AE 481 Team 01 Assignment 3

September 15, 2025

1 Initial Weight Sizing Code Validation

Validation of the initial weight sizing code was performed using mission parameters and aircraft specifications from the NAVAIR Standard Aircraft Characteristics [1] document for the F/A-18E. Two missions profiles, fighter escort and interdiction, were used as equivalents to the RFP "air to air" and "strike" missions respectively.

Input parameters for aircraft geometry and engine performance were substituted into the weight sizing code. For the fighter escort mission, the dash mach number was determined to be 1.8 with a combat time of 2 minutes at maximum thrust. The combat radius was set to 475 nm. The payload was 2946 lb. The strike mission was modified for a dash Mach number of 0.9 with a combat dash distance of 100 nm. The combat radius was 388 nm with a payload of 5422 lb.

1.1 Results and Discussion

The takeoff weight predicted by the sizing code for fighter escort was 50300 lb which was the lower than the actual takeoff weight of 58948 lb. The takeoff weight for the interdiction mission was 52950 lb compared to an actual weight of 60769 lb. This suggests that the initial sizing code has a tendency to estimate the aircraft takeoff weight. One significant factor that influenced this was the maximum lift-to-drag ratio estimation code. For the aspect ratio and cruise mach number of the F/A-18E, the code predicted $L/D_{\max} = 12.9$. This is higher than the value of 10 reported in the student guide. If the initial sizing code is modified to have a matching $L/D_{\max}$, the takeoff weight more closely matches the expected results. This means that the $L/D_{\max}$ estimation code may not have the best accuracy, and further emphasized the importance of $L/D_{\max}$ estimation for its influence on weight estimation. The results of the weight estimation code validation are compiled in Table 1.

	Fighter Escort	**Interdiction**
Actual Takeoff Weight (lb)	58948	60769
Predicted Takeoff Weight (lb)	50300	52950
Predicted Takeoff Weight ($L/D_{\max} = 10$) (lb)	61330	60400

Table 1: Takeoff weight estimation is accurate, but is influenced by $L/D_{\max}$.

Using the lower value of $L/D_{\max}$ results in more accurate values of takeoff weight for both missions, which highlights the importance of accurate L/D estimation. An additional change made to the weight estimation code was the empty weight fraction regressions. The custom regression developed by the team resulted in significant underestimates in takeoff weight, around 30000 lb. The Raymer regressions has higher empty weight fractions, which resulted in higher weights. This could be due to the takeoff weight used for the regression. The custom regressions used maximum takeoff weight, which is usually higher than the takeoff weight for typical missions. This is reflected in the higher empty weight fractions in the Raymer regression.

The mission segment analysis code is largely valid since estimated takeoff weights closely match the actual weights for different mission profiles. However, the influence of the empty weight fraction regression and $L/D_{\max}$ indicates the need for more refined analysis later in the design cycle. The continued usage of the Raymer regression is justified since it results in more accurate takeoff weights. Inaccuracies would most likely result in larger weights, which gives a more conservative result for initial sizing.

2 Cost Estimations

The total flyaway cost of the aircraft is estimated to be 113.7 million USD in the year 2025. Inflation is accounted for through a MATLAB function written using data from the U.S Bureau of Labor Statistics Inflation calculator [2].

2.1 Aircraft Cost Estimation

The code used for preliminary cost estimations is based primarily on Roskam Part 8 [3]. The numbers used for pay rates come directly from Raymer [4] and other sources are used to break down costs into smaller subsections. Roskam Part 8 gives us a number of historical regressions to calculate Research and Development Testing and Evaluation (RDTE) costs, manufacturing costs, and profit, which are all implemented in the code to calculate the majority of the financial figures given in the following sections.

2.2 Research and Development Costs

Research and Development unit cost is estimated to be 9.54 million USD in 2025. This cost is estimated using Eq. (1), coming from Roskam Part 8 [3]:

$$RDTE_{unit} = (C_{ead_r} + C_{dst_r} + C_{fta_r} + C_{fto_r}) * (1 + F_{pro_r} + F_{fin_r}) \tag{1}$$

where C_{ead_r} is Engineering and Design Cost, C_{dst_r} is Development Support and Testing, and C_{fta_r} is Flight Test Airplane Cost. F_{pro_r} represents a profit factor and F_{fin_r} represents a financing factor.

2.3 Engine(s)

According to the U.S Department of Defense [5], GE Aircraft Engines provided 110 F414 Engines for a total price 440 Million dollars for the F/A-18 E/F program. The transaction was executed in September of 2012, with each engine priced 4 million USD, now equivalent to 5.64 million USD in 2025. This aircraft will utilize two F414 Engines, resulting in a total engine price of 11.28 million USD per aircraft in 2025.

2.4 Crew and Life Support

Costs are estimated using one crew member. One crew member was chosen, as compared to two crew members, for a lighter and more feasible aircraft design according to the initial weight sizing code.

2.4.1 Crew

Crew cost is estimated to be 2352 USD per flight. This cost is estimated using Roskam [3] Eq. (2):

$$C_{\text{crewpr}} = N_{\text{serv}} * N_{\text{crew}} * R_{\text{cr}} * Pay_{\text{crew}} * OHR_{\text{crew}} * N_{\text{yr}} \tag{2}$$

where N_{serv} is the average number of airplanes of type in service, N_{crew} is the number of crew,R_{cr} is the crew ratio per airplane, Pay_{crew} is the crew hourly rate (115 USD in 2012 or 161 USD in 2025 according to Raymer [4]), OHR_{crew} is the crew overhead rate factor, and N_{yr} is years in active service.

2.4.2 Life Support

Life support cost includes helmets and ejection seats. Other aspects of life support systems were researched, but no credible sources were found regarding cost. Helmets cost 400000 USD per helmet in 2024, according to an article written on the Gen 3 HDMS helmet used in the F-35 [6]. Adjusting for inflation, a pilot helmet is 412002 USD in 2025. According to NAVAIR [7], the average cost of an ejection seat in 1999 was 195000 USD. Accounting for inflation, each ejection seat has an average cost of 379200 USD in 2025. This leads to a total cost of 791202 USD in 2025.

2.5 Oil

According to the U.S Secretary of Defense [8], Jet Engine Lubricating Oil, Grade 1010, has a cost of 14.58 USD per gallon in 2025. A density of 7.2 lb/gal at 15.6°C was derived from Radco Industries [9], an oil lubricant brand trusted by the U.S Department of Defense. The oil will cost 102.63 USD for the air-to-air mission and 72.72 USD per strike mission.

2.6 Fuel

According to the U.S Department of Defense [8, 10] in 2025, JP-5 fuel has a cost of 4.05 USD/gal and a density of 6.8 lb/gal at 15°C. For the air to air mission the aircraft has a fuel weight of 34465 lbs, meaning that a full tank of fuel will cost 20526 USD. For the strike mission, the aircraft has a fuel weight of 32458 lbs, resulting in a full tank of fuel cost of 19331 USD.

2.7 Ordnance

The total cost of ordnance in 2025, 7.41 million USD, comes from the following:

1. Air-to-air mission (6.34 million USD)
   (a) AIM-120C, Quantity 6
   (b) AIM-9X, Quantity 2
2. Strike mission (1.07 million USD)
   (a) MK-83 JDAM, Quantity 4
   (b) AIM-9X, Quantity 2

2.7.1 AIM-120C

According to the U.S Air Force, an AIM-120C costs 386000 USD when the missile first entered service in 1991, which is equivalent to 910,960 USD in 2025. The Department of Defense unclassified budget for 2024 [11] puts AMRAAM cost as 952102 USD in 2023 (1097138 USD in 2025). Given that newer, more expensive versions of the AIM-120C are available and that the Department of Defense budget does not indicate which AMRAAM is being used, 910960 USD is used in the cost estimate.

2.7.2 AIM-9X

The cost of the AIM-9X is determined from the Department of Defense unclassified budget for 2024[11]. The AIM-9X unit cost for the Navy in 2022 was 517144 USD (583243 in 2025). Thus, 583243 USD is taken as the estimate for the AIM-9X.

2.7.3 MK-83 JDAM

The cost of the MK-83 JDAM comes from the cost of the warhead [12], and the cost of the tail kit [13]. According to the U.S Air Force, the cost of the JDAM tail kit is 22000 USD in 2007 [13], and the cost of the MK-83 warhead is 3027 USD in 2001. The total cost for one MK-83 JDAM in 2025 is 40017 USD.

2.8 Avionics

The total cost of avionics is estimated to be 45.36 million USD in 2025, or roughly forty percent of the total flyaway cost. This cost is calculated in the cost estimation code by the weight of avionics, requiring iteration to back out the weight of the avionics to get the final avionics cost. The weight of avionics is found to be 5400 lbs, which includes the 2500 lbs used for both the air-to-air and strike mission in the request for proposals.

2.9 Surface Treatments

Hill Air Force Base [14] reports a 61 million USD contract for corrosion control and paint for 233 F/A-18 aircraft in 1993. In 2025, this results in a price of 136.76 million USD, or 560512 USD per aircraft.

2.10 Airframe Maintenance and Engine Maintenance

Airframe and Engine Maintenance costs are also calculated using methods from Roskam Part 8 [3]. In 2025, direct maintenance costs are calculated using Eq. (3):

$$C_{mpersdir} = C_{N_{serv}} * C_{N_{yr}} * C_{U_{ann_{flt}}} * C_{MHR_{flthr}} * C_{R_{mml}} \tag{3}$$

where $C_{N_{serv}}$ is the average number of airplanes of type in service, $C_{N_{yr}}$ is the years in active service, $C_{U_{ann_{flt}}}$ is the annual flight hours, $C_{MHR_{flthr}}$ is the maintenance man-hours per flight hour, and $C_{R_{mml}}$ is the military maintenance labor rate.

Engine maintenance costs and airframe maintenance costs are separated using an engine maintenance ratio determined from a report written by the Government Accountability Office [15]. This leads to an airframe maintenance cost of 3.13 million USD per mission and an engine maintenance cost of 1.11 million USD per mission in 2025. These costs represent the average cost per mission.

2.11 Airport Fees and Navigation Fees

Airport and navigation fees are not considered in this cost analysis as they are not considered necessary for military aviation. The International Civil Aviation Organization (ICAO) and individual country regulators impose policies on civil aviation fees, but do not mention any military aircraft requirements [16]. Since this aircraft is military and will be aircraft carrier-based, airport and navigation fees are not anticipated.

3 Group Work Split

Person	Work Percentage	Brief Description of Work Done
Michael Chen	15%	validated initial sizing weight code, helped write report
Charles Choi	15%	researched candidate engines, avionics, fuel, surface treatment, and ordnance costs
Cristina Erskine	15%	researched ordnance costs and life support options, documented sources, helped write report
James Gold	20%	researched and wrote cost estimation code, helped write report
Santiago Ramos-Assam	15%	gathered data and documented sources, inflation code, helped write report
Thomas Sheridan	20%	researched and wrote cost estimation code

Table 2: Work Split

References

[1] *Standard Aircraft Characteristics F/A-18E Super Hornet*. NAVAIR00-110AF18-6. Boeing. 2001.

[2] *CPI Inflation Calculator*. 2025. URL: https://www.bls.gov/data/inflation_calculator.htm (visited on 09/14/2025).

[3] Jan Dr. Roskam. *Part 8: Airplane Cost Estimation: Design, Development, Manufacturing and Operation*. Roskam Aviation and Engineering Corporation, 1990.

[4] Daniel P. Raymer. *Aircraft Design: A Conceptual Approach*. American Institute of Aeronautics and Astronautics, 2018. ISBN: 9781624104909.

[5] *F/A-18E/F Super Hornet Aircraft (F/A-18E/F)*. 2012. URL: https://www.globalsecurity.org/military/library/budget/fy2012/sar/f-a-18e-f_december_2012_sar.pdf (visited on 09/14/2025).

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[9] *RADCOLUBE 6081 Safety Data Sheet*. 2022. URL: https://www.radcoind.com/media/SDS-6081-20134-C-2025-08-15.pdf (visited on 09/14/2025).

[10] *Standard Practice Quality Assurance/Surveillance for Fuels, Lubricants and Related Products*. 2016. URL: https://www.dla.mil/Portals/104/Documents/Energy/Quality%20and%20Technical%20Support/E_MilSTD3004_1603.pdf (visited on 09/14/2025).

[11] *Department of Defense Budget Fiscal Year 2024*. 2023. URL: https://comptroller.defense.gov/Portals/45/Documents/defbudget/FY2024/FY2024_p1.pdf#page=112 (visited on 09/12/2025).

[12] *COMMITTEE STAFF PROCUREMENT BACKUP BOOK FY 2001 BUDGET ESTIMATES*. 2000. URL: https://www.saffm.hq.af.mil/Portals/84/documents/FY01/AFD-070223-139.pdf?ver=2016-08-19-115218-627 (visited on 09/12/2025).

[13] *Joint Direct Attack Munition GBU- 31/32/38*. URL: https://www.af.mil/About-Us/Fact-Sheets/Display/Article/104572/joint-direct-attack-munition-gbu-313238/#:~:text=Wingspan:%20GBU%2D31:%2025,68%2C509%20for%20the%20U.S.%20Navy (visited on 09/12/2025).

[14] *1990s: Hill AFB and the Ogden ALC's Navy F/A-18 workload*. 2020. URL: https://www.hill.af.mil/News/Article-Display/Article/2312178/1990s-hill-afb-and-the-ogden-alcs-navy-fa-18-workload/ (visited on 09/14/2025).

[15] *Tactical Aircraft: Operation and Maintenance Spending Varies by System, and Availability Generally Does Not Meet Service Goals*. 2024. URL: https://www.gao.gov/assets/gao-25-107870.pdf (visited on 09/14/2025).

[16] *ICAO's Policies on Charges for Airports and Air Navigation Services*. 2009. URL: https://www.icao.int/sites/default/files/2025-02/9082_8ed_en.pdf (visited on 09/14/2025).