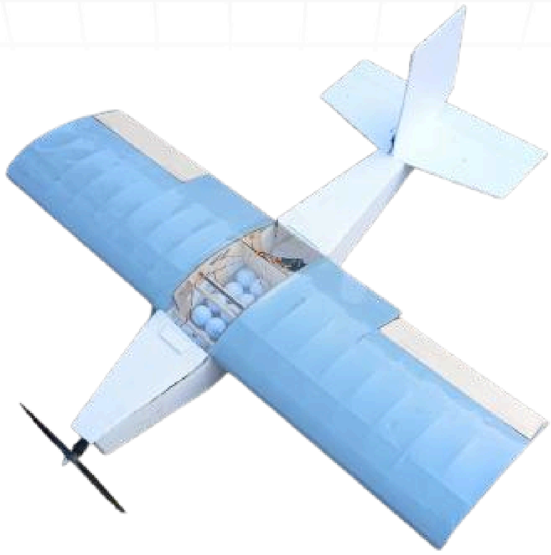
Boeing National Aeromodelling Competition 2024-25



Team Soaring Eagles

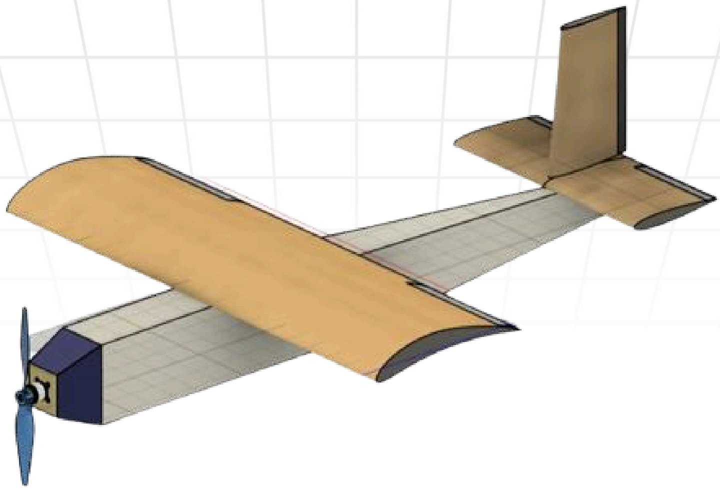
Aeromodelling Club, IIT Guwahati

IIT Kharagpur Zone

Team Details

Amogh Wadhonkar
Sourajjal Mondal
Kinjal Bunker
Gaurav Anand

1.1 Design



1.2 Dimensions and Performance Parameters

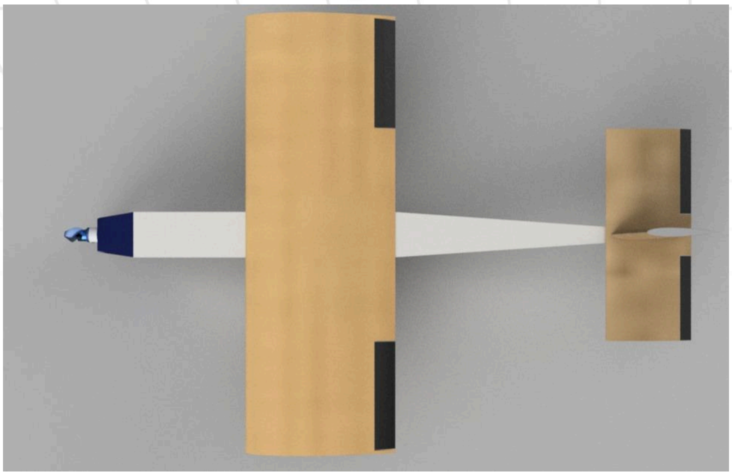
Conditions	
Air Speed	13 m/s
Air Density	1.225 kg/m³

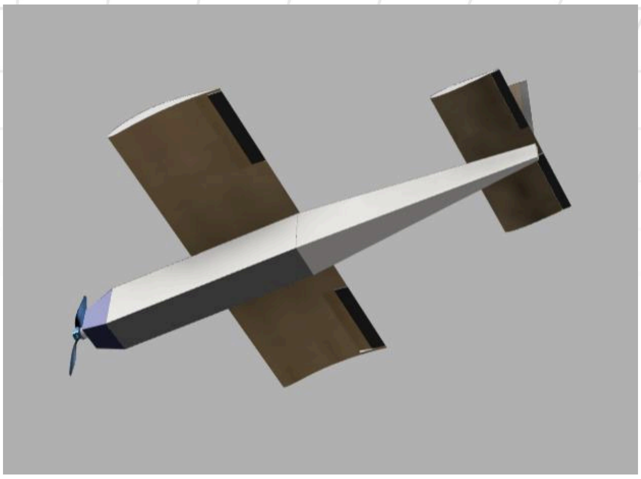
Weight	
Airplane (without paylaod)	1kg
Payload	1 kg
Total	2 kg

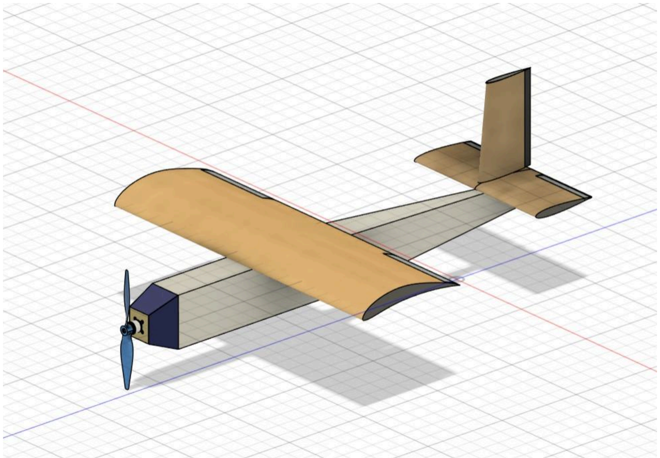
Main Wing	
Wing Loading	5.608 kg/m³
Aspect Ratio	2.9
Wing Area	0.3168 m²
Root Chord	0.33 m
Tip Chord	0.33 m
Taper Ratio	1

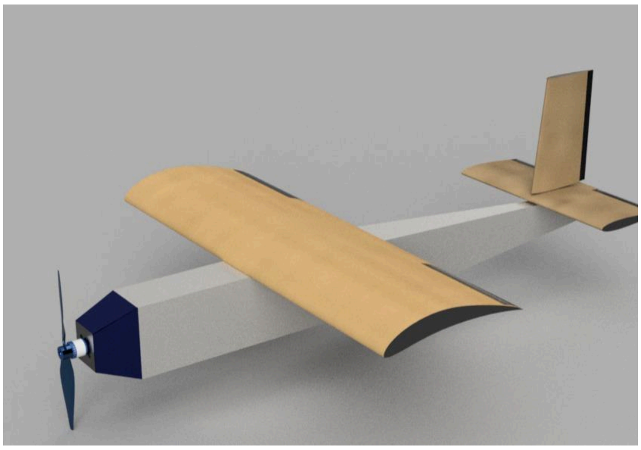
1.3 Machine Drawing Of The Aircraft

Aircraft Design

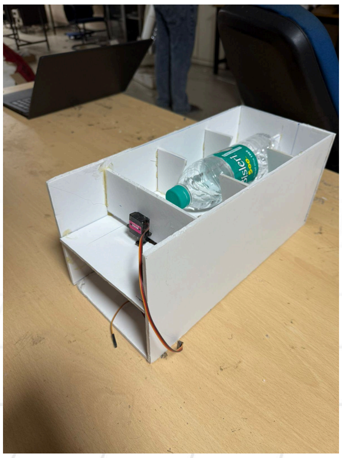


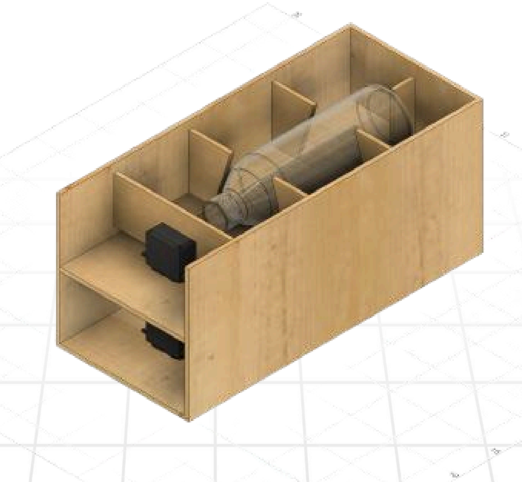






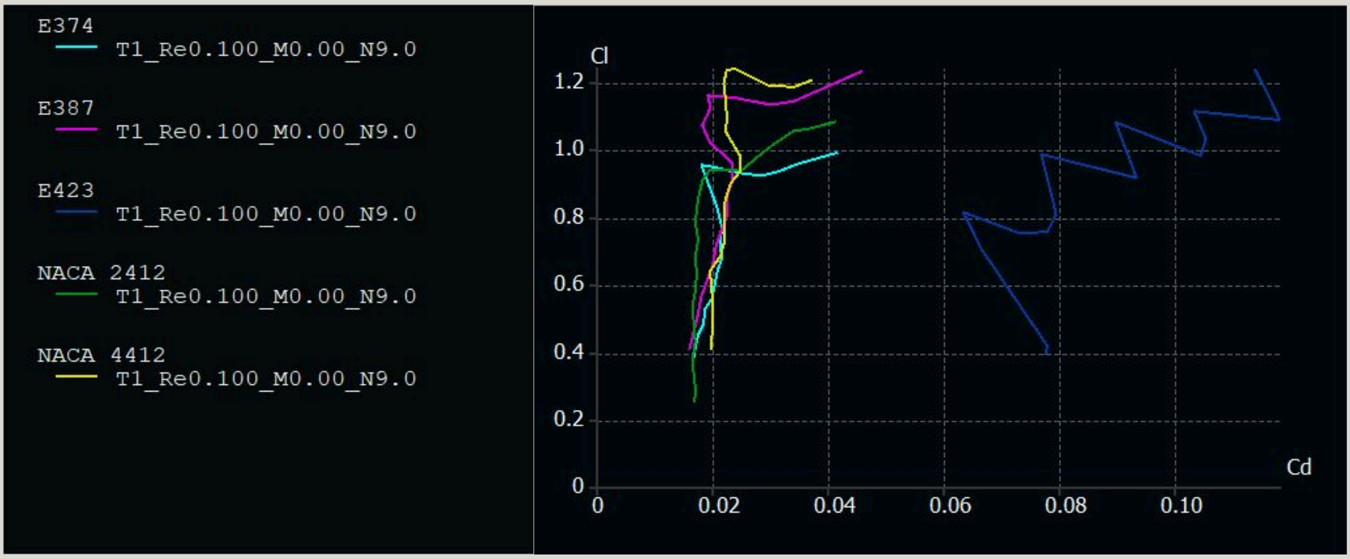
Dropping Mechanism



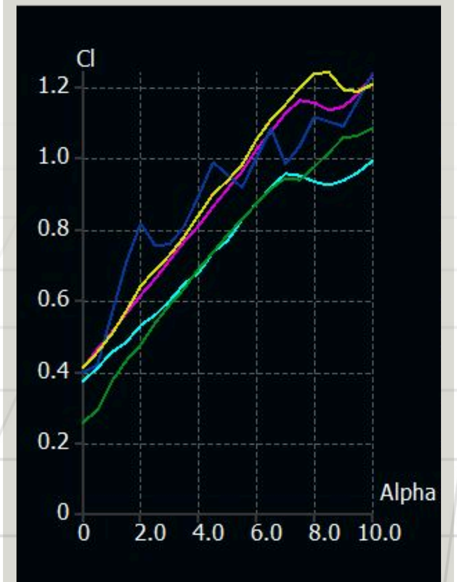


1.4 Wing Design And Specifications

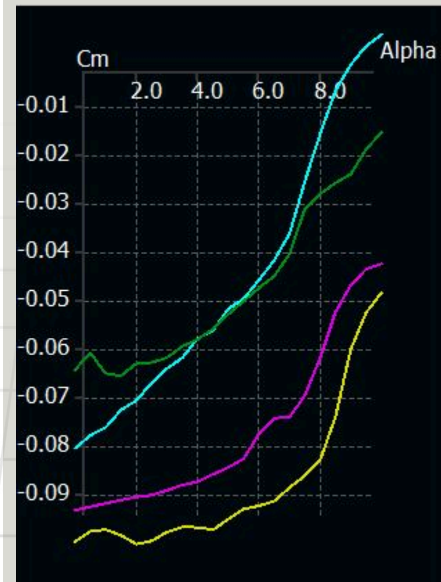
The wing design prioritizes maximizing payload, necessitating a focus on lift generation. A high-wing configuration with a rectangular cross-section was chosen, featuring a 0.96-meter wingspan and a root chord of 0.33m and a tip chord of 0.33 To achieve this, a comparative analysis of airfoil profiles was conducted. While the e423 airfoil exhibited slightly lower lift-to-drag ratios compared to some alternatives, it demonstrated superior lift generation capabilities. Recognizing that a slight compromise in efficiency was acceptable to achieve the desired payload capacity, the e423 airfoil was selected for its ability to provide the highest lift.



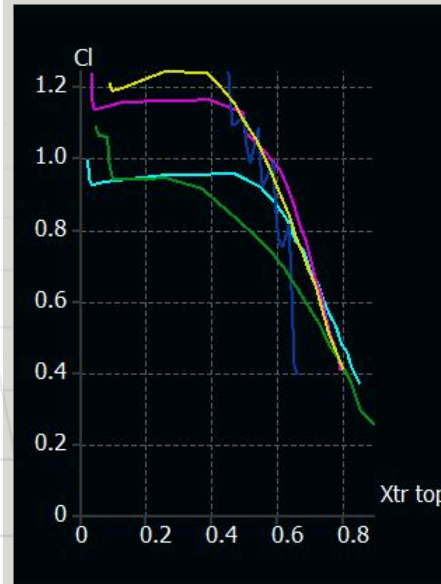
Cl vs Cd



Cl vs Apha



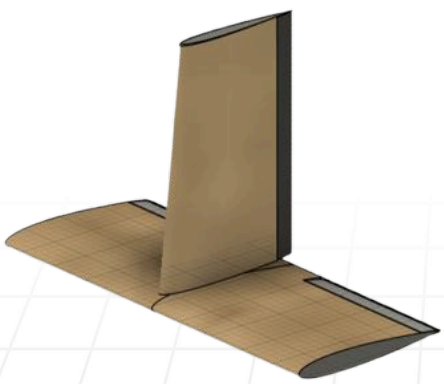
Cm vs Apha

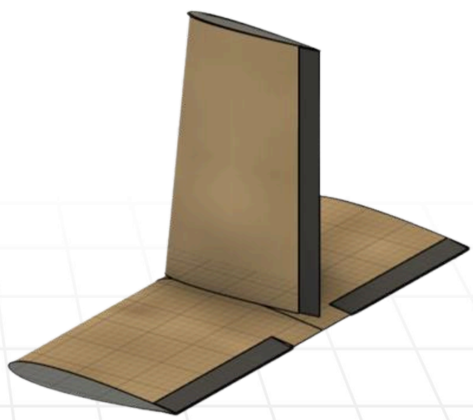


Cl vs Xtr

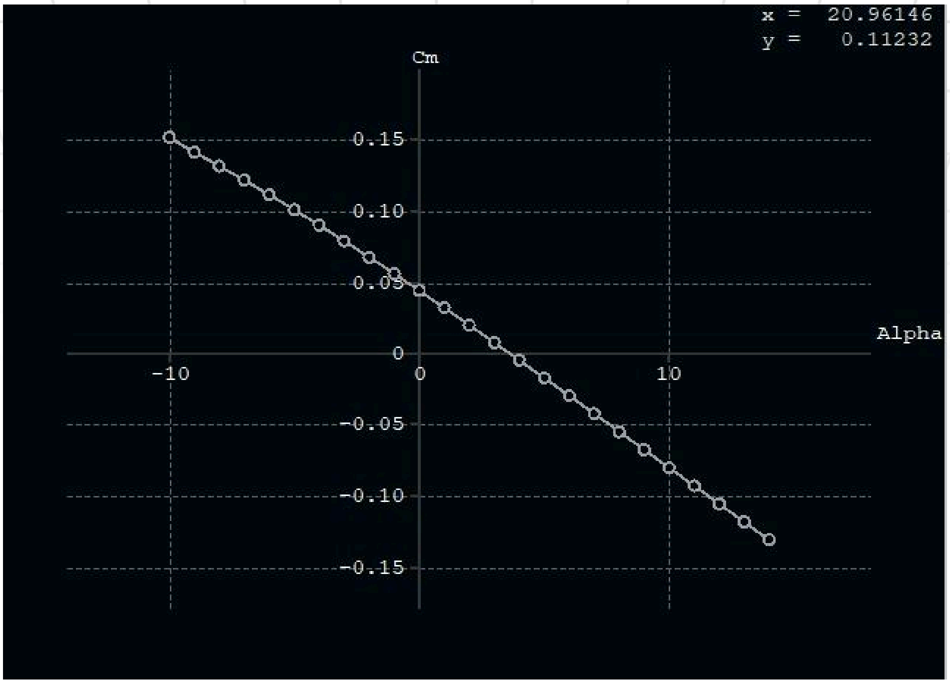
1.5 TAIL OF THE WING

- We evaluated different tail configurations, including symmetrical airfoils, cambered airfoils, and flat plates. Each configuration has its own advantages and drawbacks. While more complex shapes may provide minor aerodynamic benefits in specific conditions, the simplicity and ease of manufacturing make the rectangular configuration a practical choice for our design.
- For the horizontal tail, we aimed for an aspect ratio between 3 and 5. After analyzing the lift-to-drag ratio (CL/CD) and determining the angle of attack (α) for zero pitching moment ($Cm = 0$), we selected a span length of 47 cm and a width of 19 cm, resulting in a tail area of 893 cm^2.
- The vertical tail was designed with stability as the primary focus, targeting a smaller aspect ratio between 1 and 2. By optimizing the span and chord length (with parallel sides of 15 cm and 19 cm, and a height of 27 cm), we obtained a tail area of 459 cm^2 and a final aspect ratio of 1.59. To maximize payload-carrying capacity, the E423 airfoil was selected for its superior lift-generating capability.





1.6 STABILITY ANALYSIS



Zero lift pitching moment = 0.14
static margin = 15%

- **Tool Used**: XFLR5 analysis was performed on the complete aircraft model to evaluate longitudinal static stability.
- **Cm–α Slope:** The plot of Moment Coefficient (Cm) versus Angle of Attack (α) shows a negative linear slope, confirming longitudinal static stability.
- **Restoring Moment:** The negative slope indicates that an increase in angle of attack generates a restoring (nose-down) moment, allowing the aircraft to self-correct in pitch.
- **Cm_0 Value:** The moment coefficient at zero angle of attack (Cm_0) is slightly negative, which is consistent with the horizontal tail producing a small downward force for stability.

1.7 PROPULSION SYSTEM

Components	
Battery	4s 1800 mAh (30C)
ESC	40A
Motor	830 kv
Propeller	12x6
Power	~470-500W
Current Draw	~2.2-2.5A

1.7.1 Wattage

Since our RC Plane is to be designed with a decent payload carrying capacity but we do not need a very high flying speed, we can take the power performance level to be somewhere between basic trainer and sport flying rc plane.

Hence we take the power performance level of our plane to be 100 watts/pound or **222.2 watts/kg.**

$$\text{Wattage} = 2\text{kg} \times 222.2\ \text{W/kg}$$
$$\text{Wattage} \approx 444.2\ \text{W}$$
Wattage Required: ~445 W

1.7.2 Current

- 1 cell nominal voltage: 3.7V
- 4 cells → 14.8V nominal

$$\text{Current} = \text{Voltage}/\text{Wattage} = 14.8/444.4 \approx 30\text{A}$$
Add 20% headroom for ESC:
$$\text{ESC Current} \approx 30 \times 1.2 \approx 36\text{A}$$

ESC: 40A (4S compatible)

1.7.3 Battery C Rating

Battery capacity = 1800 mAh = 1.8 Ah

C rating required:
$$C = \text{Max CurrentCapacity} \times 2 = 30/1.8 \times 2 \approx 33\text{C}$$

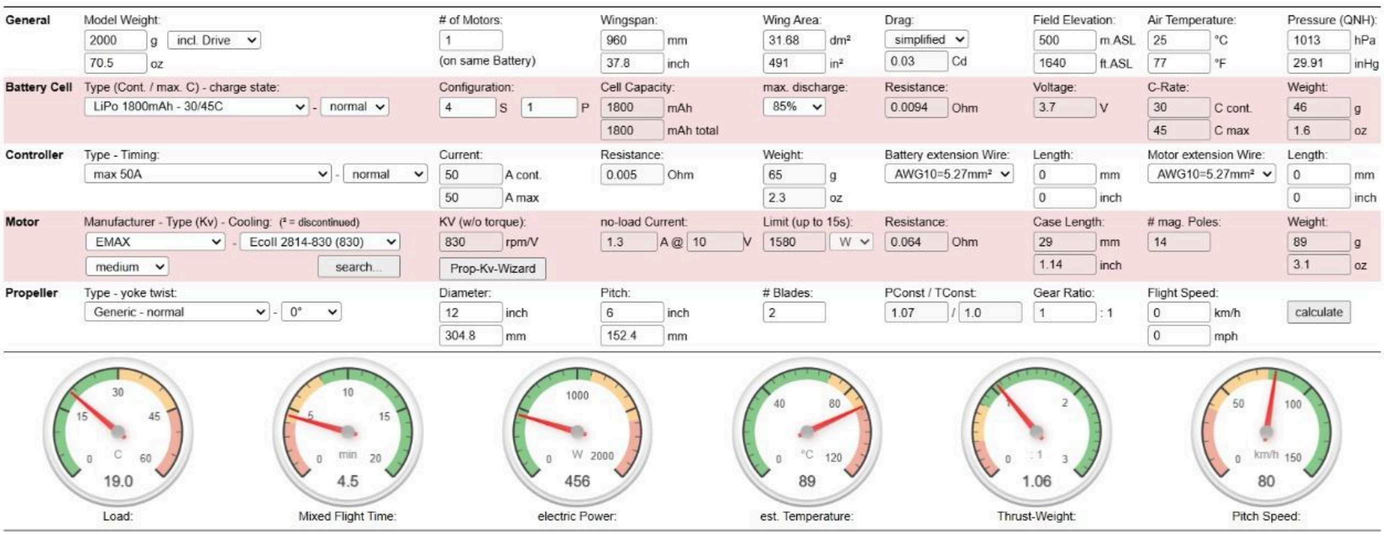
4S 1800 mAh 35C battery minimum.

1.7.4 Thrust Estimation (12×6, 4S, 800 KV)

- $RPM = KV \times Voltage = 800 \times 14.8 \approx 11{,}840$ RPM\
- Thrust (static): ≈ 1.9–2.2 kg
- Thrust-to-weight ratio: $Thrust/Weight = 2.2/2 = 1.1$

Enough for safe flight,12×6 gives more efficiency and less current draw than 12×8 → better flight time but slower climb.

1.7.5 Motor-Propeller-Battery Configuration Analysis



Conclusion

The configured power system (4S 1800 mAh, 830 KV motor, 12×6 propeller, 40A ESC) generates 445 W of power with a 1.06 thrust-to-weight ratio while maintaining a low 19% motor load.

This setup is optimized for payload-carrying missions, ensuring stable flight characteristics, reliable performance, and efficient power usage for short-duration cargo operations

1.8 Results

Our heavy-lift aircraft has been designed around the E423 high-lift airfoil, chosen for its excellent lift characteristics, which are ideal for payload-focused missions. To complement this, we employed lightweight stabilizers that ensure aerodynamic stability while keeping the structure simple and efficient to construct.

- This configuration was finalized after extensive comparisons with alternative designs, supported by stability analyses and performance graphs, ensuring a data-driven approach to maintaining steady and predictable flight behavior.
- Furthermore, through detailed aerodynamic and structural calculations, we confirmed that the aircraft fully complies with all governing regulations and competition constraints, guaranteeing safe and efficient operation.
- In conclusion, our design is not only technically sound but also precisely aligned with the specific goals and requirements of the competition.

1.9 References

- **TAIL CALCULATION**- (References: aircraft_design-libre.pdf (d1wqtxts1xzle7.cloudfront.net) (Department of Aerospace Engineering, IIT MADRAS)

- **PROPULSION SYSTEM**– Selecting a Brushless Motor, ESC, LiPo Battery and Prop for an RC Airplane

- **THRUST**- (Reference : J.D Anderson "Introduction to Flight " 8th edition)

- **DRAG**- Reference : Lee_Nicholai's_White_Paper
  : https://youtu.be/QLGW3a_U6hY
  : Nicolai, Leland M., "Fundamentals of Aircraft Design", METS Inc, 6520 Kingsland Ct, San Jose, Ca

- **PERFORMANCE**- (Reference: Nicolai, Leland M., "Fundamentals of Aircraft Design", METS Inc, 6520 Kingsland Ct, San Jose, Ca 95120, 1975)