# The Design of Futuristic Flying Cars

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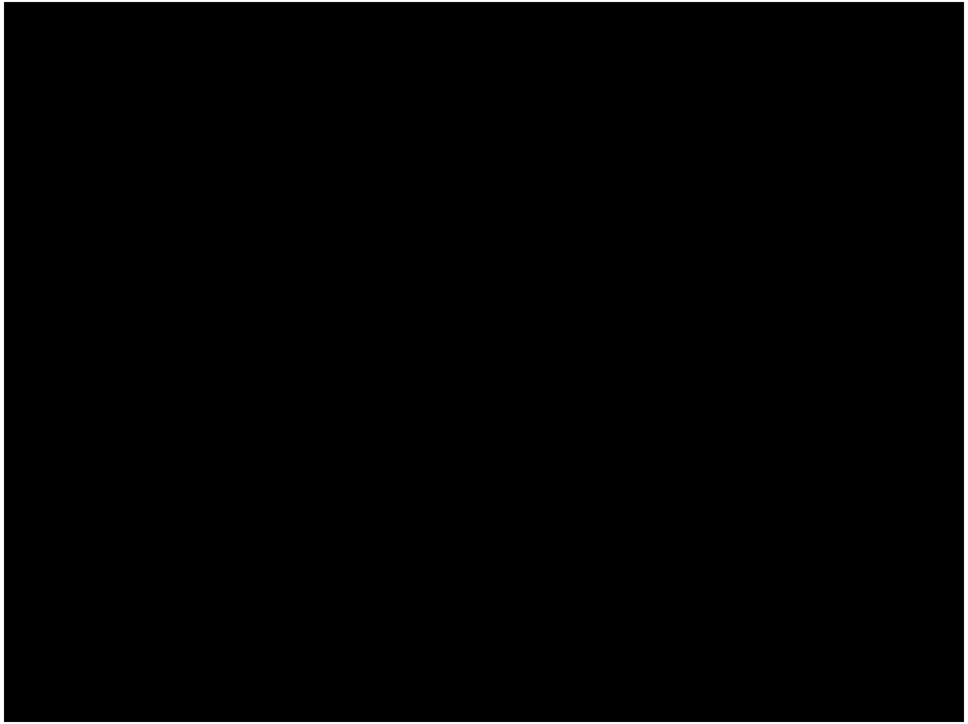
# Introduction

Things discussed in this design review:

- Created Mission Profile
- Research
- Initial Sizing
- Trade Studies
- Disciplinary Analysis
- Detailed Design
- Design of Flying Car Models



# Design Requirements and Specifications

The Flying Car shall be able to seat four people.

The Flying Car shall be able to be flown 400 miles.

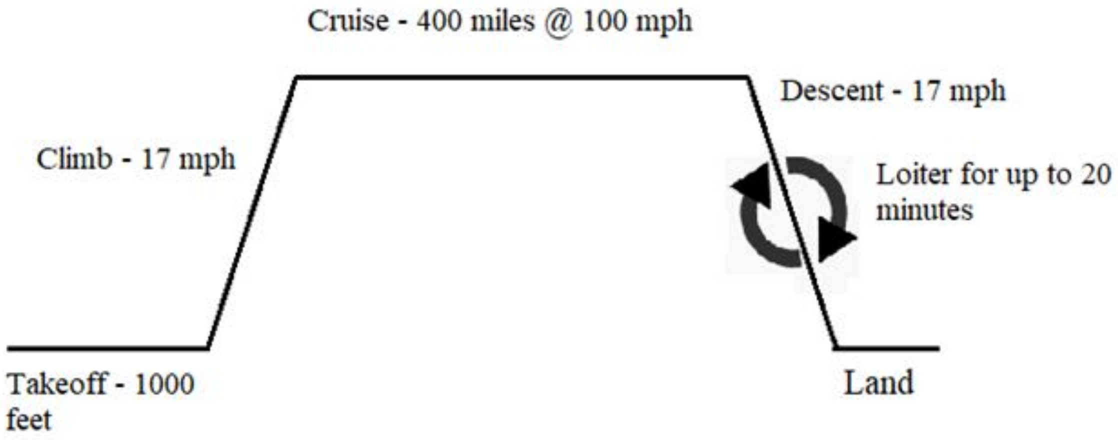
The Flying Car shall be able to fly at 100 miles per hour.

The Flying Car shall be able to take off using a runway of 1000 feet.

The GPS system of the Flying Car shall be able to self-drive the Flying Car.

The GPS system of the Flying Car shall be able to communicate with other Flying Cars.

The GPS system of the Flying car shall be able to sync with other Flying Cars.



# Research

| Flying Car | Capacity | Range | Cruise Speed | Payload | Takeoff Distance |
|---|---|---|---|---|---|
| Our Flying Car | 4 | 400 miles | 100 mph | 200 lbs | 1000 ft |
| PAL-V Liberty | 2 | 248 miles | 87 mph | 44 lbs | 1673.23 ft |
| AeroMobil 4.0 | 2 | 450 miles | 166 mph | 529 lbs | 1952 ft |
| Terrafugia | 2 | 400 miles | 200 mph | 100 lbs | 1400 ft |
| Blackfly | 1 | 25 miles | 62 mph | 200 lbs | 0 ft |
| Switchblade Flying Sports Car | 2 | 450 miles | 160 mph | 544 lbs | 1600 ft |

# Initial Sizing

Step 1. Warm-up and Takeoff W1/W0 = 0.97 (Table 3.2 [22])

Step 2. Climb W2/W1 = 0.985 (Table 3.2 [22])

Step 3. Cruise R = 400 miles = 2,112,000 ft

C = 0.5 1/hr = 0.0001389 1/s

V = 100 mph = 146.67 ft/s

L/D = 12.5takeoff

W3/W2 = e^{-RC/V(L/D)} = 0.8521

Step 4. Loiter E = 20 minutes = 1200 s

C = 0.4 1/hr = 0.0001111 1/s

W4/W3 = e^{-EC/(L/D)} = 0.9893

Step 5. Land W5/W4 = 0.995

W6/W5 = (0.97)(0.985)(0.8521)(0.9893)(0.995) = 0.80152

Wf/W0 = 1.06*(1-0.8002) = 0.21039

We/W0 = 0.93 W0^-0.07

$$W_0 = \frac{1000}{1 - 0.21039 - \frac{W_e}{W_0}}$$

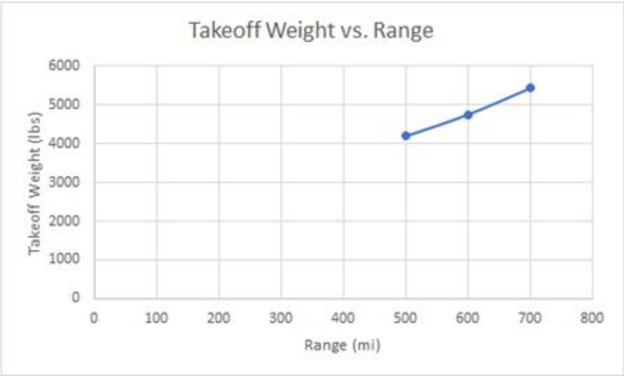
| W1/W0 | W2/W1 | C Cruise | W3/W2 | C Loiter | W4/W3 | W5/W4 | W6/W5 | Wf/W0 |
|---|---|---|---|---|---|---|---|---|
| 0.97 | 0.985 | 0.5 | 0.85214689 | 0.4 | 0.98939002 | 0.995 | 0.80152 | 0.21039 |
| | | | | | | | | |
| W0 Guess | W0 Calc | | V | E | L/D | R | | |
| 4000 | 3714.6 | | 146.67 | 1200 | 12.5 | 2112000 | | |
| 3800 | 3740.61 | | | | | | | |
| 3700 | 3754.31 | | | | | | | |
| 3750 | 3747.4 | | | | | | | |
| 3747 | 3747.81 | | | | | | | |

# Trade Study Examples

Range Tradeoff: 500 miles, 600 miles, 700 miles

| W1/W0 | W2/W1 | C Cruise | W3/W2 | C Loiter | W4/W3 | W5/W4 | W6/W5 | Wf/W0 |
|---|---|---|---|---|---|---|---|---|
| 0.97 | 0.985 | 0.5 | 0.81873447 | 0.4 | 0.98939002 | 0.995 | 0.77009 | 0.2437 |
| | | | | | | | | |
| W0 Guess | W0 Calc | | V | E | L/D | R | | |
| 4000 | 4239.12 | | 146.67 | 1200 | 12.5 | 2640000 | | |
| 4700 | 4136.68 | | | | | | | |
| 4100 | 4223.03 | | | | | | | |
| 4220 | 4204.42 | | | | | | | |
| 4205 | 4206.7 | | | | | | | |
| 4206 | 4206.55 | | | | | | | |

Range is increased to 500, 600, and 700 miles. The new weight is calculated for each value using the same process previously mentioned.

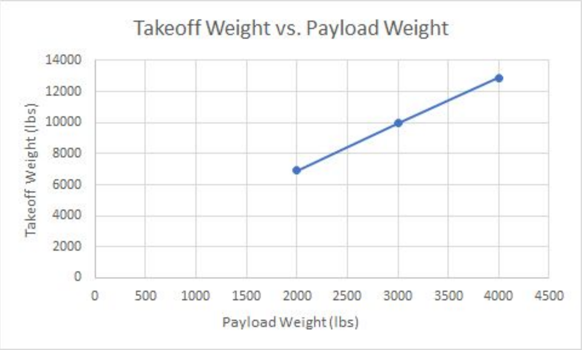


# Trade Study Examples - Continued

Payload Tradeoff: 2000 lbs, 3000 lbs, 4000 lbs.

| W1/W0 | W2/W1 | C Cruise | W3/W2 | C Loiter | W4/W3 | W5/W4 | W6/W5 | Wf/W0 |
|---|---|---|---|---|---|---|---|---|
| 0.97 | 0.985 | 0.5 | 0.85214689 | 0.4 | 0.98939002 | 0.995 | 0.80152 | 0.21039 |
| | | | | | | | | |
| W0 Guess | W0 Calc | | V (ft/s) | E (s) | L/D | R (ft) | | |
| 7100 | 6903.78 | | 146.67 | 1200 | 12.5 | 2.11E+06 | | |
| 6900 | 6927.71 | | | | | | | |
| 6920 | 6925.28 | | | | | | | |
| 6925 | 6924.67 | | | | | | | |
| 6924 | 6924.79 | | | | | | | |

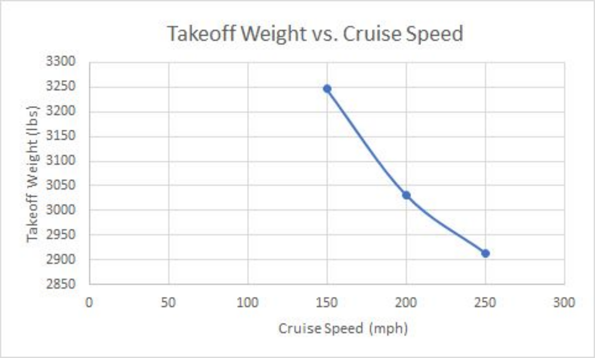
Same process as the range trade study.



# Trade Study Examples - Continued

Cruise Speed Tradeoff: 150 mph, 200 mph, 250 mph.

| W1/W0 | W2/W1 | C Cruise | W3/W2 | C Loiter | W4/W3 | W5/W4 | W6/W5 | Wf/W0 |
|---|---|---|---|---|---|---|---|---|
| 0.97 | 0.985 | 0.5 | 0.92311551 | 0.4 | 0.98939002 | 0.995 | 0.86827 | 0.13963 |
| | | | | | | | | |
| W0 Guess | W0 Calc | | V (ft/s) | E (s) | L/D | R (ft) | | |
| 3000 | 3035.99 | | 293.33 | 1200 | 12.5 | 2.11E+06 | | |
| 3030 | 3032.58 | | | | | | | |
| 3032 | 3032.36 | | | | | | | |



# Disciplinary Analysis: Aerodynamics

$C_{Lmax} = 0.9*C_{lmax} = 1.52*0.9 = 1.368$

$$C_{L_\alpha} = \frac{2\pi * 8 * \frac{S_{exp}}{S_{ref}} * F}{2+\sqrt{4+\frac{8^2}{0.95^2}(1+\frac{tan(0)^2}{1})}} = 4.623 \text{ per radian or } 0.081 \text{ per degree}$$

Total $C_{D0} = 0.05254$

# Disciplinary Analysis: Propulsion

2 Bladed Propeller with Fixed Pitch Diameter of 77.28 inches

$$J = \frac{V}{nD} = \frac{146.67}{(3000/60)(77.28/12)} = 0.45$$

$$C_P = \frac{550*206}{\rho n^3 D^5} = 0.0367$$

Fixed-Pitch Propeller Efficiency = 0.7725

$$T_{Static} = 2.55*\frac{550*206}{50*6.44} = 897\ lb$$

$$\eta_{P\ effective} = \eta_p[1 - \frac{1.558}{6.44^2} * 0.004 * 236] = 0.96\eta_P$$

Actual thrust = 0.96*897 = 865.19 lb

## Disciplinary Analysis: Individual Weight Analysis

| Item | Weight (lbs) | Item | Weight (lbs) |
|---|---|---|---|
| **Wing** | 1619 | **Fuel System** | 86 |
| **Horizontal Tail** | 33.19 | **Flight Controls** | 24 |
| **Vertical Tail** | 13.62 | **Electrical Equipment** | 129 |
| **Fuselage** | 536.55 | **Avionics** | 9.5 |
| **Main Gear** | 146 | **Furnishings** | 80 |
| **Installed Engine** | 465 | **Total** | 3142.8 |

# Disciplinary Analysis: Stability and Control

$$\bar{X}_{cg} = 64.5/57 = 1.13$$

$$\bar{X}_{acw} = 62/57 = 1.0877$$

$$C_{m_{\alpha_{fuselage}}} = \frac{0.009(48)^2(348)}{(57)(170*12*12)} = 0.005 \text{ per degree or } 0.3158 \text{ per rad}$$

$$\bar{X}_{ach} = \frac{210}{57} = 3.68$$

$$C_{L_{\alpha_h}} = \frac{2\pi*4*\frac{S_{exp}}{S_{ref}}*F}{2+\sqrt{4+\frac{4^2}{0.95^2}(1+\frac{tan(0)^2}{1})}} = 3.966 \text{ per radian}$$

# Disciplinary Analysis: Stability and Control Continued

$$\bar{X}_{np} = \frac{4.623 * 1.0877 - 0.3158 + 0.9(30.37/170) * 3.966 * 0.6 * 3.68}{4.623 + 0.9 * (30.37/170) * 3.966 * 0.6} = 1.22$$

$X_{np} = 1.22*57 = 70$ in.

$$\text{Static Margin} = \frac{70-64.5}{57} = 0.096$$

# Disciplinary Analysis: Performance and Flight Mechanics

Stall: 12.18 kts

Takeoff Distance: 1500 feet

Max Velocity at Sea Level: 139 kts

Max Velocity at 8000 ft: 136 kts

Max Rate of Climb = 1560 fpm, travelling forward at 100 kts

# Detailed Design

Power & engine selection:

$W_{crew}$ = 4*200 = 800 lbs. (up to four passengers, up to 200 pounds each)

$W_{fixed\ payload}$ = 700 lbs.

$W_{fuel}$ = 789 lb

$W_e$ = 1960 lb

P/W = 0.055

Required power = 0.055*3750 = 206.25 hp

The Lycoming IO-720 engine provides up to 400 hp, which covers the required power while allowing for some breathing room.

# Wing Loading and Aspect Ratio Optimization

(+- 20%  for wing loading, +- 30% for aspect ratio)

| | W/S | | | |
|---|---|---|---|---|
| A | | 17.64 | 22.05 | 26.46 |
| | 5.63 | **1** | **2** | **3** |
| | 8 | **4** | **5** | **6** |
| | 10.64 | **7** | **8** | **9** |

# W/S Aspect Ratio Optimization Example Calc.

$W_w = 1619 * (\frac{1}{0.8})^{0.758}(0.66)^{0.6} = 1494.28 lb$ $\Delta W = -124.72$ lb

$W_{ht} = 33.19 * (\frac{1}{0.72})^{0.896} = 44.55$ $\Delta W = 11.36$ lb

$W_{vt} = 13.62 * (\frac{1}{0.72})^{0.873} = 18.144$ $\Delta W = 4.52$ lb

$W_e = 1960-124.72+11.36+4.52 = 1851.16$ lb

$C_{D0,T} = (\frac{1}{0.8})*0.00061 = 0.0007625$ $\Delta=0.0001525$

$C_{D0,w} = (\frac{1}{0.72})*0.0042=0.00583$ $\Delta=0.00163$

$C_{D0} = 0.05254*0.8=0.0420$

Cruise: $W/S = 17.64*0.938*0.995=16.46$

$L/D = 1/\frac{35*0.0420}{16.46} + \frac{16.46}{35*\pi*5.63*0.93} = 8.48$

$W3/W2 = e\wedge\frac{-(2112000)(.0.5/3600)}{8.48*550*.78*.95} = 0.918$

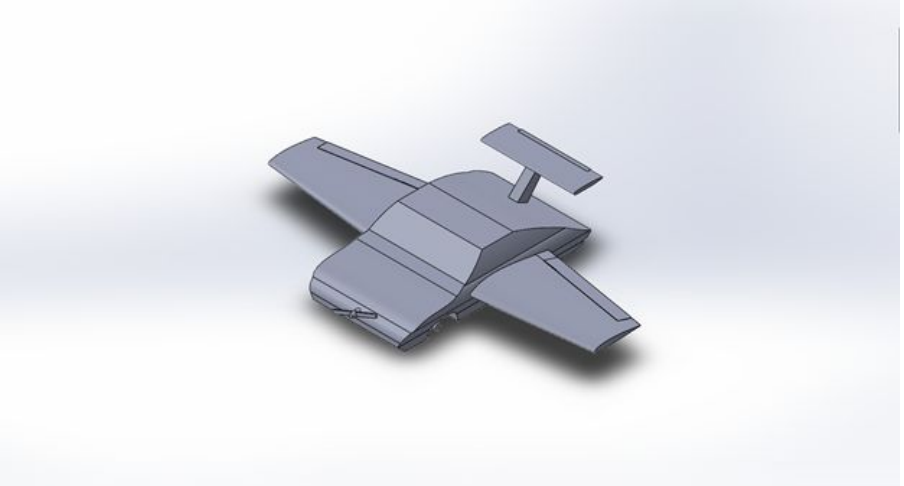
| W0 Guess | W0 Calc |
|---|---|
| 3100 | 3116.44 |
| 3110 | 3115.28 |
| 3115 | 3114.7 |
| 3114 | 3114.82 |

# Optimization Table Results

| Matrix # | Calculated Initial Weight (lb) |
|---|---|
| 1 | 3114.82 |
| 2 | 3232.47 |
| 3 | 2988.48 |
| 4 | 3055.03 |
| 5 | 3750 |
| 6 | 2913.35 |
| 7 | 2988.38 |
| 8 | 3016.38 |
| 9 | 2851.88 |

Option 5 is the initial calculation while options 1-4 and 6-9 are new. As shown, option 9 provides the lowest weight at 2851.88 pounds with an aspect ratio of 10.64 and a wing loading of 26.46 pounds per square foot.

# 3D Models



# Conclusion

We were able to design a flying car that would help to reduce traffic congestion which would in turn reduce deaths caused by stress induced heart attacks and deaths from congestion pollution