Crazy Eights

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Mission

- To design and construct an airplane that will be able to cruise over a designated target zone for five laps, autonomously drop a payload over the 20 x 20 foot target zone after the second lap, then land successfully.
- Project: Bronze Propeller competition sponsored by Boeing.
- Team Goals: To Build an aircraft the team can take pride in and performs the mission successfully. To achieve top 3 at the competition.
- Payload will be dropped autonomously when an onboard computer senses that certain parameters are met during the flight

Requirements and Constraints

- Technical Requirements and Constraints
  - Plane has to fit into a 11x7x36-inch storage box
  - Must be made out of wood as well as simple metal and plastic parts
  - Must be bonded by Cyanoacrylate, wood glue, or spray adhesive
  - Aircraft range must be greater than 4000 ft
  - Payload will be dropped autonomously at designated height
  - Take into account varying critical loads through different maneuvers of flight

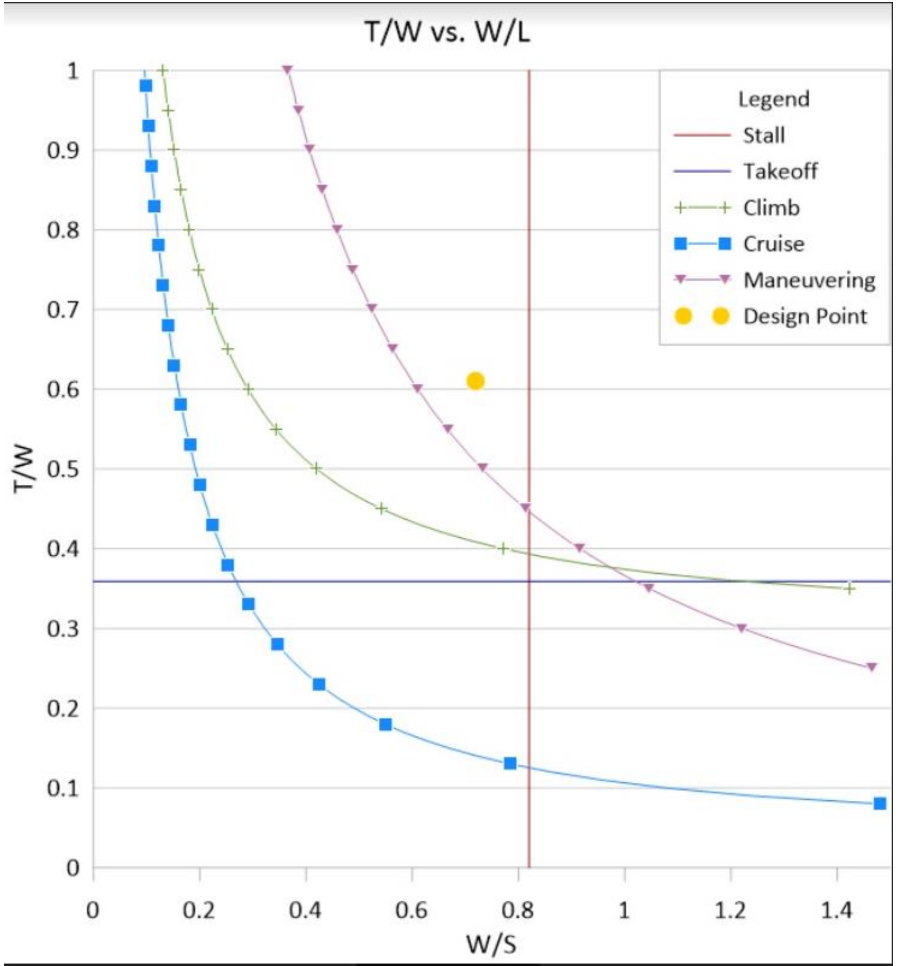
- Non-technical requirements and constraints
  - Airplane will have to be assembled, have the payload installed, pass a structural test, and launch within 5 minutes after removal from storage box
  - Airplane successfully executes a hand launch and belly landing without incurring significant damage
  - Payload will remain secure until dropped
  - Airplane fuselage will have permanent cavity for payload build into it
  - Airplane remains within a flight area for the duration of the flight

Concept Selection

- Ten design concepts initially
- Screening process used six criteria to determine strengths and weaknesses of each
  - Four concepts that failed to have enough strengths were eliminated
- Scoring process used five criteria to determine which concept would be selected
- Cargo tanker concept was chosen because of its simple design, ease of loading, and aerodynamic properties when compared to other concepts

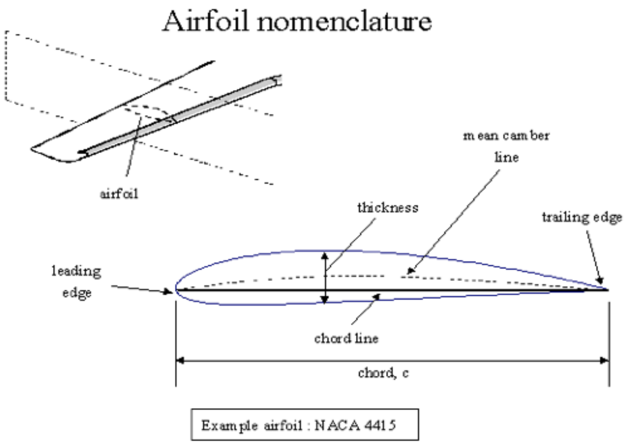
Airplane Sizing

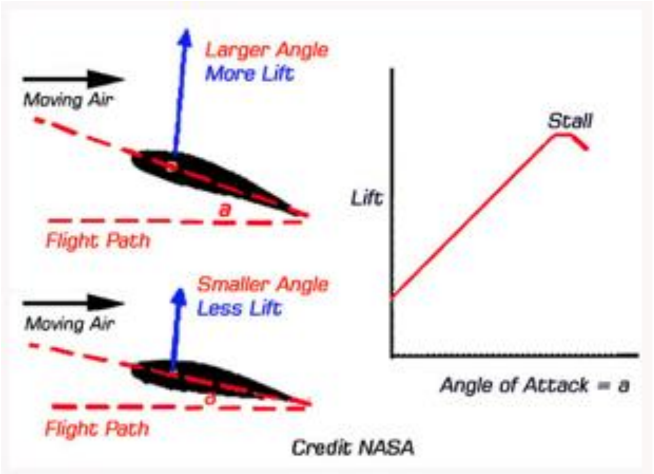
- Wing Loading: 0.72 lb/ft^2
- Thrust-to-Weight Ratio: 0.61
- Performance Parameters Considered:
  - Stall
  - Takeoff
  - Climb
  - Cruise
  - Maneuvering

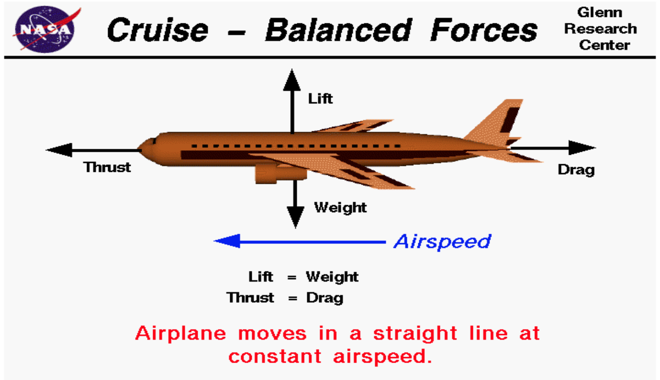


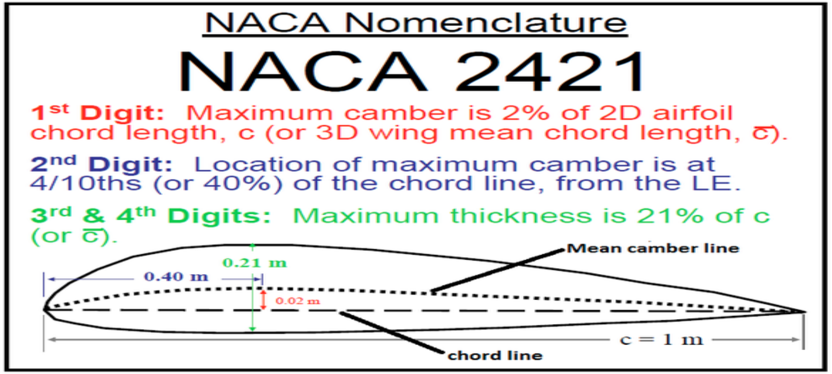
Aerodynamics

Terminology









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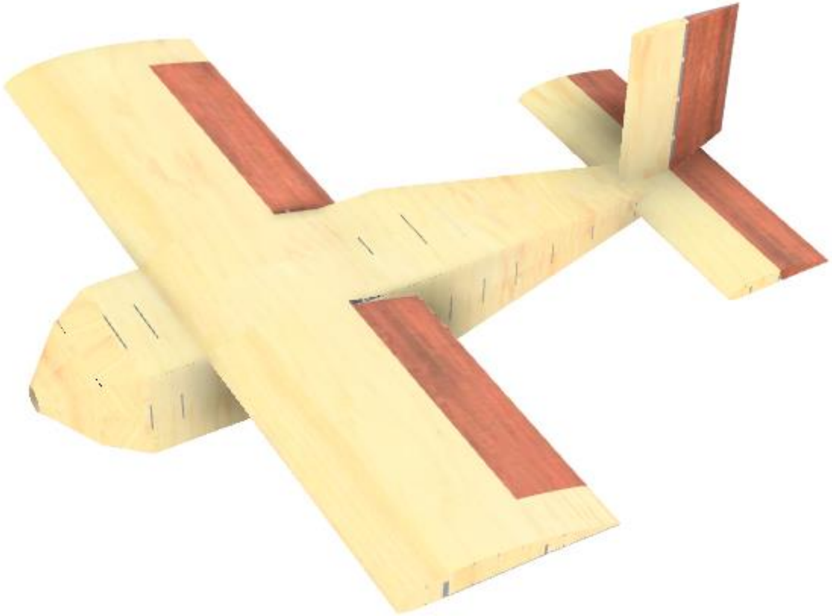
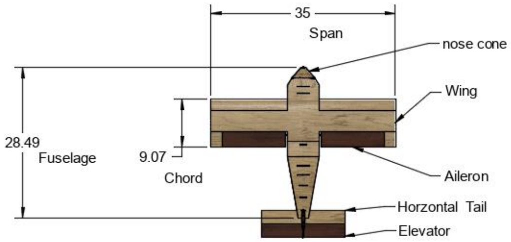
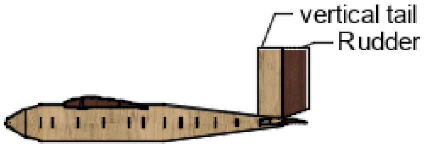
Aerodynamics cont.

- Wing
  - Airfoil: NACA 4412
  - Span: 35 in.
  - Chord: 9 in.
    - 1 Piece Design
    - 1 in. Max Thickness
    - 2 deg inclination
    - Two 12 x 3 in. Ailerons
- Horizontal Stabilizer (Tail)
  - Airfoil: NACA 4412
  - Span: 16 in.
  - Chord: 5
    - 16 x 2.5 in. Elevator

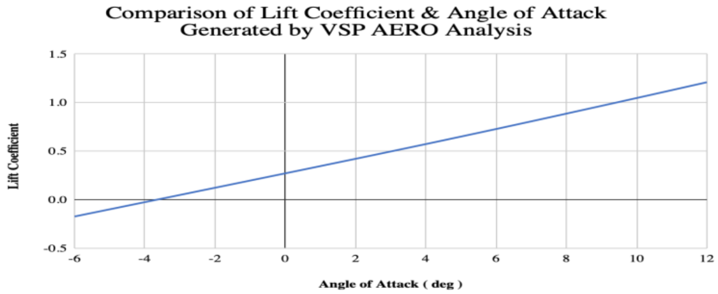


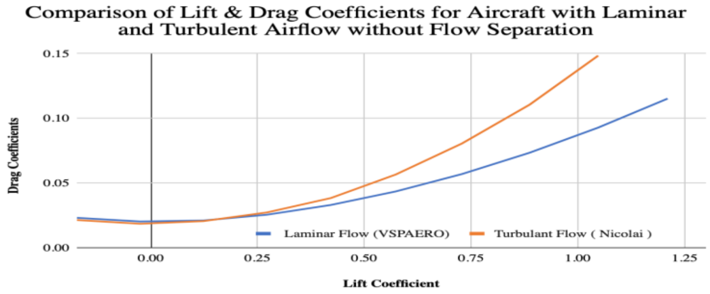


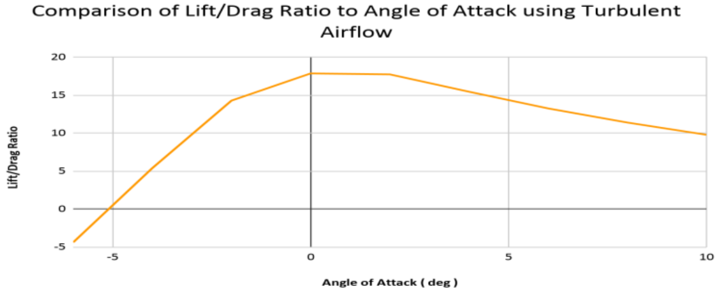


Aerodynamics cont.

- Vertical Stabilizer (Tail)
  - Airfoil: NACA 0009
  - Span: 8 in.
  - Chord: 5 in.
    - 7.5 x 2.5 in. Rudder
- Performance
  - Max lift coefficient 1.2 @ 12 deg angle of attack
  - Min drag coefficient .038
  - Max Lift: 10 lbs
  - Lifting surfaces configured to cruise at 17 L/D ratio
  - Capable of take-off at 20-23 mph

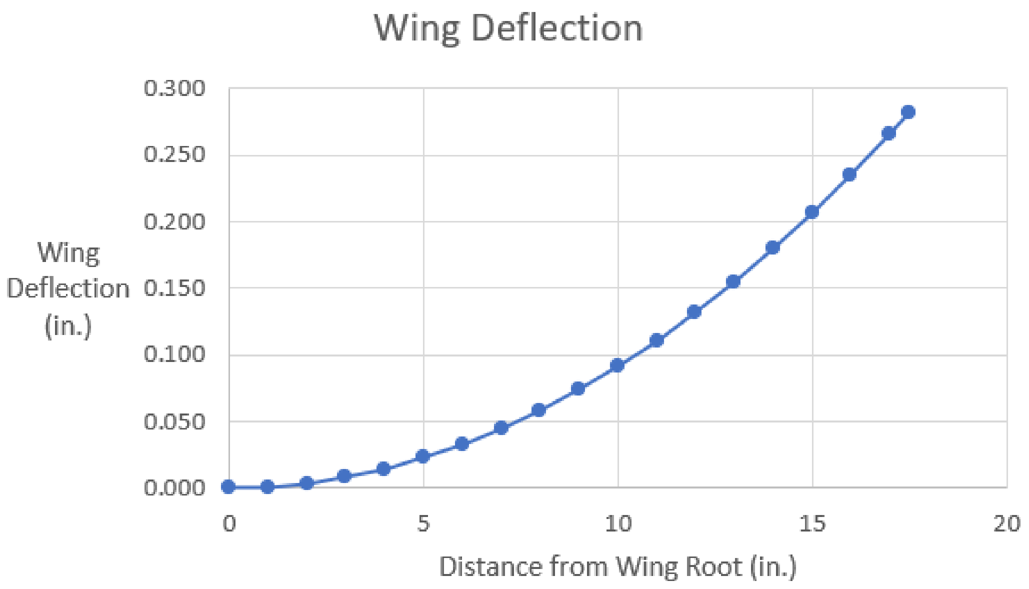






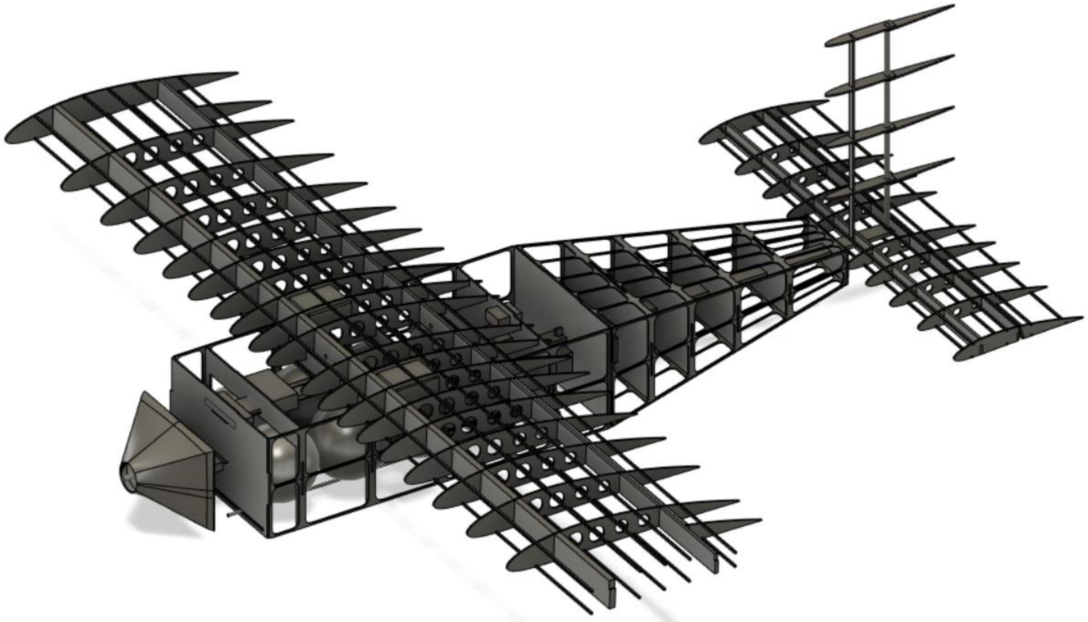
Structures

- Wing
  - Had to withstand a 3.934g turn
  - Withstand a 30 ft/s gust.
  - Total wing deflection: .281 inches
  - Composition
    - Balsa wood skin
    - 10 Basswood stringers
    - Two spars
    - 20 ribs to prevent buckling
- Horizontal and Vertical Tail
  - Similar structural arrangement
  - Horizontal tail
    - No stringers
    - One frontal spar
    - Rear dowel for turning rudder



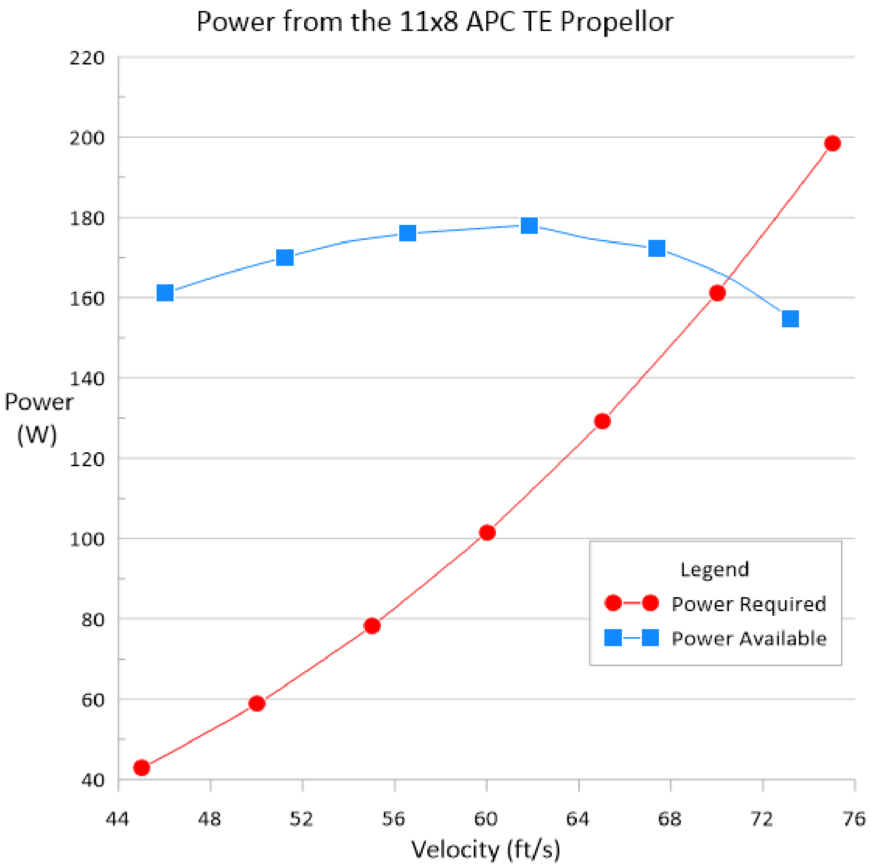
Structures cont.

- Fuselage
  - Semi-monocoque
  - Skin surrounding frame
    - Flat shapes for easy construction
  - All materials are balsa wood
  - Will withstand gusts against the fuselage
  - Bulkheads in the rear fuselage
    - Accommodates servos and tail assembly
  - Bulkheads in cargo bay
    - Where payload is located
  - Nose
    - 3d printed to accommodate the motor



Propulsion

- Propeller Diameter: 11 in
- Propeller RPM: 8,000
- Maximum Climb Velocity of 60 ft/s at AOA of 8°
  - Power Required: 101.5 W
  - Current Required: 22.98 A
- Maximum Cruise Velocity of 70 ft/s at AOA of -2°
  - Power Required: 29.99 W
  - Current Required: 6.79 A
- Battery Pack: E-flite 2,200mAh 3S 11.1V 30C LiPo 13AWG EC3
  - Current Output: 66 A
  - Weight: 6.1 oz



Propulsion cont.

- Motor: E-flite Power 10 Brushless Outrunner Motor 1,100 K_V
  - Motor Power of 375 W
  - Maximum Continuous Current: 30 A
  - RPM to Velocity ratio (K_V): 1,100
  - Weight: 4.3 oz
- Propeller: 11x8 APC Thin Electric
  - Current Required at Cruise Velocity: 16.8 A
  - Motor Power Required at Cruise Velocity: 169.7 W
  - Weight: ~1.41 oz

11x8 APC Thin Electric Propeller			
V (ft/s)	P_A (W)	P_M (W)	I_M (A)
46.04	161.2	187.5	18.57
48.51	165.8	187.5	18.57
51.23	170.1	186.5	18.46
53.82	173.8	185.8	18.39
56.54	175.9	183.97	18.22
59.13	177.0	181.8	18.00
61.85	177.9	179.7	17.79
64.44	174.7	174.7	17.30
67.40	172.2	169.7	16.80

Stability and Control

- Location of the Aerodynamic Center,Center of gravity and static margin with respect to the chord:

X_{AC} (%c)	47
X_{CG} (%c)	33
Static Margin (%c)	15

- Trim deflections needed for various flight conditions throughout the mission:

Condition	Airspeed (ft/s)	Alpha_trim (°)	Elevator_trim (°)
Cruise	70	-1.7	-2.5
1.2*Stall	36	+7.1	-7.1
Level Turn	70	+8.1	-11.7

Stability and Control cont.

- Rudder deflection required to trim in sideslip perturbation created by a crosswind:

Sideslip angle(°)	5	10
Rudder deflection(°)	-6.5	-13.1

- Expected hinge moment on the control surface using a flat plate equivalent method. The torque generated by each servo will have to be greater in order to displace the control surface

Rudder	21 oz-in
Elevator	32 oz-in
Aileron (each)	74 oz-in

Payload Release Mechanism

- Payload was tennis balls
  - Eight tennis balls would be carried in order to increase Bronze Propeller score
- Held in place during flight by two parallel rods
- Rods will move apart to drop payload autonomously
- Trigger for payload drop: airplane descending in altitude shortly before landing
- Altimeter will determine when balls are dropped