AE 481 Team 01 Assignment 2

September 11, 2025

1 Weight Regressions

Empty weight, maximum takeoff weight (MTOW), and internal fuel weight data was collected for a variety of modern fighter aircraft. This included carrier-based and ground-based aircraft. Weight data was used to fit regressions for empty weight fraction vs. MTOW and internal fuel weight vs. empty weight. The aircraft were also characterized by the number of crew, number of engines, aircraft material, and internal/external ordnance carriage.

1.1 Number of Crew

Fitting regressions on fighter aircraft, separated by crew number, revealed a clear difference in empty weight fraction. Fighter aircraft with 2 crew members tend to trend towards higher empty weight fractions when compared to single crew aircraft (Fig. 1). This can be explained by the extra equipment required for an additional person increasing an aircraft's empty weight. The regressions for fighter aircraft from Raymer [1] have higher fractions while the regression multipurpose fighters from Nicolai [2] is much closer to the new regressions. For initial weight sizing, setting the regression based on crew number is reasonable due to the clear difference in empty weight fraction.

1.2 Number of Engines

Fitting regressions based on the number of engines does not show a conclusive difference in empty weight fraction between aircraft with 1 or 2 engines (Fig. 2). This suggests that an additional engine increases both empty weight and MTOW, resulting in similar fractions. A second engine may result in increased performance which increases MTOW, offsetting the effect of the increased weight. It is important to note that the regression for 2 engines was set to have the same slope as the 1 engine regression. This was due to the original regression resulting in a positive slope, which is non-physical. The method of setting the slope was based on a recommendation from Raymer.

1.3 Composite Aircraft

Information on composite structures in fighter was collected for a subset of the fighter aircraft analyzed. Aircraft that had composite wing and fuselage structures were listed as composite aircraft. Aircraft with little or no composite components were categorized as non-composite aircraft. The resulting regressions indicated nearly no difference between aircraft types (Fig. 3). This is in contrast to the fudge factors provided in Raymer and Nicolai.

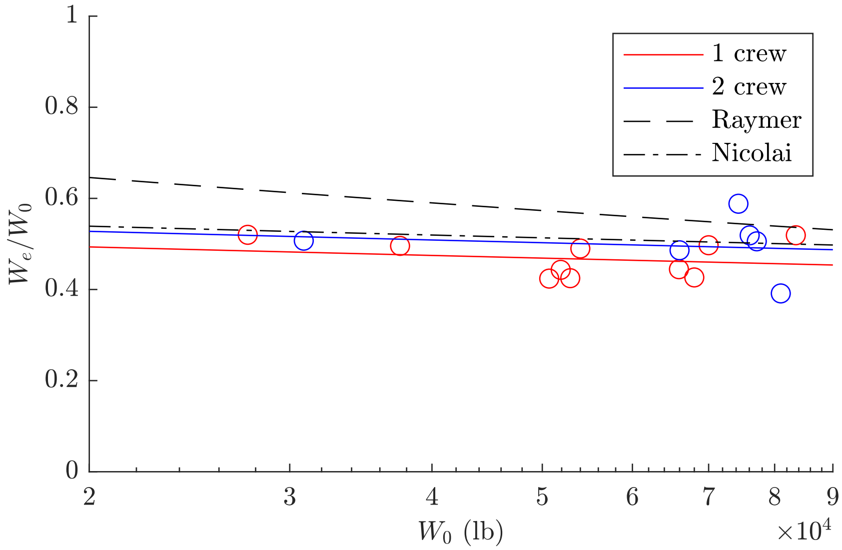

Figure 1: Empty weight fraction regressions indicate higher fractions for 2 crew vs. 1 crew fighter aircraft.

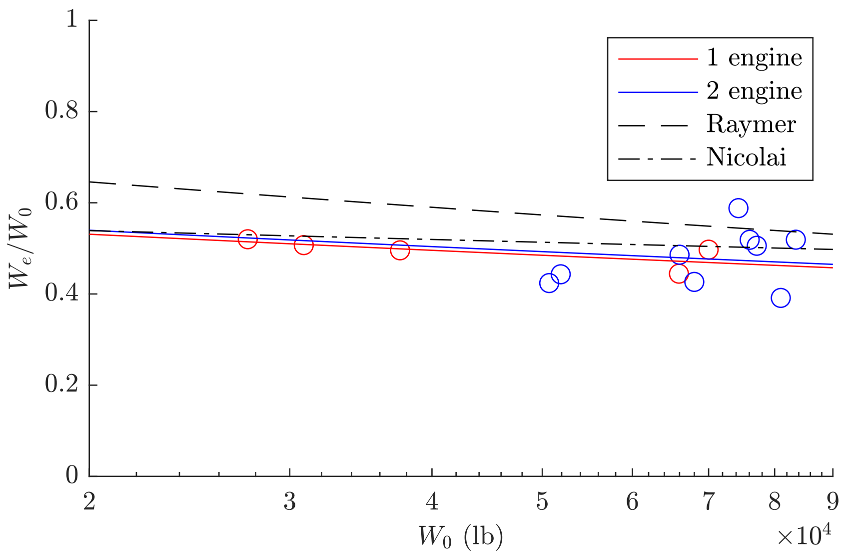

Figure 2: Engine count does not have a clear effect on empty weight fraction.

1.4 Internal and External Ordnance Carriage

Internal and external carriage of ordnance does not show a clear effect on empty weight fraction (Fig. 4). However, there was a limited set of data available on aircraft with internal stores. Additionally, the impact of ordnance storage on aircraft lift-to-drag ratio was not considered for initial takeoff weight sizing. More refined trade studies will be performed later in the design cycle.

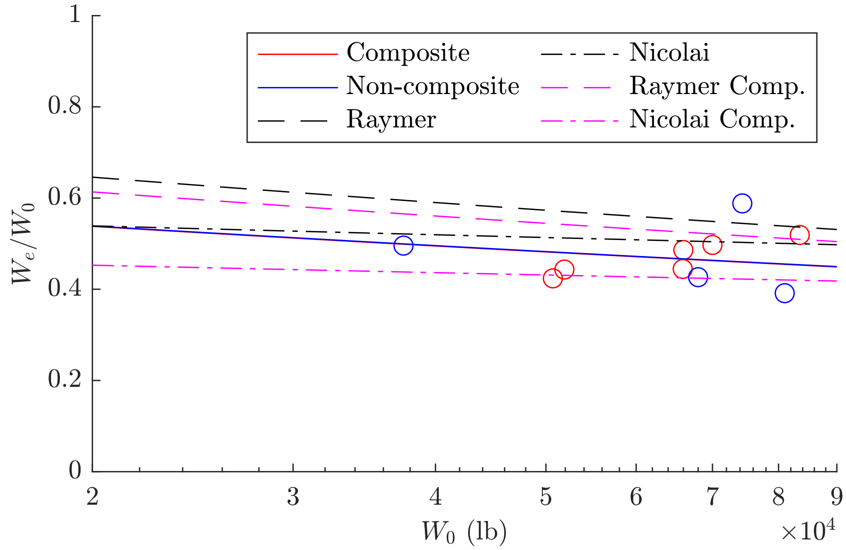

Figure 3: Composite aircraft do not show an impact on empty weight fraction, which differs from recommendations from Raymer and Nicolai.

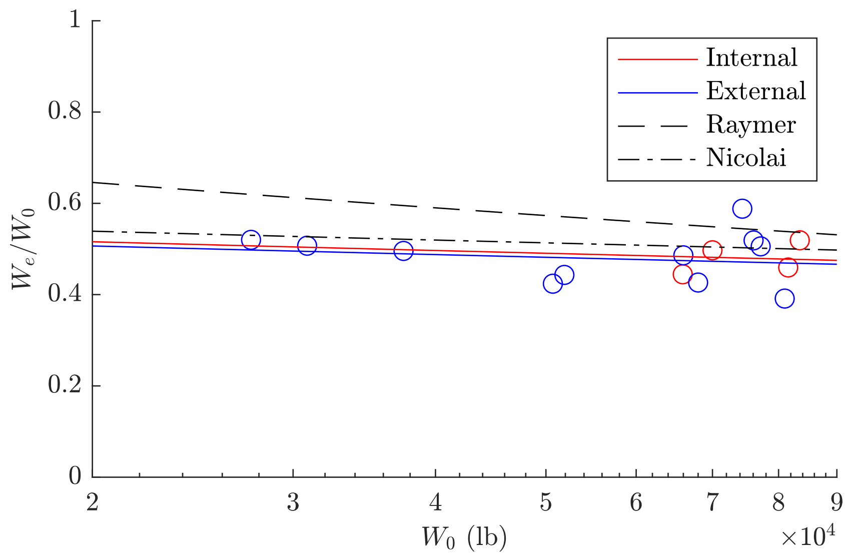

Figure 4: Internal and external carriage of ordinance did not show a clear impact on empty weight fraction.

1.5 Internal Fuel Weight

To predict internal fuel weight, a regression was fit with aircraft empty weight. This was based on the assumption that aircraft internal volume increases with empty weight, and an increased volume can allow for more internal fuel. The results of the regression is shown in Figure 5. There is a strong linear relationship between internal fuel weight and empty weight.

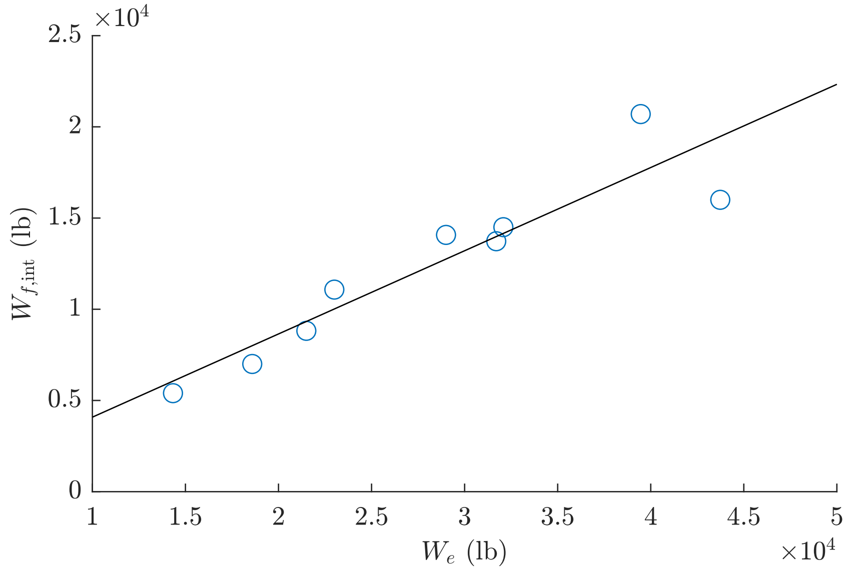

Figure 5: Internal fuel weight increases linearly with empty weight.

1.6 Regression Usage for Initial Sizing

The regressions for crew number were used for the initial weight sizing. This was because it was the only regression that showed a clear difference for each type. All other regressions did not show a conclusive impact on empty weight fraction. Additionally the new regressions are considered suitable for initial weight sizing because of their agreement with Raymer and Nicolai. The internal fuel weight regression was also used for the initial sizing.

1.7 Aircraft Data Sources

To fit the regressions, data was gathered on multiple aircraft. These aircraft are the F-35C, F/A-18E, F-16C, F-15C, F-35A, Eurofighter, F-22A, F-18A, JAS 39A, Rafale-M, F-15E, F-14D, F-18F, JAS 39B, Su-30, J-16, MiG-29K, Rafale M, J-15, J-20, and J-35. The OE Data Integration Network (ODIN) [3] provides the majority of the gathered data on the aircraft. The ODIN database is published by the United States military and thus considered a reputable source. Some specifications were found through the Air Force military website [4] and U.S. Navy [5], which are considered reputable. When possible, technical documents and manufacturer specifications were also used [6, 7, 8, 9, 10, 11]. Some aircraft did not have readily available data so the data for these aircraft may come from less reputable sources [12, 13, 14].

2 Initial Weight Sizing

Initial sizing for takeoff weight was performed using regressions for empty weight fraction and a mission segment breakdown for fuel fraction. Takeoff weight was then predicted numerically using MATLAB's `fsolve` command. The input to `fsolve` is a residual equation comparing a "guess" takeoff weight with the output after performing the mission segments.

$$R = W_{0,\text{guess}} - (W_{\text{crew}} + W_{\text{payload}}) - W_{0,\text{guess}}(\frac{W_e}{W_0} + \frac{W_f}{W_0})$$

The empty weight fraction comes from the regression

$$\frac{W_e}{W_0} = AW_e^c$$

where A and c are constants. Fuel fraction comes from evaluating the weight fractions of mission segments.

2.1 Payload Weight Estimation

Payload weight is estimated based on the request for proposal's (RFP) requirements of 6 AIM-120C missiles (air-to-air), 2 AIM-9X missiles (both missions), and 4 MK-83 JDAM's (air-to-ground). The AIM-120C weighs 348 lbs [15], the AIM-9X weighs 186 lbs [16], and the MK-83 JDAM weighs 1,013 lbs [17, 18]. These numbers come from U.S military websites and are considered reputable. The RFP payload requirement of 2500 lbs of avionics and sensors is considered to be part of the empty weight of the aircraft due to F18-E/F NATOPS manuals not indicating an additional payload weight for avionics and sensors [19, 20].

2.2 Crew Weight Estimation

Crew weight is estimated to be 200 lbs. This is based off of crew and equipments weights given by an older military technical reports [21] and validated by recent F-35C crew weight restrictions rating the F-35C seat at 103 to 245 lbs [22].

2.3 Mission Segments

Nicolai and Roskam [23] were used as references on how to calculate weight fraction for various mission segments. Weight fractions for warmup, taxi, takeoff, descent, and landing were set as constants based on a table for fighter aircraft in Roskam. Climb segments utilize Nicolai's climb-acceleration weight fraction estimate. The method predicts weight fractions using the initial and final Mach numbers. The climb-acceleration fit is used instead of constant weight fractions for climb segments to account for variation in cruise Mach number. This method is also used for accelerations to dash mission segments.

Cruise sections utilize the Breuget range equation for jet aircraft while loiter mission segments use the endurance equation. Since lift-to-drag ratio (L/D) is an input for both equations, L/D_{max} is estimated as a function of Mach number and aspect ratio. Curve fits were estimated from Nicolai. This provides a simple way for estimating L/D while including the effects of Mach number and aspect ratio. Additionally, Nicolai utilizes real world aircraft for estimation, which lends to its credibility. The primary downside is that this method does not include the effect of parasitic drag, which is important when considering external and internal carriage of ordnance. Cruise sections are assumed to be cruise-climb segments, so the input L/D is $0.943L/D_{\text{max}}$.

Combat sections calculate the weight of fuel burned using, thrust specific fuel consumption (TSFC), the thrust, and the combat time. For the strike mission segment, combat time is determined using the dash Mach number and the distance traveled.

2.3.1 Air to air

The air to air mission has mission segments in the following order

1. Warmup, Taxi, Takeoff
2. Climb to cruise altitude and Mach number
3. Cruise to the combat area
4. Accelerate to the dash speed
5. Descend into combat
6. Combat for combat time
7. Climb to cruise altitude and Mach number
8. Cruise back
9. Descend
10. Loiter
11. Land (Aborted)
12. Climb to Loiter
13. Land

2.3.2 Strike

1. Warmup, Taxi, Takeoff
2. Climb to cruise altitude and Mach number
3. Cruise to the combat area
4. Descend into combat
5. Accelerate to the dash speed
6. Combat for combat time
7. Climb to cruise altitude and Mach number
8. Cruise back
9. Descend
10. Loiter
11. Land (Aborted)
12. Climb to Loiter
13. Land

2.3.3 Reserve Fuel and Trapped Fuel

Reserve fuel is assumed to include enough fuel for a 20 minute loiter and 5% of the mission fuel weight [24]. Mission fuel weight is determined from the air-to-air and strike mission segments. Since the mission fuel weight includes a loiter before landing, as well as an aborted landing, the total fuel weight may be a slight overestimate. Trapped fuel is assumed to be 1% of the mission fuel weight, based on assumptions from Nicolai.

2.4 Takeoff Weight Estimates

The takeoff weight estimates for the air to air mission were performed by varying combat range and combat time. This resulted in a Pareto efficiency chart with contours of takeoff weight (Fig. 6. To account for potential empty weight growth, a takeoff weight of roughly 80000 lb is targeted. The selected initial design takeoff weight for the air to air mission 80040 lb, with a combat radius of 957 nm and a combat time of 4.4 min. The design takeoff weight for the strike mission is 50,840 lbs.

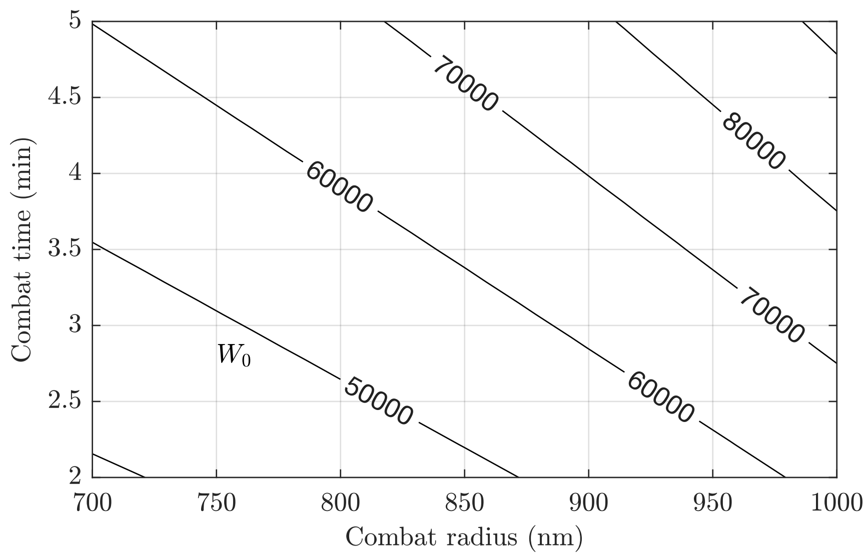

Figure 6: Pareto-optimal plot for air-to-air mission.

3 Group Work Split

Person	Work Percentage	Brief Description of Work Done
Michael Chen	20%	Researched initial sizing code equations, wrote initial sizing code, helped write report.
Charles Choi	16%	Researched aircraft internal fuel weights and engine data for sizing plots. Documented sources for report.
Cristina Erskine	18%	Researched ordnance and crew weights, researched initial sizing code equations, helped discuss how to best write initial sizing code, documented sources, helped write report.
James Gold	15%	Researched aircraft data for regressions. Found empty weight and MTOW.
Santiago Ramos-Assam	14%	Researched aircraft data for regressions.
Thomas Sheridan	17%	Collected and sourced aircraft data for regressions. Determined which aircraft were composite for comparison.

Table 1: Work Split

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