

## Defense Update

# Full afterburner into the future: what to expect from sixth generation fighters

Industry Overview

### 6th generation: range, speed, stealth, uncrewed wingman

Projecting power over distance and maintaining the most advanced weapons systems in the world have been key pillars to U.S. strategic deterrence policy. The threat environment has shifted away from less sophisticated and asymmetric threats to advanced near peer threats. Moving to counter the rise of advanced near peers and the intensifying threat environment, the DoD is evolving its arsenal to maintain supremacy. The industry has responded to the DoD's call to engineer the next batch of exquisite programs of record to maintain the U.S.'s enduring advantage. The upcoming sixth-generation fighter aircraft are among those programs of record that are attracting the most attention and budgetary support, with roughly \$4.4bn budgeted for FY24 alone. We see even further upside associated with classified work.

### Air Force and Navy funding separate programs

While both the US Air Force and Navy are referring to their next-generation fighter programs as NGAD, the Navy's approach is more colloquially known as the F/A-XX. While the F/A-XX will be carrier-based, both programs are expected to fulfill the role of "high" in the "high/low" fighter mix, indicating it will be the most exquisite fighters available. Aside from being faster, stealthier, and having longer range than its predecessors, these new platforms are also expected to reflect strides in material technology, propulsion, connectivity, and interoperability with unmanned counterparts.

### BofA design: swept wings, dual engine, composites

We expect a sixth-generation fighter could share mainly similarities with the cancelled Northrop/McDonnell Douglas YF-23 demonstrator. The aircraft could possess smaller, more swept wings and a variable V-tail design that would allow for superior high angle-of-attack (AoA) performance. Dual engines would allow for greater speed, faster climb, and extended range, which is increasingly important in a potential Indo-Pacific conflict. Additionally, two engine jets are generally seen as safer given the redundancy provided by a second engine. On the material side, we could see a combination of different composite materials, including new surface and low observability technology.

### Fighters + uncrewed a/c could unlock >\$15bn opportunity

Altogether, we believe the two fighter programs and their unmanned counterparts could unlock an opportunity larger than \$15bn. Assuming a total production count of just more than 300 units (to replace aging F-22s and provide range where F-35s cannot) and a unit cost of \$200mn for NGAD and \$225mn for F/A-XX (assuming higher unit cost for a carrier-based platform), we project that the NGAD and F/A-XX programs could create respective ~\$5.0bn and ~\$5.2bn earnings opportunities on an NPV basis. We see further opportunity on the uncrewed aspect of the program (CCA). Assuming a total program production count of nearly 1,500 units (the high end of outlined production range) and a unit cost of ~\$30mn (average of current projected price range), we estimate that the CCA program could create a ~\$2.8bn earnings opportunity on an NPV basis. A similar naval platform would likely fetch even more earnings upside given the expense of developing a carrier-borne drone aircraft.

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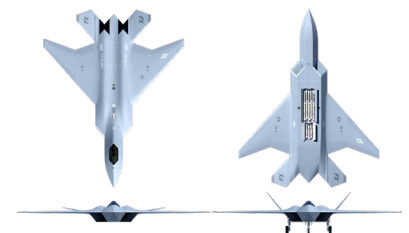
DoD – Department of Defense

NGAD – Next Generation Air Dominance

a/c – aircraft

CCA – Collaborative Combat Aircraft

**Exhibit 1: BofA NGAD fighter concept**  
Greater speed, climb, and range



Source: Rodrigo Avella

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# Historical background

## 2012: Navy issues Request for Information for F/A-XX

In April 2012, the US Navy initiated the official Request for Information (RFI) for its sixth-generation naval fighter, known as the F/A-XX, a carrier-based strike fighter. The program was launched with the primary goal of replacing the aging F/A-18 Super Hornet and the E/A-18G Growler aircraft, both scheduled for replacement by the 2030s.

The RFI marked a critical starting point, gathering industry expertise to define the specifications of the next-gen aircraft fighter. The RFI requested information on aircraft concepts that could operate in an anti-access/area denial (A2AD) environment, handle various missions (including air superiority, strike, and electronic warfare), provide additional capabilities such as reconnaissance and target acquisition, and remain cost-effective and sustainable.

In response to the RFI, leading aerospace companies, including Boeing, Lockheed Martin, and Northrop Grumman, submitted their proposals, marking the inaugural stage in the development of the F/A-XX.

## 2014: DARPA initiates replacement for F-22 Raptor

In February 2014, the Defense Advanced Research Projects Agency (DARPA) initiated the Next Generation Air Dominance (NGAD) program, with the goal of developing a sixth-generation air force fighter to replace the F-22 Raptor, an elite air superiority fighter. The US Air Force plans to replace its existing fleet of 187 F-22s with a nearly equal number of NGAD fighters (~200), entering service in the early 2030s.

The source selection process is anticipated to take place in 2024, and several US contractors are expected to bid on the contract, including Boeing, Lockheed Martin, and RTX. Additionally, the NGAD program is expected to feature a modular design, which will make it easier to upgrade with new technologies in the future.

## What defines a sixth-generation fighter?

### More range, speed, and stealth, all digitally designed and with a UAS wingman

The next generation of fighter aircraft are defined by new challenges that have emerged from technology maturation as well as the pacing threat from China. The next generation of fighters will require longer combat range, greater endurance, stronger stealth capabilities, larger load of air-to-air and surface weapons, and a greater emphasis on technology.

### Greater emphasis on technology: digital design, more connectivity, autonomy

Another important feature will be the ability to refresh software capabilities without the need for additional production blocks. Ideally, the existing fleet could be updated in real time and at will, deploying crucial software enhancements rapidly. This approach is currently being pursued by the US Air Force through its “Digital Century Series” assessment, which is expected to yield both cost reductions as well as more rapid upgrade deployment. The system will require advanced connectivity across which fidelity in highly contested multi-domain environments can be ensured. Increased autonomous operations are another major technological advantage we expect from the platform. Leveraging onboard AI (artificial intelligence), which can handle large amounts of data, improve cyber security, and EW (electronic warfare) capabilities is another key differentiator. An uncrewed component is also crucial, as it will act as a force multiplier that is capable of exerting further power at a fraction of the cost of another manned fighter.

### USAF sees NGAD program as a “portfolio of technologies”

According to the US Air Force, the priority for the Next-Generation Air Dominance (NGAD) program is to develop a “portfolio of technologies” that will enable the United States to establish and sustain aerial superiority. This departs from previous USAF

programs, in which new fighters were simply intended to replace older models with inferior capabilities (speed, range, payload capacity, etc.). The NGAD fighter is still expected to fulfill this mission profile by replacing the aging and expensive F-22 Raptor. The primary technologies that the USAF plans to develop through NGAD include the following:

- **Materials:** Unfortunately, most of the efficiency gains that can be captured through airframe design have already been captured. Therefore, airframe modifications can only yield limited performance gains. With that said, more focus is being placed on developing airframes from materials that are lighter, more durable, and have an increasingly minimal radar footprint in an effort to preserve stealth capabilities.
- **Propulsion:** The next-generation fighter is expected to feature an adaptive engine. Unlike traditional fighter engines, adaptive engines add a third stream of airflow to the engine. The third stream can be used to cool electronics, which enables higher turbine temperatures and, therefore, increased combat effectiveness. See the “NextGen engines fit the bill for any military situation” section of the report for further details.
- **Connectivity:** Through an advanced network of sensors fulfilling multiple roles on both the manned and unmanned aircraft, the NGAD “family of systems” (FoS) is expected to offer a greater level of connectivity than prior fighter generations.
- **Open Architecture:** 6<sup>th</sup> generation aircraft must utilize the DoD’s Modular Open Systems Approach (MOSA). The open architecture and modular approach allows for greater system flexibility with upgrades. New technology, capabilities, and weapons will be seamlessly incorporated through agile software upgrades and built-in hardware flexibility, helping to avoid lengthy block upgrades.
- **Uncrewed systems:** The incorporation of unmanned systems into the NGAD FoS is probably NGAD’s most blatant departure from prior military standards. These platforms are intended to supplement the mission profile by acting as force multipliers, limiting danger to the manned fighter and providing additional firepower, intelligence, surveillance, and reconnaissance (ISR), and electronic warfare capabilities. See the “Collaborative Combat Aircraft (CCA)” section of the report for further details.
- **Supply chain resiliency:** The US Air Force has also signaled that it is looking to alter its acquisition approach as well, with one company each focusing on design, production, and sustainment. The intention is to make defense contractors and, by extension, the broader defense supply chain more resilient and versatile.

#### **F/A-XX priorities: range, speed, active/passive sensors, long-range weapons**

The F/A-XX is expected to mimic its Air Force relative as a “portfolio of technologies.” In its Navy Aviation Vision 2030-2035 briefing ([link here](#)), the US Navy outlined its intentions for the upcoming F/A-XX fighter program. While still under development, the Navy’s next-generation fighter is expected to possess:

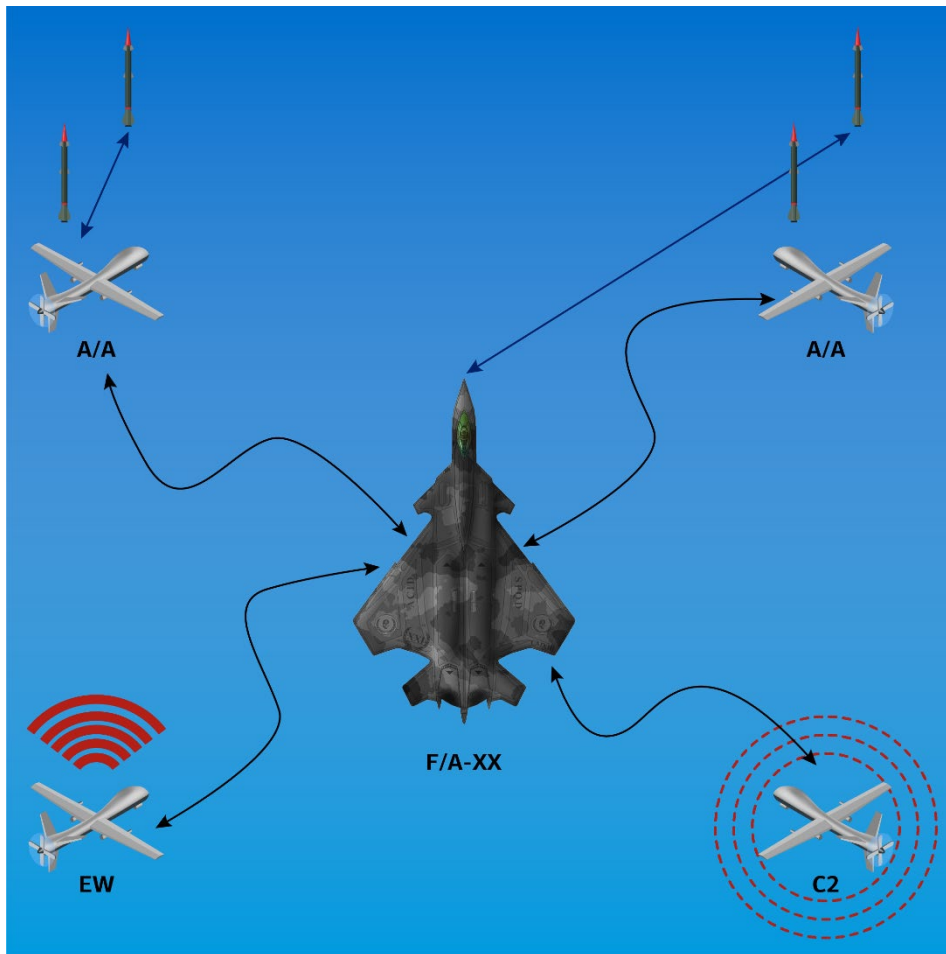
- Further range than F/A-18E/F Super Hornet (~1,200 nm);
- Greater speed than F/A-18E/F Super Hornet (Mach 1.8, 1,381 mph);
- Integrated active and passive sensor technology; and
- Longer-range weapons, such as hypersonic systems.

Additionally, as with the USAF NGAD program, the USN expects the F/A-XX to act as the primary platform within a “family of systems.” This FoS will include unmanned force

multipliers, such as the CCA, as well as uncrewed electronic warfare (EW) and command and control (C2) platforms (see Exhibit 2).

#### Exhibit 2: F/A-XX next-generation fighter family of systems (FoS)

USN expects F/A-XX FoS will include unmanned force multipliers as well as uncrewed EW and C2 platforms



Source: NAVAIR Public Release 2021-478 (Navy Aviation Vision 2030-2035)

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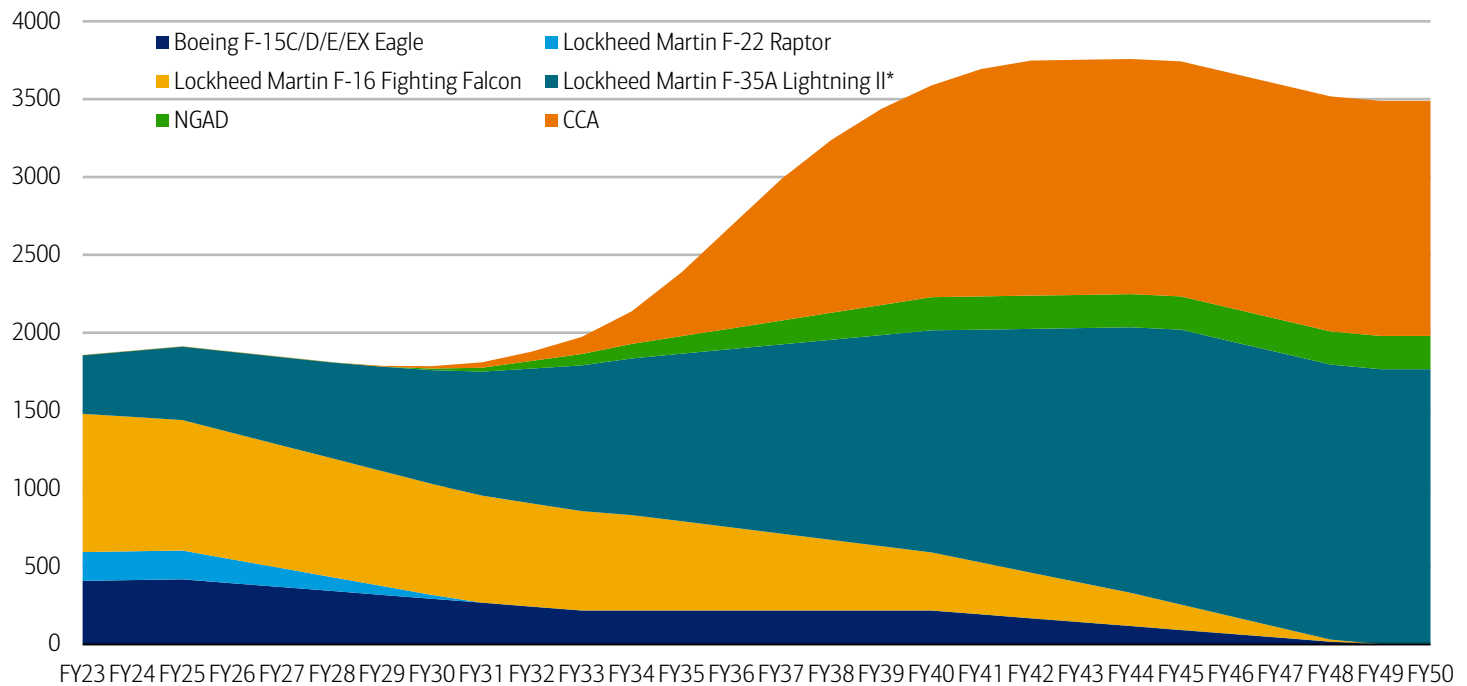
## Current and projected USAF and USN fighter fleet

### USAF approaching its fighter fleet with the '4+1' plan

In September 2021, the US Air Force Air Combat Command outlined the branch's "Fighter Roadmap", which outlines plans for the future USAF fighter fleet. The roadmap relies on the active service of "four-plus-one platforms": NGAD, F-35, F-15EX, F-16, and A-10. The "plus-one" platform is the A-10 Warthog, which serves in a more close air support (CAS) role but is crucial in securing air superiority in low tech/low intensity environments. We exclude the A-10 from our analysis, as it does not fit into the traditional fighter profile, which involves platforms capable of aircraft-to-aircraft combat (a.k.a. dogfighting). The Air Force's objective is to move seven fourth- and fifth-generation fighters to four fifth- and sixth-generation fighters that are more capable of countering near-peer and peer threats.

**Exhibit 3: Current and projected US Air Force fighter fleet**

In accordance with the '4+1' fighter plan, the US Air Force plans to field the NGAD, F-35, F-15EX, F-16, and A-10 platforms in its future fighter fleet



Source: FY24 President's Budget, Military Balance+

\* Northrop Grumman supplies center fuselage for the F-35

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**Future fighter plan involves the F-22 Raptor being phased out**

It is worth noting that the USAF's "Fighter Roadmap" does not feature the Lockheed Martin F-22 Raptor. Former Secretary of Defense Robert Gates discontinued the program in 2009 after just 187 units were produced, arguing that the platform was irrelevant for combat against Middle Eastern insurgencies like those at war with the US and its allies in the 2000s. Gates was a harsh critic of the F-22 and preferred the F-35. While slower and less evasive, the F-35 is meant to be less expensive and built in higher quantities. Gates believed the Pentagon had to improve its ability to develop cheaper and low-tech weaponry that focused on counterinsurgency missions such as in Iraq and Afghanistan.

While he was correct to see the F-22's limited role in the Middle East, Gates' decision overlooked the rise of near-peer threats like China and Russia, with the USAF fighter fleet now ill prepared to take on much larger fifth-generation fighter fleets. Additionally, the F-22 came at an exorbitant cost, amounting to \$150mn per unit. The F-22 is now pushing up against its physical service life, with more being parted out to keep the existing fleet operational. The USAF has signaled that it plans to phase the F-22 out of service in the 2030s. The FY24 budget proposal already calls for the retirement of 32 F-22s, although this will likely be delayed by one to two years.

**Navy Aviation Vision 2030-35: USN will operate 3 fighters in carrier air wing**

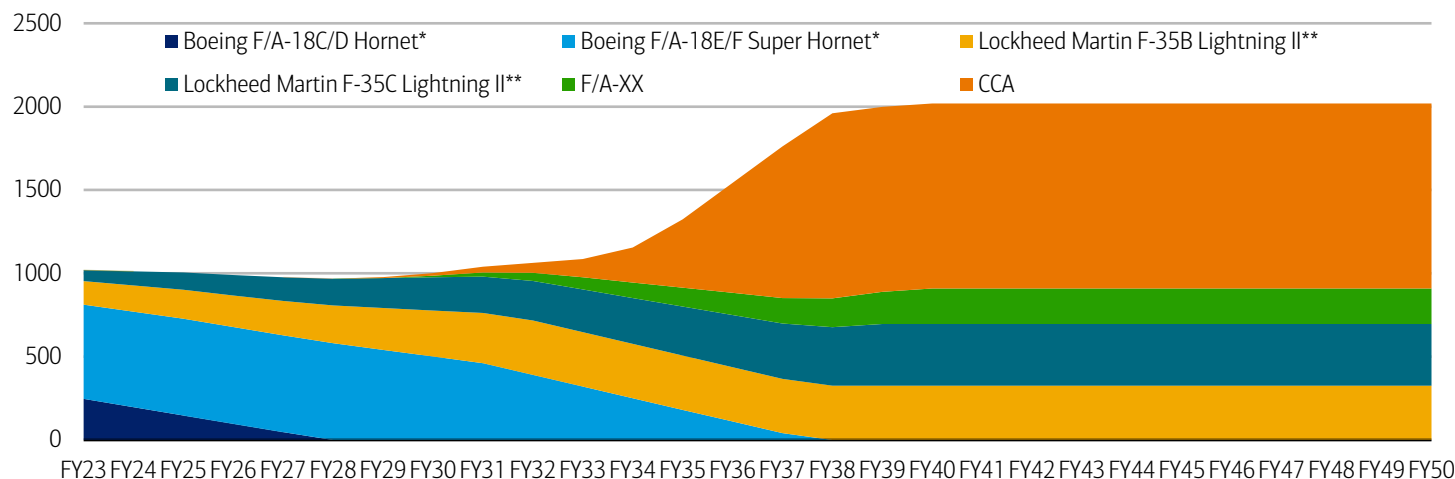
In October 2021, the US Navy published its "Navy Aviation Vision 2030-2035" plan as part of the National Defense Strategy. The plan focuses on three primary elements: (1) delivering capability and capacity to win in the Great Power Competition (GPC); (2) generating future readiness across the force; and (3) achieving revolutionary training. The plan emphasizes the development and application of advanced technologies, including manned/unmanned teaming (MUM-T). MUM-T is intended to reduce manned risk while expanding "capability, capacity, and survivability."

### F/A-18 will serve as backbone until gradually replaced by F/A-XX

With regard to the Carrier Air Wing (CVW), the US Navy foresees a mixed fighter fleet featuring the F-35C Lightning II, F/A-18E/F Block III Super Hornet, and the F/A-XX sixth-generation fighter. The Super Hornet is expected to continue serving as the “backbone” of the CVW through 2035. During that same timeframe, the F/A-XX will begin to replace the aging Super Hornet fleet. The Navy projects that the next-generation fighter will be able to fly farther, faster, and carry both active and passive sensor technology as well as longer-range weapon systems. After the Super Hornets are removed from service, the CVW fighter fleet will be comprised of the F-35C and F/A-XX.

#### Exhibit 4: Current and projected US Navy fighter fleet

After the Super Hornets are removed from service, the CVW fighter fleet will be comprised of the F-35C and F/A-XX



Source: FY24 President's Budget, Military Balance+

\*Northrop Grumman supplies aft fuselage for the F/A-18

\*\*Northrop Grumman supplies center fuselage for the F-35

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### NGAD, F/A-XX likely to be 'high' in next USAF and USN high-low fighter mix

Historically, the US Air Force fighter jet procurement and use has followed what is known as a high-low mix. This is a cheaper, multi-role aircraft matched with a more expensive air-superiority fighter jet. The F-15 and F-16 have provided the Air Force with its most recent high-low mix. In FY01, the last year both aircraft were procured together, the flyaway unit costs for the F-15 and F-16 were \$75mn and \$26mn, respectively. Over the years, the F-15, a more expensive and advanced aircraft, has been the Air Force's air superiority fighter (high), while the cheaper, more versatile F-16 has covered a wide range of roles (low).

It is widely believed that the F-35 was destined to be matched with the F-22 to make the Air Force's new high-low mix. While the F-35 may not seem like an affordable option in light of procurement costs and budgeting issues, the F-35 is relatively cheap considering its specifications and expected longevity. Built by design to endure a long life of active service, the F-35 has been developed as the Air Force's next low, a jack of all trades, and a steppingstone to the next high. As the NGAD fighter will replace the F-22, it will likely assume the post of the next “high” fighter.

## Competitors and possible designs

### BA, LMT, NOC fielded NGAD prototypes, 2 downselected

#### Lockheed Martin and Northrop Grumman have more fighter heritage

Boeing (BA) currently produces both the F/A-18 Super Hornet and the F-15EX Eagle II, both fourth-generation fighters. However, we note that Lockheed Martin (LMT) and Northrop Grumman (NOC) have come to dominate the fifth-generation fighter market. Boeing does not have a prime position or any other significant presence on fifth-



generation fighters. On the other hand, Lockheed Martin is the prime contractor of both the F-22 Raptor and F-35 Lightning II, with Northrop Grumman supplying the center fuselage for the latter platform. Additionally, both Lockheed Martin and Northrop Grumman have significant fourth-generation fighter work, with the former continuing to produce and sustain the F-16 Fighting Falcon and the latter supplying the aft fuselage for the F/A-18 Super Hornet. It is also worth noting that Northrop Grumman is already working on a sixth-generation platform, the B-21 Raider stealth bomber.

### **Two NGAD prototypes in, one out: Northrop Grumman steps out of the race**

Discussions with suppliers in early 2023 confirmed that the three main military aircraft OEMs each developed prototypes. It had been widely reported by summer 2023 that the USAF was down to two prototypes. This was confirmed when Northrop Grumman announced on its 2Q23 earnings call that it had notified the US Air Force of its intention not to respond to the NGAD request for proposal (RFP) as a prime. However, the company is responding to other bidders' requests for proposal as a supplier. We note that NOC has performed well as a major sub-contractor on other primes' fighter programs, including the F-35 and the F/A-18.

As we cited in our [2023 Paris Air Show recap \(see report\)](#), Boeing CFO Brian West noted that the majority of the BDS portfolio (60%) was earning  $\geq 10\%$  margins. However, he also conceded that 25% of the business may be seeing negative margins, including decades old platforms being manufactured out of the St. Louis facility, such as the F-15 and F/A-18. West cited labor attrition on these legacy programs as the primary drag on margins. However, we would not be surprised if the business is suffering from overhead costs related to NGAD development that are now weighing down the broader business.

### **Navy confirms BA, LMT, and NOC in running for F/A-XX**

While there continues to be significant speculation surrounding the NGAD program, we have even less clarity about the F/A-XX platform. What we do know is that the Navy has disclosed that Boeing, Lockheed Martin, and Northrop Grumman are the three contractors in the running for the Navy's sixth-generation fighter program. Both Pratt & Whitney (RTX) and GE Aerospace are also competing to provide the aircraft's powerplant.

### **Different designs, themes emerging across each**

#### **All teased designs have delta wing, no tail, dual engine in fuselage**

Official designs for the next generation of fighter aircraft have not been made public by any of the Primes or the USAF. However, concept art has been released from Lockheed, Boeing, Northrop, and RTX. In the age of social media, Northrop teased a suspected image of its NGAD aircraft via YouTube in May 2023 and in June 2023 Lockheed posted a silhouette of a never-before-seen aircraft to the company's Instagram account. Across the few conceptual images released, clear patterns have emerged. Each concept has included a delta-shaped wing platform, tailless design, and dual engines fully contained in the fuselage.

### **Design specifications**

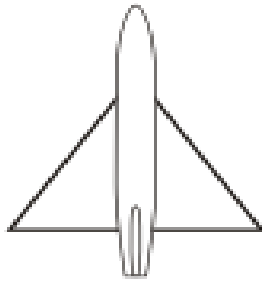
#### **Delta wing characteristic**

The delta wing design is distinguished through a triangular platform with swept leading edge and trailing tailing edge (see Exhibit 5). There are multiple variants of the delta wing, and the Compound Delta variant is the one which appears in the NGAD concepts shared publicly (see Exhibit 6). The "cranked arrow" is a sub-variant of the compound delta that is characterized by its inner section having a stepper leading edge sweep, which improves lift at high angles of attacks and can delay or prevent stalling.



**Exhibit 5: Tailless delta aircraft design**

Distinguished triangular swept wing shape

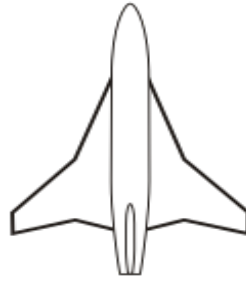


Source: Wikimedia Commons

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**Exhibit 6: Compound delta wing design**

Cranked arrow subvariant of compound delta



Source: Wikimedia Commons

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**Why use a delta wing?**

The delta wing design is intended for high-subsonic or supersonic aircraft and high-speed fighters. The delta design has been used in previous fighters including the 1954 McDonnell Douglas A-4 Skyhawk (Ogival Delta), 1955 Saab J-35 Draken (Double Delta), 1956 Convair F-106 Delta Dart (Tailless Delta), 1992 General Dynamics F-16XL (Cranked-Arrow), and the latest being the 2011 Chengdu J-20 (Canard Delta).

**Structural benefits:** Structurally the delta wing's long root cord and minimal area outboard allow the aircraft to be built stronger, stiffer, and lighter compared to a swept wing design with an equivalent aspect ratio and lift capabilities. Additionally, the long root chord allows for a deeper structure aerofoil section. The deeper structure provides greater internal storage volume for fuel, munitions, and other items without a significant increase in drag.

**Aerodynamics:** Delta wing aerodynamics are characterized by two leading-edge vortices. The leading-edge vortices form due to flow separation from the leading edges of the wing with the resultant shear layer rolling up due to a span-wise pressure gradient along the surface of the wing. The vortex formed around the leading edge provides a significant increase in lift, called vortex-lift. This second flow separation results in secondary and tertiary vortices being formed.

**Compounded delta produces more lift vs. traditional delta design**

In the compound delta design, a vortex pair over each wing is produced rather than a single vortex, which interfere with each other. This results in significantly increased lift compared to a conventional delta and improves maneuverability of a supersonic fighter aircraft. Compounded delta aircraft also have a better drag profile and generally perform well at both subsonic and supersonic speeds, unlike traditional delta aircraft.

**Exhibit 7: Delta Wing Aircraft Specifications**

Performance comparison of other delta wing fighter jets

Delta Wing Aircraft Specifications					
Aircraft	Aspect Ratio	Maximum Mach		Service Ceiling (ft)	Range (km)
		Sea level	High altitude		
MiG-21	2.2	1.05	1.8	57,400	1,470
Eurofighter Typhoon	2.2	1.25	2.0	65,000	2,900
JAS-39 Grippen	2.1	1.06	2.3	65,000	1,600
Mirage 2000	2.0	1.2	2.2	59,000	1,550
F-106	2.1		2.3	57,000	2,900
Chengdu J-10	2.3	1.2	2.2	59,055	550
Dassault Rafale	2.6	1.1	1.8	50,000	1,852
Saab-37 Viggen	2.4	1.1	2.1	59,100	2,000

Source: University of Liège



**Exhibit 7: Delta Wing Aircraft Specifications**

Performance comparison of other delta wing fighter jets

**Delta Wing Aircraft Specifications**

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**Balancing stealth and performance**

The NGAD platform design is also a balancing act of flying for extended periods of time at supersonic speeds, while also maintaining low observability. The fully contained engines, no tail, and exhaust located on the upper surface of the rear fuselage, demonstrate stealth is driving the design choices. Like the stealth goals of the B-21, the contained engines design is used to block infrared and radar reflective exhaust areas from ground sensors. The enclosed engine design does limit airflow intake for the engines. The choice of air inlet design can change the engine and stealth performance. The NOC build appears to use a diverterless inlet design, similar to the B-21, which will aid low observability. On LMT's it is difficult to distinguish if the inlets are split from the fuselage like the existing F-22, or not included in the concept art to conceal LMT's approach.

**Engines: GE or Pratt & Whitney?****GE taking advantage of P&W shortcomings to position for the NGAD powerplant**

Pratt & Whitney's (P&W, an RTX company, NYSE: RTX) F135 engine, which powers the F-35, has been plagued by multiple setbacks and quality concerns since it entered service. A coating issue that makes the F135 less durable in desert and maritime conditions has raised concerns regarding the powerplant's operability in a possible maritime (i.e., Asia-Pacific) conflict.

**P&W XA101 vs. GE XA100: real end goal is who wins NGAD**

In response, GE Aerospace (NYSE: GE) is developing the XA100 adaptive engine, which is expected to offer 30% greater range and 25% less fuel burn than the F135. We project increased range will matter more on NGAD given heightened military emphasis on the Pacific theater. To counter these efforts, P&W is developing the XA101 as a next-generation replacement. The XA101 engine, proposed through the Adaptive Engine Transition Program (AETP), has also achieved 10% thrust improvement, 25% better fuel efficiency, and 25% better thermal management in early testing.

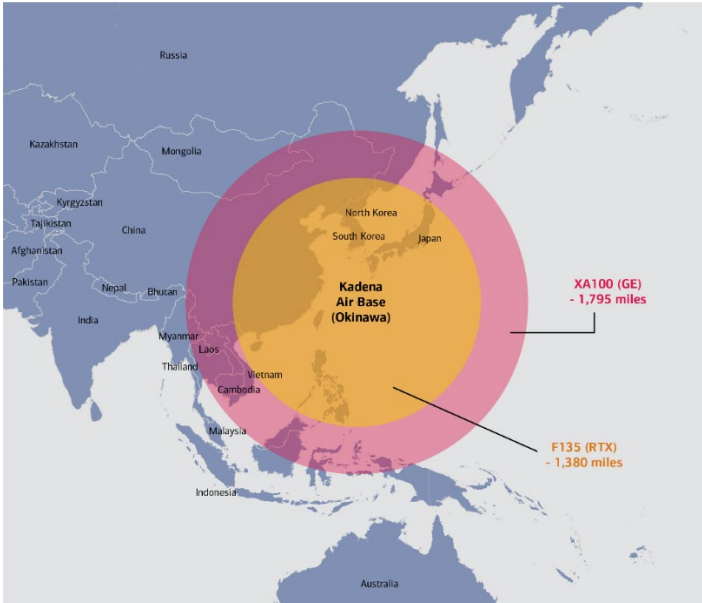
While GE Aerospace is still seeking to win placement on future F-35 deliveries, the key goal for its new engine is likely to become the NGAD powerplant. We think that the NGAD contract is likely to be awarded to GE Aerospace given that it has not been awarded a contract to power a key platform since 2000. The DoD likely wants to prevent the long-term risk of GE Aerospace closing its River Works facility outside of Boston.

**New engine could play elevated role in the Pacific****XA100 is projected to offer 30% more range than its F135 predecessor**

In our view, the proposed greater range could make the XA100 more relevant for U.S. foreign policy given rising U.S. emphasis on the Pacific theater. The F-35 currently faces criticism for its inability to hold enough fuel to reach the strategic points throughout Asia-Pacific from the U.S. military base in Guam. As a result, we believe extended range will be an even greater concern on the NGAD platform. The XA100 engine is also projected to have 25% greater fuel efficiency.

**Exhibit 8: XA100 vs. F135 range in Asia-Pacific – F-35C**

The XA100 is said to be able to provide ~400mi of incremental range to the F-35C variant

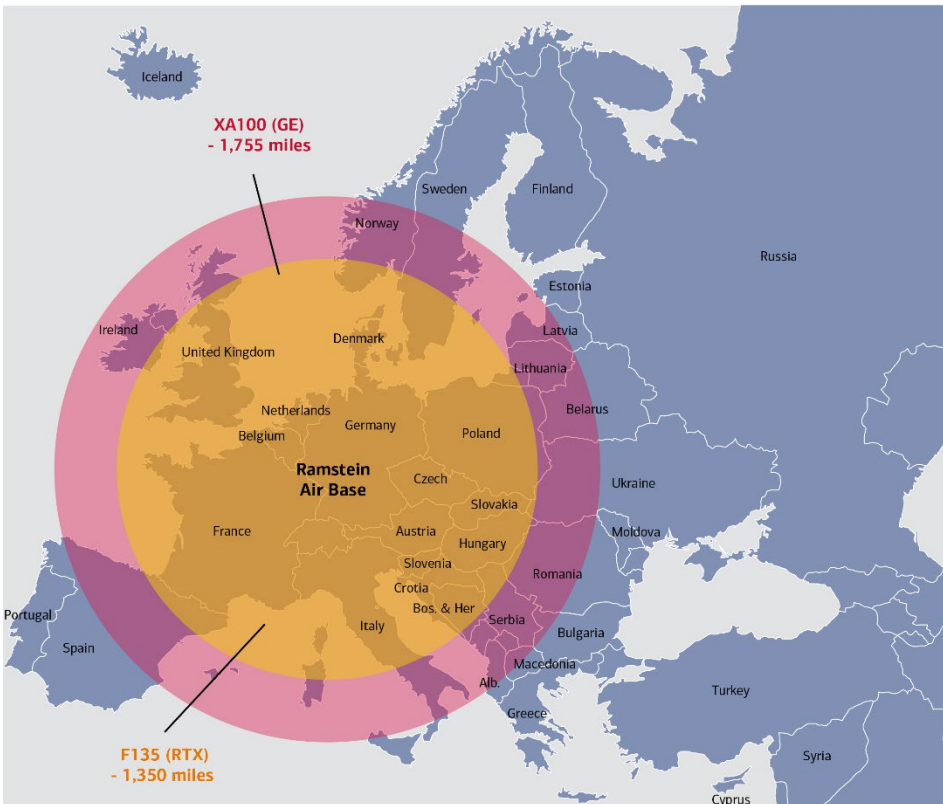


Source: US Navy

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**Exhibit 9: XA100 vs. F135 range in Europe – F-35A**

The XA100 is said to be able to provide ~415mi of incremental range to the F-35A variant



Source: US Air Force

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## NextGen engines fit the bill for any military situation

### GE's XA100 adaptive engine could enable wide range of military operations

F135 engine upgrades have had to choose between improving speed or efficiency. The XA100 adaptive engine is expected to optimize both speed and fuel efficiency, thus solving this engineering challenge. This would enable the fighter jet to adjust automatically in flight from cruise mode to fighter mode by adapting bypass ratio and fan pressure.

### Increased cooling capacity allows for increased combat effectiveness

The proposed XA100 design offers 2x the thermal management of the F135 engine and adds a third stream of airflow to the engine. The third stream can be used to help cool the F-35's electronics, which enables higher turbine temperatures for increased combat effectiveness. Additive manufacturing and heat-resistant materials also may allow for higher turbine temperatures while offsetting the higher ducting/weight of the third stream.

### 25% less fuel burn, more durable materials could help lower sustainment costs

In addition to the adaptive engine cycle design and third stream, the XA100 is being designed to utilize advanced composites, including ceramic and polymer matrix composites (C/PMC). The XA100 could have 10% greater thrust capacity and 25% lower fuel burn. Greater fuel efficiency and more durable materials could help lower sustainment costs for the F-35, which has been a sore spot of the program over the last decade.

While procurement costs have gradually fallen in recent years, sustainment costs have risen substantially over the last decade (see our [F-35 sustainment note](#)). Since 2012, the cost to sustain the F-35 program over its projected 66-year life cycle has grown from \$1.11tn to \$1.27tn, over three times the procurement costs. According to a recent Government Accountability Office (GAO) study, the F-35's runaway sustainment costs may make the program unaffordable for the DoD by 2036.

### The Air Force has funded adaptive cycle engine development since 2007

GE has worked with the Air Force on an adaptive cycle engine since 2007. GE was the only company to complete the Air Force's Adaptive Versatile Engine Technology (ADVENT) program. ADVENT was succeeded by the Adaptive Engine Technology Demonstrator (AETD) program in 2012 and the AETP in 2016. The Air Force has invested \$4bn to get more range and thrust from an engine to replace Pratt & Whitney's F135. GE and Pratt & Whitney were awarded the advanced prototype for their respective XA100 and XA101 engines, compatible with the F-35A. Each has received \$1.5bn to date in funding. GE's engine is also compatible with the F-35C.

### Commercial cross-funding opportunity from military R&D spend

We think the CFM56 engine represents the potential for a commercial cross-funding opportunity. The first product of CFM International (a joint venture between GE Aerospace and Safran Aircraft Engines) was the CFM56-2 engine, still in service on KC-135 military surveillance aircraft. It was followed by the CFM56-3, designed for the Boeing 737. Certified in 1987, the CFM56-5 was available in three versions. The -5A was the first to feature a digital engine control system. The -5B powers the A320 family of aircraft. The latest version of this engine features reduced fuel consumption and lower maintenance costs. This military engine is now placed on commercial aircraft. The -5C is the most powerful in the series and powers the A340 widebody commercial jet. Since 1997, the CFM56-7 has powered the Boeing 737NG (Next Generation) and various military aircraft. It features a number of innovations, including a larger-diameter fan, wide-chord fan blades and new low- and high-pressure components.



## Materials: composites assuming a larger role

As we previously mentioned in the “What defines a sixth-generation fighter?” section of the report, when it comes to NGAD materials, the primary focus involves the creation of airframes using materials that offer reduced weight, increased strength, and a minimal radar footprint. Although the specific materials employed are classified, potential options include:

**Composites:** Composites may be a natural choice for the NGAD, given their extraordinary strength-to-weight ratio. The aircraft could potentially incorporate various composites materials, including:

- **Carbon fiber composites:** Lightweight and exceptionally strong, already used on the F-22 Raptor;
- **Ceramic matrix composites:** Even stronger and more heat-resistant, ideal for engine components;
- **Metal matrix composites:** Combine metal strength with composite lightness, useful for landing gear and airframes.

**Additive manufacturing (AM) materials:** These materials have the potential to create intricate and efficient structures. AM materials could be utilized in engine components, sensors and actuators, and airframe components.

**Metamaterials:** Artificially engineered materials that control the flow of electromagnetic waves as well as other physical waves. Offering properties not found naturally in occurring materials, metamaterials could bolster stealth and sensor capabilities. Examples include cloaks and epsilon-near-zero materials.

**Nanomaterials:** With dimensions less than 100 nanometers, nanomaterials could reduce weight while increasing strength and heat resistance, potentially enhancing stealth capabilities. Examples include nanocrystals, nano-scale silver, dendrimers, and fullerenes.

**Warping Wing:** In addition to these materials, the NGAD could feature a warped wing, which has the following advantages:

- **Increased lift:** This type of wing generates more lift than traditional planar wings, making them suitable for aircraft carrying heavy loads or operating at high altitudes;
- **Reduced drag:** These wings also reduce drag, which is ideal for aircraft aiming to conduct long-distance flights or high-speed operations;
- **Improved maneuverability:** The design also enables aircraft to perform complex maneuvers.

## BofA NGAD and F/A-XX concept

### Smaller and more swept wing for speed, maneuverability

We took it upon ourselves to provide our take on what an eventual NGAD or F/A-XX fighter aircraft could look like. We thought the below design would make the most sense as its smaller and more swept wings maximize speed and maneuverability. A variable V-tail design allows for the tail fins to fold down from the default position. This variable design, similar to that of the Northrop/McDonnell Douglas YF-23 demonstrator, would allow for superior high angle-of-attack (AoA) performance.

**Exhibit 10: BofA NGAD and F/A-XX fighter concept**

A variable tail design would allow for superior AoA performance



Source: Rodrigo Avella

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**Powerplant: likely to be powered by two engines**

Given that the NGAD platform is expected to fill the role of the 'high' fighter in the 'high-low' mix, we would expect the eventual design to feature a two-engine powerplant. Both prior 'high' fighters, the F-15 and F-22, have been powered by two engines. These will allow for greater speed, faster climb, and extended range, which is increasingly important in a potential Indo-Pacific conflict. Additionally, two engine jets are generally seen as safer given the redundancy provided by a second engine.

**Exhibit 11: BofA NGAD and F/A-XX fighter concept**

We would expect the eventual design to feature a two-engine powerplant



Source: Rodrigo Avella

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## Materials: a combo of different composites, mix unknown

In our view, the Air Force's and Navy's upcoming fighters will likely feature a combination of different composite materials, including carbon fiber (like those used on the F-22) and ceramic matrix composites. However, we do note that the eventual mix of composite materials will likely remain classified given the sensitive nature of both the NGAD and F/A-XX programs.

### Exhibit 12: BofA NGAD and F/A-XX fighter concept

Next generation fighters will likely feature a combination of carbon fiber and ceramic matrix composites



Source: Rodrigo Avella

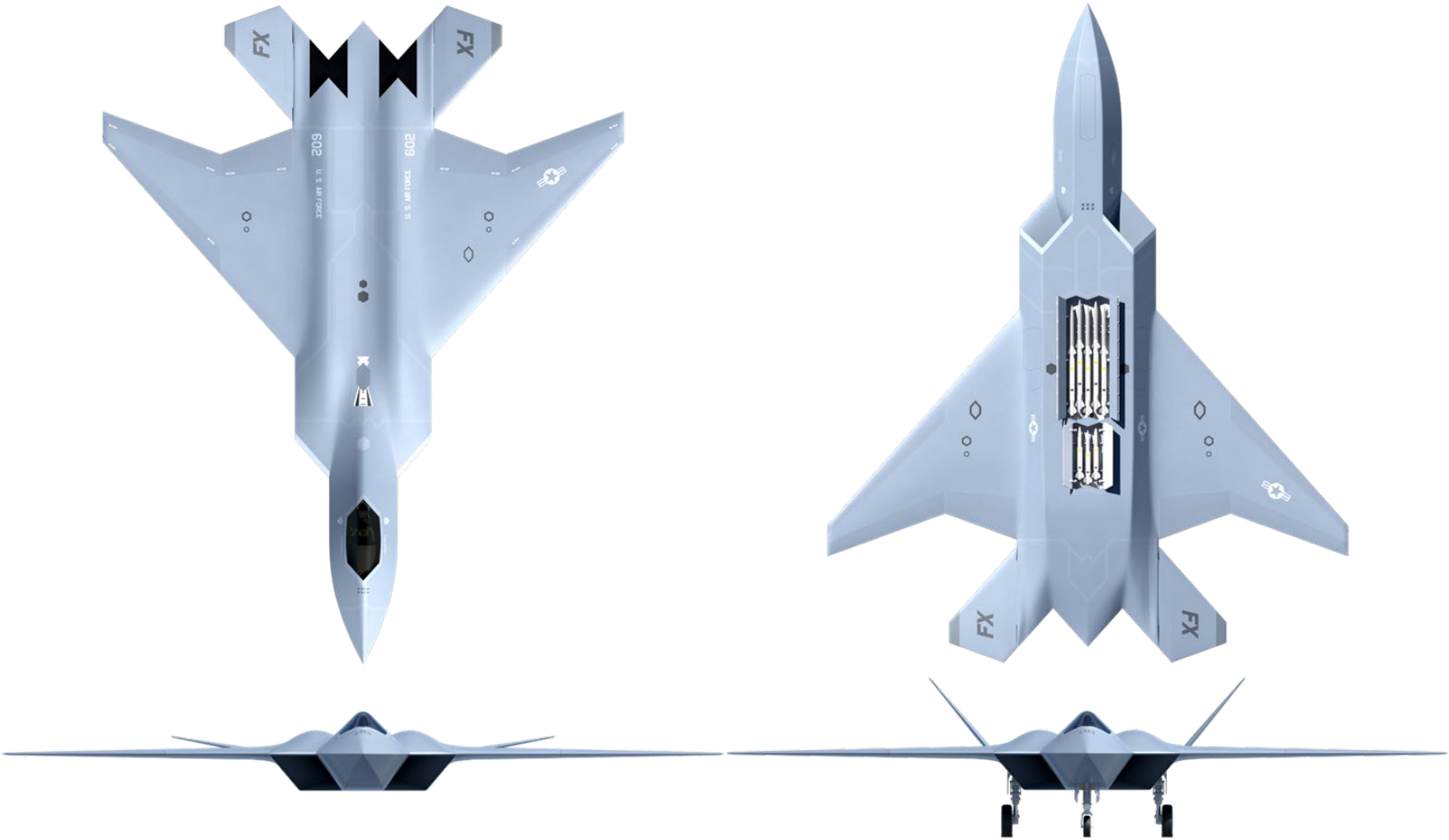
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**Exhibit 13: BofA NGAD and F/A-XX fighter concept**

Dual engines will allow for greater speed, faster climb, and extended range, which is increasingly important in a potential Indo-Pacific conflict



Source: Rodrigo Avella

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#### Exhibit 14: BofA NGAD and F/A-XX fighter concept

A variable tail design allows for the tail fins to fold down from the default V-position



Source: Rodrigo Avella

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# Potential opportunity

## NGAD funding levels

NGAD fighter expected to cost several hundred million per unit

### Exhibit 15: Next Generation Air Dominance funding levels – PB24 vs. PB23

NGAD funding accounted for roughly 5% of the US Air Force's FY243 requested RDT&E funding

	FY21	FY22	FY23	FY24	FY25	FY26	FY27	FY28	FY24-FY27
PB23	870	1,525	1,658	1,655	3,017	3,527	3,536		11,736
Air Dominance Technologies (ADT)	870	1,525	1,658	1,655	3,017	3,527	3,536		13,394
PB24		1,453	1,658	2,326	3,485	3,784	5,298	7,164	14,893
Air Dominance Technologies (ADT)		1,453	1,658	1,934	2,971	3,538	3,655	4,131	13,755
Collaborative Combat Aircraft (CCA)		-	-	392	514	246	1,644	3,033	2,796
Difference		(72)	(0)	671	468	256	1,762		3,157

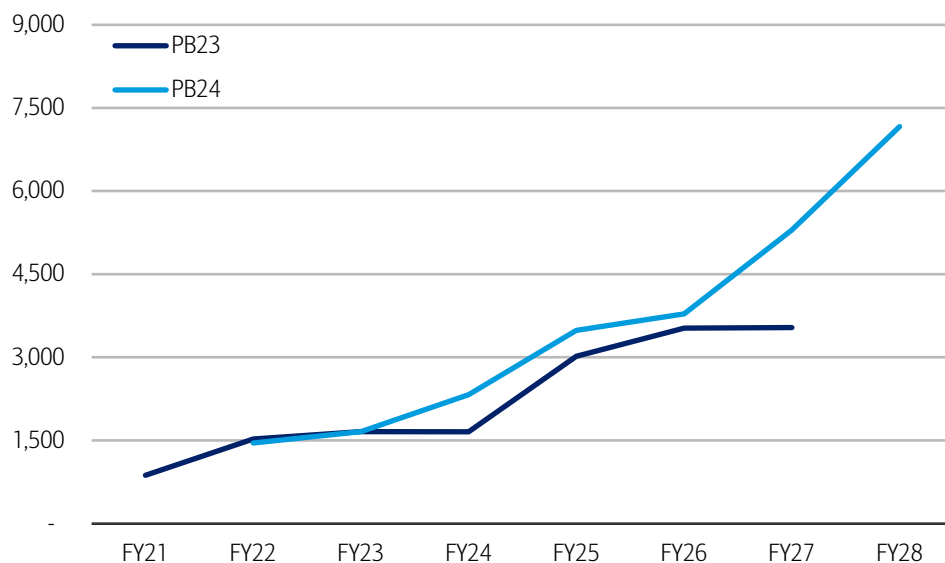
Source: FY2024 Program Acquisition Cost By Weapon System

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According to Air Force Secretary Frank Kendall, each NAGD fighter is expected to cost “multiple hundreds of millions”. This will undoubtedly make NGAD the most intentionally expensive fighter program in history. Its predecessor, the F-22 Raptor, ended up costing \$412mn per unit (vs. a prior projection of \$150mn) after program production was cut to just 187 fighters (vs. a prior projection of 750 fighters).

### Exhibit 16: Next Generation Air Dominance funding levels – PB24 vs. PB23

Much of this growth (89%) driven by the introduction of the Collaborative Combat Aircraft (CCA) component



Source: FY2024 Program Acquisition Cost By Weapon System

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## F/A-XX funding levels

Link Plumeria = F/A-XX confirmed; makes up ~8% of requested Navy RDT&E

### Exhibit 17: F/A-XX funding levels – PB24 vs. PB23

F/A-XX funding accounted for almost 8% of the US Navy's FY24 requested RDT&E funding

	FY21	FY22	FY23	FY24	FY25	FY26	FY27	FY28	FY23-FY27
PB23	478	664	1,039	2,366	2,617	2,866	2,611		11,498
Link Plumeria	478	664	1,039	2,366	2,617	2,866	2,611		
PB24		644	1,038	2,100	2,544	2,868	2,897	2,955	11,448
Link Plumeria		644	1,038	572	339	233	215	219	
Next Generation Fighter (F/A-XX)		-	-	1,528	2,205	2,635	2,682	2,736	
Difference		(20)	(0)	(266)	(72)	2	286		(50)

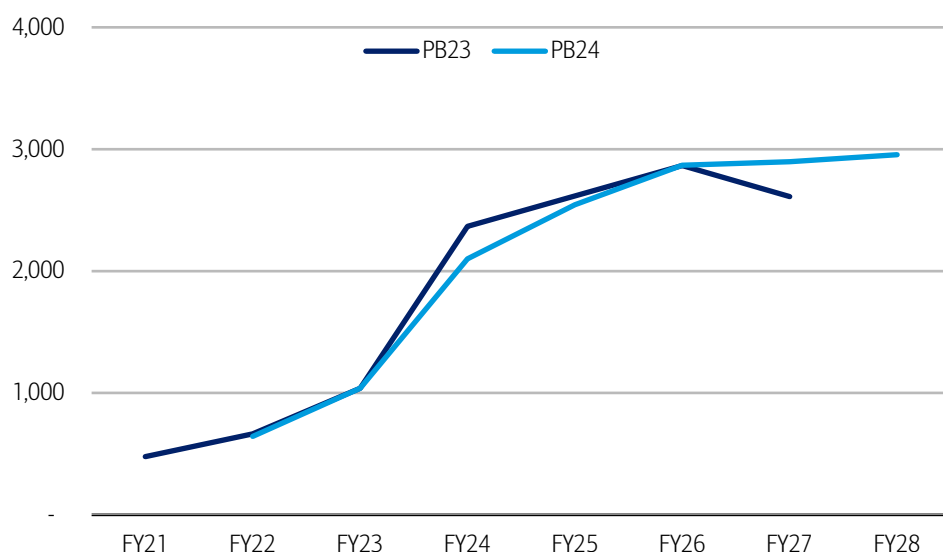
Source: FY2024 Program Acquisition Cost By Weapon System

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F/A-XX requested funding for FY24 came out to \$2.1bn, accounting for almost 8% of total request RDT&E (Research, Development, Test and Evaluation) spending for the US Navy in FY24. Previously, program funding was requested under the alias of “Link Plumeria.” There had previously been much speculation that “Link Plumeria” was in fact the next-generation naval fighter until it was confirmed in the FY24 President’s Budget request ([see our P-40 report](#)). However, the “Link Plumeria” title is not going away. As the justification book parses out projected funding for the F/A-XX, we expect the remaining “Link Plumeria” line item to be the unmanned component of the Navy Next Generation Air Dominance program.

### Exhibit 18: F/A-XX funding levels – PB24 vs. PB23

Funding is relatively unchanged in PB24 vs. PB23



Source: FY2024 Program Acquisition Cost By Weapon System

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## NGAD & F/A-XX: possible collective >\$10bn opportunity

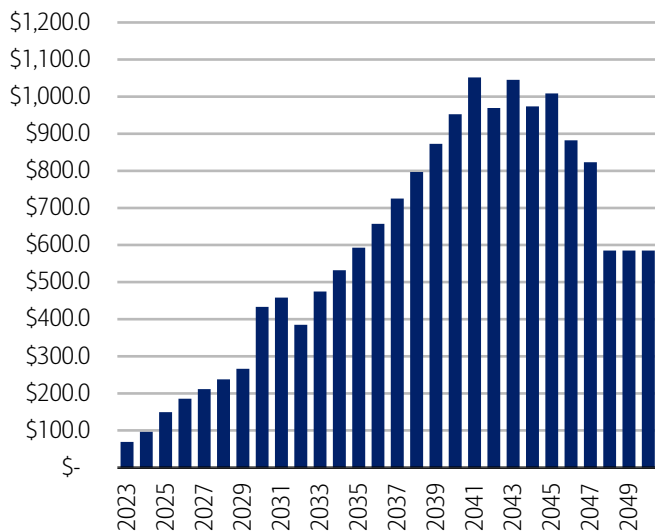
We think both the USAF and USN will procure sixth generation fighters ahead of initial expectations of roughly 200 fighters. The DoD has likely learned its lessons after procuring too few F-22s earlier this century, which are now beginning to deteriorate beyond workable conditions. Additionally, we are beginning to see the range limitations of the F-35, which has been popular among NATO countries given that it was designed for a European, not Indo-Pacific conflict. We anticipate both the USAF’s NGAD fighter and the Navy’s F/A-XX fighter will likely be procured in quantities of more than 300 units. Assuming these quantities and a unit cost of \$200mn for NGAD and \$225mn for F/A-XX (assuming higher unit cost for carrier-based platform), we project that the NGAD and F/A-XX programs could create a ~\$5.0bn and ~\$5.2bn earnings opportunity on an

NPV basis, respectively. We calculate the net present value of earnings using a weighted average of the discount rates we apply to the defense prime contractors.

While we currently know less about the F/A-XX than NGAD, we expect the program to follow a very similar earnings profile as NGAD. We note that F/A-XX production could potentially lag that of NGAD by a few years. However, we expect that the next-generation naval fighter will be procured in similar quantities and at a similar price point. We believe a slight pricing premium to the F/A-XX is warranted given that carrier-based platforms generally tend to cost more (e.g., F-35A vs. F-35B) given the need to for additional carrier-specific systems.

#### Exhibit 19: NGAD earnings opportunity through 2050

We project that over half of this upside will come available through 2035

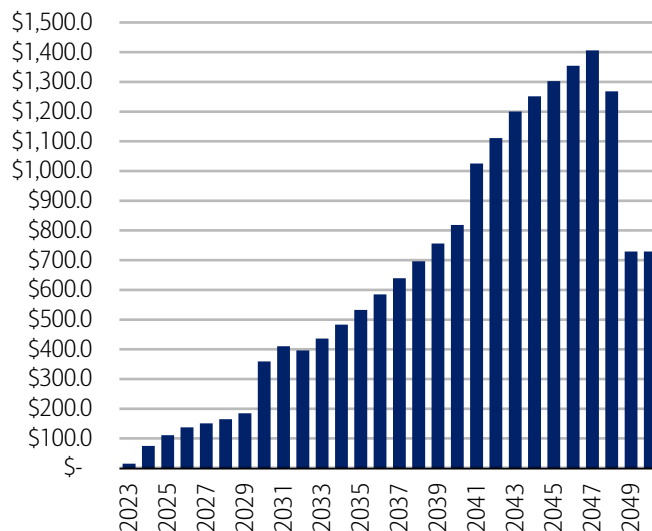


Source: BofA Global Research estimates

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#### Exhibit 20: F/A-XX earnings opportunity through 2050

We believe F/A-XX will follow similar earnings profile to NGAD



Source: BofA Global Research estimates

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# Collaborative Combat Aircraft (CCA)

## Unmanned wingman: a defining feature of 6<sup>th</sup> gen fighters

### USAF pioneered Skyborg to be an autonomous aircraft teaming structure

The USAF pioneered the Skyborg program to be an autonomous aircraft teaming structure, eventually to be used as a foundation and launch point for future air-teaming in the US military. Teamed aircraft are essentially groups of aircraft working together, with some of the aircraft being manned and some of the aircraft being unmanned (UAS). Complex algorithms, sensors, and artificial intelligence enable the unmanned aircraft to act autonomously and make decisions based on established rules of engagement set by manned teammates. Skyborg is not intended to replace humans and manned aircraft, instead the Combat Collaborative Aircraft (CCA), which the unmanned platform has been labeled, will provide manned teammates with key data to improve situational awareness and survivability. See our [UAS Deep Dive](#) for more details.

### Air Force seeking cheap, autonomous companion for manned aircraft

Fielding an effective and cheap CCA has become a top priority for Air Force Secretary Frank Kendall, who previously envisioned teams of five unmanned drones flying alongside one F-35 and the upcoming Next Generation Air Dominance (NGAD) aircraft. The unmanned aircraft are meant to act as force multipliers, with the intention of detracting attention from the manned fighter platform across several large drone companions. More recent comments from the Air Force have highlighted that initial CCAs are expected to be paired with manned fighters in a 2:1 ratio (one F-35 or NGAD fighter with two CCAs).

### March 2023 updates: 1-1.5k units, between ½ to ¼ cost of F-35, not ‘attritable’

In March 2023, the US Air Force stated that it expects base case procurement for a Collaborative Combat Aircraft to be in the 1,000-1,500-unit range. Air Force Secretary Frank Kendall also revealed that a single CCA would cost between a half and a quarter of the price of a F-35A. Assuming a F-35A unit cost of \$82.5mn, this would indicate that each CCA is expected to cost between \$21mn and \$41mn, above previous industry estimates. The unmanned aircraft was also previously expected to be “attritable” – capable yet cheap enough that the loss of a unit would not be seen as a financial burden to the service branch. While affordability is still seen as primary objective for the Skyborg program, the aircraft are not expected to be expendable. Both of these updates may imply a larger and/or more capable unmanned aircraft than previously anticipated. Additionally, the platform is expected to precede the next-generation fighter itself, with expectations for service to commence in the late 2020s. The manned fighter will likely not enter service until 2030 at the earliest.

### UAS counterparts expected to be a focal point of NGAD program

In September 2022, Air Force Secretary Frank Kendall mentioned that the USAF is in early discussions with industry partners to develop UAS (unmanned aircraft systems) counterparts to be incorporated into the NGAD program. A main demand focus is on relative affordability, as the survivability of the NGAD UAS is likely to be less than the survivability of an F-35. Another main demand focus is on having multiple variants, such as different weapons, sensors, or electronic warfare systems, to confuse enemy combatants as to which threats they are encountering.

## Competitors and prospective designs

### BA, General Atomics, LMT, NOC, Anduril are said to be developing CCA solutions

As of December 2023, it was widely reported that Boeing, General Atomics, Lockheed Martin, Northrop Grumman, and Anduril were the names on the shortlist for the CCA program.



**Downselection could come as soon as summer 2024, in service by FY2028**

A downselection of contractors could be disclosed as soon as this upcoming summer. However, it is uncertain how many companies might be downselected. Additionally, a downselection will not be the end of the road for any one supplier, as there are expected to be opportunities for contractors to win work later in the program lifetime via various “on ramps”. USAF acquisition chief Andrew Hunter has said that 20-30 suppliers are already competing in the vendor pool. This is intended to preserve an “iterative design approach” that allows for continuous competitions, enabling new competitors to participate in the program while also ensuring that the platform remains technologically relevant. The first CCAs are expected to be fielded by FY2028.

**‘Tiers’ no longer in nomenclature, but multiple increments to CCA expected**

Previously, the House FY2024 NDAA bill introduced Section 218, which outlined the following CCA tiers:

- “Expendable” (≤\$3mn unit cost);
- “Attritable” (≤\$10mn unit cost); and
- “Exquisite” (≤\$25mn unit cost).

However, the most recent bill sent to President Biden strips this language and instead utilizes ‘Increment 1’ and ‘Increment 2’ nomenclature. This likely implies that earlier generations have the potential to be improved with follow-on capabilities. The mention of an ‘Increment 2’ adds further evidence that the USAF plans to offer other opportunities to win work on later CCA versions regardless of the initial downselection.

**Large prime will be likely be selected for first fielded CCA**

Despite the language being stripped out of the NDAA bill, we believe it is likely that the ‘Increment 1’ CCA will fall into the ‘exquisite’ category. The inclusion of Anduril is somewhat unprecedented, as it is the only company on the list that focuses largely on software-driven solutions. The USAF will likely want the selected prime or team to have proven manufacturing experience on large programs of record. In this regard, the large primes with existing unmanned platforms (BA (Boeing) w/ MQ-25, MQ-28; NOC (Northrop Grumman) w/ M/RQ-4, X-47B) are best positioned to win on the first fielded CCA. With that said, we would not be surprised if Anduril were to be selected for its Lattice software that is integrated into another contractor’s airframe or if another contractor license produces Anduril’s Fury model (acquired through Blue Force Technologies in Sept. 2023).

**20-30 suppliers expected to contribute to the CCA program**

The USAF has confirmed that the CCA component of NGAD is going to be a contentious competition. Unlike with the manned next-generation fighter, the barriers to entry for firms to support the CCA platform are expected to be much lower given the smaller size and lower cost. The branch has also outlined that it expects there to be 20-30 groups to compete for the CCA aircraft. Looking more closely, Air Force acquisition chief Andrew Hunter admitted that roughly 35 suppliers are already in the vendor pool and providing autonomous subsystems/components to the CCA program. The Air Force looks to keep the supply chain and program resilient and versatile by sourcing from such a broad range of competitors. By doing this, the Air Force hopes to provide more opportunities for vendors to participate throughout the program lifetime and limit the risk of being too attached to any one supplier.

**Partnerships forming: ShieldAI partnering with both Boeing and Kratos**

Given the broad range of suppliers expected to participate in the program, some companies are already partnering with others to offer more holistic solutions. In March 2023, Boeing Phantom Works announced a memorandum of understanding with Shield AI, a defense-focused artificial intelligence company based in San Diego, California, to

collaborate on future autonomous systems. The alliance would likely involve Boeing supplying the hardware (e.g., MQ-28 Ghost Bat) with Shield AI providing the software/AI component of the program. Kratos and Shield AI announced a similar partnership in June 2023 in which the latter would supply the AI pilot for the former's XQ-58 Valkyrie.

### CCA requirements: 3,000-8,000lb thrust range excludes current frontrunners

According to the first RFI issued, the Air Force outlined a desired thrust range falling within the 3,000 to 8,000lb thrust category. This range spans a selection of engine options that include the Williams FJ44, the Rolls-Royce AE3007, as well as intermediate choices like P&W300-500 series and the Honeywell TFE731. Surprisingly, it excludes current hopefuls, such as the Boeing MQ-28 and the Kratos XQ-58, due to their lower 2,000lb-thrust capabilities.

## Funding levels: FY24 marks first breakout of CCA funding

### Exhibit 21: Combat Collaborative Aircraft (CCA) projected funding levels

FY24 President's Budget request marks the first break out of projected CCA funding

	FY23	FY24	FY25	FY26	FY27	FY28
PB24	52	511	575	319	1,718	3,109
Collaborative Combat Aircraft (CCA)		392	514	246	1,644	3,033
Autonomous Collaborative Platforms	52	119	61	73	74	76
Experimental Operations Unit (EOU)		69	44	56	57	58
Viper Experimentation and Next-Gen Operations Model (VENOM)		50	17	18	18	19

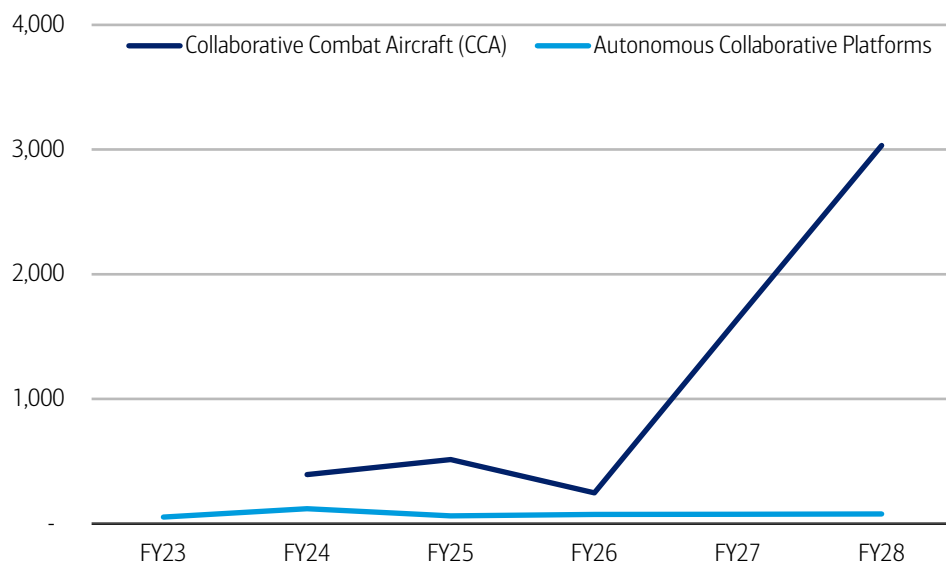
Source: FY2024 Program Acquisition Cost By Weapon System

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Requested funding levels for the Next Generation Air Dominance (NGAD) program rose by ~\$3.2bn over FY23 request levels to \$14.9bn between FY24 and FY27. Much of this growth (89%) is driven by the introduction of the program's Collaborative Combat Aircraft (CCA) component. The CCA was absent from the FY23 budget request, with all funding for the program's Air Dominance Technologies (ADT) component.

### Exhibit 22: Combat Collaborative Aircraft (CCA) projected funding levels

Annual CCA funding is expected to grow to over \$3bn by FY28



Source: FY2024 Program Acquisition Cost By Weapon System

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## CCA could create ~\$5.6bn opportunity

We assume that production quantities will be at the high end of the outlined 1,000-1,500 range. We believe the multi-increment nature of the program will likely see continued production well into the middle of the century. Assuming a total program production count of 1,485 units and a unit cost of ~\$30mn (average of current projected

price range), we estimate that the USAF CCA program could create a ~\$2.8bn earnings opportunity on an NPV basis. However, we know this will likely be divided up amongst a larger pool of contractors than the fighter program, thus limiting the earnings upside for any one company. We calculate the net present value of earnings using a weighted average of the discount rates we apply to the defense prime contractors.

**Could be upside to CCA production volumes, esp. if AF sources smaller variants**

While we utilize the average estimated production count outlined by the US Air Force, we believe there is significant upside to these levels, as the CCA will likely serve as the preeminent force multiplier through the middle of the century. With that said, as has been the case with more cheaply but highly capable fighters like the F-16, we expect production could continue well beyond the levels initially outlined by the USAF. This might be especially true if the branch succeeds in relying on multiple suppliers that can rapidly iterate to emerging platform demands. We also suspect that the Air Force might seek to source multiple CCA variants, some lower tech and, therefore, more affordable and producible.

**Naval CCA platform could more than double the potential earnings upside**

Our estimates do not account for the prospect of a naval CCA variant, which appears likely given comments from US Navy leadership and current spending trends. We believe initial naval requirements will likely be similar to those of the Air Force, albeit modified to be carrier-based. Therefore, the advent of a formal naval CCA program could possibly be more than double the earnings opportunity given that a naval variant may be slightly more expensive.



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