In this Issue...

In this issue, M-Fly will present the progress of the designs as well as justification of design decisions. We will also cover the technical advancements for each subteam in the time since the October Preliminary Design Review (PDR). The PDR offers valuable feedback from professors and students who have a wide variety of knowledge and experience. With the advice from professors, M-Fly subteam members began to make the final design decisions that will be implemented in the aircraft. Both designs have been frozen and the detailed structures CAD work is being completed. Construction will begin early in December. There has already been some preliminary construction completed and the molds are in the process of being machined. M-Fly recently had its Critical Design Review (CDR) where the team presented to industry professionals and past M-Fly members for further feedback as the designs move forward.
Structures - Regular Class

With aerodynamic sizing being finalized, Regular Class structures was able to design the major components of the M-9 while staying true to our design philosophy of being low in weight and manufacturable. Because the wing was the first component to be sized, that was the first component designed. Our first concern was how the main spar would hold the 10.5 foot wing. We ran analysis and calculated the deflection to be less than 2 inches on the wing tips, which is only a 1.5% deflection, well below the margin for concern.

![Deflection of 63.00 Inch Wing](image)

This plot shows the deflection of one half of the wing, with the maximum deflection of 1.8” at the wing tip.

After verifying that the wooden spar structure was stiff enough, the detailed CAD of the wing was created. The design features a continuous (instead of two-part) wing to minimize weight and manufacturing time. The competition rules state that Regular Class is not allowed to use composites, so a standard wooden rib and spar structure, as shown below, is used. Stringers were also added to maintain the airfoil’s shape as much as possible, where the Ultracote can cause distortion in the airfoil shape.

![This CAD model shows the rib-and-spar structure in the continuous wing.](image)

3 November 2016
Once the wing was completed, focus shifted to passenger housing. We created a balsa wood passenger floor where the tennis balls can sit tightly packed together (as stated in the competition rules that the maximum distance between each passenger should not exceed 0.25”). These passengers must be easily accessible, meaning they must be loaded and unloaded quickly, as well as touch counted. To avoid disrupting airflow, an aerodynamic cover was designed to modularly fit in between ribs of the passenger bay.

This CAD model shows the storage structure of the tennisballs.

Another major project was the tail design and the tailboom selection. A conventional tail configuration was selected, which will be built with a standard rib-and-spar structure. Aerodynamics provided vertical forces acting on the tail to be about 13.5 lbf, and with such a long tailboom, it was necessary to select a much larger tailboom than in previous years, which ended up being an aluminum tube with 1.5” diameter and 0.065” thickness. With a length of 63”, this gives us a deflection of 3.5%, which we determined to be an acceptable amount of deflection for a maximum loading case. The fuselage is similar to last year’s design, which is a simple truss structure with a raised motor mount to allow for propeller clearance, as well as a removable cargo bay for easy “luggage” loading.

This shows the design of the M-9 empennage.

The M-9 fuselage is similar to the M-8’s. The motor mount is raise to allow for propeller clearance.

4 November 2016
With the M-8’s landing gear failures, this year’s gear was analyzed extensively with FEA software. Different loading cases, including a perfect vertical 4g landing on both wheels, a worst case 4g landing on one wheel, as well as a 4g landing 15 degrees offset from the vertical axis of the wheels were the test conditions. With an aluminum landing gear thickness of 0.25”, all cases passed with a maximum deflection of 0.3”, which was deemed acceptable. There will be prototype testing done in the future to validate this analysis, as well as further FEA on different configurations, to optimize strength while still minimizing weight.

We calculated the CG location of an empty and fully-loaded plane, both of which created a static margin of above 4%, which means the center of gravity of the M-9 is located 4% of the mean aerodynamic chord in front of the neutral point. This makes the aircraft statically stable, which makes it tend to recover from perturbations in the pitch direction.

The M-9 landing gear is a standard tricycle configuration. The crossbar will help the landing gear in compression or tension on non-ideal landings.

This figure shows the stress distribution on the landing gear in one of our test cases.
Advanced structures has been working on a detailed CAD model. Some specific tasks projects include mass budget allocations, static payload configuration, avionics storage, and dynamic payload mechanisms. Our current CAD model, which is a compilation of both structures and composites subteams’ work, is pictured below. It features a mixture of carbon fiber, wood and aluminum components. The fuselage will be comprised of a structural carbon skin, housing a variety of wooden components. The tailboom, spar, and leading edge are also going to be made of carbon fiber. Throughout the wings and tail, balsa structures/ribs will ensure retention of shape.

We have also begun testing out a few designs for the dynamic payload bays using lessons learned from last year and emphasizing simplicity. The one pictured below is our leading candidate. It features two dynamic payloads (blue) stacked vertically and a single servo supporting two doors via a flange. The doors are essential for keeping the payload streamers from deploying prematurely. We are currently looking into hinges that are able to support 4 lbs without too much deflection of the doors. This design, as well as two others, is currently being prototyped. After testing, a final design will be selected and tested further to ensure reliability.

Last year’s landing gear did not have issues at competition, but reconsidering the design revealed a lot of potential vulnerabilities in the design. This year, we have been doing analysis on a new landing system using Altair Hypermesh. After iterating through various designs and analyzing their stress distributions and deflections, we have concluded that our best option is .25” thick aluminum with an 18” stance width and 9.3” height, ensuring sufficient room for propeller clearance and takeoff rotation, as well as overturn angle stability. Prototyping of the landing gear will begin shortly, which will be followed by testing of the assembly.
The Regular Class aerodynamics subteam has made considerable progress since October. From tail sizing to control surfaces, the M-9 is now very close to its final design. Following the taper ratio trade study, the preliminary wing design was frozen to allow the structures team to start CAD work on conceptual passenger layouts and general structural design. The aerodynamics subteam moved forward by looking at various tail configurations. Team members modified AVL geometry files to create various empennage structures including T-tail, conventional, and H-tail designs. The tail’s performance was characterized by its effects on the aircraft’s overall L/D (Lift-to-Drag ratio), efficiency, and required control surface deflections.

The Regular Class competition has no dimension constraint, allowing more freedom to explore more creative alternatives for a tail structure. After a tail structure was modeled in AVL, its benefits were quantified in both an AVL straight-and-level flight analysis and a steady banked-turn analysis. Further analysis was done regarding control surface optimization by virtue of manipulating the control surface hinge location. This was done to ensure that the control surface not only deflects the correct amount, but also that this deflection does not overload the servos. Hinge position analysis indicated that the location of the rudder and elevator is insignificant. Therefore, for the sake of manufacturability, the rudder and elevators are located 50% of the 1.07’ stabilizer chord.

The aerodynamics team down-selected its potential tail configuration to three designs: a conventional tail, triple tail, and an H-tail. Given the added manufacturing complexity required in triple and H-tails and additional servo requirements, the conventional tail was chosen for its simplicity and proven performance in general aviation aircraft. A pivotal part in tail design is the tail moment arm, a metric which governs the aircraft’s trim conditions at various phases of flight. The optimal tail boom length was selected by running an Multidisciplinary Optimization (MDO) software that varied hundreds of tail boom lengths within a realistic specified range. The most favorable design point was determined by filtering boom lengths that provided the highest L/D ratio, efficiency, and surface area.

7 November 2016
Aileron control surface sizing was performed as well. The aileron hinge location was aligned with the secondary spar of the wing to provide a stable housing for the aileron servos.

The team is currently looking at high-lift devices to improve the overall lift capabilities of the aircraft and ultimately maximize our flight score. Flaps in the non-tapered section of the wing would enable a shorter ground roll period to allow the aircraft to satisfy the 200’ runway requirement more easily. Preliminary AVL analysis indicated that flaps allowed the aircraft 5 to 8 lbs more lift at cruise. This comes at an expense however as the aircraft’s L/D diminished from approximately 12 to around 10. Additionally, the flap deflection leads to earlier flow separation, for these reasons alone, flaps might not be a feasible option for this design. Moreover, the need for an additional servo and control surface deflection near the tail boom add increased complexity where the benefits of flaps are far outweighed by the costs.

A more feasible option is flaperons, a hybrid control surface that can function as a flap and an aileron. This device does not require any additional manufacturing resources or servos since the existing ailerons can just be positioned to act as flaps. AVL analysis indicates that L/D is minimally affected and the team is heavily considering using them as a high-lift device for the M-9. The team is also utilizing CFD to optimize Hoerner wing tip design to reduce lift-induced drag. As the aircraft produces lift, the kinetic energy lost due to wingtip vortices is directly the result of work done by drag. Aircraft typically have tip devices designed to reduce induced drag in the form of wingtips. A Hoerner tip minimizes the “pressure bleed” to maintain a favorable pressure distribution on both upper and lower surfaces of the wing without adding an additional weight. Current simulation results indicate that a Hoerner tip between 40-50 degrees provides the best performance.
Aerodynamics - Advanced Class

The Eppler 420 airfoil was selected for the main wing with the Eppler 435 used for the blended fuselage. Selection was based upon the parameters in the following tables, with values chosen by comparing percent differences from the best value for each category. Stall angle was weighted heavily for the wing airfoil this year as a low stall angle last year made climb difficult and resulted in a stall-induced at a test flight.

The geometry of the fuselage this year was selected by plotting initial splines using control points (based on structures requirements) in Matlab and comparing CL/CD. The design was then hand-iterated and modified.

The geometry of the main wing was constrained to have a constant taper to allow for improved manufacturability. This comes at a direct cost to our efficiency, but will result in a more realistic build schedule and accurately built aircraft. Preliminary selection was done by varying parameters such as root chord, tip chord, and span while satisfying the sizing reference area of 20.5 ft^2 and the structures weight budget of 3.11 lbs for the wing. From there, we picked the aircraft that had the best CL/CD ratio while having a minimum CL of 1.05 at our expected cruise angle of 2 degrees. Our CL of 1.05 corresponds to our expected cruise speed of 36 ft/s.

We then compared different taper ratios locally around this configuration and selected the taper ratio that offered the best efficiency with its maximum local Cl 10% inboard of the ailerons, which reside in the outboard 60-95% of the span. This constraint came from the MX-1 stalling first on the outboard wing, creating the rolling behavior associated with a tip stall. The MX-2 wing is 14.09’ in span, has an area of 20.54 ft^2, aspect ratio of 9.77, and a taper ratio of 0.686.
Our tail sizing was then conducted using the volume coefficient method presented in Raymer’s Conceptual Design. We then extended the tail further to accommodate necessary changes to our CG and neutral point. For Advanced Class, a static margin of less than 10% was deemed unacceptable due to the inherent minor inaccuracies of our CG estimations and the necessity of a very stable aircraft for accurately dropping payload.

For tail trade studies, we analyzed modifying the aspect ratio of the horizontal tail and found that increasing the aspect ratio can significantly reduce our required control surface deflections and improve our CL/CD. We limited the horizontal stabilizer chord to 7.5” for manufacturing purposes.

Effect of horizontal stabilizer aspect ratio on necessary elevator deflection plots illustrate our sizing trade study. The highlighted red points are all beyond our set limit of a 7.5” chord.

The elevator hinge positioning was analyzed and found that increasing the elevator’s percentage of the surface resulted in lower deflections, as expected. We limited our maximum percentage of the surface being elevator to 50%, based on past experience and manufacturing concerns.

10 November 2016
Construction and Composites

The construction subteam has continued its work prototyping and testing throughout the design phase. An additional dynamic (droppable) payload bay was manufactured to confirm exact sizing and volume for the structures team. This was made out of ⅛” balsa wood as a simple prototyping material and was found to be far too weak for use in the actual design. Thus, the prototyped design was cut out of ⅛” plywood instead of balsa and has yet to be assembled.

On November 20, the composites subteam, held a two hour tutorial on composite material handling and protocol. Proper space was allocated among the M-Fly workbenches to safely and efficiently maneuver and work with the materials. The trainees were introduced to mold design and how the mold tools were used to form the composite parts of last year’s Advanced Class aircraft, the MX-1. After discussing the CNC routing and hand polishing processes required for each tool, the group’s attention was moved to the raw composite materials themselves. A large roll of unimpregnated carbon fiber was laid before the students and small portions were cut off for them to handle. The difference in cuts and orientations of the material were explained and how to lay borders of tape on the fiber before cutting to avoid frayed ends was demonstrated.

After cutting the fiber, a square of the same size of foam board was cut and its importance in compression rigidity was explained. At this point, a workbench was coated in plastic and a short lesson on epoxy began. Members learned how to properly mix resin and hardener in appropriate amounts (relative to the mass of the carbon fiber being worked with) and about the work timeline of the adhesives. While some students worked to spread th epoxy over the fiber, others cut equal squares of release film, breather (for protecting the vacuum hose), and vacuum bag for containing the layup. Members were then instructed on how to lay down the sealing tape around the area of the mold. The students placed the layers of impregnated carbon and foam core into the mold and covered with the release film and breather. The vacuum puck was inserted before the students sealed the vacuum bag around the piece, learning to be careful about leaks. Connecting the vacuum, the group was able to bring pressure on the part down to 0.184 atm with no leaks.

11 November 2016
P & C - Regular Class

The Regular Class propulsion system coming together, with the propeller and motor currently being prepared for testing. With a thick, 24” diameter propeller, a special shaft adapter is being designed that will allow the motor to actually interface with the propeller.

Servos were selected based on torque requirements derived from deflection and load data provided by the aerodynamics subteam. The servos will soon be arriving and tested in an iron-bird test and with the rest of the electrical system in order to ensure adequate, reliable performance. Part of the servo selection is shown in the table below.

<table>
<thead>
<tr>
<th>Minimum Torque (oz-in)</th>
<th>Safety Factor 1.5 (oz-in)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aileron</td>
<td>2.11</td>
</tr>
<tr>
<td>Rudder</td>
<td>9.95</td>
</tr>
<tr>
<td>Elevator</td>
<td>67.16</td>
</tr>
</tbody>
</table>

P & C - Advanced Class

Advanced class propulsion is progressing, despite some performance issues. The selected Novarossi engine (shown below) produces 6.5 lbs of thrust; this is much lower than the projected 9 lbs of thrust. However, our current task is to optimize engine performance through troubleshooting the engine, propeller sizing and an exhaust tune pipe. These factors should allow the engine to produce enough thrust for our design constraints.

<table>
<thead>
<tr>
<th>Novarossi R46CR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power Output (HP)</td>
</tr>
<tr>
<td>Max Theoretical RPM</td>
</tr>
<tr>
<td>Price</td>
</tr>
<tr>
<td>Weight (oz)</td>
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</tbody>
</table>
Avionics

Avionics has made lots of progress in the past month. The biggest accomplishment has been getting the majority of the ground station software running. Last year’s software, though functional, was not very well organized and written in Java, making it very difficult to work with the user interface. For easier interaction with the user interface, the team switched to using C# and Visual Studio for the ground station software. This allows the user interface to be developed very easily so that a majority of the focus can be diverted to the underlying logic, as opposed to trying to get things to work right on screen.

Progress on the Data Acquisition System (DAS) has been made as well. The uBlox M8N GPS sensor has been integrated. There was initially some trouble receiving data from the GPS because it outputs in a different format than expected. This is due to the fact that it can connect to three different GPS constellations: GPS, GLONASS, and BeiDou. However, after that was discovered and the parsing algorithm was updated, the GPS can now provide location and altitude information for use in our target prediction algorithms.

Additionally, the subteam has been working on making the existing DAS code more efficient. Last year’s code had numerous places for improvement with regard to efficiency. The new code will only request sensor information when we needed, has increased serial baud rates where possible, has the telemetry transmissions split into multiple sub-messages sent at the appropriate frequency, and includes a reduced amount of floating point numbers. The logic behind reducing the count of floating point numbers comes from the ATmega 2560 processor on the Arduino Mega not having a floating point unit. Reducing the number of floating point operations that performed allows more arithmetic to be done in the faster hardware rather than the slower software.

13 November 2016
For incorporating the avionics, an initial custom PCB design has been created in Altium Designer to accommodate the majority of our systems. The schematics below show the GPS, Xbee, and OpenLog data recorder connected to serial ports, the MPXV7002DP airspeed sensor connected to an analog input, and Adafruit 10-DOF sensor connected to the I2C connector. We also have preliminary locations for connecting the board to external power in order to power the servos controlling the drop mechanism.

The initial PCB layout shows the locations of some of the circuit board’s key components.

The circuit diagram better illustrates the connections in the PCB.