United States Air Force

Report to Congressional Committees

F-22A Production Restart Assessment

February 2017

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House Report 114-537, page 38

Introduction

This report is provided to the congressional defense committees as directed on page 38 of House Report 114-537 to accompany the National Defense Authorization Act for 2017:

F–22 production restart assessment
The committee notes that production of the F–22 fifth-generation tactical aircraft concluded in 2009, and notes 187 aircraft were produced, far short of the initial program objective of 749 aircraft, as well as the Air Combat Command's stated requirement of 381 aircraft. The committee also understands there has been interest within the Department of the Air Force, Department of Defense, and Congress in potentially restarting production of the F–22 aircraft. In light of growing threats to U.S. air superiority as a result of adversaries closing the technology gap and increasing demand from allies and partners for high-performance, multi-role aircraft to meet evolving and worsening global security threats, the committee believes that such proposals are worthy of further exploration. Therefore, the committee directs the Secretary of the Air Force to conduct a comprehensive assessment and study of the costs associated with resuming production of F–22 aircraft and provide a report to the congressional defense committees, not later than January 1, 2017, on the findings of this assessment. The committee expects the report to be unclassified, but may contain a classified annex. Further, the committee directs that the assessment and report consider and address the following:

(1) Anticipated future air superiority capacity and capability requirements, based on anticipated near-term and mid-term threat projections, both air and ground; evolving F–22 missions and roles in anti-access/area-denial environments; F–15C retirement plans and service-life extension programs; estimated next-generation aircraft initial operating capability dates; and estimated end-of-service timelines for existing F–22As;

(2) Estimated costs to restart F–22 production, including the estimated cost of reconstituting the F–22 production line, and the time required to achieve low-rate production; the estimated cost of procuring another 194 F–22 aircraft to meet the requirement for 381 aircraft; and the estimated cost of procuring sufficient F–22 aircraft to meet other requirements or inventory levels that the Secretary may deem necessary to support the National Security Strategy and address emerging threats;

(3) Factors impacting F–22 restart costs, including the availability and suitability of existing F–22A production tooling; the estimated impact on unit and total costs of altering the total buy size and procuring larger and smaller quantities of aircraft; and opportunities for foreign export and partner nation involvement if section 8118 of the Defense Appropriations Act, 1998 (Public Law 105–56) prohibiting export of the F–22 were repealed;

(4) Historical lessons from past aircraft production restarts; and

(5) Any others matters that the Secretary deems relevant.

Executive Summary

The Air Force prepared this assessment in response to House Report 114-537 direction to conduct an F-22 Production Restart Assessment. It builds upon a 2011 RAND study, "*Retaining F-22A Tooling, Options and Costs,*" that addressed options for F-22 production tooling retention with respect to expected future requirements, to include production restart. The RAND study also provides a summary of past Congressionally-directed reports.[3]

F-22 production was halted by the Secretary of Defense at 195 of 381 required units produced (8 test aircraft, 187 production), with last delivery in May 2012. Five major cost factors would make restarting the F-22 production line challenging in today's fiscal environment: restoring production lines, re-establishing and re-qualifying the manufacturing and supplier network, procuring critical long lead raw materials, restoring and re-training a skilled production workforce, anticipated re-design of major subsystems, and government costs. These non-recurring restart costs could range between $7-$12 billion base year 2016 dollars (BY16$).

The Air Force estimates procurement unit costs could range between $206 and $216 million (BY16$) for 194 aircraft (Fiscal Year (FY) 2025-2034). A 2011 RAND study estimated a procurement unit cost, adjusted to Base Year 2016, was $266 million (BY16$), but only assumed an additional 75 aircraft. Assuming a buy of 194 aircraft, the total procurement cost is estimated to be between $40 and $42 billion (BY16$). When the total procurement cost is combined with the non-recurring restart estimated costs of $9,869 million (BY16$), the total restart cost is estimated to be $50,306 million (BY16$). Total estimated costs are summarized in Table 1. Further fidelity to build an official cost estimate for budgetary planning purposes would require an additional nine to twelve months and contractual engagement with industry.

Table 1: F-22 Production Restart Estimates for 194 Aircraft

	(BY16$) ($M)
Estimated procurement cost of 194 aircraft	40,437
Non-recurring restart costs	9,869
Total estimated cost	**50,306**
Time to first aircraft production from contract award	**5 years**

As reported in 2010, F-22 Foreign Military Sales (FMS) are still technically feasible. The cost estimate to develop an export version of the F-22 was reported as $1.94B (BY16$) for non-recurring development and $684 million (BY16$) for estimated production restart, for a total $2.62 billion (BY16$).[4] Adjusting to Base Year 2016 and estimating additional procurement expenses, the estimated procurement unit cost for an FMS variant is $330 million (BY16$), assuming a quantity of 40 aircraft and first delivery of an operational aircraft would occur ~6.5 years from the beginning of a developmental contract. If accomplished today, it is anticipated additional development costs above the 2010 estimate would be necessary due to the rapid rate of change in technologies and the growing cyber threat to Air Force Weapon Systems.

The costs to restart production of the F-22 would be extensive even with the involvement of foreign partners. Just as F-22 production would compete for fiscal and contractor resources with other Air Force programs, any F-22 export would compete with FMS customers' resources as well, including countries already committed to F-35 purchases. Most nations are not likely to have the resources available for procurement of an export F-22, which extremely limits the ability of FMS to reduce the costs associated with restarting production.

The timeline associated with pursuing F-22 production restart would see new F-22 deliveries starting in the mid-to-late 2020s. While the F-22 continues to remain the premier air superiority solution against the current threat, new production deliveries would start at a point where the F-22's capabilities will begin to be challenged by the advancing threats in the 2030 and beyond timeframe. F-22 production re-start would also directly compete against the resources necessary to pursue the Chief of Staff of the Air Force-signed Air Superiority 2030 (AS 2030) Enterprise Capability Collaboration Team (ECCT) Flight Plan, which addresses the critical capabilities required to persist, survive, and be lethal in the rapidly evolving *highly contested* Anti-Access/Area Denial (A2/AD) threat environment. If funding was provided from outside Air Force Total Obligation Authority (TOA) to assist in the capability and capacity challenges associated with prematurely ending F-22 production, the Air Force recommends that those resources be applied to the capability development plans outlined in the AS 2030 ECCT Flight Plan.

Report

Section 1: Air Superiority Capacity and Capability Requirements

1.1 Background

The F-22 is currently the United States Air Force's premier capability for gaining and maintaining air superiority and its primary role is conducting counterair missions in a *contested* environment. For this reason, F-22 modernization is a high priority for the Air Force in order to gain and maintain air superiority through the 2020's. However, moving closer to 2030, it is important to acknowledge that threat capabilities have and will continue to evolve at a rapid rate, creating *highly contested* environments. The threat drives what capabilities are needed to achieve air superiority in the future, and the rate of threat evolution drives the timelines for the needed capability. Therefore, a conversation regarding restarting the F-22 production line should include an analysis of what capability and capacity is needed in order to achieve air superiority in future *highly contested* environments. An understanding of the threat along with necessary capability development will help provide an understanding of how restarting F-22 production will not fulfill capacity and capability requirements in the future. It also will help to understand what capabilities would compete with F-22 production restart for future resources.

An analysis of future air superiority capability requirements was conducted by the Chief of Staff of the Air Force (CSAF)-chartered Air Superiority 2030 (AS 2030) Enterprise Capability Collaboration Team (ECCT). Following the analysis, the CSAF signed the AS 2030 Flight Plan in May 2016, which is included as an attachment to the classified "F-22 Production Restart Assessment – Appendix." The AS 2030 ECCT was chartered to develop capability options to enable joint force air superiority in the *highly contested* environments of 2030 and beyond. CSAF-chartered ECCTs bring users and operators from all Air Force domains and core functions together with the requirements, acquisition, and Science and Technology (S&T) communities. These experts collaboratively examine, comprehend, and quantify operational needs, including current and emerging capability gaps that span the Air Force enterprise. As part of the Air Force capability development process, ECCTs formulate and explore innovative multi-domain options for materiel and non-materiel solutions that may wholly or partially mitigate capability gaps or provide opportunities for greater effectiveness and efficiency. Optimizing investments requires a full and integrated understanding of Air Force capabilities and missions in order to ensure the Air Force fulfills joint warfighting requirements. The unclassified Air Superiority 2030 ECCT Flight Plan is included as an attachment to this assessment and excerpts are summarized in the following sections.

1.2 Air Superiority

Counterair operations are designed to gain control of the air and wrest such control away from an adversary. Air superiority is a condition on the spectrum of air control, which ranges from adversary air supremacy to air parity to friendly air supremacy. The air superiority condition is achieved when friendly operations are able to proceed without prohibitive interference from opposing forces.

In modern military operations, achieving this level of control of the air is a critical precondition for success. Air superiority provides freedom from attack, freedom to attack, freedom of action, freedom of access, and freedom of awareness. Importantly, it also precludes adversaries from exploiting similar advantages. As such, air superiority underwrites the full spectrum of joint military operations and provides an asymmetric advantage to friendly forces. A lack of air superiority significantly increases the risk to the joint force as well as the cost to achieve victory, both in terms of resources and loss of life.

In common discourse, air superiority is often envisioned as a theater-wide condition. In *highly contested* environments, such a concept may be unrealistic and unnecessary. Air superiority is only needed for the time and over the geographic area required to enable joint operations. The specific amount of time and space required varies significantly across scenarios, mission objectives, and phases of conflict. Accordingly, capability development for air superiority must provide options for commanders to array their forces across a range of durations and geographies.

1.3 The 2030 Operational Environment

Emerging integrated and networked air-to-air, surface-to-air, space, and cyberspace threats, as well as aging and shrinking fleets of United States weapon systems, threaten the Air Force's ability to provide air superiority at the times and places required in the *highly contested* operational environments of 2030 and beyond.

Threat capabilities are likely to advance along two major vectors over the next 15 years. First, traditional threat systems will continue to evolve and proliferate. Along this threat vector are advanced fighter aircraft, sensors, and weapons. While near-peers have most of these capabilities today, advanced air and surface threats are spreading to other countries around the world. Air superiority forces will face growing numbers of these threats across a wide range of locations and scenarios in 2030.

The second threat vector is a series of comprehensive capabilities with a less-predictable impact on warfare. These include increased threat capabilities to negate our advantages in the space domain, increased quantity and sophistication of cyberspace threats, and air threats including hypersonic weapons, low observable cruise missiles, and sophisticated conventional ballistic missile systems. How, when, and where these capabilities emerge is less clear, but it is certain air superiority forces will face many of these threats by 2030.

The Air Force's projected force structure in 2030 will be challenged by this array of potential adversary capabilities. Developing and delivering air superiority for the *highly contested* environment in 2030 requires a multi-domain focus on capabilities and capacity. Importantly, the rapidly changing operational environment means the Air Force can no longer afford to develop weapon systems on the linear acquisition and development timelines using traditional approaches. Air superiority capability development requires adaptable, affordable, and agile processes with increasing collaboration between S&T, acquisition, requirements, and industry professionals. Failure to adopt agile acquisition approaches is not an option. The traditional approach guarantees adversary cycles will outpace U.S. development, resulting in "late-to-need" delivery of critical warfighting capabilities and technologically superior adversary forces.

1.4 Capabilities Required in the 2030 Environment

Adversaries are increasingly deploying integrated and networked capabilities as part of the Anti-Access/Area Denial (A2/AD) strategy in *highly contested* environments. To achieve air superiority against this strategy in support of joint force mission objectives, the Air Force needs to develop a family of capabilities that operate in and across the air, space, and cyberspace domains—there is no single capability that provides a "silver bullet" solution. This family must include both stand-off and stand-in forces, integrated and networked to achieve mission effects.

The speed of capability development and fielding will be critical to retain the U.S. advantage in the air. As the pace of technological advancements continue to increase, the Air Force must leverage experimentation and prototyping to more rapidly infuse advanced technologies into the force. Additionally, the Air Force must reject thinking focused on "next generation" platforms. Such focus often creates a desire to push technology limits within the confines of a formal program. Such efforts should be accomplished within the S&T portfolio and proven through effective prototyping, harvesting when mature to a sufficient level for transition. Pushing those limits in a formal program increases risk levels and results in cost growth and schedule slips. This puts such programs at risk of cancellation due to their nearly inevitable underperformance, and results in delivery of capabilities "late to need" by years or even decades.

The AS 2030 Flight Plan, including the classified versions, integrates multiple upcoming Analyses of Alternatives (AoAs) across the air superiority family of capabilities. Follow-on development planning will continue to refine and appropriately scope these capability development efforts. Additionally, Air Force Core Function Leads will develop and bring forward options for resourcing these capability development efforts through the Air Force's Strategic Planning and Programming Process to be included in the long range plan for eventual inclusion in the President's Budget. AS 2030 capability development will need to be balanced against other Air Force mission areas and operational environments.

There are five major Capability Development Areas directed in the AS 2030 Flight Plan. These include Basing and Logistics; Find, Fix, Track, and Assess; Target and Engage; Command and Control; and Non-Materiel (Doctrine, Organization, Training, Materiel, Logistics, Personnel, Facilities, and Policy). Eight relevant aspects of these developmental areas that are germane to the F-22 production restart discussion are included below.

1. *Data-to-Decision Campaign of Experiments.* This experimentation campaign will examine how to fuse data from cloud-based sensor networks into decision-quality information for use from the tactical to the operational levels. The campaign will include machine-to-machine options for turning data into information and knowledge, thus allowing humans to make the required decisions. Furthermore, it will examine options and opportunities for building the appropriate architectures necessary to integrate and network the AS 2030 family of capabilities and leverage big data analytics.

2. *Penetrating Counterair (PCA).* Capability development efforts for PCA will focus on maximizing tradeoffs between range, payload, survivability, lethality, affordability, and supportability. While PCA capability will certainly have a role in targeting and engaging, it also has a significant role as a node in the network, providing data from its penetrating sensors to enable employment using either stand-off or stand-in weapons. As part of this effort, the Air Force should proceed with a formal AoA in 2017 for a PCA capability. Consistent with an agile acquisition mindset designed to deliver the right capability on the required timeline, this AoA will include options to leverage rapid development and prototyping in order to keep ahead of the threat.

3. *Agile Communications.* Capability development for agile communications will examine options for increasing the resiliency and adaptability of integrated networks. The focus of this capability development will be on responsive, adaptable network architectures with functionality across multiple platforms, weapons, apertures, and waveforms operating in the *highly contested* environment.

4. *B-21.* Long-range strike against counterair targets is a critical part of gaining and maintaining air superiority. The penetrating capability of the B-21 will allow survivable and repeatable attack operations.

5. *Electronic Warfare.* This capability development effort will focus on providing the right mix of electronic warfare (i.e., electronic attack and electronic protection) capabilities in support of the AS 2030 stand-off and stand-in force structure.

6. *Weapons.* Capability development in this area should focus on leveraging opportunities to create trade space between platforms, sensors, and weapons. Specific weapons development efforts will be paired with platform development efforts. Both long-range and high capacity weapons will enhance the overall effectiveness of the AS 2030 family of capabilities.

7. *Defeat Agile Intelligent Targets (DAIT) Campaign of Experiments.* The DAIT experimentation campaign will focus on the most challenging targets across multiple domains. Defeating such targets will require new, multi-domain technologies and concepts.

8. *Continue to pursue "game-changing" technologies.* Directed energy, hypersonic weapons, and autonomy are potential game-changing technologies for air superiority. The Air Force roadmaps for these and similar technologies should include targeted decision

points to assess the maturity and readiness to on-ramp these technologies into a variety of systems.

1.5 AS 2030 ECCT Conclusion

Gaining and maintaining air superiority to enable joint force operations in 2030 and beyond requires a new approach. This approach requires strategic agility through experimentation, prototyping, and agile acquisition strategies. If successful, this strategic agility will provide future commanders with options through fielding of the integrated and networked family of capabilities in the AS 2030 force structure. Stand-off and stand-in forces will work together to provide effects at the desired time and place, enabling the Air Force to fulfill its fundamental responsibility to provide air superiority in 2030 and beyond in support of joint force objectives.

1.6 F-15C Service Life Extension

Even though the F-15C is less capable in the A2/AD environment than the F-22, due to the decision to reduce F-22 procurement, the F-15C was kept in service to augment the F-22 in performing the Air Superiority core function/mission. Similar to the conversation about F-22 production restart competing for future capability resources, the same could be said for F-15C service life extension competing for capability resources identified in the AS 2030 Flight Plan.

Ongoing full scale fatigue testing (FSFT) on F-15C aircraft indicates that a Service Life Extension Program (SLEP) will be required to operate beyond 2025. Phase I of the SLEP would replace both wings and various forward fuselage longerons for 235 F-15C/D aircraft during Programmed Depot Maintenance. The Phase I cost estimate is currently $29.2 million Research, Development, Test & Evaluation, spread between FY18 and FY19, and $1.662 billion Production funds, beginning in FY20 at ~$250 million a year. Specific F-15C/D SLEP funding requests will be presented in the FY18 President's Budget request.

Per a May 2014 Required Service Life memo from Air Combat Command, in addition to Phase I, a Phase II upgrade would be required if the F-15C fleet must operate to 2045. The scope, cost, and timing of Phase II are still under evaluation based on continuing FSFT, but it would involve replacement of at least one bulkhead.

Section 2: Estimate Assumptions and Factors Impacting F-22 Restart Costs

2.1 Assumptions

A number of assumptions were made to balance building a timely, relevant assessment based upon previous RAND production restart studies with the available resources to provide an update to those studies. This updated cost assessment assumes that production of the 194 new aircraft would be preceded by a five year development. LRIP would begin in the last year of development and last for four years. Production would eventually work up to 24 aircraft per year in a six-year Full Rate Production, for a total of ten years of production, and fourteen total years from contract award to final aircraft delivery.

Neither the F-22's radar nor the F-119 engine are still in production, so their original production costs with adjustments are placeholders, in advance of a decision to build original or updated items in a new production line. The study also did not consider integration of any F-35 parts or sub-systems, reconstitution/development of labs/facilities, costs for additional base level infrastructure (MILCON/Base Activation), personnel or operations and maintenance costs associated with adding 194 aircraft to the current Air Force fleet.

Finally, the study assumed that significant non-recurring engineering will be required to bring the F-22 Initial Operational Capability (IOC) baseline up to combat configuration. Cost estimates to date have assumed production of an F-22A aircraft with IOC capabilities only, not one which includes current and projected modernized F-22 capabilities. Significant non-recurring engineering and testing would be required to bring the IOC baseline configuration up to modern technology standards and to a standardized configuration with the rest of the fleet at the time of new aircraft delivery.

2.2 Factors Impacting Restart Costs

The size and scope of the original F-22 production line were extensive. Original production involved nearly 40,000 tools located at six major F-22 fabrication/assembly sites and ~1,000 first-tier supplier locations. Seven hundred Tier 1 suppliers produced almost 90,000 unique parts for the F-22 air vehicle and the F119 engine. Critical long lead raw materials, such as titanium, were procured and a highly sophisticated forging capacity was contracted for and stood-up very early in the manufacturing phase. The total production workforce at all manufacturing, assembly and supplier tiers was estimated at 50,000 people.

The RAND study made a number of assumptions, to include that 95% of F-22 tooling would be available for a production restart. While this assumption is still accurate, many of the other assumptions associated with the non-recurring portion of the RAND cost estimate are no longer valid: the RAND study assumed a maximum three-year pause; that all production facilities would still be available and not in use by another program; and that the sub-vendor base would be willing and able to support production. Since it is composed of a wide variety of aerospace suppliers, it remains very difficult to verify RAND's assumption that the sub-vendor supply base would be willing and able to support production without further in-depth supply chain analysis. For the Prime contractors, the F-22 air vehicle production human resources would require wholesale re-hiring and re-training, which would affect production learning curves.

Today, two F-22 Prime contractors (Lockheed Martin and Pratt & Whitney) and major vendors (Northrop Grumman and BAE) are engaged with F-35 development, sustainment, production, and follow-on modernization. It would require extensive capital investment for them to support two production programs (F-35 and F-22). The F-35, in production today, has procurement funding until at least 2038, and would most likely compete for resources and facilities with any F-22 production restart. Additionally, next generation aircraft development is planned in the same timeframe, and would also compete for limited funds.

Section 3: Estimated Costs to Restart F-22 Production

3.1 Background

F-22 production was halted by the Secretary of Defense at 195 of 381 required units produced (8 test aircraft, 187 production), with the last delivery in May 2012. The production line was shut down and dispersed with no restart plan.

In 2010, RAND conducted a study titled "*Ending F-22A Production*" that looked at four options for the F-22 program that ranged from continuing production to a cold shutdown.[2] A 2011 RAND study discussed options for F-22 production tooling retention with respect to expected future requirements, to include production restart.[3] Informed in part by these studies, the Air Force selected retention of the tooling primarily for program sustainment. As a result, primary production tooling is in storage at Sierra Army Depot, retained to produce spare parts if required in the future.

Assuming a three year break in production starting in 2012, the 2011 RAND study estimated that the procurement unit costs for 75 additional aircraft would be, adjusted to Base Year 2016, approximately $266 million per jet, for a total cost of $19.9 billion (BY16$). Restart costs were estimated at an additional $350 million (BY16$).[3] This production restart assessment uses that estimate as a baseline and builds upon it. All further references to a RAND study will be to the 2011 "*Retaining F-22A Tooling, Options and Costs*" report unless otherwise noted.

3.2 Reconstituting the F-22 Production Line

The RAND study outlines a nominal restart case study that provides an order of magnitude of potential costs to restart F-22 production. The additional 75 aircraft would be produced over five years, with estimated total non-recurring start-up costs of approximately $350 million (BY16$). Recurring production costs were approximately $266 million (BY16$) per aircraft assuming a nominal learning curve.

The RAND study researched and provided re-start costs for three scenarios: Hypothetical, Transition, and Future. The Hypothetical scenario assumed no production break, the Transition scenario a two-year break, and the Future scenario a three-year break. Each of these scenarios assumed non-recurring restart costs in each of the five following categories: planning/administration, facilities, tooling, personnel, and requalification. Restart costs escalated as more time passed from production shut-down.

While loss of learning in the production work force was assumed to reach 100 percent after three years, the other non-recurring cost categories were generally assumed to continue to escalate as time progresses. Realizing the limiting factor of only three data points, a linear extrapolation was performed using three RAND scenarios to estimate the cost associated with a 10-year gap between shut-down and restart. This totaled $1.16 billion (BY16$).

The next step in this assessment's update methodology was to add any additional costs not included in the RAND restart cost categories. Four additional categories of costs were identified: tooling refurbishment; additional requalification; redesign of major subsystems for Diminishing Manufacturing Resources and Material Shortages (DMSMS) and obsolescence beyond what is programmed for the current fleet; and additional government costs.

As mentioned above, production tooling is in storage Exemption b(3) for sustainment purposes, retained to produce spare parts if required in the future. As manufacturing methods have changed over the years, it is probable that some tooling will need to be re-created to meet today's manufacturing practices. Accordingly, this assessment assumed 20% of the original tooling would need refurbishment to support a production line above the tooling restart costs incorporated in the original RAND model. The original F-22 Government Furnished Equipment tooling cost was $1.1 billion, so $228 million (BY16$) was estimated for tooling refurbishment. Tooling refurbishment includes calibration, qualification, transportation, and all other costs associated with providing a set of tooling that is ready to manufacture parts.

The next additional category is requalification of subcontractors/vendors from the original production program. The RAND study estimated five vendors would need requalification under a three-year production restart (Future) scenario at $152.3 million (BY16$) total, or an average of $30.5 million each. With a longer 10-year production break the exact status of the production industrial base and extent of required requalification remains uncertain. As a conservative estimate, this assessment assumes approximately half (40) of all subcontractors/vendors would need at least some requalification, using the average requalification cost of $30.5 million each. This added an additional $1.2 billion (BY16$) for production requalification to the restart estimate.

The major driver of non-recurring costs is the redesign (to include DMSMS updates) of major subsystems. The F-22 radar, engine, and software will need some redesign and this assessment assumed one other as yet undetermined subsystem will need redesign, such as Electronic Warfare or Communication/Navigation/Identification. Major subsystem redesigns costs were estimated using $1.44 billion (BY16$) per subsystem, based off the original radar's development cost. This adds $5.8 billion (BY16$) additional non-recurring engineering costs.

The final additional non-recurring category is government costs. Since the RAND study accounted for government costs, this requirement only pertains to the categories that are not based off the study (tooling refurbishment and DMSMS redesign). A historically-based Air Force factor was used and applied to the aforementioned categories. This resulted in an estimate of $1.5 billion (BY$16) for government costs. Table 3.1 summarizes the total estimated non-recurring startup costs, which are estimated to occur over a six year period (FY20-25 in this case).

Table 3.1: Updated Estimated Non-Recurring Restart Costs

Non-Recurring Startup Costs	BY16$ ($M)
Restart Costs (linear extrapolation)	1,156
Tooling Refurbishment	228
Source Requalification	1,218
Redesign (4 subsystems)	5,768
Additional Government Costs	1,498
Total*	**9,869**

*** Sums may not match due to rounding**

As the RAND study also notes, non-recurring restart cost estimates are highly uncertain and dependent upon baseline assumptions, such as the amount of redesign and/or requalification needed. Consequently, while the analysis above estimates $9.9 billion, non-recurring restart costs could range between $7 and $12 billion (BY16$).

3.3 Cost of Procuring 194 F-22 Aircraft

Recurring production estimates are more certain than non-recurring estimates. The updated estimate in this assessment is based on the RAND study, which considered actual costs from the original F-22 production. The RAND study assumed 75 aircraft produced and reported a procurement unit cost. The procurement unit costs consists of fly-away, support equipment, spares, and all other procurement costs divided by the number of aircraft. The RAND study's Future scenario procurement unit cost, $266 million (BY16$), was used as a valid starting point for this production restart estimate as most of the cost increase for procurement recurring costs would be captured within the first three years of shutdown, due to lost learning in the production work force.

This F-22 procurement estimate also assumes that aircraft would be produced in a configuration close or equal to the modernized combat-coded fleet at the time of delivery. The fleet is expected to be installing the Tactical Mandates (TACMAN) upgrade in that time period. The TACMAN "baseline" will bring Open Missions Systems to the F-22 and Mode 5 Identify Friend Foe, as well as contain all previous post-production upgrades, to include Increment 3.2B (Inc 3.2B). Only TACMAN and Inc 3.2B come with associated hardware costs, and their procurement unit costs are included in this assessment's estimate to account for additional post-original production hardware costs. Any other modification upgrades planned after TACMAN would be installed on the new aircraft as part of the individual modernization programs' retrofit schedules.

Assuming an 85% learning curve in production (the actual learning experienced during the original production program), this assessment used the RAND study Future scenario's procurement unit cost to estimate a theoretical first unit cost. That first unit cost was then used with the same 85% learning curve to project an procurement unit cost for 194 aircraft: $213 million (BY16$). Adding in Inc 3.2B and TACMAN hardware costs, the final procurement unit cost is $217 million in BY16$. Table 3.2 shows a nominal production schedule, assuming an overall program start (contract award) in FY20 and production start in FY25.

Table 3.2: Updated Nominal Production Schedule

Fiscal Year	Aircraft Purchased
2025	5
2026	10
2027	15
2028	20
2029	24
2030	24
2031	24
2032	24
2033	24
2034	24
Total	194

In general, the impact of total buy size on unit cost is inversely proportional: as total buy size increases, unit cost decreases. Figure 3.1 shows the estimated changes to APUC with various total buy sizes for an aircraft in an original production configuration, i.e., with no upgrades beyond what the last original production aircraft included. Additional configuration upgrades such as Inc 3.2B or TACMAN are not included in this curve, but they could be tailored and added to a given original configuration, as desired. Actual learning curves for production restarts are typically shallower than original production, but how much so are difficult to estimate.[1] Savings from producing more aircraft would be equal to or less than the savings modeled in Figure 3.1. Examination of Air Force programs has shown some evidence that the rate of learning may experience a "flattening" after the one hundredth unit. Accordingly, final estimated procurement cost ranges are $206-$216 million (BY16$), for a total of $40-42 billion (BY16$) for 194 aircraft (FY2025-2034).

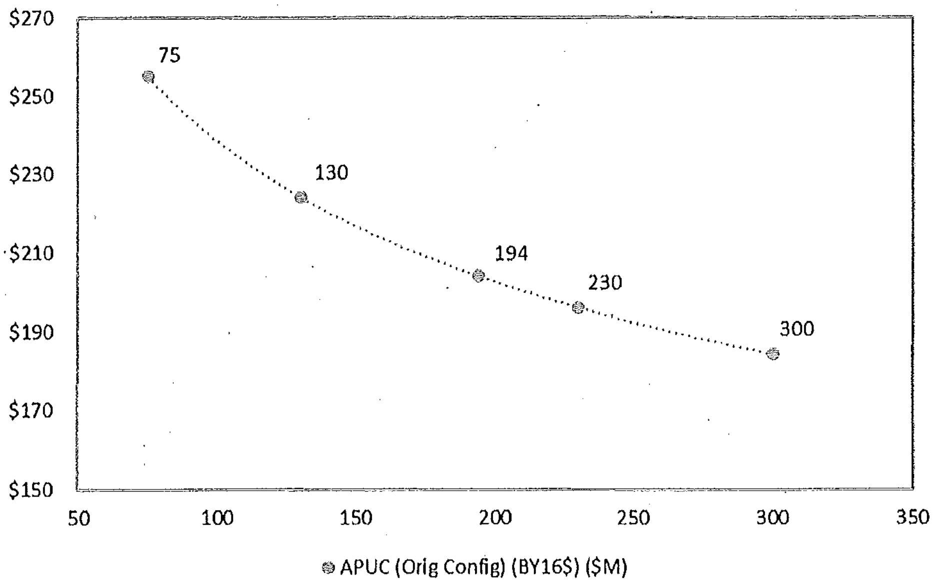

Figure 3.1: Impact of Total Buy on Unit Procurement Cost

Table 3.3 summarizes the Air Force's updated nonrecurring and procurement estimates for F-22 production restart, with comparison to the RAND study.

Table 3.3: F-22 Production Restart Estimates

	Production Break (Years)	Non-recurring cost (BY16$)($M)	Procurement Unit (BY16$)($M)	Quantity (acft)
RAND 2011	3	350	266	75
USAF 2017	10	9,869	206-216	194

Section 4: Opportunities for Foreign Export and Partner Nation Involvement

Section 8118 of the Defense Appropriations Act, 1998 (Public Law 105–56) prohibits export of the F-22. Section 1250 of the NDAA for Fiscal Year 2010 (Public Law 111-84) required a report on the potential for Foreign Military Sales (FMS) of the F-22. The general conclusions of the resulting Air Force report remain largely relevant and accurate.[4] They are summarized and updated below.

F-22 FMS is still technically feasible. The 2010 Air Force report estimated the cost to develop an export version of the F-22 to be $1.94 billion (BY16$) for non-recurring development and $684 million (BY16$) for estimated production restart, for a total of $2.62 billion (BY16$).[4] The estimate includes costs for airframe, engines, Exepmtion b(3), but does not include costs for support and training systems that would be required to export an entire Air System. The non-recurring developmental cost is a best case estimate: additional development would be necessary due to the rapid rate of change in technologies since 2010 and the growing cyber threat to Air Force Weapon Systems.

First delivery of an operational aircraft would occur 6.5 years from initial award of an Engineering, Manufacturing, and Development (EMD) contract, assuming long lead authorization and production startup at EMD start. Adjusting the report's production estimate to Base Year 2016 and estimating additional procurement expenses, resulting in estimated procurement unit cost of $330 million (BY16$), for 40 aircraft purchased. This price is in line with unit costs estimated by the RAND report and the updated cost estimated by this assessment. Program costs for both FMS export versions and new Air Force aircraft could both lower if production is in the same years by leveraging common parts and physical production lines but overall cost reduction would be dependent upon final configurations. As a best case the reduction would follow the general cost reduction curve in Figure 3.1.

While export is technically feasible, the complete Air System contains significant technology transfer and security concerns that must be addressed in any future FMS efforts. No F-22 export configuration currently exists; it was not incorporated into the initial design. In contrast, the F-35 was developed from the ground up as an export aircraft. An F-22 export configuration could leverage [redacted] Exemption b(3) programs and processes from the F-35 making compliance with [redacted] Exemption b(3) requirements more attainable. Even if the 1998 prohibition on export of F-22 is removed, there are several agencies that would need to approve export of the F-22: [redacted] Exemption b(3)

Just as F-22 production would compete for fiscal and contractor resources with other Air Force programs, any F-22 export would compete with FMS customers' resources as well, including countries already committed to F-35 purchases. Most nations will likely not have the resources available for procurement of an export F-22, which extremely limits the ability of FMS to reduce the costs associated with restarting production.

Section 5: Historical Lessons from Past Aircraft Production Restarts

RAND's "*Restoring a Production Capability*" study examined cost and schedule of program restarts relative to those of new programs, as well as criteria for selecting restart candidates.[1] Based off eleven aircraft programs that were shut down and restarted or seriously considered for restart, there is a one-to-two year savings in delivery of first aircraft when compared to original production. First restart production units are cheaper than original first units. They require approximately half as much production and quality-assurance labor, about 40 percent of the tooling labor, and 20 percent of the engineering labor. While first restart production units are cheaper than original first production units, they are more expensive than the last original production unit. Production learning curves are also slower (shallower) in general than original production resulting in less decrease in unit cost for the same production quantity.

Data presented in the study indicates that restarting aircraft programs that have reached Full Operational Capability and have been shut down should result in follow-on programs that require less time to first unit delivery and should be less expensive than the original program. For two programs that had a detailed breakdown of costs, the C-5 and the S-3, non-recurring restart costs are 10 percent of the original program's startup costs.[1] This assumes a somewhat "carbon copy" production of the original units, or a single model designation change in the case of the C-5, from C-5A to C-5B. Given the continuing modernization that F-22s have undergone, the Air Force projects non-recurring restart costs for F-22s with modernization upgrades ($9.9 billion BY16$) required to create a homogeneous fleet will be closer to 20 percent of the total development costs through FY18 ($49.8 billion BY16$).

The RAND study also examined whether aircraft from a restarted production line could be available soon enough to be operationally relevant for a worthwhile amount of time.[1] The appendix to this assessment briefly discusses this.

Section 6: Other Relevant Matters

6.1 Alternative: Modify Block 20 Aircraft

Assuming a FY20 contract award, the first new squadron of combat-capable aircraft would deliver seven years later, in 2027. The time, money, and manpower required for this effort would be better directed toward existing acquisition programs, or a program new start. As directed by page 118 of Senate Report 114-263, to accompany the Defense Appropriations Act for 2017, an alternative to restarting F-22 production would be to upgrade all, or a portion of, the remaining F-22 Block 20 aircraft to a combat-coded configuration. This would increase the number of Raptors available for combat operations and reduce the fleet sustainment costs of supporting two different aircraft configurations (training versus combat). The Air Force is preparing a report to address that as well, due 120 days after enactment of the act.

6.2 Summary

The costs to restart production of the F-22 would be extensive, even with the involvement of foreign partners to reduce restart and/or procurement unit costs. Further fidelity to build an official cost estimate for budgetary planning purposes would require an additional 10-12 months and contractual engagement with industry. Just as F-22 production would compete for fiscal and contractor resources with other Air Force programs, any F-22 export would compete with FMS customers' resources as well, including countries already committed to F-35 purchases. Most nations are not likely to have the resources available for procurement of an export F-22, which extremely limits the ability of FMS to reduce the costs associated with restarting production.

The timeline associated with pursuing F-22 production restart would see new F-22 deliveries starting in the mid-to-late 2020s. While the F-22 continues to remain the premier Air Superiority solution against the current threat, new production deliveries would start at a point where the F-22's capabilities will begin to be challenged by the advancing threats in the 2030 and beyond timeframe. F-22 production re-start would also directly compete against the resources necessary to pursue the CSAF-signed AS 2030 ECCT Flight Plan, which addresses the critical capabilities required to persist, survive, and be lethal in the rapidly evolving *highly contested* A2/AD threat environment. If funding was provided from outside Air Force TOA to assist in the capability and capacity challenges associated with prematurely ending F-22 production, the Air Force recommends that those resources be applied to the capability development plans outlined in the AS 2030 ECCT Flight Plan.

Attachment
Air Superiority 2030 Enterprise Capability Collaboration Team Flight Plan, May 2016

References
[1]National Defense Research Institute. *Reconstituting a Production Capability*. RAND, 1993. http://www.rand.org/pubs/monograph_reports/MR273.html

[2]RAND Project Air Force. *Ending F-22A Production.* RAND, 2010. http://www.rand.org/pubs/monographs/MG797.html

[3]RAND Project Air Force. *Retaining F-22A Tooling- Options and Costs.* RAND, 2011. http://www.rand.org/pubs/technical_reports/TR831.html

[4]U.S. Air Force. *F-22 Export Configuration Study.* March 2010. Control Number: AQL S-01100305

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