Aircraft Final Project
GD3-200

Prepared by:
Group 3

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The GD3-200 is a twin engine, new technology jet airplane designed for low fuel burn and short-to-medium range operations. This airplane uses new aerodynamics, advanced composite materials, structures, and systems to fill market requirement that cannot be efficiently provided by existing equipment or derivatives.

The GD3-200 will provide airlines with unmatched fuel efficiency. The airplane will use 20 percent less fuel for comparable missions than any other airplane in its class. The key to this exceptional performance lies in the use of advanced composite materials for the majority of the airplane’s fuselage and wing structure. GD3 has also enlisted General Electric to develop engines for the new airplane.

The GD3-200 is a highly fuel efficient low-noise airplane powered by General Electric new GEnx CF6-6 engines. These 9.5 to 1 high-bypass-ratio engines are reliable and easy to maintain. Using GEnx derived technology means these engines bring an average 15 percent improvement in specific fuel consumption over all other engines in its class.

In the passenger configuration, the GD3-200 can typically carry 186 passengers (200 including crew) in a six-abreast, mixed class configuration over a 3000 mile range with full load.

The GD3-200 can be equipped for Extended Range Operations (EROPS) to allow extended over-water operations. Changes include a backup hydraulic motor-generator set and an auxiliary fan for equipment cooling.
**Mission Requirement**

Payload: -200 passengers/crew at 200 lb each (includes baggage) 40000lb
-5000 lb

Cruise: 0.8 Mach at 33000 ft

Cruise Range: 3000 miles

Cruise Altitude: 33,000 ft

Loiter: 30 minutes at 0.8 m Mach at 33000 ft

Climb: Initial climb to cruise altitude starting at maximum takeoff weight

Take-off distance: 5000 to 6000 ft with 50 ft clearance at sea level and standard conditions at maximum takeoff weight

Power plant: more than 1; high-by-pass turbofan; choose from existing ones.

Structure: Composite material

Ground run: 2500 to 3000 ft
Summary of the Critical Performance Parameters of the Airplane

Maximum lift coefficient: \( (C_L)_{\text{max}} = 2.32 \)

Maximum lift-to-drag ratio: \( \left( \frac{L}{D} \right)_{\text{max}} = 18 \)

Wing loading: \( \frac{W}{S} = 279 \text{ lbm/ft}^2 \)

Thrust to Weight Ratio: \( \frac{T}{W} = 0.336 \)

Takeoff gross weight: \( W_0 = 247,060 \text{ lb} \)

Empty weight: \( W_e = 125,170 \text{ lbs (51\%)} \)

Total payload: \( W_{\text{payload}} = 45000 \text{ lb (18\%)} \)

Fuel weight: \( W_f = 73460 \text{ lb} \)

Fuel tank capacity: \( 12,240 \text{ gal} \)

Wing Span: \( b = 126 \text{ ft} \)

Wing Area: \( S = 1648 \text{ ft}^2 \)

Zero-lift Drag Coefficient: \( C_{D,0} = .028 \)

Drag-due-to-lift coefficient: \( K = 0.044 \)

Aspect ratio, \( AR = 9.6 \)

Velocity at 33000 ft at 0.8 Mach: \( V = 535 \text{ mph} \)

Fuselage cross sectional Area \( A_c = 153\text{ft}^2 \)
Estimating Takeoff Gross Weight, Empty Weight and Mission Fuel Weight

\[ W_o = W_{\text{passenger}} + W_{\text{payload}} + W_{\text{fuel}} + W_{\text{empty}} \]

\( W_o \) = the Takeoff Gross Weight

\( W_{\text{passenger}} \) = the weight of passengers and crew including baggage

\( W_{\text{payload}} \) = the weight of payload

\( W_{\text{fuel}} \) = the weight of fuel

\( W_{\text{empty}} \) = the weight of the airplane unloaded and unfueled

1) Determine mission passenger and payload
   a. Passengers (including crew) (given requirement)
      \[ W_{\text{passenger}} = 200 \times 200 \text{ lbs each} = 40,000 \text{ lbs} \]
   b. Payload (given requirement)
      \[ W_{\text{payload}} = 5,000 \text{ lbs} \]

2) Guess a likely takeoff weight:
   Using data from other aircraft of this size (i.e. 757-200), guess a likely takeoff weight, \( W_o = 255,000 \text{ lbs} \)

3) Estimate \( W_{\text{empty}} / W_o \)

Using collected data from other aircraft in the table below:

<table>
<thead>
<tr>
<th>Aircraft</th>
<th>We/Wo</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boeing 717</td>
<td>0.59</td>
</tr>
<tr>
<td>Boeing 727-200</td>
<td>0.48</td>
</tr>
<tr>
<td>Boeing 737-700</td>
<td>0.52</td>
</tr>
<tr>
<td>Boeing 747-100</td>
<td>0.48</td>
</tr>
<tr>
<td>Boeing 757-200</td>
<td>0.50</td>
</tr>
<tr>
<td>Boeing 767-200</td>
<td>0.48</td>
</tr>
<tr>
<td>Boeing 767-300</td>
<td>0.50</td>
</tr>
<tr>
<td>Airbus A300</td>
<td>0.55</td>
</tr>
<tr>
<td>Airbus A300-600</td>
<td>0.56</td>
</tr>
<tr>
<td>Airbus A310-200</td>
<td>0.56</td>
</tr>
<tr>
<td>Airbus A320-200</td>
<td>0.52</td>
</tr>
<tr>
<td>Airbus A330-200</td>
<td>0.48</td>
</tr>
<tr>
<td>Airbus A340-200</td>
<td>0.48</td>
</tr>
<tr>
<td>Airbus A380-800</td>
<td>0.50</td>
</tr>
</tbody>
</table>

Table 1: Typical We/Wo Values for Commercial Aircraft
Estimated We/Wo value to be the average of values in the table above.

\[ W_{\text{empty}} / W_o = 0.48 \]

Using the online Preliminary Design Weight Estimator:

\[ W_{\text{empty}} / W_o = 0.48 \]

The online calculator assumes passengers weigh 210 lbs each, so to correct for this, we remove 2000 lbs from the cargo. As long as the total payload is 45,000 the calculation is still correct.

4) Adjust \( W_o \) and \( W_{\text{empty}} / W_o \) based on developed data.

\[ W_o = 247,060 \text{ lbs} \]
\[ W_{\text{empty}} = 125,170 \text{ lbs} \]
\[ W_{\text{fuel}} = 73,460 \text{ lbs} \]
\[ W_{\text{empty}} / W_o = .51 \]
\[ W_{\text{fuel}} / W_o = .30 \]
$W_{\text{empty}}$ is approximately 51% of the Gross Takeoff Weight.

$W_{\text{fuel}}$ is approximately 30% of the Gross Takeoff Weight.

5) Fuel estimation in fraction of Gross Takeoff Weight

### Fuel Estimation

<table>
<thead>
<tr>
<th>Mission</th>
<th>Fuel Consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>T.O.</td>
<td>0.03</td>
</tr>
<tr>
<td>Climb</td>
<td>0.02</td>
</tr>
<tr>
<td>Cruise</td>
<td>0.194</td>
</tr>
<tr>
<td>Loiter</td>
<td>0.051</td>
</tr>
<tr>
<td>Landing</td>
<td>0.005</td>
</tr>
</tbody>
</table>

Following these Fuel Consumption Ratios:

$W_{\text{fuel, takeoff}} = \text{Takeoff Fuel Ratio} \times \text{Gross Takeoff Weight} = 7,411.8 \text{ lbs}$

$W_{\text{fuel,climb}} = \text{Climb Fuel Ratio} \times \text{Gross Takeoff Weight} = 4,941.2 \text{ lbs}$

$W_{\text{fuel,cruise}} = \text{Cruise Fuel Ratio} \times \text{Gross Takeoff Weight} = 47,929.6 \text{ lbs}$

$W_{\text{fuel,loiter}} = \text{Loiter Fuel Ratio} \times \text{Gross Takeoff Weight} = 12,600.06 \text{ lbs}$

$W_{\text{fuel,landing}} = \text{Landing Fuel Ratio} \times \text{Gross Takeoff Weight} = 1,235.3 \text{ lbs}$
Estimation of Wing

**Wing Calculator**

<table>
<thead>
<tr>
<th>Enter Aircraft Weight:</th>
<th>247060 lbs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Desired Airport Altitude</td>
<td>33000 ft</td>
</tr>
<tr>
<td>Desired Landing Speed:</td>
<td>535 mph</td>
</tr>
</tbody>
</table>

**High Lift Devices**

<table>
<thead>
<tr>
<th>Trailing Edge Devices</th>
<th>☐ Hinged Flaps</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>☐ Slotted Flaps</td>
</tr>
<tr>
<td></td>
<td>☐ Double Slotted Flaps</td>
</tr>
<tr>
<td></td>
<td>☐ No Flaps</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Leading Edge Devices</th>
<th>☐ Leading Edge Slats</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>☐ Leading Edge Slots</td>
</tr>
<tr>
<td></td>
<td>☐ No Leading Edge Devices</td>
</tr>
</tbody>
</table>

**Wing Area**

<table>
<thead>
<tr>
<th>Landing Speed</th>
<th>535 mph</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wing Area:</td>
<td>1648 ft$^2$</td>
</tr>
<tr>
<td>Total cost penalty:</td>
<td>0</td>
</tr>
</tbody>
</table>

Estimation of L/D Max

1) Estimate Aspect Ratio
   Based on Table 4.1 of the Handout, we estimate an Aspect Ratio = 8

2) Estimate $\frac{S_{wet}}{S_{ref}}$
   Based on page 128 of the Handout, we estimated the $\frac{S_{wet}}{S_{ref}} = 8$

3) Using estimated wing area of 1648 ft$^2$ as $S_{ref}$ we solve for $S_{wet}$:
   $S_{wet} = 13,184 \text{ ft}^2$
4) Use $S_{wet}$ and find wetted AR

\[
\text{Wetted AR} = \frac{b^2}{S_{wet}}
\]

\[
\frac{(126)^2}{13,184} = 1.204
\]

5) Referencing page 128 of the Handout we find the corresponding $L/D_{max} = 18$

**Wing Loading**

For estimating the Wing loading (W/S) we took 4 different approaches. The first approach was directly based from the previous Weight and $(L/D)_{max}$ estimations. Since we estimated $(L/D)_{max}$ to be approximately 18 we are able to use the tables provided to find an estimation for the aspect ratio(AR). We know $AR = \frac{b^2}{S}$ and we have our wing span ‘b’ from the specifications online, so we are able to calculate for S. AR is approximately 9.6, b is approximately 126ft, and S was calculated to be approximately 1648 ft$^2$. From the section earlier we have the gross take-off weight (Wo) to be 247,060 lbm. With these numbers known we can calculate the Wing loading at gross take-off weight (Wo/S).

\[
\frac{W_o}{S} = \frac{247,060\text{lbm}}{1,648\text{ft}^2} = 149.9 \text{lbm/ft}^2
\]

The next estimation for the wing loading was for cruise flight. This is given by the following equation:

\[
\frac{W_{(cruise)}}{S} = q\sqrt{\pi e AR \frac{C_{D,0}}{3}}
\]

All of these values have been estimated either from one of our website sources or were calculated from the equations given in the handouts.
We were able to calculate $C_{D,0}$ from one of our website references.

We found the following values $q = \frac{1}{2} \rho \nu^2$, $e = 0.8$, $AR = 9.6$, $C_{D,0} = 0.028$. It needed the cross-sectional area, so we estimated that from past information known about the aircraft. Since this is for cruise flight the velocity is at 0.8 Mach for 33,000 ft, which is equal to 535 mph. This will give us the following calculation:

$$W_{\text{(cruise)}} = q \sqrt{\pi e AR C_{D,0}} = \frac{1}{2} \times 535^2 \times 0.00237 \times \sqrt{\pi} \times 0.8 \times 9.6 \times 0.028 =$$

$$W_{\text{(cruise)}} \frac{\text{lbm}}{\text{ft}^2} = 279 \frac{\text{lbm}}{\text{ft}^2}$$

The next Wing loading that was estimated was for the loiter endurance. This comes from an equation similar to that for the cruise flight.
\[ W \left( \text{loiter} \right) = q \sqrt{\pi eAR \ 3C_{\text{D,o}}} \]

We are using the same values as the first equation for all of the parameters. We are able to use the same \( q \) since it is loitering at 0.8 Mach for 33,000 ft which gives us a velocity at 535 mph again. We are also presuming the same density at sea level equal to 0.00237 slugs/ft\(^3\).

\[ W \left( \text{loiter} \right) = q \sqrt{\pi eAR \ 3C_{\text{D,o}}} = \frac{1}{2} \times 535^2 \times 0.00237 \sqrt{\pi \times 0.8 \times 9.6 \times 3 \times 0.028} \]

\[ W(\text{loiter}) = 482.86 \text{ lbm/ft}^2 \]

The final estimation for the Wing loading we made was for the Stall Speed. This was another equation given as

\[ \frac{W(V_{\text{stall}})}{S} = \frac{1}{2} \rho V_{\text{stall}}^2 \left( C_L \right)_{\text{max}} \]

With this equations we are presuming \( \rho \) to be at sea level which is 0.002237 kg/m\(^3\). The typical value for \( V_{\text{stall}} \) is about 70 mph, and we are presuming that value through these calculations. Also the \( C_{L_{\text{max}}} \) was presumed earlier in the (L/D)\(_{\text{max}}\) estimations to be approximately 0.064.
From these numbers we get the following

\[
\frac{W (V_{\text{stall}})}{S} = \frac{1}{2} \rho V_{\text{stall}}^2 C_{L_{\text{max}}} = \frac{1}{2} \times 1.29 \times 70^2 \times 0.604 = 1908.94 \text{ lbm/ft}^2
\]

From these estimations we were able to calculate the Wing loading for different aspects of the flight. Depending on which point of flight we are at we will use a different Wing loading.

**Thrust-to-Weight Ratio**

1) Estimate Thrust to Weight Ratio

\[
T/W \text{ Ratio estimation was a simple calculation of dividing the total available Thrust from the two engines by the GTOW}
\]

\[
T/W_{\text{ratio}} = \frac{\text{Thrust}_{\text{Total}}}{\text{GTOW}} = \frac{2 \times 41,500}{247,060} = 0.336
\]

**Airplane Configuration**

Number of engine: 2 (GE: Model CF6-6 ENGINES)

Air craft type: Jet

The general configuration and dimension of GD3-200

Seating Configuration

The GD3-200’s seating is shown below: 14 crew in the airplane, 170 economy class seats which are shown in the blue section and 16 first class seats which are shown in red section.
The seating dimensions are shown below. In first class seating, 2 twin seats in a row and separate by a distance of 21 in. In economy class seating, there are 6 seats in a row, 3 seat on a side separate by a distance of 17 in

**Engine information (Based on GEnx technology)**

**GE: Model CF6-6 Engine**

- Fan/Compressor Stages: 1F/1LPC/16HPC
- Low-pressure Turbine /
- High-pressure Turbine Stages: 5/2
- Dry Weight: 8571 lb
- Maximum Diameter: 108 inches
- Length: 188 inches
- Specific Fuel Consumption: 0.30345 lb/hp.h
- Thrust Rating at sea level: 41,500 lbs
Structure Material

Composite material for the structure of the airplane is shown below:
**Wing Configuration**

The evolution of wing design for GD3-200 jet is shown below. The GD-3-200 has

Location of Wing: Low Wing

Wing Sweep: 35°

Wing Span, b: 126 ft

Wing Area, S: 1648 ft²

Aspect ratio, AR: 9

Base on considerations of the airplane’s structural and landing gear of the airplane; we choose the low-wing configuration. For a low-wing design airplane, the landing gear can be retracted directly into the wing box, which is usually one of the strongest elements of the aircraft structure.
**Tail Configuration**

We have decided to use the conventional location for our horizontal tail, which is centered on the tail end of the fuselage. It is called a conventional tail because over 70% of airplanes on the market use it. It has sensible stability and control along with being lighter in weight, which makes it a great choice. Also with the wing being lower to the ground it makes maintenance easier. By using a conventional wing we are also using the absolute minimum battery size in order to save weight. Also with this configuration the conventional tail gives better low-speed handling, especially in yaw.
Comparison of GD3-200, Boeing 757, and Airbus 321:

<table>
<thead>
<tr>
<th>Parameters</th>
<th>GD3-200</th>
<th>Airbus 321</th>
<th>Boeing 757</th>
</tr>
</thead>
<tbody>
<tr>
<td>Take-off weight</td>
<td>247,060 lbs</td>
<td>206,100 lbs</td>
<td>265,000 lbs</td>
</tr>
<tr>
<td>Empty weight</td>
<td>125,170 lbs</td>
<td>108,400 lbs</td>
<td>127,520 lbs</td>
</tr>
<tr>
<td>Fuel weight</td>
<td>73,460 lbs</td>
<td>162,700 lbs</td>
<td>184,000 lbs</td>
</tr>
<tr>
<td>Lift coefficient</td>
<td>2.32</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Aspect Ratio</td>
<td>9</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Wing Area</td>
<td>1648 ft^2</td>
<td>1320 ft^2</td>
<td>1994 ft^2</td>
</tr>
<tr>
<td>Thrust-to-weight Ratio</td>
<td>0.336</td>
<td>0.32</td>
<td>na</td>
</tr>
</tbody>
</table>

From the table above, it can be seen that the preliminary design parameters found from our design method compare quite favorably to the actual parameters of the Boeing 757-200. This was because our aircraft design was modeled more closely after it. One can vividly see that the fuel weight of our design is far more less than that of the Airbus 321 and the Boeing 757.

**Conclusion:**

The GD3-200 operating costs are below those of equivalently sized competitors. It is the result of many technological improvements in many areas.

Selection of GEnx technology driven engines was a major factor in designing an aircraft that provides exceptional fuel economy.

Advances in aerodynamics have led to more efficient wing and airframe shaping, which reduces fuel burn, operating cost and emissions. Extensive use of lighter composite materials saves weight, another important element in saving fuel and increasing payload on weight-limited routes.

“Leave your competition at the fuel truck”. While they are still filling up, you are up and away in a GD3-200. Our ramparts are in the sky.
References:


