Outline

- PMR Recap
- Aerodynamics
- Propulsion
- Structures
  - Design Implementation
  - Accessories
- Test and Evaluation Plan
- Program Management
  - Scheduling
  - Budget
  - Performance
Gantt Chart

Legend
Grey Arrow = Current day
Black Boxes = Completed percentage of task
Orange Boxes = Incomplete percentage of task
Speedfest Mission

Contractors are requested to demonstrate their ability to quickly design, develop and test, a high-speed and efficient aircraft powered by a very small turbojet. The aircraft must not only demonstrate specific speed and efficiency characteristics, but it also must be easy and fast to assemble, and reliable.

Contractors will develop and demonstrated prototype aircraft subject to the objectives set by the Statement of Work (SOW). The winning design will be chosen by a qualified team of judges selected from the aerospace industry, government, and academia.
OPEN CASE, ASSEMBLE CRAFT WHILE SIMULTANEOUSLY STARTING ENGINE, THEN LAUNCH VEHICLE AS QUICKLY AND SAFELY AS POSSIBLE.

Perform a simple and safe maneuver showing control of the craft then land.

- Phase #1: Takeoff and speed run 25 flags in figure 8 pattern.
- Phase #2: Cut engine and climb to optimal altitude.
- Phase #3: Endurance glide with landing and recovery.
PMR Recap

- Internal, High-Mount Engine
- Rigid, Custom Fuel Tank
- Low, Attachable Wing
- H-Tail Empennage
- Tall, Thin Fuselage
Any Questions Before We Get Started?
Aerodynamics
Timothy Runnels
Airfoil Downselect

- Candidate airfoils were run through mission plan analysis
- Glide times for each airfoil were estimated
- Glide times were used to estimate score of each airfoil

Airfoil Glide Scores

*not all airfoils shown*
Selected Airfoil

NACA 2212

- Best predicted score compared to other candidate airfoils
- Compromise between high speed performance and low speed (higher and lower Reynolds number)
- Best glide time and easy manufacturability
Wing Sizing

- Off optimum chord for minimum sink rate
- Increasing chord has a small impact
- Increasing wing area allows for larger margin of safety for hand launch
Hand Launch

- Aircraft will have the capability to be hand launched
- Hand launch was analyzed at worst case scenario
  - 25 ft/s throw (35ft/s nominal)
  - No wind
  - Aircraft over MTOW

![Image with graphs and charts related to hand launch analysis.]
Stabilizer Sizing

- Sized using Raymer method and validated in CFD

- $NP_H = 16$ in from nose

- $NP_V = 20$ in from nose
  - Slightly over stable in yaw, helps to compensate for no yaw control
Horizontal Stabilizer

- Horizontal static margin: 13.8%
- Decent agreement between theoretical approach and
  - Theoretical $AC_H = 15.8$ in
  - CFD $AC_H = 16$ in
- Tail Volume: 0.4
Vertical Stabilizers

- Vertical Static Margin: 66%

- Initial sizing via theoretical approach gave oversized stabilizers
  - Size was reduced from this estimate
  - Difference likely due to odd fuselage shape

- Tail Volume: 0.03
H-Tail

- Allows vertical stabilizers to fit in box
- No assembly required
- Increase effective aspect ratio of horizontal stabilizer
Internal Vs. External Engine

- Initial comparisons using drag buildups from Raymer, then with CFD

- Internal is predicted to have lower parasite drag
  - 15% less in cruise
  - 40% less in glide

- Internal is expected to increase score by 20 points compared to external
\( C_{D0} \) Refinement

- First iteration modeled Fuselage, Wing, and Empennage and estimated a \( C_{D0} \) of 0.02

- Second iteration split aircraft into Fuselage, Cowl, Wing, Horizontal Stabilizer, and Vertical Stabilizer and yielded a \( C_{D0} \) of 0.018
$C_{D0}$ Refinement Cont.
Control Surface Sizing

- Elevator was sized so that stall $\alpha$ can be reached at maximum aileron deflection
- Aileron sizing driven by handling qualities
Trimmability

- $C_{M0}$ value determined through CFD
- Value higher than expected through theoretical means, but still within trammable range
- Likely due to odd fuselage shape

![CM Vs α With Elevator Deflection](image)
Exhaust Impingement

- CFD models used to investigate exhaust
- Simulations show exhaust near fuselage
- Temperatures are approximately 450°F
Engine Effect on Stability and Control

- Engine causes pitch down moment
- Engine exhaust over tail increases tail effectiveness
- Tail incidence set at 0° to avoid large change in trim point with engine shut off
Hinge Moment Estimate

- Sizes taken from earlier analysis
- Coefficient of hinge moment determined in Xfoil
- Scaled to span of control surfaces
Wing Placement

- Rounded fuselage causes issues with low wing
- Move wing up to avoid this rounding
- Helps prevent pre-mature stall
Taper

- Taper was selected for aesthetic purposes

- Study on effect of taper has shown no detriment to overall design
C.G. Travel

- Fuel is placed slightly off of C.G.
- Full fuel static margin: 14.9%
- Empty fuel static margin: 16.5%
- 1.6% total change in static margin
Aero Related Questions?
Propulsion
Shelby Webb
Engine Mount

◊ **Stock**
  ◦ Horizontal Two Point Attachment
  ◦ More Width Required

◊ **Custom**
  ◦ Vertical Single Point Attachment
  ◦ Extended Base
    ◦ Reduce Possible Moment

◊ **Purpose**
  ◦ Reduce
    ◦ Fuselage Width
    ◦ Parasitic Drag
Inlet Selection

- Total Area
  - 3.0 in² - Benchmarked

- Shape
  - Blow Hole

- Location
  - Upper-Half of Fuselage

- Inlet Built Into Hatch
  - Easy to Modify

Top: "Blowhole"

Side: "Gilled"
Inlet in Flight Simulation

- **Purpose**
  - Start Up Time
  - Take – Off Characteristics
  - In-Flight Characteristics

- **Further Testing Required**
  - Gilled
  - Blow Hole
Fuel Tank

- **Custom**
  - Commercial Tanks Not Compatible
  - Utilize Fuselage Internal Volume

- **Materials**
  - Tool Glass
  - 3 oz. Fiber Glass
  - 30 Minute Epoxy

- **Estimated Fuel Required**
  - 1.23lbs
Exhaust Profiling

- **Exhaust Tests**
  - Temperature Distribution
  - Temperature Probe
  - CFD Analysis
  - Exhaust Flow

- **Purpose**
  - Characterize Flow Over Fuselage
  - Reduce Material Damage
    - Fuselage
    - Empennage
Custom Nozzle

◊ **Nozzle Analysis**
  ◇ Parametric Cycle Analysis (PCA) - Completed
  ◇ Mass Flow Parameter (MFP) - Completed
  ◇ CFD Analysis
    ◇ Stock Nozzle
    ◇ Custom Design Nozzle

◊ **Purpose**
  ◇ Point Increase with 15% Thrust Increase
    ◇ Glide
      ◇ 5pt+ Increase
Thrust vs Temperature

Thrust (LBF) vs Temperature (F)
Weather Predictions

- **Speedfest Day Historically**
  - Temperature Range
    - 49.3F – 78.3F

- **Speedfest 2020**
  - Cool Day
    - Thrust: 6.8lb
  - Warm Day
    - Thrust: 6.5lb

![Speedfest Temperature History Graph]

- Max: 78.3 F
- Min: 49.3 F
- Avg: 65.2 F
Propulsion Moving Forward

- Solidify Inlet
- Test Meshes over Inlets
- Slosh Tests
- Temperature Profile of Exhaust Flow
- Finish Nozzle Modifications
- Modify ECU Settings
  - Reduce Start Up Time
  - Change Stage(s) RPM Settings
Propulsion Related Questions?
Structural Decisions and Concerns

- Design Implementation Team (DIT)
  - Material Selection
  - Avionics
  - Wing mounting and internals
  - Tail mounting and internals
  - Fuselage structural supports

- Prototype Accessory Testing Team (PATT)
  - Thermal Soaring
  - Inflatable Structure
  - Launch Dolly
Material Selection: Core

✧ Pre-cut Divinycell
  ◆ Sheets – 32x48 (10.6 ft²)
  ◆ 0.07 lbs/ ft²
  ◆ $31.95/sheet or $3.02/ ft²
  ◆ 1/8” thick

✧ Balsa
  ◆ Sheets – 12x24 (2 ft²)
  ◆ 0.03 lbs/ ft²
  ◆ $10.52/sheet or $5.26/ ft²
  ◆ 1/16” thick
Material Selection: Weave

Costs Less and Weighs Less
✓ Fiberglass – 3 oz
  ✓ 0.03 lbs/ ft²
  ✓ 0.01” thick
  ✓ Equal weight epoxy

Costs More and Weighs More
✓ Carbon Fiber
  ✓ Strong in tensile
  ✓ Use
    ✓ Key structure support
✓ Kevlar
  ✓ Tear Resistant
  ✓ Use
    ✓ Hinges
Wing
Wing Skin

- Top/Bottom Mold
- Materials
  - Layup 1
    - 90-45-DIV-45-90
  - Layup 2+ (Tentative)
    - 45-DIV-45
- Estimated Weight: 1.4 lbs
- Dropping layer weight = Points
Wing Connection: ~8 Seconds

Forward
- Dowel rod connection
- Tried and True

Aft
- Quarter Turn
- Quick and Simple
- Length ~1 inch
- Difficult to find
- Sink
The Wing Connection (Video)
Servo Wing Connection: ~3 Seconds

Wire Harness
- $2.20/Connection
- Self manufacturable
- Quick and Simple

Placement in the box
Wing Spar and Ribs

- **Spar**
  - 74% wingspan
  - Lay-up
    - Carbon Toed in
    - 2x 1/8\textsuperscript{th} aeroply
    - 1x 45 fiberglass

- **Ribs**
  - 2 for fuselage support
  - 4 for ailerons support
  - 2 for servo support
  - 8x 1/8\textsuperscript{th} aeroply
Tail
Tail Skins

- **Horizontal Stab**
  - Top/Bottom Mold
  - 45-balsa-45
  - 0.15 lbs

- **Vertical Stab**
  - Flat Layups
  - 45-div-45
  - 0.1 lbs
Horizontal Stabilizer Connection

- Cut in Fuselage
- Epoxy into place
- Hole for servo rod
Horizontal Stabilizer Internals

- Spar – ¾ span
- Elevator Ribs and Support
- Vertical Stabilizer Supports
Vertical Stabilizer Connection

- Epoxy and screw into place
Fuselage
Fuselage Skin

- Left/Right Mold
- Materials
  - Layup 1
    - 90-45-Div-45-90
  - Layup 2+ (Tentative)
  - 45-Div-45
- Estimated Weight: 0.62 lbs
Engine Bulkheads

Forward

Aft
Engine Support
Wing Bulkheads

¼ Chord

Trailing Edge
Avionics
Avionics List

- Batteries
- Servos
- ECU
- JETI receiver
- Airspeed Indicator
- Variometer
Batteries

Engine

- Runs the ECU
- 3S 9.9V 2100 mAh
- 0.353 lbs

Avionics

- Runs JETI, Servos, and Airspeed
- At least 2S-6.6V 1100 mAh
- 0.180 lbs
Aileron Servos

- Internal Wing Mount
- HS 5087 MH or comparable
  - Up to 7.4 Volts
  - 60 oz*in
  - Sized from Aerodynamics
- Incorporating (CAD Image)
- Thinner core
- Magnetic Hatch
Elevator Servo

- Internal Fuselage Mount
- HS 5087 MH or comparable
  - Up to 7.4 Volts
  - 60 oz*in
  - Sized from Aerodynamics
- Incorporating (CAD Image)
- Magnetic Hatch
- Straw Tube
Weights and CG

- Large Table on slide 111
- Estimated structural weight is 4.4 lbs
- Estimated total weight is 7.0 lbs
- Using final item locations the cg is at 14.6 inches from the nose
Aircraft Structural Order List & Cost

- Shell cost
  - ~$500

- Material cost per flightworthy aircraft
  - ~$2000
Build Related Questions?
PATT
Andrew Cole, Cameron Bright, Hunter Billen, and JW Wallace
Overview

Concepts Moving Forward
- Thermal Soaring
- Inflatable Structure
- Launch Dolly

Concepts Moving Past
- Augmented Flight Modes
- Squirrel Suit Gliding
- Deployable Wing Extensions
Thermal Soaring
$M_{Brown} = \frac{\pi pr^3}{2}$
Launch Dolly

**RATO Cart**
- Rocket mounted on launch dolly instead of directly onboard plane

**Electric Cart**
- Fully electric cart designed for high acceleration
- Enables launch during and before engine spool up
- Low design impact
- RATO is cheap
- Promising initial tests

**Assembly Score vs Time**

![Graph showing Assembly Score vs Time](image)
Electric Dragster

- Similar performance as RATO
- Cheaper long term than RATO
- Safer storage and handling
- Higher impact on cost bid
Test and Evaluation Plan

- Accessory Evaluations
- Structures Evaluations
- Propulsion Engine Tests
- Aero Flight Tests
PATT Related Questions?
Legend
- 8 days for mold process
- 7 days per layup
- First orange box is prototype rollout
- Second orange box is design freeze
- Third orange box is Speedfest
**Budget**

- **Material Costs**: Everything except avionics

- **Launcher Costs**: Potential powered speed sled divided per 4 planes

- **Machining Hours**: CNC mold and laser cut divided per plane

- **Labor Hours**: Mold, layups, and builds

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Performance

- Assembly Mission: 30 seconds
- Efficiency Mission: 180 seconds
  - Takeoff: 60 seconds
  - Flags: 210 seconds
  - Glide: 180 seconds
  - Recovery: 60 seconds
  - Total: 8.5 out of 10 minutes
- Total Weight: 7.00 pounds
- Estimated Speed: 175+ knots
- Static Margin: 14.9%
- Expected Points: 200 pts

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Final Configuration

Questions?