a fighter aircraft requires performance levels that call for a propulsion system that could make the drone overly expensive. Of course, where possible, modularity of aircraft components will certainly be sought to reduce costs. Moreover, as the Americans explain, compromises will also have to be made on equipment redundancy levels, and hence on reliability.

Next, it will be necessary to develop specific sensors and weapons adapted to these platforms, as already seen on existing drone systems, such as the *Bayraktar* and its miniaturized bombs. For example, the Mitchell Institute's wargame players point to the need to develop smaller air-to-air missiles, less costly than current systems.

Furthermore, the MUM-T concept is based on the cardinal principle of connected collaborative combat, whereby the various elements (manned aircraft, RCs, weapons) of the NGWS behave as a single, disaggregated weapon system.

The first condition is to build the much-vaunted combat cloud, which must provide the "informational glue", the connective tissue of the system of systems. As we have devoted a separate note to this subject, we will not go into the subject in detail here[68]. We will simply highlight a few specific points. First of all, it is not self-evident that all RCs must be part of this cloud. For example, will this be necessary for certain expendable RCs?

Be that as it may, connectivity will of course be of critical importance in this context. It will obviously be conditioned first and foremost by the function of the drones and the type of MUM-T, implying, for example, the possible need to transmit on-board sensor data back to the manned platform. Obviously, it will also depend on the concepts of employment and the resulting distances of engagement. Connectivity can range from a simple point-to-point line-of-sight connection between one or more drones and the manned platform, to much more complex architectures. We could, for example, imagine large numbers of RCs operating hundreds of kilometers away from manned platform(s). Such concepts could then require Internet of Things-type battlefield architectures. Such architectures would, for example, combine SATCOM and relay drones, with some RCs at the end of their mission providing communication services within salvos or swarms of RCs or weapons forming local star or mesh networks. The exposure of this architecture to electronic warfare and offensive information warfare threats will of course be a major criterion. The use of technologies such as optical communications between relays and 5G could be of particular interest here.

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[68] Philippe Gros, *op. cit.*

MUM-T also assumes a certain level of autonomy. This "semi-autonomy" concerns first and foremost the information systems of manned aircraft, which constitute the main nodes of the combat cloud. These systems will have to manage multiple information-processing tasks with an even greater degree of autonomy than today. The difference between a *Rafale* and a *Mirage 2000* is already noticeable. In the former, pilots now spend only around one-third of their time flying the aircraft, with the remaining two-thirds devoted to mission management, tactics, etc., an inversion of proportions compared with the *Mirage*. The management of drones and collaborative combat as a whole will require still further advances, using multiple artificial intelligence techniques. Of course, the drone systems will also have to possess partial autonomy. It is essential, first of all, to relieve the operator of all drone piloting tasks (as is still the case today), an obligation if the operator in question is the pilot of a fighter aircraft and if the number of RCs per operator increases. It is also necessary in the context of operations in electromagnetically challenged environments, where links are disconnected, intermittent or limited (DIL). However, autonomy will remain tightly bounded. The same should apply, for example, to the maneuvering space granted to the drone. Above all, it is unlikely to go beyond "man-in-the-loop", with the operator remaining fully in charge of critical decision-making, such as engagement. In this respect, determining the rules of engagement is obviously critical.

The question of how to manage the actions of the RCs is also an issue. The term command and control (C2) is often applied, but here again, the notion can be problematic. C2 authority is exercised over people. Conversely, the management of a drone by an operator does not usually fall under this function. It is therefore proposed to distinguish two potential levels of RC management:

⇒ The majority of drones will probably be controlled at the "mission management" level by a crew within a patrol. Traditionally, mission management covers routes, patrol configuration and tactics. This is akin to the American concept of a "tethered" drone, linked to a manned platform, even if the drone is in practice far removed from the mission leader. This typically includes the use of the drone as a loyal wingman for the manned aircraft. However, other configurations are also possible.

⇒ However, we must not exclude a second level of drone action management, that of "battle management" (BM), which is the level of execution of decisions taken by C2 authorities (hence the term BMC2)[69]. It may be necessary to manage the tactical maneuvering of a large number of drones operating on their own, untethered from the missions of a manned aircraft. It will be recalled that, in concrete terms, the BMC2 function consists of coordinating and synchronizing the actions and activities of all the assets (ISR, effectors, tankers, etc.) involved in the air battle. Today, BMC2 is generally decentralized at the level of airborne early warning aircraft (such as the Navy's E-3 or E-2 *Hawkeye*), battlefield surveillance aircraft (such as the American JSTARS), ground-based detection and control centers or combat ships. FCAS, like the U.S. NGAD, plans to give pilots of new-generation fighters like the NGF local BM capabilities. The F-35 appears to be a precursor in this respect[70].

[69] Battle Management is "*the management of activities within the operational environment, based on the commands direction, and guidance given by appropriate authority*" (U.S. Doctrine *Joint Pub* 3-01).

[70] See Philippe Gros, "La décentralisation du commandement et du contrôle (C2) des opérations aériennes", *Recherches & Documents*, n° 12/2020, FRS, September 18, 2020.

This management should be dynamic, depending on the context. According to the Americans, these issues of mission management level, rules of engagement and the degree of operational autonomy granted to drones are in fact interdependent. In some cases, for example in a highly DIL environment, management by the BMC2 function, even if logical, may not be possible. In their view, the stronger this DIL constraint, the more semi-autonomous drone action will be needed, obviously within the framework of tightly fixed ROEs.

The current situation, therefore, fully justifies the fact that FCAS architects, like their counterparts from other major powers, are banking on a Next Generation Weapon System (NGWS) combining manned platforms and off-board capabilities on drone systems, all integrated within a combat cloud.

3. Options for collaborative combat aircraft systems: some considerations for each mission

The starting point for this analysis is to look at each of the priority missions/functions: ISR, C2, DCA, OCA/SEAD, CL (AI/CAS) and CS. In absolute terms, for each of these missions, we would need to consider the nature of the main capabilities required as a whole, then define the contribution of RCs in this context as a complement to manned platforms, and from that infer different concepts for the use of different types of RCs and MUM-T constituting variants of the system of systems. From these concepts we can deduce RC characteristics in terms of type and employment: expendable or recoverable, characteristics (range, flight performance, etc.), types of payload and mission equipment, mode of deployment (air-launched or ground-based system) and recovery, where applicable, mission management modes in MUM-T with manned aircraft, etc.

In this field, only advanced technical-operational studies, carried out by manufacturers and the DGA, can combine these multiple parameters to determine the best system options. It is beyond the scope of this note to describe all of them, especially as research in this field is not yet complete. We will simply propose a few plausible examples.

3.1. RCs in the intelligence function

In this context, the airborne ISR function will mainly complement space-based capabilities to support in-depth operations in all domains, for all decision-making cycles, from operational planning to dynamic cycles. This means that, in the first place, ISR relies on broad-zone IMINT collection capabilities, as it is not clear that France will have access to a sufficiently massive space-based IMINT capability in the reactive (and therefore sovereign) radar domain within the timeframe under consideration. Although our country is better equipped in terms of space ELINT, these capabilities are nonetheless limited, and would rely on a significant contribution from the airborne component.

Non-permissiveness means that these sensors need to be penetrating and more numerous. Next generation combat aircraft, including the NGF, will presumably be excellent assets in this respect, but they will be largely occupied with engagement/combat missions, particularly in the conduct of operations. Theater drones like the *Eurodrone* will be too vulnerable. Dedicated ELINT platforms such as *Archange*, already in short supply, will be confined to stand-off operations. Their ELINT detection range will be limited to line-of-sight, *i.e.* tactical depth. We can therefore logically assume that RCs will be at the crux of this function, performing stand-in intelligence gathering in the midst of the enemy's defense systems.

Based on this observation, one can envision multiple concepts, including RCs operating:

- ⇒ in MUM-T with the *Archange*, equipped of course with ELINT sensors but also possibly with IMINT sensors for multi-sensor fusion based on the perceptions achieved;
- ⇒ as autonomous IMINT/ELINT sensors or multi-sensors for deep penetration, as envisioned by Lockheed Martin with its NGUAS;
- ⇒ in direct ISR support (escort and opening up access) for attacks or weapons.

The resulting RC options are potentially highly varied. For example, at one end of the spectrum, we could envision stealthy, or at least reduced-signature, recoverable drone systems capable of carrying IMINT and ELINT sensors, as well as a high-speed data link to transfer the data, or even *in situ* data processing capabilities[71] to save on bandwidth. We could also imagine smaller RCs carrying Electronic Support Measures (ESM)-type sensors, operating in MUM-T with manned platforms to extend the detection zone.

3.2. RCs in defensive counterair (DCA) missions

The role of fighter aircraft in DCA missions will be to provide zone defense as far upstream as possible of the assets or sites to be protected from enemy strikes. A conventional posture based on AWACS for airborne early warning and battle management, and a limited number of manned fighters, will encounter a number of challenges:

- ⇒ those linked to the operational environment, *i.e.* the size of the airspace to be covered and the reactivity or permanence of coverage;
- ⇒ those linked to the adversary's operating modes and capabilities: number of engagements to be carried out simultaneously, particularly in the event of a saturation attack by the adversary, but also the adversary's range of engagement.

Moscow and Beijing, which have long been confronted with the challenge of Western air power, are banking on the range of engagement to be able, if not to shoot down, at least to repel, and thus effectively neutralize, airborne early warning platforms, which are a decisive element in guaranteeing information superiority, a vital asset in air combat. Witness Russia's upgraded R-37 missile, with its 200km range, and China's new PL-17, with a claimed range of 400km. Admittedly, the latest fighter capabilities (stealth on coalition F-35s, less interceptable radar waveforms, infrared optronics, ESM sensors) and those to come (NGF stealth,

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[71] This is referred to as far-edge computing, *i.e.* a type of cloud in which computing capacity is dispersed at the platform level, on the tactical fringe.

decentralized BMC2 capabilities) are designed, to a certain extent, to cope with this risk of AWACS elimination. But are the quality and extent of detection coverage equivalent?

In this respect, RCs would have a first role to play, that of contributing to a distributed MUM-T detection system with fighters, by forming an airborne mesh of sensors, probably IR or even radar, ahead of manned aircraft. A second role would be that of decoys with varying degrees of sophistication, replicating the signature of fighters.

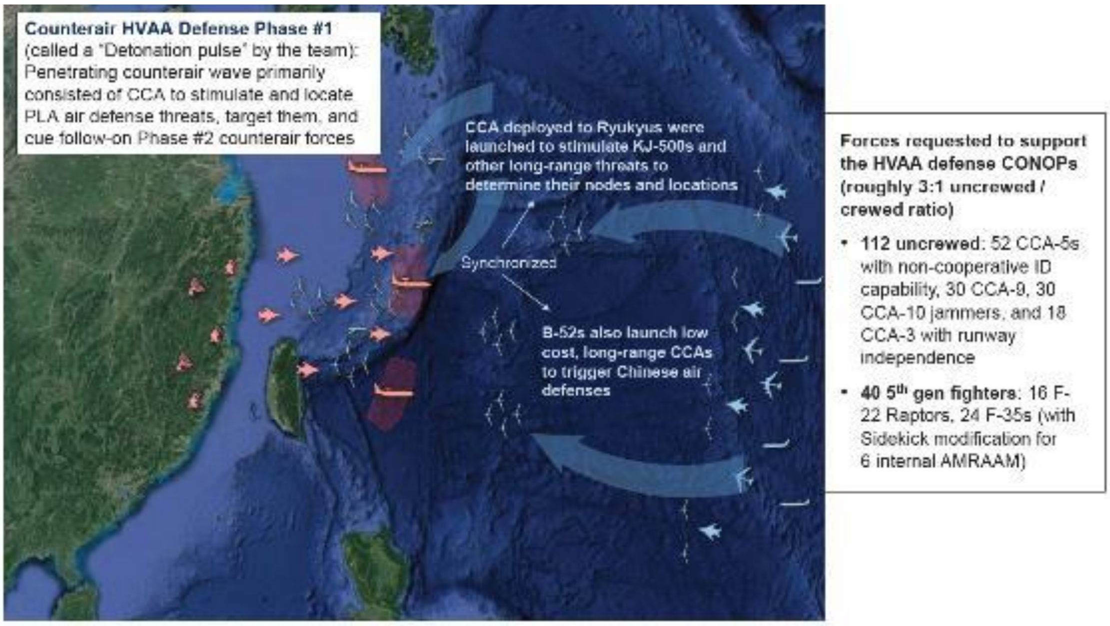
Multiple types of RC would be possible, for example:

- ⇒ land-based RCs, with sufficient autonomy to last the duration of a long patrol, equipped with sensors and high-speed data links, thus high-cost, and therefore recoverable;
- ⇒ smaller, expendable RCs contributing to sensor networks or acting as decoys. These drones would be deployed by other RCs, manned fighters or large platforms deployed beyond the missile range of adversary fighters.

Then comes the actual engagement. At first sight the sensors and stealth characteristics of the aircraft, as well as the range of the missiles (*Meteor*, new American AIM-260), should guarantee a certain superiority factor. That said, RCs deployed ahead of the patrol, in multi-platform collaborative engagement, could play a role in the detection and approach phases. Above all, in the event of an enemy saturation attack involving multiple fighters, and more likely a large number of drone munitions, friendly fighters could run out of munitions. RCs can also have a major impact as off-board missile carriers. In this case, one might consider less expensive RC missile trucks. However, in the event of non-engagement, it is difficult to envision sacrificing the drone and its missile payload. The use of recoverable RCs therefore seems logical, but expendable RCs held in reserve and engaged when needed would also be a possibility. Finally, in terms of control, the loyal wingman concept of RCs tethered to the fighter, or at least to the patrol leader, seems particularly appropriate.

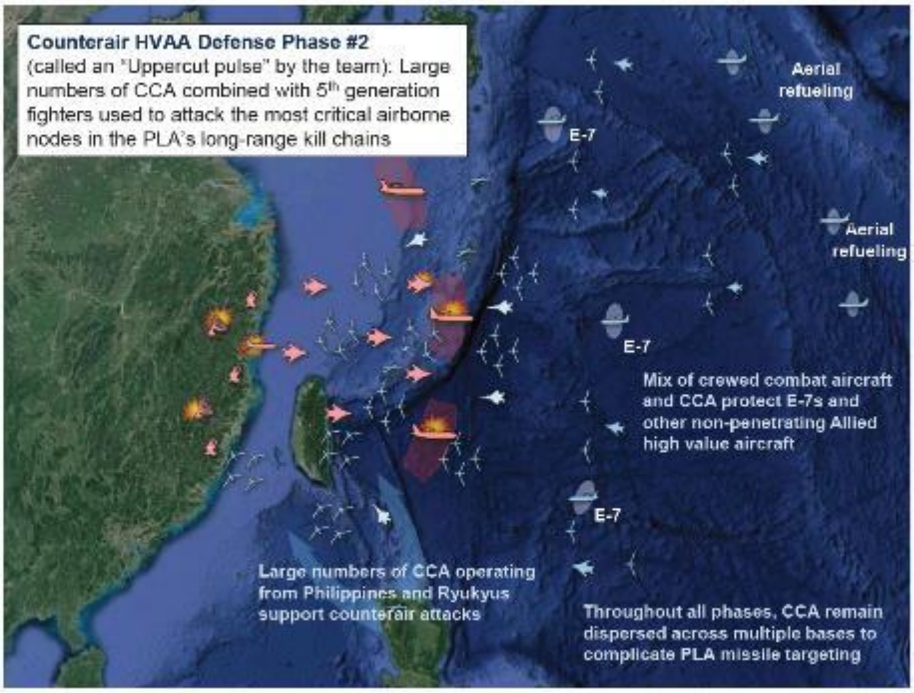
For example, during the Mitchell Institute wargame, the team that was focused on a combined DCA/OCA mission (in this case, an offensive mission to protect AWACS aircraft and tankers) devised a two-phase plan to attack enemy airborne early warning aircraft and fighters:

- ⇒ An initial phase (shown below) employing several dozen expendable CCAs, combining long-range drones, either low-observable ISR and communications drones (CCA-9 in the table in 1.3.2), or stealthy electronic attack drones (CCA-10), along with smaller air-launched counterair drones (CCA-5), for identification. The whole system is designed to stimulate and locate Chinese assets and communicate the coordinates to AWACS platforms several hundred kilometers away;



Source: Col. Mark A. Gunzinger, USAF (Ret.), Maj. Gen. Lawrence A. Stutzriem, USAF (Ret.), Bill Sweetman, *The Need For Collaborative Combat Aircraft For Disruptive Air Warfare*, The Mitchell Institute for Aerospace Studies, Air & Space Forces Association, February 2024, p. 28

⇒ A second, even larger wave, to attack the Chinese aircraft just as they are running out of fuel (see diagram below). The American fleet comprises several dozen F-22/F-35 fighters and around twenty stealthy, subsonic CCA drones (CCA-3), equipped with IR sensors and AESA radar, and carrying six AMRAAM missiles.



Source: Col. Mark A. Gunzinger, USAF (Ret.), Maj. Gen. Lawrence A. Stutzriem, USAF (Ret.), Bill Sweetman, *The Need For Collaborative Combat Aircraft For Disruptive Air Warfare*, The Mitchell Institute for Aerospace Studies, Air & Space Forces Association, February 2024, p. 29

Long-range drones operate from austere bases in the area where they have been dispersed or even dynamically relocated, according to the Agile Combat Employment concept.

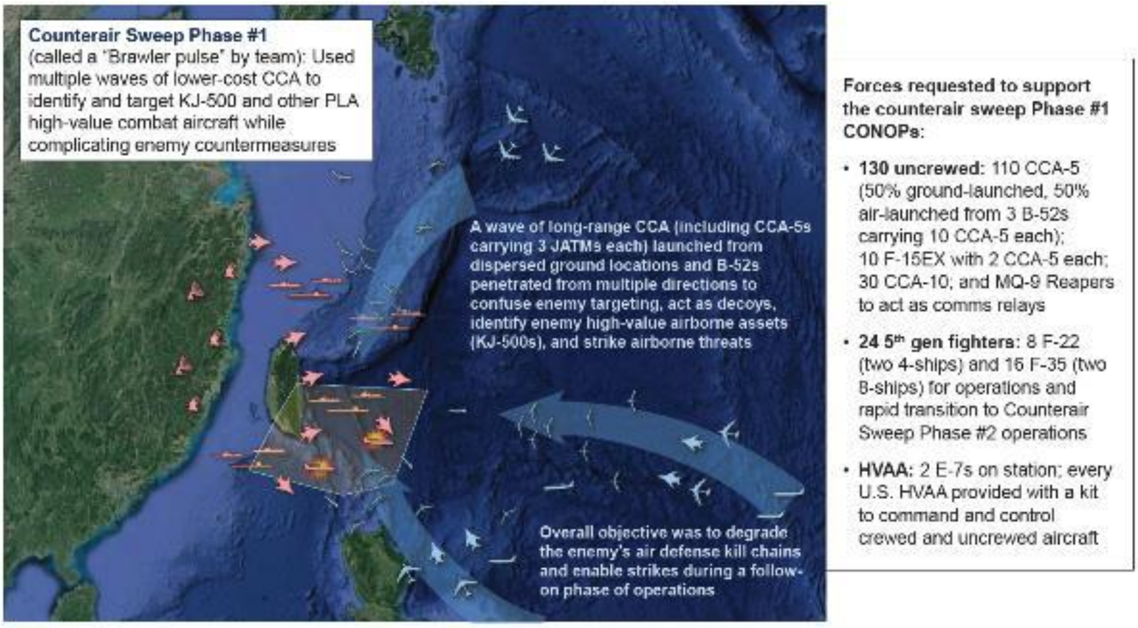
3.3. RCs in offensive counterair (OCA) missions

3.3.1. Fighter sweep

In offensive counterair, the first mission is fighter sweep to acquire air superiority over the enemy's territory by shooting down the enemy's fighters and the airborne early warning assets that guide and control them, sometimes in conjunction with the enemy's IADS and within the range of its surface-to-air missiles. The mission would therefore be performed in parallel with SEAD.

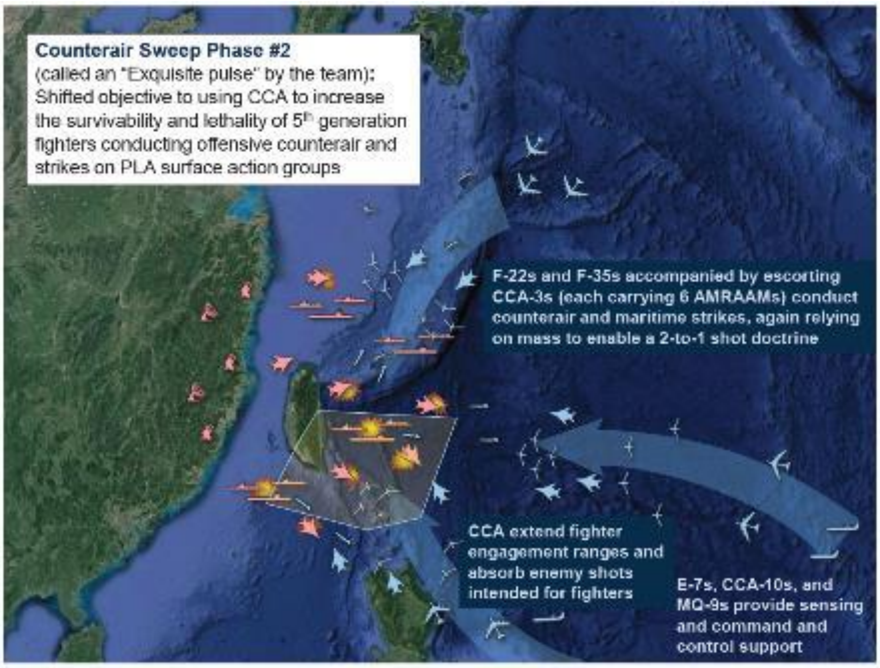
The mission requires information superiority over enemy fighters, while limiting the detectability of friendly fighters by airborne and ground systems. In such a situation, there is a particularly strong case for collaborative combat between stealthy manned fighters and RCs. The RCs could be employed in packs combining decoys to stimulate enemy radars by replicating the signature of fighters or cruise missiles, RCs equipped with ESM, IR or radar sensors, and finally RCs equipped with air-to-air missiles operating as remote effectors. It is conceivable that these RCs could operate in a staggered pattern, with the decoys in the front line, then the sensor and effector RCs, themselves well ahead of the manned fighters to limit the latter's exposure and enable them to exploit the maximum range of their missiles.

Let us refer once again to the work of the Mitchell Institute as an illustration. To breach a well-formed Chinese system at the start of the campaign, the team concentrating on this OCA mission chose to engage a large number of expendable CCA-5s acting as decoys, elements of multi-static passive sensor networks and air-to-air missile carriers, in collaboration with F-22s and F-35s positioned well behind. Again, these CCAs are operated from forward bases, where they have been positioned or dropped by fourth-generation bombers and fighters. Long-range CCA-10s, in conjunction with MQ-9 *Reapers*, act as relays between attack aircraft and the E-7 AWACS providing BMC2 (see diagram below).



Source: Col. Mark A. Gunzinger, USAF (Ret.), Maj. Gen. Lawrence A. Stutzriem, USAF (Ret.), Bill Sweetman, *The Need For Collaborative Combat Aircraft For Disruptive Air Warfare*, The Mitchell Institute for Aerospace Studies, Air & Space Forces Association, February 2024, p. 25

The American experts only engage recoverable RCs in the next phase, when the enemy's capability has been sufficiently degraded to limit attrition and make the campaign sustainable. These are the same CCA-3s as in the previous case. Two loyal wingman drones are used for each manned fighter, arranged as forward combat patrols. Together, they form several successive attack waves, also carrying out parallel strikes on Chinese surface vessels. Expendable CCAs are also employed as decoys in these attack waves (see diagram below).



Source: Col. Mark A. Gunzinger, USAF (Ret.), Maj. Gen. Lawrence A. Stutzriem, USAF (Ret.), Bill Sweetman, *The Need For Collaborative Combat Aircraft For Disruptive Air Warfare*, The Mitchell Institute for Aerospace Studies, Air & Space Forces Association, February 2024, p. 26

3.3.2. Suppression of enemy air defenses (SEAD)

In a previous note, we considered four levels of SEAD: non-lethal SEAD, defensive SEAD, limited offensive SEAD and the broader counter-IADS line of operation combining SEAD and Attack Operations against airbases. In the latter case, at least in the early stages of the campaign, SEAD would be integrated into the fighter sweep. It would include the following phases, to varying degrees:

⇒ blinding the main early warning systems of the enemy's IADS through long-range strikes, particularly at high velocity (high supersonic or even hypersonic);

⇒ secondly, initial disintegration of IADS by saturating C2 and neutralizing long-range systems through a combination of kinetic and non-kinetic effects (decoys, electronic attack and offensive information warfare), which requires the ability to orchestrate parallel effects on a large number of system elements along with massive firepower, including at long range;

⇒ finally, wearing down the enemy's residual surface-to-air capabilities and point defenses over the longer term (several weeks), bearing in mind that SEAD as performed over the last thirty years suppresses SAM batteries rather than destroying them. It requires a strong dynamic targeting capability.

Of course, it all depends on the context. The three phases may well overlap. This is unquestionably the combat mission for which European air forces, including the French ASF, are the least well equipped and prepared. It is on this mission, therefore, that the presence of RCs could make the greatest impact.

Once the surveillance systems have been blinded, RCs are the ideal means of stimulating the enemy radars to be targeted. In addition to the ISR drones mentioned above, we could envision either long-range ground-based drones, or air-launched RCs dropped from other platforms: stealth aircraft, but also, potentially, other drone-carrying drones or even long-range rockets. In any case, these would have to be long-range systems, with a range of several hundred kilometers. Their payloads could be of two kinds: ESM systems for communicating target data to long-range anti-radar systems, and decoy payloads, *e.g.* missile and fighter signatures. Logically, these would be expendable RCs, especially as these two types of payloads are not among the costliest. To ensure these systems remain sufficiently affordable, it would be logical to control these drones via radio link and relay drones, in preference to a communications satellite link. Finally, management by the BM function would be of particular interest in this case.

This type of operation would be even more useful in the disintegration phase of the IADS, targeting other surveillance radars, SAM battery tracking and engagement radars, C2 nodes, etc. It is at this stage that RCs would be used most extensively to generate a high degree of confusion in the situational awareness of personnel manning the adversary's IADS. At this point, the types of possible RCs become more diversified. If several of the enemy's surveillance radars have already been neutralized, creating breaches in detection coverage, the RCs used here would need less range. In terms of payload, decoys could be complemented by kinetic and electronic countermeasure payloads, including, for example, distributed antenna arrays, cyber-electronic intrusion capabilities via the adversary's radars and data links, and high-power electromagnetic weapons.

The modus operandi would be to organize a system capable of congesting the contested airspace with a large number of RCs. The aim would be to leave the adversary facing the classic dilemma between continuing operations and risking destruction (through dynamic targeting by drone-munitions in near-autonomous operation, or by missiles from manned platforms) or shutting down radars in order to survive, which for the coalition results in a suppression effect, leaving aircraft free to strike other targets. Such a system could, for example, be made up of a mix of expendable RCs (loitering munition "trucks", decoys, ESM systems) and recoverable RCs equipped with the highest-value electronic payloads. Here too, however, the players at the Mitchell Institute felt that expendable RCs should be preferred, to avoid excessive losses in the inventory of high-value drones.

This disintegration effort would require a saturation mode of action with firepower that could be sustained for several hours. This may well exceed the payload capacities of manned platforms, especially if they are already engaged in air-to-air combat or airfield strikes. In this case, it would be logical to multiply deployment solutions for these RCs: land-based drone-carrying drones carrying several RCs, heavy platforms positioned beyond the range of the enemy's long-range ground-to-air missiles, etc. Finally, loitering munition RCs should have a degree of autonomy enabling them to carry out quasi-autonomous collaborative attacks, potentially also including weapons (cruise missiles, glide bombs) as part of composite maneuvering salvos within areas defined by specific rules of engagement.

There is, however, considerable uncertainty as to the viability of this concept against the most capable IADS. Saturation with expendable vehicles is already the norm in Yemen and Ukraine, even though Houthi and Russian attacks do not involve loitering munitions, but rather GPS-guided attack drones. In any case, all the major powers' air defense systems are already adapting to this saturation threat: modified detection methods (combining microwave radars, acoustic detectors, etc.), rediscovering the use of cannons, arrival of directed-energy weapons and much less costly missiles over the next few years, and ultimately distributing these detection capabilities more widely, given technological developments in radars and C3, etc. Such a transformation is likely to raise the saturation threshold to several hundred devices deployed in parallel.

The complexity of this initial battle of disintegration could imply management of the whole system by a BM function, which would gain in responsiveness and resilience through its decentralization to tactical C2 nodes: AWACS, in the future NGF, etc. In this respect, the deployment of RCs loitering for one or more hours could involve the transfer of their tactical control from one BM platform to another, from mission command to the BM function, or vice versa. This C2 agility requires connectivity that is fully MANET (Mobile Ad Hoc Network) and particularly resilient.

The final, much longer phase is that of attrition of point defenses by reactive SEAD. In absolute terms, this would require a dynamic targeting system with a quasi-permanent layer of sensors capable of creating kill webs with any available air-to-surface or surface-to-surface effector, as soon as the target is revealed or detected. One modus operandi is to saturate the target system with attacks from all directions. RCs are obviously the resource of choice for the MUM-T detection system with ISR platforms, but they can also provide effectors. While the detection system will probably need to be managed by the BM function, RCs used as Loyal Wingmen with fighters are of particular interest.

3.4. RCs in offensive counterland (OCL) missions

3.4.1. Interdiction missions

In Air Interdiction, as with SEAD, a distinction must be made between Deliberate Targeting and Dynamic Targeting, the latter being undertaken according to the Find, Fix, Track, Target, Engage, Assess (F2T2EA) cycle.

In order to achieve sustained destruction, disruption, diversion or delay effects on the adversary's lines of communication, telecommunications, logistics, indirect fire, reinforcement echelons or even more strategic target systems, these AI operations generally require considerable firepower. This firepower can be applied over time, with multiple "revisit" strikes to prevent the adversary from rebuilding capabilities. As the war in Ukraine has shown once again, sporadic strikes generally have equally sporadic effects, failing to really shape the battlefield. Similarly, dynamic targeting requires deployment of significant ISR and effector capabilities.

Furthermore, AI is synonymous with deep penetration, and therefore necessarily carried out in a non-permissive or at best semi-permissive environment, unless undertaken once OCA missions have established air superiority, which the desired operational effects may not allow.

Manned aircraft and cruise missiles provide adequate capabilities for deliberate targeting attacks, at least for the time being. By financing the acquisition of sufficient munitions, the LPM will undoubtedly increase the number of such attacks. On the other hand, penetrability in non-permissive environments remains contingent on the volumes of long-range munitions and the number of tactically capable combat aircraft available to the coalition. What's more, the number of such platforms is unlikely to be sufficient to guarantee the maintenance of both SEAD and AI dynamic targeting operations. For both these reasons, RCs appear to be indispensable.

Notwithstanding the needs associated with the OCA efforts accompanying these missions, deliberate targeting could, for example, involve stealthy, recoverable, long-range RCs carrying air-to-ground munitions, or even expendable RCs, operating either as LW with manned aircraft whose range they would extend in less permissive space, or on independent missions under the management of the BMC2 function. The F2T2EA system would involve stealthy ISR RCs and expendable, kinetic-payload loitering RCs with a link enabling transmission of designated target coordinates, with an autonomous coordinated terminal attack capability, launched by manned aircraft, drone-carrying RCs, ground force rockets or even land vehicles or ships.

3.4.2. Close air support (CAS)

With respect to CAS, two concepts come to mind:

- ⇒ The RC as a loyal wingman for the manned platform to provide additional ISR support to the platform and to the Joint Terminal Attack Controller (JTAC) providing further details on the tactical situation. In this case, a MUM-T with the JTAC could be envisioned, with control of the drone being transferred between the JTAC and a manned platform;
- ⇒ In the longer term, it may be possible for an RC to provide the required fire support under the full control of the JTAC, but this could pose a number of problems, in particular the JTAC's ability to control the drone under stress in the zone of engagement. The concept appears more viable in an operating situation, albeit degraded, where JTACs are deployed to the rear in liaison with forward observers, as was the case during Inherent Resolve.

3.5. RCs in battle management (BM) functions

RCs could also have an interesting role to play in the BMC2 function, supporting AWACS, extending their coverage if they are forced to withdraw in the face of the ground-to-air or air-to-air threats, and increasing the capabilities of NGFs, and perhaps even *Rafale* F5s, which will be employed as distributed BMC2 nodes as planned under FCAS. We could also envision a collaborative intelligence function, as the American OBSS program seems to be doing, based on a network of stealthy RCs, used in less permissive environments, equipped with IR or even radar sensors, used as LW at a distance from the battle management nodes. Recoverable or expendable RCs could also be used, depending on the threat level and the choice of sensors deployed. Expendable RCs could also be used as BMC2 relays within ammunition salvos to coordinate maneuvers.

3.6. RCs in the communications function

In addition, the Armed Forces General Staff intends to implement improved multi-domain integration, and to this end has started development of a multi-sensor/multi-effector network (RM2SE), in reality a complete information and communication system (SIC) architecture including not only the evolution of the joint forces information system, from the strategic level to the component command post level, but also a better alignment of tactical SICs. Improving connectivity between the sensors, C2 centers and effectors of the various components is obviously a crucial part of this project. The aim is to be able to provide an end-to-end connection and relay between the elements involved in a given mission, should the need arise. The communications architecture envisioned must be hybrid, combining the different SATCOM and line-of-sight radio frequency transmissions.

As we have seen, RCs can also play a role here, for example, by acting as communication relays or even gateways between tactical networks, taking advantage of the translation tools currently being developed for heterogeneous networks. These relays would enable lower-latency communication compared with existing SATCOM bridges. Of course, current non-penetrating tactical or theater drones can fulfil this role, but their low penetration capability prevents them from being deployed too close to the contact zone, within range of enemy ground-air systems. In this context, a stealthy RC equipped with low-vulnerability optical communications would be a particularly judicious solution.

Conclusions

C2, ISR, SEAD, fighter sweep, interdiction, CAS... As we have seen, there is no shortage of potential avenues for employment of RCs in future air combat, to restore the "affordable mass" that the Americans talk about and that Europeans sorely need. Nevertheless, there are many challenges to overcome if we are to exploit the full potential of these systems.

In reality, the real question concerns their efficiency in relation to manned fighters. This efficiency depends on a delicate tradeoff between:

- ⇒ on the one hand, the expendable nature of these vehicles, which must therefore have unit costs that allow them to be produced in large quantities;
- ⇒ on the other hand, the performance and reliability thresholds influencing their design (not only drone design but also recovery processes) and perhaps even more so their equipment (such as communications or payloads) will make these RCs genuinely interesting as extensions, complements or even, where appropriate, substitutes for manned aircraft.

The question of comparative efficiency also arises between expendable RCs and munitions. In fact, at first glance, it seems to us that there is an increasingly fine line between these concepts of expendable RCs and connected munitions such as the American Network Collaborative & Autonomous Weapons – provided they are powered – some of which have already demonstrated fully autonomous collaborative attacks. This helps to understand the debate still raging within the U.S. Air Force today, which we discussed in Part 1. This tradeoff is all the more difficult to find as the threat is evolving, as we have seen, and we need to anticipate the confrontation with IADS systems transformed to survive saturation by a significant mass of vehicles. This brings us back to the need to carry out system of systems "value analyses" much more than we do now, upstream of program selections, even if necessary with a range of costs, which the administration still seems reluctant to do.

In the face of the evolving threat, the design of these RC systems must necessarily align with excellent multi-domain integration, optimizing synergies with the many other elements of the force's apparatus, such as airborne ISR and effector platforms, as well as naval and land-based platforms, munitions and other non-kinetic payloads. This obviously raises the question of the tactical doctrine for drone C2, and the evolution and agility not only of patrol leaders, mission commanders and air battle management, but also of the C2 function at joint force level. This means, for example, envisioning the dynamic management of transfers of drone control between tactical C2 elements of different components.

In terms of technical resources, this presupposes that combat clouds – in particular via projects such as RM2SE – are actually developed as planned. It also raises the question of multinational interoperability. Since the Gulf War, we have known that coalition air operations have trouble adapting to national areas of responsibility. This obviously poses a major challenge in terms of situational awareness, but it also a reason to consider, from the earliest design stage, strong interoperability between FCAS, NGAD, GCAP and other systems of systems, at least for the deconfliction of drone operations, and at best to develop data links, translation tools and, above all, procedures enabling C2 to be shared – at least for some drones – just as the BM function does today with manned fighters.

Secondly, while this construction of MUM-T will of course exploit multiple existing technologies, for example in terms of connectivity, it is also based on technological presuppositions that have yet to be demonstrated. The most important of these is probably the maturation of artificial intelligence techniques which will give these systems autonomous decision-making capability – although this may not, paradoxically, be the greatest challenge – and which will ensure the autonomy of manned aircraft navigation and attack systems, allowing pilots to concentrate on tactics and on managing the employment of RCs without cognitive overload.

These various conditions naturally argue in favor of incremental development, starting as soon as possible, for both RCs and the combat cloud, in order to open avenues leading to concrete solutions to these multiple challenges, as the demonstrations already undertaken or planned fortunately tend to indicate.

Last but not least, if an affordable-mass tradeoff can ultimately be found in operational terms, the transformation will have a significant initial cost, particularly in terms of human resources, whether for flying some of these drone systems in the absence of on-board pilots, or more generally, for their handling, preparation and deployment. The benefits in this area will be felt in terms of operational readiness, with a greater emphasis on digitized training and far fewer actual flying hours. However, the entire FCAS project, whatever its future scope, will be subject to severe resource constraints. As a result, it is conceivable that the development and acquisition of a significant volume of RCs could have a crowding-out effect on a fraction of NGF volumes, further reducing the target number of manned aircraft, complicating modernization plans, with consequences to be managed in terms of pilots' operational readiness, among other things. Getting people to accept such a shift could represent a real political challenge.

As we see, the road to the development of remote carriers within the FCAS program, as envisioned in current concepts, is fraught with pitfalls. Nevertheless, we must tread this path if we are to restore balanced air power, with sufficient "affordable mass" to meet the increasingly tough challenges of current conflicts and those of the decades ahead.