

Learning Like Lightning: Lessons from JSF F-35 Sustainment Activities

Abstract

The U.S. Air Force, Navy, and Marine Corps launched a trillion dollar program in 2001. This program has since been restructured several times. A recent study by the U.S. Government Accountability Office detailed critical needs for this program to succeed.

This article derives lessons learned from the F-35 program. The author highlights five key financial management lessons about business cases and projects that are applicable to small organizations and large.

In 2001 United States Air Force, Navy, and Marine Corps launched a \$1 trillion program to develop the F-35 Lightning II family of single-seat, single-engine, multirole fighter aircraft. This combat aircraft is designed to perform ground attack, aerial reconnaissance, and air defense missions. Its development is funded principally by the United States with participation from the United Kingdom, Italy, Australia, Canada, Norway, Denmark, the Netherlands, Turkey, and other countries.

The US Government Accountability Office (GAO) issued a report on the program in September 2014. This report, *F-35 Sustainment: Need for Affordable Strategy, Greater Attention to Risks, and Improved Cost Estimates*, to the Committee on Armed Services, House of Representatives provides many details about the program's current state, future plans, and management to date. The Joint Strike Fighter (JSF) F-35 Sustainment Report highlights key management control system challenges. The pitfalls noted by the GAO are the same ones encountered by hundreds of organizations, large and small, each year.

This article draws upon the GAO report to highlight some critical factors in financial management today, including risk management, cost estimation, supply chain management, and decision-making on projects.

This cautionary tale isn't intended to bash the hard-working folks involved with the program or to nitpick the GAO report; rather, the findings highlight our challenges as managers and provide guidance on where we should place our efforts and planning—these types of problems aren't easily solved.

The F-35 program's goals were to develop and field more than 2,400 stealthy strike fighter aircraft for the Navy, Air Force, and Marine Corps and potentially several hundred more aircraft for U.S. allies. The F-35 is intended to provide greater capability and to replace the U.S. Department of Defense's (DOD's) aging fighter and attack aircraft. International participation in the development of this system is a vital part of the acquisition strategy.

The F-35 is not only the most ambitious weapon system in DOD's history, but also the most costly.



Exhibit 1, F-35 Program Logo



Exhibit 2, F-35 Drawing

Lesson 1. Begin with the End in Mind

In his best-selling book, *The Seven Habits of Highly Effective People* (1989), Stephen R. Covey identified as a best practice—Begin with the end in mind. This is one of the cornerstones of systems thinking—a critical competency for successful organizations and programs.

The DOD has admitted to a long history of program cancellations and reductions resulting from starting programs that proved to be unaffordable—and yet, in order to be effective, the F-35 program must be affordable. And, it must be affordable for a long time; 66 years in fact as 2066 is the projected retirement year for the last F-35 to be produced. As the timeline in Exhibit 3 indicates, the program must be sustained for 48 years following the end of its 18-year design phase.

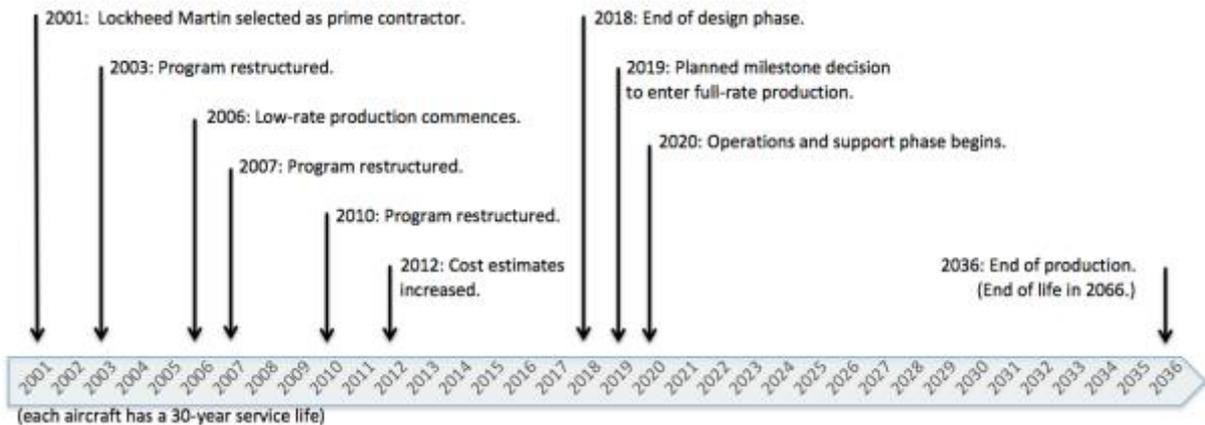


Exhibit 3, F-35 Program Timeline

The GAO pointed in its 2014 report that the program failed to start with the end in mind:

The F-35 acquisition program...began in October 2001...and DOD has only recently begun to focus on how it will sustain the nearly 2,500 aircraft it plans to procure.

Lesson 2. Measurement Inversion Happens, Manage It

Product design/development requires a great deal of planning. It also requires a great deal of information. Information, like the end-products of projects, must be designed and developed. This, too, requires careful planning.

Unfortunately, many projects suffer from what has been termed, the measurement inversion phenomenon. That is, in many projects, the effort to develop needed information tends to be earliest for the information that has the lowest potential to make a difference—and the information that holds the greatest potential make a difference is developed last.

The human side of project management—addressing potential behavioral issues—is critically important. Eli Goldratt (1997) drew attention to the “student syndrome” of procrastination in projects. Specifically the student syndrome is the tendency for humans to start tasks later than they might, wasting time buffers (safety margins). Goldratt recommended certain methods, “critical chain project management,” for addressing this tendency.

Similarly, Douglas Hubbard (2014) has written of his experience with projects, noting an ironic pattern in information development, one that he has labelled “measurement inversion”:

the variables that clients used to spend the most time measuring were usually those with a very low (even zero) information value (i.e., it was highly unlikely that additional measurements of the variable would have any effect on decisions)... In a business case, the economic value of measuring a variable is usually inversely proportional to how much attention it gets.

Like most laws governing human behavior, the tendency toward measurement inversion can be overcome by concerted action. Hubbard’s antidote to the measurement inversion paradox is to look ahead first, estimating the value of measurements. Two measurement issues are notable for the F-35 program: cost estimation and affordability assessment.

Noting that F-35 program managers failed to begin with the end in mind, the GAO provided evidence that program managers had avoided measurement inversion in its cost estimation by tackling contractor and sustaining support estimates after operating and maintenance estimates.

Contractor and sustaining support represent less than 20% of total projected costs; operating and maintenance costs nearly three-quarters (71%) as shown in Exhibit 4. Until 2013 program managers focused primarily on the operating and maintenance costs while leaving the contractor and sustaining support activities for later.

While GAO has pointed out some flaws in operating and maintenance cost estimates, these received the most attention early in the program—consistent with managing the program to avoid “measurement inversion.”

Total Estimated Operating & Support Costs

Then-year dollars in billions

Operating costs	\$ 381	42%
Maintenance costs	270	29
Indirect support for operators	106	12
Contractor and sustaining support	159	17

Source: GAO analysis of program office data developed in 2013

Exhibit 4, Total Estimated F-35 Program Operating & Support Costs

As to assessing the affordability of the F-35, the program seems to have suffered from measurement inversion.

The key objective of the program acquisition strategy is affordability--reducing the development, production, and ownership costs of the program relative to prior fighter aircraft programs (United States General Accounting Office, 2000). And yet the DOD has only recently begun numerous efforts to plan for program support activities. The strategy for supporting the program may not be affordable—and aircraft production has already begun. The late start on affordability planning remains an area of critical concern—for program managers, current customers, and for potential customers.

In 2012, DOD established affordability targets for the program, stating that the cost per flying hour for the Air Force, Marine Corps, and Navy F-35 variants could not exceed \$35,200, \$38,400, and \$36,300 respectively. However, DOD officials...stated that they believe that based on this threshold, the program is not affordable. To address increasing costs, DOD has taken steps focused on cost reduction including, but not limited to, establishing a Cost War Room in 2013.... The Cost War Room is a collaborative group...established with the purpose of reducing costs and providing support for transitioning to performance-based logistics....However, it is unclear whether these cost-saving measures can result in an affordable approach to the long-term operations and sustainment of the F-35 because the established affordability targets that must be achieved may not be representative of what the services can actually afford.

The DOD began the F-35 program in 2001. Eleven years later in 2012, the DOD established affordability targets and quickly determined that, based upon the targets, the program is not affordable.

The most important decisions regarding the F-35 program have been go/no-go decisions and suitability of the design. Yet, important information about these decisions has been late in coming—developed many years after the program began.

About 80% of all costs are committed by the time a product's design is completed. The F-35 design phase is scheduled to conclude in 2018. If the 80% of lifecycle costs are determined by that time, then the program's affordability will have been largely determined.

Recently taking on the affordability challenge in a disciplined, structured manner, program managers are reporting successes. *Defense News* reported in March 2015:

A spokesperson for the F-35's Joint Program Office said the team has taken "a disciplined approach to analyzing and reducing sustainment costs. Ongoing activities include conducting a sustainment business case analysis and operating a cost war room to find program savings and attack operational, sustainment and total ownership costs."

Lorraine Martin, F-35 program manager at Lockheed Martin, said in a statement that the company is "extremely pleased with the nearly \$60 billion

decrease in operations and support costs of the F-35 program during the last year alone." Martin added that there are numerous other initiatives in place, "including the Blueprint for Affordability, that will drive program costs even lower...by the end of the decade."

In 2013 a Cost War Room was established; cost reductions are being reported. In the interim, though, potential customers have been put off by concerns about affordability. The hope now is that the effort is not too late.

Lesson 3. Don't Set Arbitrary Targets and Then Manage to Them

In his 1986 book, *Out of the Crisis*, Edwards Deming laid out 14 key principles for managing.

Deming's Point 11: Eliminate arbitrary numerical targets

Eliminate work standards that prescribe numerical quotas for the workforce and numerical goals for people in management. Substitute aids and helpful leadership; use statistical methods for continual improvement of quality and productivityⁱ.

Point 11 reflected three key ideas that relate to his other principles:

- Most variation in the capability of a system results from common causes and is the result of the normal random variation present in all processes. Reducing common-cause variation can only be achieved by changing the system.
- If the system is stable (and only common-cause variation exists), specifying numerical targets is useless because the system will deliver whatever it delivers. On the other hand, if the system is unstable, predicting what it will deliver is problematic.
- It is useless to specify a goal without developing a method for achieving it.

This third idea is key in understanding DOD's shortcoming on the F-35 program. DOD officials stated their view that deriving affordability targets from budgets would serve to focus the program. However, two years after DOD set the targets, GAO found no evidence indicating improvement resulting from the focus.

When the DOD established affordability targets for the F-35 program in 2012, the methodology for determining that threshold was not informed by actual resource constraints within service budgets at the time. Specifically, DOD officials stated that the targets were determined by arbitrarily lowering...estimated F-35 Cost per Flight Hour by 10 percent. However, without informed affordability constraints, based on military service budgets, DOD cannot be sure whether the costs savings it achieves through current efforts will lead to an affordable sustainment strategy, and DOD may miss additional areas for savings.

"Informed affordability constraints" would result from specifying goals with methods for achieving them. That is, rather than arbitrarily lowering cost per flight hour estimates, the DOD would have been better off determining—as it has now begun—how it will achieve affordability.

Lesson 4. Develop Adequate Information Before Making Decisions

Planning to do but not planning to decide can cripple a project.

In John Boyd's (1987) observe-orient-decide-act loop and in W. Edwards Deming's (1993) plan-do-study-act cycle, deciding precedes doing; decision-making precedes taking action. Planning efforts in projects often focus on actions alone rather than decision-making and actions. When planning emphasizes acting and overlooks decision-making, problems follow. The GAO identified this shortcoming in the F-35 program:

We have reported on F-35 issues for many years. Over time we have reported significant cost, schedule, and performance problems and have found that those problems, in large part, can be traced to (1) decisions made at key junctures without adequate product knowledge; and (2) a highly concurrent acquisition strategy with significant overlap among development, testing, and manufacturing activities.

Enormous effort has gone into planning the design, production, and deployment of the F-35. And, the F-35 is flying. So, much of the planning has been successful.

What the GAO is pointing out here is that planning has been inadequate for decision-making. That is, the Program leaders failed on more than one occasion and at key points to produce adequate information with which to make informed decisions.

Just as physical parts and software are the materials used in producing aircraft, information is the material used in making decisions. GAO charged that program managers failed to plan adequately to have important knowledge available when needed.

One might argue that such errors may be more costly than errors in planning to have physical parts ready for assembly—because of the human tendency to go ahead with decision-making, even in the absence of adequate knowledge.

Lesson 5. Use Interval Rather than Point Estimates

Although the use of intervals (range) estimates as a means to address the risk of underestimating or overestimating costs has been promoted for many yearsⁱⁱ, the practice of presenting cost estimates as single values rather than as ranges of probable values remains quite common. Molenaar (2005) collected survey questionnaires from seventeen agencies about transportation capital projects ranging from \$2 to \$234 million and found that 15 (88%) presented project cost estimates as single values. Akintoye & Fitzgerald (2000) found similarly; most UK construction contractor companies chose not to use range estimating based on probabilistic techniques.

The GAO criticized the F-35 program for providing point estimates without intervals:

The GAO Cost Estimating and Assessment Guide states that risk and uncertainty analyses should be performed to determine the level of risk associated with the estimate. [Program office] cost estimators have not conducted uncertainty analyses to understand the potential range of costs around their point estimates and to convey their level of confidence that the estimates reflect the most likely costs. [Program office] officials stated that they did not conduct uncertainty analyses because they are not a standard practice for DOD when creating...cost estimates. However, according to the GAO Cost Estimating and Assessment Guide, an estimate without a risk and uncertainty analysis is unrealistic because it does not assess the variability in the estimate.

Program officials, through 2013, performed sensitivity analyses but did not provide interval (range) estimates of costs.

Upon receiving the GAO critique, the DOD concurred with the recommendation to conduct uncertainty analysis on future operating and support cost estimates; it intends to conduct risk and sensitivity analysis in future updates (Peters, 2014). When it does so, the DOD will be leading others in “best practice” cost estimation and following the DOD’s high tradition in acquisition planning that began in the mid-1950s.

Lessons Learned from F-35 Lightning II Program

- Begin with the End in Mind
- Measurement Inversion Happens, Manage It
- Don’t Set Arbitrary Targets and Then Manage to Them
- Develop Adequate Information Before Making Decisions
- Use Interval Rather than Point Estimates

Exhibit 5, Management Control Lessons Learned from F-35 Program

Conclusion

In 2001 Lockheed Martin, the US Department of Defense and others began development of the F-35 program. This bold program was and remains massive in scope and scale. Its successes and shortcomings provide excellent examples, highlighting key financial management considerations—for similar programs and for organizations in general.

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ⁱ The wording for Point 11 has been taken from Henry R. Neave, *The Deming Dimension* (1990). See Roehm & Castellano (1997) for a discussion relating Point 11 to other principles espoused by Deming.

ⁱⁱ For recommendations of using range estimates, see for examples, Sobel (1965) and Curran (1989).

List of Exhibits

- Exhibit 1, F-35 Program Logo
- Exhibit 2, F-35 Program Photo
- Exhibit 3, F-35 Program Timeline
- Exhibit 4, Total Estimated F-35 Program Operating & Support Costs
- Exhibit 5, Financial Management Lessons Learned from F-35 Program