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R E P O R T

Retaining F-22A Tooling

Options and Costs

John C. Graser, Kevin Brancato, Guy Weichenberg,
Soumen Saha, Akilah Wallace

Prepared for the United States Air Force

Approved for public release; distribution unlimited



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Preface

In April 2009, the Secretary of Defense announced that production of the F-22A fighter would stop at 187 aircraft. In the fiscal year (FY) 2010 National Defense Authorization Act (NDAA), Congress stipulated a requirement for several reports about the F-22A. One, for example, required an evaluation of the feasibility of creating an export version of the F-22A. Section 133 of the NDAA also required a plan to deal with the preservation and storage of the unique tooling related to the production of the F-22A. The intent of Section 133 was to help policymakers decide whether to dispose of production tooling by comparing the difference in the cost of preserving all F-22A unique government tooling required for a production restart with the cost of preserving only the tooling required to sustain the F-22A during its life.

This technical report responds to the Section 133 requirement for a plan addressing the preservation and storage of unique tooling related to the production of hardware and end items for F-22A fighter aircraft. Section 133 stipulates that the plan must accomplish the following: ensure that the tooling will be available to allow restart of the program after a period of idleness; ensure that the tooling will be available to support the long-term sustainment and repair of the F-22A; identify the costs of restarting production; and identify contract modifications, facilities, and funding required to carry out the plan.

RAND Project AIR FORCE (PAF) was asked to prepare an answer to the tooling-plan requirement. The resulting study, “Retaining F-22A Tooling: Options and Costs,” was conducted from December 2009 through March 2010 within PAF’s Resource Management Program. This study should interest those involved in the acquisition of weapon systems, those concerned with the cost of such systems, and those interested in production-shutdown decisions.

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Summary

Background

Through FY 2010, Congress has authorized the procurement of 187 F-22A aircraft, the last of which is scheduled for delivery in early 2012. The Air Force plans to continue contracts that provide for modernization and sustainment work but not those that provide for new production. As the last component is fabricated, assembled, or integrated at each of the many facilities involved in producing the F-22A, decisions must be made as to what tooling will be retained for sustainment¹ or modernization support and what will be disposed of. (See p. 1.)

Complicating these decisions are the differing views about future F-22A production. The Obama administration has repeatedly rejected the idea of building more than 187 F-22A aircraft for the Air Force. In February 2010, Secretary of Defense Robert Gates, during a hearing before the Senate Armed Services Committee, reaffirmed that he was not going to revisit the decision to produce more than the 187 F-22A aircraft.² In addition, Congress continues to prohibit the sale of the F-22A to other countries, precluding the continuation of production for foreign sales. However, in the FY 2010 Department of Defense Appropriations Bill, Congress removed the previous restriction on spending appropriated funds on the development of a foreign military sales (FMS) version of the F-22A. In fact, the FY 2010 NDAA calls for the Secretary of Defense to conduct a study on the cost, technical feasibility, and strategic implications of permitting FMS of the F-22A and to identify any associated required modifications to current law (see p. 2).³ Just as the F-22A contractors have entered shutdown planning (and in some cases have actually ended production of F-22A parts), production at some future point has emerged as a possibility. Reflecting this possibility, the following language was included in the FY 2010 NDAA:

- (a) PLAN.—The Secretary of the Air Force shall develop a plan for the preservation and storage of unique tooling related to the production of hardware and end items for F-22 fighter aircraft. The plan shall—
 - (1) ensure that the Secretary preserves and stores required tooling in a manner that—
 - (A) allows the production of such hardware and end items to be restarted after a period of idleness; and

¹ In this report, *sustainment* is used to denote all the postproduction activities that would require tooling to support the F-22A during its operational life (i.e., spare-parts production, depot-level repair and maintenance, base-level maintenance, and modification work).

² U.S. Senate Committee on Armed Services, Military Posture Hearing, Washington, D.C., February 2, 2010, p. 50.

³ Public Law 111-84, National Defense Authorization Act for Fiscal Year 2010, October 28, 2009, Section 1250.

- (B) provides for the long-term sustainment and repair of such hardware and end items;
 - (2) with respect to the supplier base of such hardware and end items, identify the costs of restarting production; and
 - (3) identify any contract modifications, additional facilities, or funding that the Secretary determines necessary to carry out the plan.
- (b) RESTRICTION ON THE USE OF FUNDS.—None of the amounts authorized to be appropriated by this Act or otherwise made available for fiscal year 2010 for aircraft procurement, Air Force, for F-22 fighter aircraft may be obligated or expended for activities related to disposing of F-22 production tooling until a period of 45 days has elapsed after the date on which the Secretary submits to Congress a report describing the plan required by subsection (a).⁴

Purpose

This report is designed to answer the requirement for the tooling plan. Its contents reflect the outcome of discussions among congressional staffers, the Air Force, and RAND regarding congressional intent. The report focuses on two key questions:

1. How much more would it cost to retain all the F-22A unique government tooling required for a future F-22A production restart than to retain only the tooling required for the sustainment support of the aircraft during its forecasted operational life?
2. How much would it cost to restart production at some future date?⁵

The Earlier RAND Report on the F-22A

This report updates portions of an earlier RAND report on options for the F-22A program;⁶ reflects program decisions made since early 2008, when data gathering for the earlier report was completed; and focuses more specifically on tooling and other restart issues. This report addresses only two of the four scenarios addressed in the earlier report: *shutdown* and *shutdown and restart*.⁷ Two other scenarios from that report, *warm production* and *continuing production*, are now deemed infeasible given the current administration's declared intention to fund no more F-22A production, the unlikelihood that supplemental FY 2010 funds will be appropriated for further production of F-22A aircraft for the Air Force, and the fact that an FMS

⁴ Public Law 111-84, National Defense Authorization Act for Fiscal Year 2010, October 28, 2009, Section 133.

⁵ Despite interest in an FMS variant of the F-22A, this report is based on production restart of the current Air Force variant.

⁶ Obaid Younossi, Kevin Brancato, John C. Graser, Thomas Light, Rena Rudavsky, and Jerry M. Sollinger, *Ending F-22A Production: Costs and Industrial Base Implications of Alternative Options*, Santa Monica, Calif.: RAND Corporation, MG-797-AF, 2010.

⁷ The *shutdown* scenario in Younossi et al. (2010) is very similar to the *shutdown and sustain* scenario described in this report.

variant cannot be developed before production lines are shut down and the tooling is dispositioned.⁸ (See p. 2.)

Two Major Options

Without the likelihood of additional production in the near future, the Air Force has two options for the tooling at the end of production. The first option is *shutdown and sustain*. In this scenario, the production lines are closed once the last aircraft (or aircraft part) is delivered. As work is completed on the last aircraft, government-owned special tooling, special test equipment, and other equipment unique to the F-22A production is transferred to other F-22A activities (such as F-22A sustainment), transferred to other programs, or scrapped. In essence, no tooling is retained aside from that required to support the F-22A during its operational life.

The second option is *shutdown and retain*. In this scenario, the production line is shut down in such a way that restart could occur efficiently at an undetermined point in the future. This option requires the wrapping, packing, transporting, storing, and maintaining of nearly *all* F-22A government-unique tools and equipment and technical information, not just what is required for sustainment.⁹ (See pp. 4–5.)

Other Factors in a Restart

Tooling retention is a major factor in a plan to restart production. Other key ingredients for a restart include the following: the expertise of production personnel, the capabilities and capacities of key suppliers of parts and subsystems (particularly those with unique processes and products that may require requalification), and the availability of contractor-owned production facilities and capital equipment. (See pp. 7–12, 25–28.)

The Window for Efficient Shutdown Is Narrowing

The window to efficiently implement F-22A shutdown is narrowing. Shutdown activities have already begun at some suppliers and will continue through 2012. In addition, Lockheed Martin will begin to shut down F-22 production at Air Force Plant 4 in Fort Worth, Texas, in 2010 as the last aircraft center section is completed. As each facility completes production, tooling-disposition decisions must be made to ensure efficient shutdown execution of either of the major options. Absent direction from the Air Force, the contractors must hold all government tooling as a temporary measure. However, at some point in the future, each item of tooling must be either disposed of or retained for sustainment purposes. (See pp. 7–12.)

⁸ In this report, *disposition* refers to the decision process that determines whether tools are ultimately retained or disposed of.

⁹ If a restart of the F-22A production were to result in 20 new aircraft per year, virtually all current tooling would be required.

The tooling-disposition decision process requires an estimate of the differential cost of keeping the production-only tooling.¹⁰ Through analysis of the nonrecurring costs of wrapping, packaging, and transporting the production-only tooling and analysis of the recurring annual storage and maintenance costs, this research estimates the differential funding required in FY 2011 and beyond to maintain the production-only tooling. It also estimates both the nonrecurring costs of planning and administration, setting up tooling and facilities, and hiring personnel for the production line and the recurring costs of restarting F-22A production for 75 new Air Force aircraft either in FY 2012 or between FY 2013 and FY 2016.¹¹ It also highlights other key but largely unquantifiable issues that may emerge over time, such as the loss of certain critical suppliers and processes that may not be immediately available for a restart. (See pp. 13–15.)

Conclusions

Costs of Tooling Options

Table S.1 shows the differential cost of the *shutdown and sustain* and *shutdown and retain* options,¹² comparing their nonrecurring and annual recurring costs. The basis for these cost estimates is the Conex storage approach detailed in Chapters Two and Three. Those chapters document what a plan to preserve the tooling would entail at this point in the F-22A shutdown-decision process.

The costs are relatively modest. The \$17 million represents about 9 percent of the original acquisition cost (\$194 million in FY 2010 dollars) of the production-only tooling, and the recurring costs are a tiny fraction of a percent of the original acquisition cost. (See p. 15.)

Table S.1
The Differential Cost of the *Shutdown and Retain* Option Compared with the *Shutdown and Sustain* Option (FY 2010\$, millions)

	FY 2011–FY 2013	FY 2012	FY 2013	FY 2014 and Beyond
Nonrecurring	\$17.0	N/A	N/A	N/A
Annual recurring	N/A	\$0.07	\$0.15	\$0.15

The Cost of Restart

Table S.2 shows the recurring production costs under three restart scenarios. The hypothetical scenario is a baseline to show what the estimated cost of producing 75 aircraft might have been had funding been appropriated for a Lot 11 advance procurement for 20 units in FY 2010 and

¹⁰ In this report, the term *production-only tooling* is used to denote duplicate tooling (i.e., tooling required for rate production but not for sustainment activities, and tooling for which no anticipated need has been identified for sustainment whatsoever). As noted earlier, another congressionally mandated study of the feasibility and cost of an FMS version of the F-22A may have a role in informing this decision.

¹¹ A quantity of 75 aircraft is consistent with Younossi et al. (2010).

¹² Unless otherwise noted, in these analyses, the term *cost* includes profit and fee, so the dollar amounts represent the appropriated amounts required. Constant FY 2010 dollars are used due to the unknown length of the shutdown period.

Table S.2
The Recurring Production Cost of 75 Additional Aircraft (FY 2010\$)

	FY 2010	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016	FY 2017	Total	APUC
Hypothetical	\$0.6B	\$3.6B	\$3.6B	\$3.3B	\$2.7B	N/A	N/A	N/A	\$13.7B	\$183M
Transition	N/A	\$0.8B	\$3.8B	\$4.0B	\$3.9B	\$3.4B	\$1.0B	N/A	\$16.7B	\$222M
Future	N/A	N/A	\$0.5B	\$2.4B	\$3.1B	\$4.1B	\$3.8B	\$3.5B	\$17.4B	\$233M

NOTES: APUC = average procurement unit cost. B = billion. M = million.

had there been a clear intent to continue production instead of shutting down the production line. (See pp. 21–22.)

In the transition scenario, advance-procurement funding for ten F-22A aircraft is appropriated and available at the start of FY 2011; full funding for ten aircraft is appropriated in FY 2012, and there is clear intent to conduct future production. Quantities in FY 2013, FY 2014, FY 2015, and FY 2016 are 20, 20, 20, and five, respectively. The transition scenario has a production gap of 9–18 months at many sites due to variations in the approved production quantities.

In the future scenario, restart occurs sometime between FY 2013 and FY 2016. To simplify presentation, we chose restart in FY 2013 for our estimate. Restart begins at some point after all production-only tooling has been stored after shutdown, and it involves the production of 75 aircraft, with a ramp-up in quantity of five, 10, 20, 20, and 20 aircraft in the first through fifth production years. The future scenario has a production gap of at least two and a half years, and there will be at least an additional two-year lead time before production starts.

Under all three scenarios, production is followed by another *shutdown and sustain* period for the life of the F-22A, at a cost of \$82 million. In addition to the recurring production costs shown in Table S.2, there would be a nonrecurring restart cost of \$307 million for the future scenario and of \$127 million for the transition scenario. (See pp. 22–23.)

The Costs and Benefits of *Shutdown and Retain*

For a one-time cost of an additional \$17 million (in FY 2010 dollars) and a very small additional annual recurring cost, the Air Force can retain all F-22A unique government tools. Retention of all tools reduces the risk that tools may not be available for unanticipated future restart, for a service-life extension program, or for major accident-repair requirements. Additionally, retention permits an expeditious near-term tooling disposition process, and the Conex approach for storing tooling obviates the need for new warehouse space. This work, moreover, can be accommodated within normal Air Force contracting activities. (See pp. 29–30.)

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¹³ All ranks and offices were current as of the time of the research.

Abbreviations

AGS	Arresting Gear System
AMNS	Aircraft Mounted Nozzle Sidewall
APP	agency-peculiar property
APUC	average procurement unit cost
BDS	Boeing Defense Systems
CAN	Combustor, Augmentor, and Nozzle
DoD	Department of Defense
EB	electron beam
FMS	foreign military sales
FY	fiscal year
LM	Lockheed Martin Aeronautics Company
N-ray	neutron ray
NDAA	National Defense Authorization Act
P&W	Pratt & Whitney Company
PAF	Project AIR FORCE
PCARSS	Plant Clearance Automated Reutilization Screening System
REDI	Raptor Enhancement Development and Integration
RTM	resin transfer molded
SLEP	service-life extension program
SPO	System Program Office
STE	special test equipment
TFT	Thin Film Technology, Inc.
TJC	Thermal Joining Center
UCD	University of California, Davis
VSA	Vertical Stabilizer Assembly

Introduction

Background

The postproduction strategy for the F-22A has entered a state of flux. As late as mid-2009, the strategy was to preserve unique tooling and critical capabilities not required for sustainment activities after final aircraft production is completed.¹ Various options to extend F-22A production beyond 183 aircraft were being considered by Congress and the Department of Defense (DoD). In fiscal year (FY) 2009, Congress appropriated advance-procurement funds to be used to initiate production of no more than 20 aircraft in FY 2010. The Office of the Secretary of Defense, however, chose to release funding for only four aircraft, with an option for 16 additional aircraft if the incoming Obama administration chose to continue F-22A production. Because of this possibility of additional aircraft being procured in FY 2010, a strategy of keeping production capabilities “on hold” was followed. However, DoD decided for the FY 2010 President’s budget not to fund any additional F-22A aircraft. Congress accepted that decision and did not add additional aircraft as part of the FY 2010 appropriation. However, it did appropriate additional funds in FY 2009 as part of a supplemental appropriation to fully fund the four aircraft. Given those decisions and early estimates of the cost of keeping all tooling, the Air Force changed its strategy, choosing to retain only the tooling and capabilities required to support sustainment activities, with all other (i.e., production-only²) tooling to be disposed of after the prime contractors and suppliers completed the final production efforts.

In addition, because of the perceived likelihood of receiving full funding for 20 aircraft being added in the FY 2010 DoD appropriation, a likelihood signaled by the advance-procurement funding for 20 aircraft originally appropriated in FY 2009,³ planning for shutdown was oriented toward completing a full lot of 20 aircraft in FY 2010. With the truncation of Lot 10 to four aircraft, however, planning time for shutdown was shortened by about nine months. Thus, the Air Force and its contractors are currently engaged in analyses and negotiations regarding how to efficiently shut down the F-22A. They are reassessing the entire tooling-

¹ In this report, *sustainment* is used to denote all the postproduction activities that would require tooling to support the F-22A during its operational life (i.e., spare-parts production, depot-level repair and maintenance, base-level maintenance, and modification work).

² In this report, the term *production-only tooling* is used to denote duplicate tooling (i.e., tooling required for rate production but not for sustainment activities) and tooling for which no anticipated need has been identified for sustainment whatsoever.

³ Because of the lead time for some aircraft materials and parts, Congress often appropriates advance-procurement funds one year before appropriating the full funding required to produce a specified quantity of aircraft.

storage framework, now considering the use of the new Conex⁴ approach and of less-expensive outside storage.

RAND discussed options for the continued production, shutdown, and possible restart of the F-22A in a report released earlier in 2010.⁵ The present research uses some of the basic methodologies and analysis from that earlier report but incorporates both updated data on the costs of production and other changes that have occurred since data gathering for that report was completed in early 2008. For example, tool storage in Conexes will reduce tooling-storage costs, an innovative shutdown concept used in this report but not in the earlier report.

When the earlier report was being written, little consideration was being given to an export version of the F-22A due to a restriction placed in legislation by Congress annually since 1998 that prohibited appropriated funds from being used to approve or license the sale of the F-22A to any foreign government (a restriction commonly known as the Obey Amendment).⁶ Despite that restriction, Section 1250 of the FY 2010 National Defense Authorization Act (NDAA) required two reports from the Secretary of Defense concerning potential foreign military sales (FMS) of the F-22A. The first report must supply four elements:

- an estimate of the costs of developing an exportable version of the F-22A
- an assessment of whether an exportable version is technically feasible and executable, plus a timeline for achieving it, if doing so is feasible
- an assessment of the potential strategic implications of permitting foreign sales of the F-22A
- identification of any modifications to current law required to authorize foreign sales.

A second report required from the Secretary of Defense is to address the effect of FMS of the F-22A on the U.S. aerospace and aviation industry and identify the advantages and disadvantages of such sales in terms of sustaining that industry. Given the interest in a potential production restart for an FMS variant of the F-22A at some point in the future, Congress, in 2010, allowed (but did not require) DoD to conduct or participate in studies, research, design, and other activities to define and develop an exportable version of the F-22A if DoD agreed to protect classified and sensitive information and technologies.⁷

The Purpose of This Study

Another report was required by Section 133 of the FY 2010 NDAA as follows:

- (a) PLAN.—The Secretary of the Air Force shall develop a plan for the preservation and storage of unique tooling related to the production of hardware and end items for F-22 fighter aircraft. The plan shall—
- (1) ensure that the Secretary preserves and stores required tooling in a manner that—

⁴ *Conex*, originally a contraction of *Container Express*, a company name, refers to any large metal cargo container suitable for transportation or storage of materials, parts, or tools.

⁵ Obaid Younossi, Kevin Brancato, John C. Graser, Thomas Light, Rena Rudavsky, and Jerry M. Sollinger, *Ending F-22A Production: Costs and Industrial Base Implications of Alternative Options*, Santa Monica, Calif.: RAND Corporation, MG-797-AF, 2010.

⁶ The original restriction, first included in the Department of Defense Appropriations Act for FY 1998, was written by Rep. David Obey, who is the former chair of the House Appropriations Committee.

⁷ See Public Law 111-118, Department of Defense Appropriations Act, 2010, December 19, 2009, Section 8059.

- (A) allows the production of such hardware and end items to be restarted after a period of idleness; and
- (B) provides for the long-term sustainment and repair of such hardware and end items;
- (2) with respect to the supplier base of such hardware and end items, identify the costs of restarting production; and
- (3) identify any contract modifications, additional facilities, or funding that the Secretary determines necessary to carry out the plan.
- (b) RESTRICTION ON THE USE OF FUNDS.—None of the amounts authorized to be appropriated by this Act or otherwise made available for fiscal year 2010 for aircraft procurement, Air Force, for F-22 fighter aircraft may be obligated or expended for activities related to disposing of F-22 production tooling until a period of 45 days has elapsed after the date on which the Secretary submits to Congress a report describing the plan required by subsection (a).⁸

That language and a subsequent meeting involving the Air Force, RAND, and congressional staffers made it clear that there is interest in keeping the production tooling for a potential restart of the F-22A sometime in the future. This report has been prepared to meet the requirements of Section 133 and is based on the information available as of February 2010. Because of ongoing analyses and negotiations among the F-22A contractors and the Air Force, subsequent analyses and negotiations may result in decisions and costs that differ from those presented in this report.

The Definition of *Tooling*

Tooling is a general term referring to the host of items required to produce a weapon system that do not themselves become part of the system. These items range from large holding fixtures used to align major parts of an aircraft so they can be fastened together to small hand tools designed for specific functions to special test equipment (STE) that verifies the functioning of a system or subsystem after it is assembled. Tooling can be divided into many separate categories, but this report focuses on two basic categories: government owned and contractor owned.⁹ In general, tooling that is designed and built for the express purpose of producing one weapon system (or part thereof) and has no other use (e.g., a wing-holding fixture) is normally paid for by DoD as part of the tooling budget of that program. This government-unique tooling may be located at the prime contractors' or their suppliers' production facilities.¹⁰

Tooling that is useful for producing more than one system (e.g., an overhead crane in a factory) is usually procured and owned by the contractor, who charges depreciation of the equipment against the contracts for all the systems being produced at the production location through an overhead charge. This report focuses on tooling that has been funded by the Air Force because it is that tooling that would be critical to a production restart. Although contractor capital equipment would also be required for a restart, it is assumed that, for a restart

⁸ Public Law 111-84, National Defense Authorization Act for Fiscal Year 2010, October 28, 2009, Section 133.

⁹ See the appendix for a full discussion of the many categories of tooling.

¹⁰ Other government property, called agency-peculiar property (APP), also described in the appendix, is nonunique government property, essentially loaned to the contractors for the purpose of developing or producing a weapon system. At the end of production, it is returned to the government to be dispositioned. Since such property is not unique to the F-22A, it is not addressed in this report.

of significant quantities (such as 75 aircraft), contractors would make available the nonunique tooling and facilities required to resume production, the cost of which would be reflected in the recurring cost of the aircraft produced after the restart. Chapter Two discusses instances in which capital equipment may be an issue for restart at certain prime-contractor locations, and Chapter Five addresses capital issues as they are related to key suppliers.

This report deals with tooling for the production of the F-22A air vehicle and of the F119 engine. Based on our discussions with avionics experts associated with the F-22A, we consider avionics tooling to be sustainment tooling. Many of the avionics producers will continue to participate in the production of spares, in the F-22A modernization program, and in the diminishing manufacturing sources¹¹ efforts, so their tooling will be active and will receive updates. Also, much of the avionics tooling and test equipment is not F-22 unique, as it is useful for producing avionics parts for other aircraft. Furthermore, many of the avionics producers are participating in the F-35 program, which will help maintain personnel skills. To be clear, however, the estimated nonrecurring restart costs in Chapter Four do include the full costs of producing the F-22A, including avionics-tooling costs.

The Air Force has made a major investment in the unique tooling required to produce the F-22A. Approximately \$1.6 billion worth of government tooling and associated materials exists today.¹² Therefore, careful analysis is called for when determining what tooling may be required in the future for sustainment efforts and when assessing the likelihood that a restart of the F-22A production line may be required.

What Is Involved in Production Shutdown and Tooling Disposition?

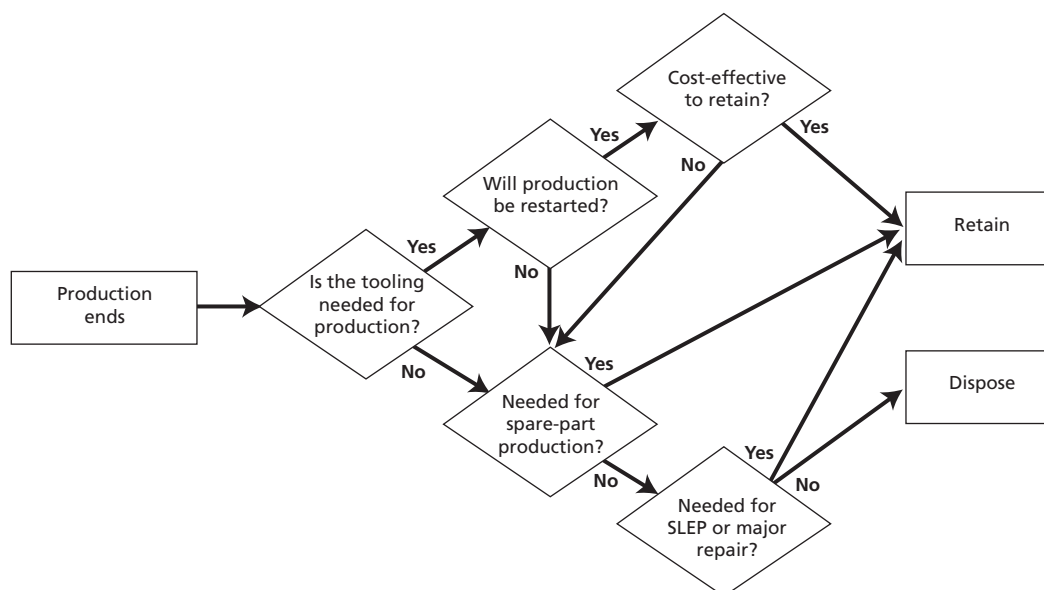
Deciding to retain tooling for sustainment, modernization, or restart purposes rather than disposing of tooling at the end of the production run is a complex process involving analyses of such issues as spare-parts requirements, past aircraft accident rates and resulting damage produced, and depot-overhaul and update requirements.

Figure 1.1 shows the decision process at a high level. In addition to technical analyses, major strategic decisions (such as the likelihood of foreign sales) are part of the process. The first determination is whether there are any tools needed for production. As shown, if a production restart is anticipated at or near the same rates previously achieved, all tooling is retained, as long as the cost-effectiveness of the retention is not an issue. The next decision involves whether individual tooling items will be needed for spare-parts production. If spares production is not forecasted, a more complicated set of analyses and assumptions must be undertaken regarding the possible tooling requirements needed to make repairs due to accidents or major battle damage and to support a service-life extension program (SLEP). The Air Force and its contractors are in the process of determining requirements for spares, accident repair, and potential SLEPs.

¹¹ Diminishing manufacturing sources relates in general to parts that have either become technologically obsolete and are no longer produced or to situations in which an only-source producer is no longer willing or able to produce those parts. Hence, other sources or approaches must be found, which may entail redesigning the parts or systems to be compatible with newer manufacturing technologies.

¹² This cost, presented in FY 2010 dollars, was the acquisition cost of the tooling in the property database; installation and preparation for use on the production line are not included.

Figure 1.1
Tooling Decision Flowchart



RAND TR831-1.1

Table 1.1 lists the actions required for tooling disposition¹³ for both tooling that is retained for sustainment purposes and tooling that would be disposed of (i.e., not retained for a production restart). The table highlights two issues concerning production shutdown and tooling disposition. First, significant work-years are expended in analyzing, processing, and accounting for government tooling, regardless of whether it is retained or disposed of following production. Basically, the major cost difference between the two is incurred in wrapping, packing, and transporting the retained tooling (a nonrecurring cost) and storing it (a recurring annual cost). However, in the end, all tools must be demilitarized and disposed of, so the last four steps in the table occur for all tools at some point, whether immediately after production or later when they are no longer required during or after sustainment. Thus, those costs are not included in the differential cost.

As a percentage of the acquisition cost of the government tooling required for production restart, our analysis showed that the nonrecurring cost for retaining tools represents about 9 percent of the original \$194-million acquisition cost of the production-only tooling, and the recurring annual storage and maintenance cost is a fraction of a percent of this original acquisition cost.¹⁴ (Unless otherwise noted, costs in this report are in FY 2010 dollars.)

The second issue is the process of tooling disposition. Removing the tooling and STE from the contractor and government books can literally take years, as each tool is processed through the steps in the table. Just under 40,000 tools are located at the F-22A prime contractors and suppliers, so the process will be lengthy. With the number of government personnel working tooling disposal being limited, it is expected that F-22A tooling disposition will not be complete until long after production ends.

¹³ In this report, *disposition* refers to the decision process that determines whether tools are ultimately retained or disposed of.

¹⁴ A further discussion of these costs can be found in Chapter Three.

Table 1.1
Steps in the Tooling-Disposition Process

Step	Retained Tooling and STE	Tooling and STE Disposed of Following Production Shutdown
Conduct physical inventory	✓	✓
Determine whether the tooling is needed for sustainment or modernization (i.e., determine hot, warm, cold status)	✓	✓
Request title determination for right-to-title special tooling	✓	✓
Notify the contractor's government-furnished property representative	✓	✓
Update the DD 610 database ^a	✓	✓
Submit the DD 610 (with a recommendation) to the SPO	✓	✓
Send disposition instructions back to the contractor	✓	✓
Prepare the tools (e.g., drain fluids, de-energize, disassemble)	✓	✓
Wrap, pack, transport, and store	✓	
Update the property-asset database with new location	✓	
Enter tool data into PCARSS ^b		✓
Transfer, demilitarize, or dispose		✓
Update the property-management system		✓
Reconcile the DoD registry for unique identification		✓

NOTES: SPO = System Program Office. PCARSS = Plant Clearance Automated Reutilization Screening System.

^a DD 610, the "Government Furnished Equipment Requirements Schedule," is the form used to notify the government of changes in an item of government property managed by a contractor.

^b PCARSS is a Defense Contract Management Agency database of tooling made available for use by other DoD programs.

Report Organization

This chapter provided an overview of tooling and the disposition process. Chapter Two provides the plan for tooling disposition (by F-22A prime-contractor site) and identifies issues likely to arise following shutdown and the decision to restart. Chapter Three provides the differential costs of retaining the production-only tooling required for a restart that would not otherwise be retained for sustainment purposes. Chapter Four describes the analysis and estimated costs of restarting production under three different scenarios. Chapter Five discusses critical suppliers and the issues involved in reengaging those with unique capabilities. Chapter Six presents our conclusions, and the appendix discusses types of tooling.

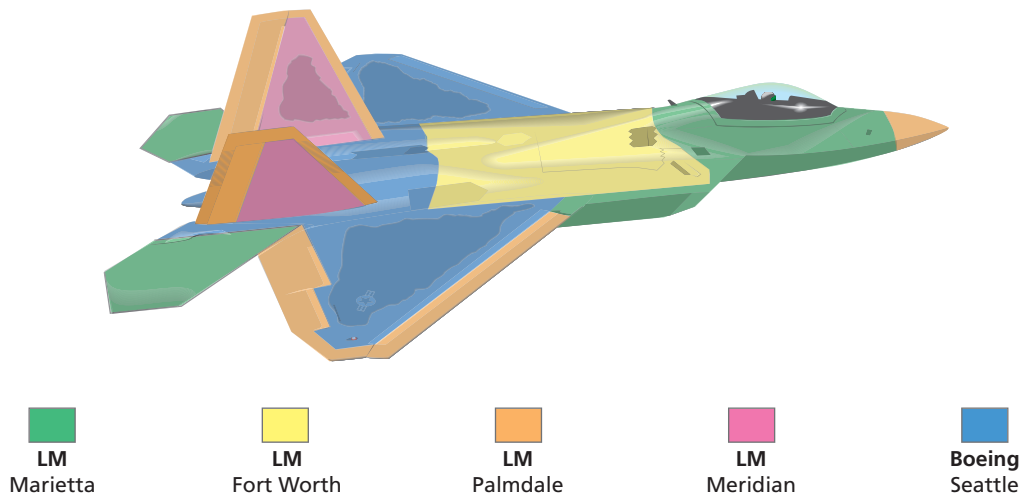
The Plan for Tooling Disposition

The prime contractor sites for the F-22A production are as follows:

- Lockheed Martin Aeronautics Company (LM), Marietta, Georgia; Fort Worth, Texas; Palmdale, California; and Meridian, Mississippi
- Boeing Company, Seattle, Washington
- Pratt & Whitney Company (P&W), East Hartford and Middletown, Connecticut.

The division of responsibilities for the air vehicle is depicted in Figure 2.1. (The propulsion system is supplied by P&W's East Hartford and Middletown, Connecticut, sites.) The contractor sites listed in the figure are responsible for managing all 39,700 F-22A unique tools, which are located at these sites and at the sites of their suppliers. A more detailed description of the sites follows.

Figure 2.1
F-22A Prime-Site Responsibilities



SOURCE: Adapted from a figure provided courtesy of the Lockheed Martin Aeronautics Company.

RAND TR831-2.1

Marietta, Georgia

The LM Marietta site hosts the F-22A Program Office and is the site of the F-22A's forward-fuselage build, fuselage mate, final assembly, flight operations, and delivery. Approximately 1.25 million square feet of space is used at the site for F-22A operations, comprising 675,000 square feet dedicated to F-22A production, 172,000 square feet of labs, 316,000 square feet of office space, and 89,000 square feet of warehouse space. In addition to F-22A operations, the Marietta site supports manufacturing and flight operations for such platforms as the C-130J Super Hercules and the C-5 Galaxy.

Marietta has about 4,700 F-22A unique government tools on location and about 4,800 at its suppliers' facilities. It will begin production on the last F-22A (tail number 4195) in November 2010, complete production in November 2011, and deliver the aircraft in February 2012. At that point, the primary production area in Building B-1¹ will be shut down, and the facility's tooling will be disassembled, wrapped, and placed in Conexes outside the plant. Supplier tools will be disassembled, wrapped, and shipped to Marietta, where they will be placed in Conexes. A mix of environmentally controlled (i.e., air-conditioned) and non-air-conditioned Conexes will be used to accommodate the tools. At the current time, there are no identified production requirements for the approximately 240,000 square feet of space at Marietta used for the forward-fuselage, major mate, and final assembly and checkout of the F-22A. If a need arose in the future, the tooling would be taken out of storage and reinstalled. Some tooling refurbishment, realignment, and start-up activities would be required, and personnel would need to be retrained.

Fort Worth, Texas

The LM Fort Worth site is the headquarters of the Lockheed Martin Aeronautics Company and hosts production of the F-22A mid-fuselage, gun-port door, infrared-countermeasures doors, ammunition-load doors, gun-safing doors, in-flight-refueling-receptacle doors, louver-assembly spares, and the auxiliary power unit inlet and exhaust doors. Approximately 342,000 square feet of space is used at the site for F-22A operations, comprising 239,000 square feet dedicated to F-22A production, 75,000 square feet of office space, and 28,000 square feet of warehouse space. In addition to conducting F-22A production activities, the Fort Worth site produces the F-16 and the F-35 fighters.

Fort Worth has about 5,000 F-22A unique government tools on location and about 5,900 at its suppliers' facilities. It began production on the mid-fuselage for the last F-22A in April 2010 and will complete production of and ship the mid-fuselage to Marietta in May 2011. As production of the last mid-fuselage progresses, tooling will be disassembled, wrapped, and placed in Conexes outside the plant. Supplier tools will be disassembled, wrapped, and shipped to Fort Worth, where they will be placed in Conexes. A mix of environmentally controlled and non-air-conditioned Conexes will be used. The production area at Fort Worth will be restored and used by the F-35 program, so there will be a need to free up the space expeditiously after production of the last F-22A mid-fuselage. If F-22A production were to be restarted, another facility would have to be found, and the F-22A tooling would have to be installed there. Some

¹ Building B-1 is a government-owned building operated by LM, which pays DoD annually to lease it.

tooling refurbishment, realignment, and start-up activities would be required, and personnel would need to be retrained.

Palmdale, California

The LM Palmdale site hosts the F-22A modification facility for postproduction (i.e., depot) modifications and is the site of production of the following F-22A assemblies: the vertical stabilizer trailing edge, the vertical stabilizer leading edge, the integrated forebody, the leading-edge flap, the rudder, the wing stub, the wing tip, the aft boom, the antenna, the blade seals, the bullnose detailed parts, the flaperon, the aileron, the diverters, the cover assemblies, and urethanes. Approximately 270,000 square feet of space is used at the site for F-22A operations, comprising 213,000 square feet dedicated to F-22A production and depot operations, 9,000 square feet of labs, 13,000 square feet of office space, and 35,000 square feet of warehouse space. In addition to F-22A operations, the Palmdale site hosts other advanced development programs and operates advanced test ranges.

Palmdale has about 1,500 F-22A unique government tools on location and fewer than 100 at its suppliers' facilities. It will begin production on parts for the last F-22A in February 2011 and will complete production of and ship the last parts to Marietta in August 2011. To meet its requirement to produce spare parts, Palmdale will then reduce the amount of space devoted to F-22A operations. Tooling not required for spares production will probably be placed in a government-owned, on-site warehouse as a temporary measure. About 12,000 square feet of space would be required for this storage. Alternatively, tooling could be stored in Conexes located on-site or elsewhere. The freed-up production area at Palmdale will be used to continue to produce parts for the F-35. If F-22A production were to be restarted, another facility would have to be found, and the F-22A tooling would have to be installed there. Some tooling refurbishment, realignment, and start-up activities would be required, and personnel would need to be retrained. However, due to the site's F-35 production activities and F-22A spares production activities, personnel expertise at the site will generally be maintained. One critical supplier, Thin Film Technology, Inc. (TFT), could complicate restarting production at Palmdale. This issue is discussed in Chapter Five.

Meridian, Mississippi

The LM Meridian site hosts production of the F-22A vertical stabilizer assembly, which does not include the leading edge, the rudder made at the Palmdale site, or the finishes applied at the Marietta site. Approximately 12,000 square feet of production space in a single building is dedicated to this purpose. In addition to F-22A operations, the Meridian site supports production of the C-130J fuselage.

Meridian has about 40 government-owned F-22A tools. It will begin production on vertical stabilizers for the last F-22A in April 2011 and will complete production of and ship the stabilizers to Marietta in June 2011. At that point, the primary production area will be shut down. Tooling will be removed, wrapped, shipped to Marietta, and packed and stored in Conexes. At the current time, there are no identified production requirements for the space used for F-22A production. If F-22A production were to be restarted, the Meridian F-22A tooling

would be reinstalled at Marietta or elsewhere. Some tooling refurbishment, realignment, and start-up activities would be required, and personnel would need to be retrained.

Seattle, Washington

The Boeing site, located at the Boeing Defense Systems (BDS) Puget Sound Development Center, hosts production of the F-22A aft-fuselage and wing assemblies, associated hardware deliverables, and spares. F-22A fabrication and assembly facilities are located in a Boeing-owned building in Puget Sound. Fabrication activities take place in the Composite Fabrication and Assembly Center, which also supports fabrication for multiple BDS and Boeing commercial programs. In addition to F-22A operations, the Puget Sound site hosts several major BDS programs, including Airborne Early Warning and Control, the Airborne Warning and Control System, and P-8A Poseidon programs. About 125,000 square feet of total space is used for the F-22A, with 100,000 square feet being production space.

Puget Sound has about 1,700 F-22A unique government tools on site and another 3,300 at its suppliers' facilities. It will begin production on the wing assemblies for the last F-22A in December 2010 and complete production and ship the assemblies to Marietta in June 2011. As production of the last aft-fuselage and wings progresses, tooling will be disassembled, and most of it will be wrapped, placed in Conexes, and shipped to an off-site Boeing-owned or leased storage facility. A few larger tools may have to be stored in the traditional warehouse manner. Supplier tools will be disassembled, wrapped, and shipped to Boeing, where they will be placed in Conexes and shipped to the off-site storage facility. A mix of environmentally controlled and non-air-conditioned Conexes will be used. The production area at Puget Sound will be restored and used for other Boeing programs, so there will be a need to free up the space expeditiously after producing the last F-22A wing assemblies. If F-22A production were to be restarted, another facility would have to be found, and the F-22A tooling would have to be installed there. Some tooling refurbishment, realignment, and start-up activities would be required, and personnel would need to be retrained.

One major obstacle to production restart at Puget Sound would be reestablishing the capability of the Precision Drilling Center, whose large machine tools drill holes in the composite wing skins and wing structure. Three precision drilling machines are used, and all are nearing the end of their useful lives. Because they are capital assets owned by Boeing, the company would either have to make a commitment to fund replacement machines and reconstitute the capability in the event of a restart or find an alternate method of drilling. In addition, three major critical suppliers would have restart issues. These issues are discussed in Chapter Five.

East Hartford and Middletown, Connecticut

P&W fabricates parts for, assembles the five modules of, performs final assembly of, and tests the F119 engine at its two sites in Connecticut and at another fabrication facility in North Berwick, Maine. It also produces the Aircraft Mounted Nozzle Sidewall (AMNS) and the Arresting Gear System (AGS) for the F-22A, which are supplied to Boeing. The facility at Middletown has about 2,200,000 square feet of production space, of which 100,000 square feet is dedicated to F119 production. East Hartford has about 4,560,000 square feet of pro-

duction space. Much of the space used for fabrication and module assembly is shared with other engines being produced by P&W. Production of the AMNS and AGS requires another 10,500 square feet. P&W will deliver its last F119 in May 2011.² However, there are continued sustainment requirements for AMNS and AGS beyond production. The last production of an AMNS and an AGS will be completed in May 2011, and spare requirements are projected to last through December 2011.

P&W has about 9,200 F119-unique tools at its facilities and manages another 3,500 at approximately 100 vendor sites. Because the production time for the F119 is shorter than for the airframe, P&W is just beginning its planning for shutdown operations. However, it will likely adopt an approach that is similar to that of other prime sites: Tooling will be disassembled, and most of it will be wrapped, placed in Conexes, and shipped to an off-site leased storage facility. Since most F119 vendors are expected to play a role in producing F119 spare parts (some at high, and some at low, production rates), few of their government-owned tools are expected to be moved in the foreseeable future. Eventually, though, data on spare-parts usage will help refine the need for tooling at some vendor facilities. As will occur at other prime sites, these vendor tools will likely be disassembled, wrapped, and shipped to P&W, where they will be placed in Conexes and shipped to the off-site storage facility.

Although there are concerns about the size of the annual spares buys from P&W suppliers and whether they will be interested in retaining such production capabilities, a major production-restart concern is the production of the Combustor, Augmentor, and Nozzle (CAN) module for the F119. The CAN-module area in the P&W East Hartford facility consists of about 400,000 square feet, and about two-thirds of that area is dedicated to F119 production that involves significant amounts of P&W large-capital equipment. There are no postproduction spares requirements for the F119 CAN modules, and P&W will not be making these same parts for the F135 engine. Thus, the capability to efficiently restart production of these parts for the F119 in the future is in serious doubt.

Table 2.1 on the following page summarizes various facts about each of the sites discussed in this chapter.

² The Air Force and P&W are analyzing requirements for additional F119 spare engines at this time. Restarting production of the F-22A would necessitate a restart of the F119 production line. However, F119 production could, depending on operational requirements for spare engines, be continued or restarted in the future independently of decisions about the F-22A.

Table 2.1
F-22A Production Site Data

Site	Total Space Dedicated to the F-22A (ft ²)	Space Dedicated to F-22A Production (ft ²)	Number of F-22A Unique Tools at Prime Facility	Number of F-22A Unique Tools at Supplier Facilities	Date of Last Delivery
Marietta	1,250,000	675,000	4,700	4,800	February 2012
Fort Worth	342,000	239,000	5,000	5,900	May 2011
Palmdale	270,000	213,000	1,500	<100	August 2011
Meridian	12,000	12,000	40	N/A	June 2011
Puget Sound	125,000	100,000	1,700	3,300	June 2011
East Hartford/ Middletown	4,560,000 ^a / 2,200,000	278,000 ^b / 100,000	9,200	3,500	May 2011
Total	8,759,000	1,617,000	22,100	<17,600	N/A

NOTE: Totals may not sum due to rounding.

^a Much of this space is shared with other production programs.

^b This figure includes about two-thirds of the total 400,000-square-foot facility designated for the CAN module area and 10,000 square feet for production of the AMNS and the AGS.

The Differential Cost of Retaining Production-Only Tooling

In this chapter, we present an estimate of the differential cost of retaining production-only tooling. Recall that retention of this tooling is the key difference between the *shutdown and retain* option and the *shutdown and sustain* option.

Methodology

The first step in estimating this differential cost was obtaining copies of the master tooling lists of F-22A unique government-owned or government right-to-title tooling from each contractor. Each list identified whether the tooling was located at the prime contractor's facility or at one of its suppliers' facilities. These lists were analyzed to determine which tools would likely be used for sustainment purposes and which would not be required for sustainment. An example of tooling not required for sustainment is the duplicate tools acquired for rate production of the F-22A. (APP was excluded because this tooling and other items are expected to be returned to the Air Force upon production shutdown.) The outcome of this tooling assessment is summarized in Table 3.1, which displays the approximate tool count by location, how many tools are considered to be required for sustainment, and how many tools are considered production only at this point in time (i.e., would be retained only if a restart were considered likely). As stated in Chapter One, much analysis regarding ultimate tooling disposition is now being conducted by the Air Force and the F-22A contractors, so the analysis in this report should be considered preliminary.

After determining the number of tools in each category, we computed the differential nonrecurring and annual recurring costs of retaining the production-only tools. Specifically, we estimated the costs of wrapping, packing, transporting, storing, and maintaining the production-only tooling, using the plans described in Chapter Two for each location.¹ The relevant task sheets formulated by LM for tooling disposition activities at Fort Worth were employed as a starting point for estimating these costs. The same basic approach was also used for the Marietta, Puget Sound, and East Hartford/Middletown sites: Tools are wrapped and packed into Conexes, which can then be kept at a storage facility at low cost. The advantages of the Conex approach for tooling retention as compared with the traditional warehousing approach are (1) reduced recurring costs, since the containers can be stored at inexpensive outdoor facilities, which, over the long term, more than compensates for the initial upfront cost

¹ Note that these activities, which correspond to the steps listed in Table 1.1, are required for tool retention but not for tool disposal.

Table 3.1
F-22A Unique Government Tooling, by Location and Functional Categorization

Contractor	Sustainment	Production Only	Total
LM Marietta			
On-site	3,300	1,400	4,700
Suppliers ^a	3,400	1,400	4,800
LM Fort Worth			
On-site	3,500	1,500	5,000
Suppliers	4,100	1,800	5,900
LM Palmdale			
On-site	1,400	200	1,500
Suppliers	<100	<100	100
Boeing ^b			
On-site	1,400	300	1,700
Suppliers	2,300	900	3,300
P&W			
On-site	7,600	1,600	9,200
Suppliers	2,800	700	3,500
Total	29,900	9,800	39,700

NOTE: Totals may not sum due to rounding.

^a The 40 Meridian tools are included in the Marietta suppliers row.

^b Approximately 100 production-only tools managed by Boeing are already in storage and therefore would not entail nonrecurring costs associated with wrapping, packing, and transporting. However, the annual recurring costs of storage and maintenance would apply.

of purchasing the containers, and (2) flexibility and potentially lower nonrecurring costs for restart, since Conexes can be easily transported without the need to unpack and repack tools. At a high level, the methodology for estimating the cost of this Conex approach to retaining production-only tooling is as follows:

- For each of the prime sites, the costs of administrative and planning activities associated with tooling retention that were sensitive to tool count were scaled in proportion to the total number of production-only tools on-site and at supplier facilities.²
- For each of the prime sites, tools were further categorized according to size (i.e., small, medium, large, extra large) because tools vary considerably in size and therefore entail different associated wrapping, packing, transporting, and storing costs.

² Note that many of the overall shutdown and tooling-disposition activities (e.g., shutdown planning, engineering, process documentation) will occur regardless of whether production-only tools are retained or disposed of. Therefore, they are not included in the differential cost.

- For each category of tool size, we computed the typical cost of wrapping, packing, transporting, and storing a tool and then multiplied that cost by the number of tools of that size.
- Consistent with Chapter Two, we handled production-only tooling at supplier facilities in the same manner as on-site prime tools, but we added the cost of temporarily crating and transporting this tooling (which is also sensitive to tool size) to the prime's location.
- We computed the number of Conexes required (a significant cost driver) using the aggregate footprint of tooling to be stored, also accounting for packing efficiency and risk margin.
- When possible, we independently verified and updated the basic cost parameters, including those associated with storage, transporting, Conexes, and electricity.

As discussed in reference to Table 1.1, at some point in the future, all F-22A tooling will be disposed of, either when it becomes obvious that a restart will not occur or when the operational life of the F-22A ends and even sustainment requirements cease. Those ultimate disposal costs will be incurred for the production-only tooling under both the *shutdown and sustain* and *shutdown and retain* options. In constant FY 2010 dollars, these costs should be roughly the same³ and are therefore not included in the differential cost.

Results

Table 3.2 summarizes the resulting differential nonrecurring (i.e., wrapping, packing, transporting) and annual recurring (i.e., storage, maintenance) costs⁴ of retaining the production-only tooling. Since the nonrecurring costs of the disposition process will occur over three years and will depend on the availability of personnel and the speed with which each site processes the prime and supplier tooling, the nonrecurring costs are lumped into a three-year window (FY 2011–FY 2013). Annual recurring costs would ramp up during the same period but would reach steady state by FY 2013, at approximately \$150,000 per year.

Table 3.2
The Differential Cost of the *Shutdown and Retain* Option Compared with the *Shutdown and Sustain* Option (FY 2010\$, millions)

	FY 2011–FY 2013	FY 2012	FY 2013	FY 2014 and Beyond
Nonrecurring	\$17.0	N/A	N/A	N/A
Annual recurring	N/A	\$0.07 ^a	\$0.15	\$0.15

^a Recurring costs will begin partway through FY 2012, so half of the recurring annual cost at steady state is assumed for FY 2012.

³ Accomplishing disposal by crushing an entire Conex with tooling inside would be, if it is permitted, less expensive than disposing of individual tools immediately following production. However, this decision will have to be made by DoD officials in the future.

⁴ Unless otherwise noted, in these analyses, the term *cost* includes profit and fee, so the dollar amounts represent the appropriated amounts required.

Contract Modifications and Funding Required

Apart from securing the funding required, the changes needed to retain the production-only tooling in terms of the F-22A contracts would be modest. The current Raptor Enhancement Development and Integration (REDI) contract structure will allow the funding of activities to wrap, pack, transport, and store the production-only tooling and of activities related to sustainment tooling. When the period of performance for the REDI contract ends in FY 2016, the annual storage costs of the production-only tooling will have to be switched to a contract line item on the F-22A sustainment contract, known as the Follow-on Agile Support for the Raptor contract (or its successor contract), with the costs most likely paid out of the Air Force operation and maintenance appropriation.

Restart Costs

The total costs of restart consist of the cost of preparing for production restart, the cost of actually producing additional aircraft and engines, and the cost of then shutting down production (i.e., executing *shutdown and sustain*) a second time. This chapter begins by laying out the scenarios considered, all of which assume that the *shutdown and retain*¹ option will be selected, and then identifies all of the costs involved: the cost of preparing for restart, the cost of producing 75 additional F-22A aircraft, and the cost of final shutdown. The basic methodology relies on the earlier RAND study but has been updated with the most-current information available.

Scenarios

This section describes the procurement of 75 additional aircraft under three scenarios:

- *Hypothetical scenario.* In this baseline scenario, advance-procurement funds are made available in FY 2010, and there are funds for production in FY 2011.
- *Transition scenario.* In this scenario, Congress appropriates advance-procurement funds in FY 2011 and appropriates funds for production in FY 2012.
- *Future scenario.* In this scenario, Congress appropriates advance-procurement funds in FY 2012 or later and appropriates funds for production beginning in the next FY.

The timing of funding has a considerable influence on the cost of producing additional aircraft, and, in the case of the latter two scenarios, on the activities required for restart. Table 4.1 shows the annual production quantity by FY and, in the final two columns, the major restart cost drivers for each scenario: loss of learning and low-rate production.²

In the hypothetical scenario, Congress appropriates Lot 11 advance-procurement funding for 20 units in FY 2010 and indicates its intent to continue production of 55 additional units in FY 2011 and beyond rather than shutting down the production line. This scenario can be used as a baseline against which to compare the cost of producing 75 aircraft after production restart, as it avoids the costs of both loss of learning and low-rate production. However, because advance-procurement funding was in fact not appropriated, this scenario is now impossible to implement. Even if Congress were to immediately appropriate advance-procurement funds for

¹ The *shutdown and retain* option is considered a “smart” shutdown in which the tooling, equipment, knowledge, and data required to meet future production needs are identified before shutdown and retained.

² The costs shown include the costs for the associated number of F119 engines, which is calculated as 2.25 times the number of aircraft, rounded up to the nearest whole engine.

Table 4.1
Annual Production Quantity and Restart-Cost Drivers

	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016	FY 2017	Loss of Learning?	Low-Rate Production?
Hypothetical	20	20	20	15	N/A	N/A	N/A	No	No
Transition	N/A	10	20	20	20	5	N/A	Yes	Yes
Future	N/A	N/A	5	10	20	20	20	Yes	Yes

additional F-22A production and do so before the time at which such funds would become available in the transition scenario, there would already be cost increases and schedule delays.

Note that neither the transition nor the future scenario has production quantities in FY 2011. This is a result of the decision to limit F-22A Lot 10 production to four aircraft and not to fund Lot 11 advance procurement. Since long-lead items for potential future lots were not ordered, the shutdown of some suppliers has already begun, unavoidably increasing the cost of procuring additional aircraft. Halting the shutdown process and reinitiating production would take some time and could not be accomplished for most suppliers in FY 2011. In short, there is no longer a seamless way to continue F-22A production after the four aircraft in Lot 10 are produced.

In the transition scenario, advance-procurement funding for ten F-22A aircraft is appropriated at the start of FY 2011, and full funding for ten aircraft is appropriated in FY 2012. Additionally, there is a clear intent to fund future production lots. This yields a production gap of 9–18 months at many sites. The transition scenario will entail a loss of learning similar to that seen in many historical restart programs and will thus result in higher recurring costs for the production of aircraft.³ The first year of restarted production will result in a higher unit recurring cost due to the lower production rate. However, compared with the future scenario, the transition scenario will entail lower nonrecurring restart costs because the shutdown issues of many critical suppliers will be mitigated.

In the future scenario, production does not restart until FY 2013, at the earliest.⁴ By that time, all suppliers not supporting sustainment have shut down their F-22A production, all tooling not being used actively in sustainment has been stored, and most prime production facilities have been reorganized or shut down.⁵ A restart two and a half years after shutdown leads to a requirement for very-low-rate production at restart but also to the same loss of learning that occurs in the transition scenario (but, in this case, that loss translates into a higher recurring production cost than in either the hypothetical or transition scenario). In addition, it leads to a requirement for substantial nonrecurring costs at restart to cover facility and tooling reorganization, rehiring, supplier-part and supplier-process requalification, and possibly part redesign and testing. Upon restart under the future scenario, many production activities cur-

³ The loss-of-learning assumption used for the transition and future scenarios is the same used in Younossi et al. (2010): that the length of a production gap does not have a substantial effect on the recurring cost after restart.

⁴ The recurring cost of a production restart that occurred later but before FY 2016 would be similar, although the non-recurring costs might increase in constant dollars as the gap lengthens. Results are reported in constant dollars, and the recurring cost in the future scenario applies across all potential restart dates.

⁵ Unlike the transition scenario, in which the anticipation of new production would mitigate the gap for some prime locations and suppliers, in the future scenario, all locations will experience a gap.

rently performed at prime and Tier 1⁶ supplier facilities will have to be started from scratch, perhaps at different facilities entirely.

The Cost of Preparing for Production Restart

The nonrecurring costs of an F-22A restart include the costs of every activity needed to reinitiate production: planning and administration, opening facilities and conducting plant engineering, reorganizing tooling, rehiring personnel, and requalifying suppliers. A summary of the costs associated with these requisite restart activities is provided in Table 4.2.

The hypothetical scenario, which does not require a restart, has a nonrecurring restart-support cost of zero dollars. The transition scenario's estimated nonrecurring restart-support cost is \$127 million, and the future scenario's is \$307 million.⁷ The costs for these latter two scenarios are based on the methodology detailed in the earlier report but were calculated using updated inputs for the sites' square footage of production, number of F-22A unique tools, and number of workers. In the earlier report, the nonrecurring costs of restart were assumed to be the same as the nonrecurring costs of the "smart" shutdown of the production line. In this report, the costs of restart are directly estimated.

Planning and Administration

A substantial portion of the planning and administration costs of a shutdown and restart is incurred during the shutdown period. The planning and administration activities include first-stage restart-planning documentation, executive and engineering management, maintenance of program management data, and outside analyses. The cost of restart planning and administration reported here includes neither those shutdown costs nor detailed production-planning costs, which are considered part of the recurring-production cost model. RAND's earlier

Table 4.2
Nonrecurring Costs of Restart Activities Under the Three Scenarios
(FY 2010\$, millions)

Activity	Hypothetical	Transition	Future
Planning and administration	\$0	\$18.6	\$18.6
Facilities	\$0	\$2.2	\$10.7
Tooling	\$0	\$12.9	\$74.0
Personnel	\$0	\$50.7	\$70.3
Requalification	\$0	\$42.4	\$133.5
Total	\$0	\$126.8	\$307.1

⁶ A Tier 1 supplier is a company that makes products that are provided directly to the prime aircraft manufacturer. Tier 2 suppliers produce parts furnished to the next higher tier (i.e., a Tier 1 supplier).

⁷ These point estimates of nonrecurring restart costs are highly uncertain: RAND's earlier analysis indicated a low/high range of -60 percent to +75 percent around the most likely nonrecurring restart estimate, which yields a range of \$51 million to \$222 million for the transition scenario and of \$116 million to \$507 million for the future scenario.

F-22A study found a restart planning cost of \$18 million in FY 2008 dollars (or \$18.6 million in FY 2010 dollars); that figure is used here for the transition and future scenarios.

Facilities

At the end of production, significant portions of the F-22A prime contractor facilities' floor space will be cleared and readied for production of another aircraft.⁸ The cost of reestablishing facilities involves the installation of government-owned tooling and contractor-owned equipment in either government-owned or contractor-owned facilities. This cost is assumed to be proportional to the square feet of floor space required for the reestablished production.

The transition scenario assumes that sufficient lead time is given to prime contractors such that most of them would not clear out their facilities at all. In the transition scenario, both the LM Fort Worth F-22A production area, which is already being taken up by F-35 production, and the Boeing Puget Sound F-22A production area, which will be converted for production of commercial aircraft, need to be reestablished. A total of 339,000 square feet must be reestablished at \$6 per square foot, yielding a total price of \$2.2 million, including a 10-percent profit.

In the future scenario, it is assumed that funding does not arrive in time to maintain tooling at facilities and that all facilities at all sites must be reestablished. A total of 1,617,000 square feet of production floor space must be reestablished at \$6 per square foot, yielding a total price of \$10.7 million, including a 10-percent profit.

Tooling

The tooling-restart account includes the costs of tool planning, removing tools from storage, cleaning the tools, checking the tools against records, assembling the tools, and aligning the tools. The inputs used to estimate tooling cost are the number of tools, the labor hours required to perform each task for each tool, the cost of labor, and a 10-percent profit. All tooling, including sustainment tooling, would be used in a production restart.

In the transition scenario, tooling will not have yet been sent from suppliers to prime contractors, nor will prime sites, except those at Fort Worth and Puget Sound, have begun storing their tooling. Some 6,700 tools (both sustainment and production only) are estimated to be required on the production lines at Fort Worth and Puget Sound at a cost of roughly \$12.9 million.

In the future scenario, all prime and supplier tooling has been stored. An estimated 39,700 tools (both sustainment and production only) would be required on prime and supplier production lines at a cost of approximately \$74.0 million.

Personnel

The personnel-restart account covers the cost of hiring and training personnel. Some 3,200 salaried and hourly personnel are now directly supporting the F-22A program across all prime-contractor facilities. It is assumed that the same number of personnel are required at restart. All hires require 20 days of training, which is directly charged to the F-22A program. Many of these personnel would be less experienced (having just been hired), so an average hourly rate of \$140 per hour is used.⁹ The transition scenario assumes that 65 percent of the person-

⁸ Supplier floor space will also be cleared, but these types of costs are accounted for in the prices paid for parts and material.

⁹ This includes all indirect charges and profit.

nel required have to be hired, implying a personnel cost of \$50.7 million. The future scenario assumes that 90 percent of personnel required have to be hired, implying a personnel cost of \$70.3 million.

Requalification

After restart, requalification of parts or processes will be required. In the transition scenario, \$42.4 million is required to maintain the capability of the five key suppliers described in the next chapter: GKN Chem-tronics, Goodrich Aerostructures Group, Thin Film Technology, Inc., the University of California, Davis (UCD) McClellan Nuclear Research Center, and GKN North America. This figure is based on high-level estimates. For example, GKN Chem-tronics estimates that it would require \$30 million to keep operating for one and a half years until a production restart. In addition, we estimate that \$4 million¹⁰ each would be required to maintain the capabilities of Goodrich, TFT, and GKN North America. UCD McClellan estimates that it would require \$0.4 million to maintain its capabilities until a production restart. The cost of requalification in the future scenario is taken from the earlier F-22A report, which presented a likely estimate of \$128.4 million (after profit) in FY 2008 dollars (\$133.5 million in FY 2010 dollars).

Note that these most-likely estimates of requalification cost are highly uncertain. In RAND's earlier study, the low estimate for requalification was 70-percent less than the likely estimate, and the high estimate was 118-percent more than the likely estimate.

The Cost of 75 Additional Aircraft

The F-22A cost model detailed in RAND's earlier report was used to compute the costs of procuring 75 additional aircraft under each scenario.¹¹ This model generates costs by using F-22A historical data to estimate cost-improvement curves for labor hours at prime airframe contractors and to estimate material costs for all suppliers and the engine. The cost effects of a production break are inferred from the average of previously restarted aircraft programs. The model was updated with current inflation rates and labor rates, resulting in the costs of producing 75 additional F-22A aircraft presented in Table 4.3.¹²

If production continues into FY 2011 at the full rate and without a production break (i.e., as in the hypothetical scenario), the total cost of 75 aircraft would be approximately \$13.7 billion. If advance-procurement funding is immediately available in FY 2011 (i.e., as in the transition scenario), the recurring cost would be approximately \$16.7 billion. The \$3-billion difference between the transition and hypothetical scenarios is mostly due to the increased cost

¹⁰ This figure of \$4 million comes from an average of proprietary contractor cost estimates for supplier-process requalification.

¹¹ A total repurchase of 75 aircraft was chosen to be consistent with RAND's earlier report. For a top-level view of the structure of the model, see Obaid Younossi, Mark V. Arena, Kevin Brancato, John C. Graser, Benjamin W. Goldsmith, Mark A. Lorell, Fred Timson, and Jerry M. Sollinger, *F-22A Multiyear Procurement Program: An Assessment of Cost Savings*, Santa Monica, Calif.: RAND Corporation, MG-664-OSD, 2007. For a description of how restart is handled, see Younossi et al. (2010).

¹² This table includes roughly \$50 million in annual costs normally funded under the sustainment contract if no production is occurring. If production were under way, they would be funded under a production contract and then transferred back to the F-22 sustainment contract after shutdown.

Table 4.3
The Recurring Production Cost of 75 Additional Aircraft (FY 2010\$)

	FY 2010	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016	FY 2017	Total	APUC
Hypothetical	\$0.6B	\$3.6B	\$3.6B	\$3.3B	\$2.7B	N/A	N/A	N/A	\$13.7B	\$183M
Transition	N/A	\$0.8B	\$3.8B	\$4.0B	\$3.9B	\$3.4B	\$1.0B	N/A	\$16.7B	\$222M
Future	N/A	N/A	\$0.5B	\$2.4B	\$3.1B	\$4.1B	\$3.8B	\$3.5B	\$17.4B	\$233M

NOTES: APUC = average procurement unit cost. B = billion. M = million.

of production after restart owing to loss of learning, but it is also the result of a production rate of ten units in the first year. If advance-procurement funding is not available until FY 2012 (i.e., as in the future scenario), an additional increase of approximately \$0.7 billion to \$17.4 billion would be required. This cost increase is the penalty associated with a production rate of five and ten units, respectively, in the first and second years of the future scenario.¹³

“Smartbooks”—Mitigating the Loss of Learning?

The largest component of the cost increase at restart in both the transition and future scenarios is loss of learning in touch and engineering labor among both primes and suppliers, which leads, in the RAND model, to increased labor hours for the primes and to a higher cost of materials from the suppliers. Previous RAND research has identified the vast array of information one would want to retain to restart production efficiently after a gap.¹⁴ Current F-22A shutdown planning includes funding prime-contractor and select supplier construction of “smartbooks” containing just such information: particulars about the fabrication, assembly, and integration of the F-22A, such as work instructions, tools used, shortcuts implemented, videos of complex procedures, and the unique knowledge of production workers. The actual effectiveness of such an approach in mitigating loss of learning after a gap in production, however, is largely an open question. One unknown is whether the increased complexity of the F-22A production after restart would be offset by more-thoroughly capturing knowledge gained during current production. As result, this study assumes conservatively that loss of learning is *not* mitigated as a result of these efforts.

The Costs of Final Shutdown

After the production of 75 additional aircraft is complete, a disposition of tooling and facilities will be made, and the cost of these activities (in constant dollars) will be identical regardless of the scenario followed. This shutdown will be done with the assumption that no further pro-

¹³ The recurring costs for the scenarios presented here are point estimates; actual recurring costs could vary considerably for several reasons. In particular, the amount of learning that will be retained at restart is highly uncertain. Retaining more or less learning than modeled here would decrease or increase, respectively, the cost of producing the 75 aircraft by as much as several billion dollars.

¹⁴ See John Birkler, Joseph P. Large, Giles K. Smith, and Fred Timson, *Reconstituting a Production Capability: Past Experience, Restart Criteria, and Suggested Policies*, Santa Monica, Calif.: RAND Corporation, MR-273-ACQ, 1993, Figure 3.1.

duction will occur. In its earlier F-22A study, RAND estimated that the cost of this type of shutdown would likely be \$79 million in FY 2008 dollars (\$82 million in FY 2010 dollars).¹⁵

Summary

Table 4.4 sums the estimates of nonrecurring and recurring restart costs.¹⁶ As great as the nonrecurring restart costs seem (\$127 million in the transition scenario, \$307 million in the future scenario), they are dwarfed by the additional recurring cost of procuring 75 aircraft after a restart (\$16.7 billion in the transition scenario, \$17.4 billion in the future scenario). A restart is never inexpensive compared with continued production (compare the \$13.8 billion in the hypothetical scenario with both the \$16.9 billion in the transition scenario and the \$17.8 billion in the future scenario), but a restart that quickly returns to full-rate production results in substantial cost avoidance (in this case, a total of \$0.9 billion) in both nonrecurring and recurring costs. If a decision is made to build additional aircraft, production should be initiated as quickly as possible so that the costs are those of the transition scenario rather than the future scenario.

Table 4.4
The Total Cost of Procuring 75 F-22A Aircraft (FY 2010\$, billions)

	Nonrecurring Restart Cost	Cost of Procuring 75 Additional Aircraft	Nonrecurring Final Shutdown Cost	Total Cost
Hypothetical	\$0.0	\$13.7	\$0.1	\$13.8
Transition	\$0.1	\$16.7	\$0.1	\$16.9
Future	\$0.3	\$17.4	\$0.1	\$17.8

¹⁵ See Younossi et al. (2010, Table 2.7).

¹⁶ The total cost in Table 4.4 does not include the costs of the first shutdown for the transition and future scenarios. Costs for shutdown are currently being negotiated between the Air Force and the contractors. The resulting costs, which would not be incurred under the hypothetical scenario, are relatively minor compared with the total costs.

Critical Supplier Considerations in a Production Restart

Chapter Two discussed the issues associated with restarting production at the prime sites. Because each F-22A has almost 90,000 unique parts, production involves literally hundreds of suppliers. There are more than 700 Tier 1 suppliers that produce parts for the F-22A air vehicle and the F119 engine. In general, suppliers will finish producing parts for the last F-22A months before aircraft delivery. Some suppliers have already completed production for the last F-22A, and virtually all will have finished by the end of FY 2011. Some will continue producing spare parts in varying quantities as part of sustainment activities. Many are “build-to-print” suppliers whose technological sophistication is such that they can make the parts from the digital design data. Others, such as the avionics suppliers, will continue design and production activities as part of the F-22A modernization and diminishing-manufacturing-sources program.

RAND’s earlier report discussed in detail the effect of the production gap on F-22A suppliers. The results of a supplier survey indicated that, although few vendors would go out of business, nearly 20 percent were at high risk of experiencing an issue that would compromise their availability after a two-year production gap.

There are certain critical suppliers currently involved in F-22A production that have unique capabilities that would be difficult to re-create after production ends. The following sections discuss the capabilities of some of these critical suppliers. The suppliers are listed in descending order in terms of the potential effect of their unavailability on an F-22A restart. This availability issue is considered one of the larger challenges in retaining or restarting F-22A production.

GKN Chem-tronics, Kent, Washington

GKN Chem-tronics manufactures electron beam (EB) welded structures in its Thermal Joining Center (TJC) as a supplier to Boeing. The parts of the F-22A manufactured at GKN Chem-tronics are the forward side of body, the aft side of body, and the aft boom.

GKN Chem-tronics conducts eight key processes, which include EB welding, chemical processing, robotic bead shaving, vacuum stress relieving, robotic nondestructive inspection with x-ray, 5-axis machining, and precision dimensional inspection. The quality of the GKN Chem-tronics parts has been very high. For example, more than 170 aft booms have been produced with an acceptance rate of 99.9 percent.

The F-22A is the only customer of the plant’s output, and there are no plans to find other customers for its exotic processes. Without additional orders, production is scheduled to end in September 2010. The current plan is to shut the plant down, store the unique government

tooling at the Boeing site, and distribute the capital equipment to other GKN sites or auction it off. The purchase of insurance spares¹ would delay this date, but to keep the capability in place would require about 20 shipsets of F-22A orders for FY 2011, at a cost of roughly \$20 million.

The TJC processes are unique, and personnel skills will be lost in a shutdown. Today, it takes 24 months to order and receive raw material and parts for the side of the body. GKN estimates that it would require 48–60 months to reestablish and requalify production after a shutdown. However, EB welding is not unique to GKN, so other possible sources of parts may be available. Nonetheless, cost and schedule for qualification would still be required in the case of an alternate vendor, and the qualification period would likely last for 18 months after the production line is established. The acceptance rates for initial efforts would also likely be lower. Another issue with moving production and with requalification is competition for this technology from the B-787 program, which is ramping up at a different company. The EB vacuum chamber is GKN capital equipment, and an 18- to 30-month lead time would be required to obtain another one.

Finally, it is estimated that it could take a year to obtain a permit to reestablish production, much as it did in 2001.

Goodrich Aerostructures Group, San Marcos, Texas

Goodrich is a 173,850-square-foot facility. The parts of the F-22A manufactured at Goodrich are the engine-bay doors (four per shipset) and keel panels (six per shipset). The facility specializes in high-temperature liquid interface diffusion bonding of titanium, inconel brazing, and vacuum super-plastic forming of titanium. It uses a patented and unique process called Delta P, which is only used on the F-22A engine-bay doors.

The last delivery from Goodrich for the F-22A will occur in October 2010. Goodrich estimates that it can then maintain the existing F-22A manufacturing capability in place until December 2011. After that time, all government-owned equipment will be stored in humidity-controlled Conexes outside of the San Marcos facility or another location. In early 2012, the A350 program will begin to use the capacity at San Marcos.

If the Air Force were to restart production of additional F-22A aircraft, the time required for restart would be about one year. The length of time between ordering titanium and completing the first engine-bay door per lot is currently ten months, although this span can change as economic conditions vary. Other Goodrich locations could be considered for a restart of the F-22A program, but tools would have to be procured and funded by Goodrich. Furnaces alone have a 64-week lead time and require an in-depth qualification process.

Thin Film Technology, Inc., Buellton, California

TFT processes the F-22A integrated forebody (radome). After LM Palmdale produces the integrated forebody, it is shipped to TFT for metal deposition, a capability unique to TFT. Equip-

¹ Insurance spares are items purchased by the Air Force (1) in excess of known production requirements, (2) that may be needed in the future for aircraft repairs, and (3) for which a future production source is unlikely. The purchased items would be stored until needed.

ment used in the process can be reconfigured for other uses, but personnel expertise in using the deposition process is critical. Reject rates have been reduced over time but are still a challenge due to the complexity of the deposition process. Production capability is unlikely to be readily reconstituted, and TFT will not be providing support to the F-35. However, TFT will remain open and reconfigure its test chambers for commercial work, and F-22A tooling will be stored in case it is needed. TFT plans to make its last delivery in August 2011, but the production of insurance spares, currently being negotiated, could extend production to August 2012.

The UCD McClellan Nuclear Research Center

UCD performs neutron ray (N-ray) inspection of the F-22A rudder actuator housing, a thick-walled titanium casting. This N-ray is used to find shell inclusions (casting abnormalities) that can lead to fracture of the structural part. There are no other reactors with test bays in the United States large enough to handle this part, and the process requires very specialized and certified personnel. The loss of this critical and unique inspection capability will lead to an inability to inspect additional rudder actuator housings for shell inclusions because there is no other known similar industry capability. This loss could result in life-limiting future rudder actuator housings (i.e., replacement parts would have a shorter installed life). The last rudder actuator housing was scheduled to be inspected in June 2010.

There are three options for preserving the UCD N-ray inspection capability. The first is to purchase a lifetime buy of spare Vertical Stabilizer Assemblies (VSAs). The rudder actuator housing is an embedded component of the VSA and is not removable. Analyses are under way to determine whether additional VSAs should be procured before UCD shuts down its inspection capability. The second option is to retain key personnel until sustainment needs are determined. The funding required would be an estimated \$300,000, which would retain reactor operators and radiographers at UCD for a period of one year (August 2010 through August 2011). Workforce resources at PCC Structural (the fabricator of the casting) may require recertification and training at a projected cost of \$40,000. The third option is to let key personnel go and to retrain them in the future. The funding required would be an estimated \$175,000, and personnel recertification would take 12–18 months. If a sustainment need is not determined by December 2010, some certified and specialized personnel will be released from employment. The reactor may be shut down if other commercial business is not found.

GKN North America, St. Louis, Missouri

GKN North America manufactures the F-22A's horizontal stabilators and other machined and composite parts. It is the largest supplier of resin transfer molded (RTM) parts for the F-22A, and it has unique RTM processes for injection and clamping pressures. The St. Louis facility also houses unique cutters, large presses, monument tools, and composite tooling. The company plans to end RTM fabrication capabilities in December 2010 after producing parts for the last F-22A. It will then transition to other business opportunities. The technology is not so unique that other manufacturers could not be qualified, but there would be time and cost penalties associated with re-creating the capability elsewhere.

Summary

Table 5.1 summarizes all five critical-supplier issues. Although each vendor has a unique capability that would be lost at shutdown, this does not preclude an F-22A restart. However, upon restart, sufficient lead time and funding would have to be made available to set up similar capabilities.

Table 5.1
Summary of Critical-Supplier Issues

Supplier	Importance to F-22A	Last Delivery	Capability-Loss Driver
GKN Chem-tronics	EB welding processes	September 2010	Facility shutdown
Goodrich	Unique fabrication process for engine-bay doors	October 2010	Equipment repurposed
TFT	Unique coating process for integrated forebody	August 2011	Equipment reconfigured/ personnel expertise lost
UCD	Unique process for inspecting rudder actuator housing	June 2010	Possible facility shutdown
GKN North America	Largest RTM part supplier	December 2010	Equipment repurposed

Conclusions

The production-shutdown process of the F-22A has begun and will continue long after the last aircraft delivery in early 2012. As part of the process, just under 40,000 unique government tools will have to be dispositioned—kept to meet sustainment requirements, kept for possible use in a production restart, or disposed of as expeditiously as possible. As shown in Chapter One, the process of making these decisions is complex and lengthy and must be done with great care so that tooling is not prematurely disposed of should unforeseen needs arise.

The Tooling Plan and Additional Funding

Chapter Two summarizes how the Air Force plans to proceed with F-22A tooling disposition at the prime contractor and supplier sites. Tooling that is not being actively used for F-22A sustainment, such as for spares production, could be stored in Conexes at the primes' locations or at off-site storage facilities. The advantages of the *shutdown and retain* option are that

- It preserves the option to restart production at reduced cost at a future date.
- It keeps all the tooling until better data become available about which tooling is required for sustainment.
- It eliminates the risk of premature disposal of tooling that might be required later for SLEP or major repairs.
- It eliminates the need for temporary storage of 9,800 production-only tools immediately following the end of current production.
- It allows for the ultimate disposition of tooling to be made over a longer period, which would level the workload of government and contractor personnel over several years.

The disadvantage of *shutdown and retain* is the differential cost of retaining all tooling rather than just the tooling identified for sustainment purposes. This would entail an estimated \$17 million in additional nonrecurring costs over FY 2011–FY 2013 and about \$150,000 annually for storage and maintenance. In terms of the overall F-22A program, these are relatively small amounts (about 9 cents on the dollar of the initial acquisition cost of the production-only tools), but they nonetheless represent expenditures on tooling preservation for some tools whose likelihood of future use is low unless further Air Force production or FMS of the F-22A is anticipated.

The Cost of Restarting Production

Estimates of nonrecurring and recurring costs for restarting production of 75 F-22A aircraft range from \$16.9 billion (if funds are made available to restart production in FY 2011) to \$17.8 billion (if a complete shutdown occurs).

Contract Modifications and Facilities

In terms of contract activities, there are no significant impediments to storing all government-unique tooling or even to restarting production in the future. Any of these activities should be permissible within the current Federal Acquisition Regulation and DoD contracting guidelines.

Beginning in FY 2011, vacated factory space at the LM Fort Worth site would have to be found to restart production. If a complete shutdown in F-22A production occurs, additional replacement space would also be required for the vacated space at the Boeing Puget Sound site, as would a replacement for the CAN facility at the P&W East Hartford site. In addition, several of the critical suppliers identified in Chapter Five would have to be replaced, or their capabilities would somehow have to be resurrected.

Future Uncertainties

The assessments in this report are a snapshot in time as of February 2010. The Air Force and its contractors are currently conducting thorough analyses required to support a final decision on all tooling, so tooling classified today as production only could eventually be categorized as required for sustainment (or vice-versa) as the F-22A fleet matures and experience is gained through more flying hours. The fleet is not projected to achieve the 100,000-hour milestone until sometime in 2011.

As time passes, however, restart will become more difficult because more and more companies will decide to shed their F-22A tooling and equipment or even leave their current line of business. In addition, changes made to the F-22A design as a result of modernization efforts would have to be incorporated into any restart activities. These costs, combined with the likelihood of a restart, will play a role in deciding whether retention of production-only tooling strictly for restart purposes is cost-effective.

Another factor in the tooling-retention decision is the importance of the F-22A to the fighter force structure, especially in terms of the high-end capabilities it provides. The traditional approach to deciding whether to repair an aircraft that has experienced extensive battle or accident damage involves assessing the repair cost, the tooling availability, and the importance of the damaged aircraft to the force structure. Analyses performed today may not anticipate the full range of possibilities of damage (and associated tooling requirements) that might affect one or more aircraft, and unforeseen SLEP needs may arise. The F-22A may represent a new paradigm wherein, because of its small force structure (each aircraft represents almost 1 percent of the operational F-22A fleet), high capabilities, and high cost, investing more in repairs than has been usual for traditional aircraft may be desirable in the future, provided that tooling is readily available.

Types of Tooling

This appendix describes the types of tooling and equipment found in the production of military hardware and supplies the definitions used in this report. Tooling is either paid for and owned by the government or paid for by the contractor. In the latter case, the contractor's costs are reflected in the overhead costs charged to the program.

Government-Funded Tooling¹

Special tooling. This includes jigs, dies, fixtures, molds, patterns, taps, gauges, other equipment and manufacturing aids, and all components of these items that are of such a specialized nature that, without substantial modification or alteration, their use is limited to the development or production of particular supplies or parts thereof or to the performance of particular services. It does not include material, STE, facilities (except foundations and similar improvements necessary for installing special tooling), general or special machine tools, or similar capital items.

Special test equipment. This includes either single or multipurpose integrated test units engineered, designed, fabricated, or modified to accomplish special-purpose testing in performing a contract. It consists of items or assemblies of equipment, including standard or general-purpose items or components, that are interconnected and interdependent so as to become a new functional entity for special testing purposes. It does not include material, special tooling, facilities (except foundations and similar improvements necessary for installing special test equipment), and plant-equipment items used for general plant-testing purposes.

Right-to-title tooling. This includes tooling fabricated or procured under a fixed-price contract and to which the government can claim title.

Agency-peculiar property. This includes government-owned personal property that is peculiar to the mission of one agency (e.g., military or space property). It excludes government material, STE, special tooling, and facilities. APP may be furnished to contractors when necessary for use as a standard or model, for testing the contractor's end item (when suitable commercial equipment is not available), to establish equipment compatibility, or for other reasons that the contracting officer determines to be in the government's interest.

¹ This section is based on provisions of the Federal Acquisition Regulation, Subparts 45.101 and 45.306, October 1, 2010.

Contractor-Funded (Capital) Equipment

This includes equipment items, such as machine tools, furniture, test equipment, vehicles, and accessory and auxiliary items used in conjunction with government tooling for production of a weapon system. Generally, this category of items is not unique to the production of a specific weapon system, so it is funded by the contractor and depreciated, with depreciation charges applied to any production for which such equipment is used.

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