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**Case Study: Mission Capacity and Life Cycle Cost Analyses
for New Fighter Aircraft, F-XX**

by

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Abstract

This case is intended to illustrate key trade-offs in planning the acquisition of a major weapon system. In particular, the impact of logistics and maintenance decisions on life-cycle costs and readiness are examined. The case provides sufficient data to allow a rich discussion of issues and trade-offs—without being overwhelming. The case raises strategic policy issues but provides an analytical framework and data so that the policy issues can be discussed in detail, and not merely with generalities.

Logistics and maintenance issues examined within the case include the spare parts service levels and reliability of major components, depot and preventive maintenance turnaround times, as well as planning for exogenous factors such as variability in the price of petroleum, oil, and lubricants. By examining a set of related decisions simultaneously, the case allows students to explore the relative leverage of logistics and maintenance decisions on cost and readiness. By examining endogenous as well as exogenous factors, the case allows students to examine the impact of factors within the control of program managers as well the impact of factors beyond their control on budget and readiness risk. The intent of the case is to move beyond planning simple budget and readiness targets and to encourage students to discuss methods of robust *contingency* planning.

Specific learning objectives include

an understanding of the life-cycle cost implications of logistics and maintenance decisions,

an understanding of the readiness implications of logistics and maintenance decisions,

an understanding of the trade-offs between life-cycle cost and readiness,

an understanding of the implications of logistics and maintenance factors on readiness risk, and

an understanding of the implications of logistics and maintenance factors on budget risk.

The development of this case was supported by the Naval Postgraduate School. This case was prepared by Dr. Keebom Kang and Dr. Kenneth Doerr for use in Dr. Kang's Logistics Engineering class at the Naval Postgraduate School. A teaching note is available for instructors at educational institutions by requesting a copy from Dr. Kang.

Keywords: life-cycle cost analysis; major weapon system; risk analysis on readiness and budget, spare parts critical protection levels; inventory fill rates; reliability, availability and maintainability (RAM); logistics and maintenance factors

Introduction

Given the looming controversies over the Joint Strike Fighter (JSF), a small group of naval acquisition mavericks began meeting in secret to discuss the development of an alternative aircraft that would incorporate many of the state-of-the-art technologies of the JSF but would be dedicated to the narrower missions of the Navy and Marines. Unlike past design projects, the aircraft would have cost targets, and especially ownership cost targets, as a primary design criteria. The secret group called themselves *the F-Team*, reflecting either their focus on fighter aircraft or the grades they received in graduate school.

Knowing that the project would be doomed to failure without the design and manufacturing support that industry could provide, the F-Team used its contacts in the Aerospace Industry Association (AIA) to reach out to like-minded individuals from multiple defense companies. These defense company engineers were dedicated to rescuing the tarnished image of their profession by developing a design for an affordable, state-of-the-art aircraft in record time. They took as their role model the North American Aviation team that had designed and built the P-51 Mustang aircraft prototype (arguably the best American fighter aircraft in World War II) in 100 days.

The F-Team had assembled the skills it needed for its project, but it still needed development funding. It knew that seeking funds through official channels would kill the project. The AIA professionals needed resources. The F-Team needed \$2 billion in a hurry. It was then that Bill Gates came to his nation's rescue. Retiring from Microsoft, he secretly hired an actor to play the part of CEO so that he could pursue his dream of helping the nation's defense. Under the guise of a humble business school dean at the Naval Postgraduate School, the "real" Bill Gates devoted his considerable business acumen to managing the secret project, funded with his own wealth.

The project has now reached a critical stage, and it is time to go public with a business plan that the nation's civilian and defense leaders can review. In this hour of need, Dean Gates has reached out to your project group (which, for some reason, he



has dubbed *the D-Team*) to develop the business case analysis to be submitted for public scrutiny. Defenders of the status quo will be merciless in their review of your work. Your analysis must be thorough, precise, and exhaustive. The nation's future may depend on how you perform this task.

The data you need are all described as follows. You must use this data to predict yearly costs and life-cycle costs for the new aircraft. The public is weary of cost overruns on projects like these, so you must not only project a budgeted life-cycle cost but also assess the risk that the projected cost will be exceeded.

Although the technical design of the aircraft is complete, several design alternatives are still available for critical components. They involve, for example, the ability to invest in more expensive materials in order to reduce wear on a component, and hence, lengthen the mean time between failures (MTBF) for those components. Also, design of the logistics support process is not complete. Key decisions such as the proper spare-parts inventory level for critical components must still be made. Dean Gates looks to your project group, as logistics experts, to complete the design of the support processes for the aircraft.

Typically, a small number of components contribute to most of the major logistics costs and degradation of readiness. For this case study, you will consider only six components (as shown in the next section) for life-cycle cost and operational availability computation, assuming that these are major readiness degraders and high-cost items.

With the logistics process and key component reliability still in play, life-cycle costs of course cannot yet be determined. It will be possible to reduce up-front costs—and possibly life-cycle costs—by reducing reliability and availability of aircraft. So, your analysis must not only examine life-cycle costs but also reliability and, hence, the availability of the aircraft. But you must keep in mind that planning for military operations will assume a certain guaranteed level of availability for this aircraft. You must set that “planning threshold” for operational availability and also assess the risk that aircraft availability will fall below this threshold.



The F-XX

The new aircraft that the F-Team has designed is code-named *the F-XX*. It is a single-pilot, single-engine weapon system. Its mission profile is classified. The F-XX program life cycle is estimated to be 35 years (beginning in the current year), with an operational life of 30 years (beginning four years from now). As aircraft are brought into service and lost (attrited), the effective operating life of a single aircraft will average 27 years.

The following three life-cycle cost categories should be covered in your analysis:

1. Acquisition and Research, Development Test and Evaluation (RDT&E)
Squadron Stand-up and Phase-Out and Disposal Cost & Salvage Value
2. Personnel Requirements and Training Costs
3. Operations and Maintenance (O&M)

All dollar values that appear in this case study are in current-year constant dollars. The current year is designated FY00, the next year is designated FY01, and so forth.

Research, Development Test & Evaluation (RDT&E) and Acquisition Costs; Squadron Stand up and Phase out and Disposal Cost/Salvage Value

<u>RDT&E Costs:</u>	FY00	\$150,000,000
	FY01	\$175,000,000
	FY02	\$200,000,000
	FY03	\$200,000,000

Initial year RDT&E costs can be taken as a constant. Subject matter experts estimate that later-year costs may vary by as much as 10%.



Acquisition Cost:

Acquisition Time Line:	Begins in FY03 (F-XXs will be fielded in the year following their production).
Total Aircraft Acquired:	96 aircraft
Annual Acquisition:	24 aircraft
Unit Acquisition Cost:	\$50,000,000
Support Equipment	\$20,000 per aircraft

Each copy of the F-XX has an average unit cost of \$50 million. Support equipment costs \$20,000 per aircraft. These one-time costs are incurred when the F-XXs are phased into the squadrons.

Your life-cycle cost model does not need to incorporate factors such as reductions in unit cost attributable to learning curve theory and economies of scale, nor does it need to consider potential cost overruns due to change orders later in the life cycle. The \$50 million unit cost is the best-estimate average unit cost of all F-XX aircraft produced across the life cycle, accounting for those factors.

If the F-XX production line closed and were reopened later in the life cycle, it would likely incur significant setup cost. However, it is reasonable to assume that the production will be open for many years, since these aircraft will be sold to allied countries in the future. (See the Squadron Stand up and Phase Out Plan section.)

Squadron Stand up and Phase out and Disposal Cost/Salvage Value

The F-XX squadrons will be stood up and phase out two squadrons at a time with the following time line:

Stand up:	FY04: 2 squadrons/12 aircraft each (24 total)
	FY05: 2 squadrons/12 aircraft each (24 total)
	FY06: 2 squadrons/12 aircraft each (24 total)
	FY07: 2 squadrons/12 aircraft each (24 total)



Decommission: FY31: 2 squadrons/12 aircraft each (24 total)
FY32: 2 squadrons/12 aircraft each (24 total)
FY33: 2 squadrons/12 aircraft each (24 total)
FY34: 2 squadrons/12 aircraft each (24 total)

Note that the acquisition and maintenance costs of the training aircraft will not be included in the case study.

We assume that all aircraft will be in full operational mode at the beginning of the fiscal year when a squadron stands up; for example, 24 aircraft will be in operation in FY04 for the entire year. We also assume that the aircraft will be decommissioned at the end of the fiscal year.

As squadrons stand down, the assigned aircraft will be sold to foreign military sales (FMS)–eligible countries. The expected salvage value of each aircraft is \$12.5 million, 25% of the average procurement unit cost. The salvage value as well as disposal costs, if any, will be realized at the time of decommissioning. Classified weapon systems will be removed before the FMS sales. This disposal cost is estimated to be \$250,000 per aircraft.

An attrited aircraft will be replaced as needed at a future time. The average attrition rate is estimated to be approximately 2% per year.

Personnel and Training Requirements and Costs

The F-XX aircraft system will be set up with eight squadrons. Two squadrons on each coast of the continental U.S. (CONUS), and one squadron each for the Pacific, Indian, Mediterranean, and Atlantic Oceans will be stood up to accommodate the new system. Each squadron will have a total of 12 aircraft.



Personnel requirements and costs are as follows:

Pilots and Ground Support Personnel (per squadron):

- 17 Pilots
- 4 Ground Support Officers
- 16 Non-commissioned Officers (NCOs)
- 176 Enlisted

Headquarters Personnel (per squadron):

- 2 Commanding Officer (CO) and Executive Officer (XO) (both are pilots)
- 1 Administration Officer (non-pilot)
- 2 NCOs
- 4 Enlisted

Average Personnel Cost per Year (cost to the DoD):

- | | |
|------------------|-----------|
| - Pilot Officer | \$180,000 |
| - Ground Officer | \$160,000 |
| - NCO | \$110,000 |
| - Enlisted | \$60,000 |

See http://www.defenselink.mil/comptroller/rates/fy2013/2013_k.pdf for the DoD standard composite pay that includes standard benefits (housing, food, medical, etc., not including re-enlistment bonuses, combat pay, etc.).

All F-XX personnel will require both basic and advanced levels of training. To meet the requirements to fill an assigned billet, each person must be fully qualified in accordance with the designated classification code and pilots must complete all levels of flight training. The squadron CO and the XO are both pilots. It is assumed that these two senior officers (CO and XO) have previously completed basic flight training and that they only need to go through the advanced pilot training. They also will take headquarters (HQ) basic and advanced training.



The annual personnel attrition rate is 20%, and additional personnel must be trained due to attrition. The initial training will start one year prior to squadron activation, and the training program will be closed by the end of FY30. The personnel attrition rate at the beginning of the life cycle would be lower than 20%, but we will assume a flat rate of 20% per year once the initial training cycle starts. Required training time and costs are as follows:

Pilots and Ground Personnel

	<u>Basic</u>	<u>Advanced</u>
Officer		
Pilot	36 weeks	12 weeks
Ground	12 weeks	2 weeks
NCO	12 weeks	2 weeks
Junior Enlisted	24 weeks	24 weeks

Headquarters Personnel

Basic Administration Training (Officers, NCOs, enlisted): 10 weeks

Advanced Administration Training (Officers and NCOs): 3 weeks

Training Costs

Basic Training:	\$2,000 / person / week
Advanced Training:	\$3,000 / person / week
Pilot Basic:	\$11,000 / person / week
Pilot Advanced:	\$11,000 / person / week

Operations and Maintenance (O&M)

Operations

F-XX Flying Hours per Aircraft 40 hrs/month, or 480 hrs/year

Operating Cost including Petroleum, Oil, and Lubricant (POL)

\$2,000 per flying hour



Corrective Maintenance (CM)

The MTBF, cost, and required protection level (spare fill rate, or customer service level) for some of the major components are as follows:

Component Name	MTBF	Criticality	Protection Level	Unit Cost
APU	250	Non-Critical	0.85	\$100,000
GEN	400	Critical	0.95	\$ 250,000
PAS	1000	Critical	0.95	\$ 400,000
AC	1000	Critical	0.95	\$ 500,000
LG	500	Critical	0.95	\$ 400,000
ENG	500	Critical	0.95	\$ 2,000,000

APU: Auxiliary Power Unit

GEN: Generator

PAS: Phased Array System (Radar)

AC: Avionic Computer

LG: Landing Gear

ENG: Engine

Management of spare parts will be on a one-for-one exchange at the squadron level (organizational level, or O-level). It takes two days to swap the failed component with a spare part, if the part is available. For a critical component failure, the aircraft will be grounded until a ready-for-issue (RFI) spare part becomes available. A failed component is sent to the Navy depot or contractor-managed depot for repair. The required O&M factors are as follows:

Each squadron's activity has start-up fixed costs, which are incurred at \$10,000,000 per activity prior to squadron activation. Additionally, operating variable costs, which are estimated at \$5,000,000/year per O-level activity, are incurred for each year that a squadron is operational.



Transportation Cost:	\$200 per failure
Spare Inventory Carrying Rate:	15% of spare value per year
Spare Parts Service Levels Levels (Protection Levels)	
Critical Units	95%
Non-Critical Units	85%
Repair Turnaround Time (TAT)	40 days
Depot-Level Repair Costs	\$5,000 per repair
O-Level Activation	\$10,000,000 for each O-Level activity
O-Level Operating Costs	\$5,000,000/yr per squadron

Some uncertainty remains in certain O&M factors. Engineers from F-Team have proposed alternatives that involve additional up-front investments that can potentially lower turnaround times and increase MTBF for critical components to improve readiness and reduce the life-cycle cost.

Preventative Maintenance (PM)

Cost	10% of aircraft acquisition cost
Interval	5 years
TAT	90 days

Mid-life Component Improvement Plan (CIP)

Mid-life CIP	Begins in FY18 2 squadrons per year
CIP Costs	25% of aircraft procurement cost + 4% of aircraft procurement cost for engineering RDT&E
Interval	Scheduled once during the life cycle per aircraft
TAT	90 days

Case Questions

1. What happens to the readiness and LCC of the F-XX Program if operating cost increases to \$3,000 per hour from the current price of \$2,000?
2. What happens to the readiness and LCC if one of the components fails more often than advertised and the MMBF for that component drops down to 20% of the target value due to major design flaws?
3. What happens to the readiness and LCC if the assumed depot repair turnaround times take three times longer than planned?
4. What happens to the readiness and LCC if the assumed preventive maintenance (PM, or overhaul) turnaround times take three times longer than planned?
5. Estimate the life cycle cost using the real annual discount rates ranging between 1 – 15% per year, respectively, and discuss what rate should be used for this project.
6. Estimate the cost risk (e.g., the probability that the NPV of LCC of the program exceeds a certain threshold value) and the mission-readiness risk. First, try with the Crystal Ball built-in distributions embedded in the spreadsheet model. Then change or add some distributions and try one more time.
7. If the Boss wants to cut down the critical spare parts service level from 95% to 85% to save inventory cost, describe what might happen to the readiness and LCC after considering the vicious cycle of the operational availability, reliability and the maintenance downtime as discussed during the class. Develop a hypothetical scenario to illustrate the impact.
8. The sequestration has arrived, and requires an average of 5% cut to the NPV of LCC from the base case scenario provided in the spreadsheet. These cuts should be made to minimize the impact on mission capacity. Make some suggestions.