Executive Summary (Page numbers start here) *One page MAX leaving the three subheadings for easy reading (This is where we have gotten to with this so far, several bits need to be edited for wording and content, and the Key Performance Metrics section needs to be written when we have some testing results) The main body of the report with images included should be less than 24 pages with less than 17 pages of text total and the images making up less than another 40% of that.*

Project Objective Statement: Design and fabricate a scalable proof-of-concept liquid oxygen fuel tank prototype using composite material for use on a rocket capable of reaching an altitude of 100km.

Final Status of Design Project:

- Tank is LOX safe for duration of fill cycle and launch.
- Tank does not fail when pressurized to 6 ATM (~90 psi).
- Tank will not fail at expected scaled LV4 flight loadings (meets Factor of Safety of at least 2) for combined loads of thermal and propellant stresses.
- Tank manufacturing process must be able to be performed in the ME department machine shop, or outsourced for a reasonable fee (< $500 per part).
- Tank design and manufacturing process is scalable to final launch vehicle dimensions.
- Complete documentation of testing, manufacturing process, analysis, and research made available publicly on PSAS' Github repository.

The primary challenge in designing a composite fuel tank is making the tank compatible with Liquid Oxygen (LOX). Therefore the conceptual design phase of the project focused on creating an inert and fully sealed liner for the existing airframe design created by the 2014 LV3.0 Composite Airframe Capstone Team[1]. Two primary designs were explored incorporating a PTFE liner and sealed end-caps to address this issue.

Since the main focus of the design is to isolate the LOX from the structural components of the tank module; the liner, end-caps, and seals were the subsystems that received the most attention. Following evaluation and experimentation a design combining the most promising aspects of the leading concepts was adopted. The design involves custom machining a PTFE tube in-house and a shrink-fit end-cap design that effectively seals the LOX from potential ignition sources by creating a wide sealing surface along the wall of the tank.

Key Performance Metrics:

How does the design meet the requirements? Provide brief evidence for the answers. This should reflect the three main deliverables that PSAS wanted addressed. This needs to line up with our RM matrix .

Quick discussion of compression, tensile, and LOX spot testing as well as some discussion of calculations regarding the quality of the seal created by the final design. This would also be a place to mention some of the scalability calculations performed as well as any tools created that we're handing off to PSAS to assist in those calculations for future teams.

1 https://github.com/psas/lv3.0-airframe

Client Requirements: *We have 2-3 pages for this, so we can take a solid paragraph at least to thoroughly explain each requirement. Structure them in such a way that the requirement is easy to identify as the main topic of the paragraph, and so that the importance of the requirement is clear by the end of the section describing it.*

Main Point: The main requirements; LOX compatibility, scalability from our proof-of-concept design to 'full size' LV4.0 Rocket dimensions, a functional factor of safety (FS) of 2, and a well documented manufacturing procedure available through the PSAS repository.

Conceptual Design Summary: *3-5 pages for this. Begin the section by offering a high-level view of our final design highlighting the ways in which it meets the client requirements.*

Analysis of Concept Selection: Here is where we will mention other designs that we considered. We can go into them a little bit if needed, pointing out where they fell short of the final design, and where their strong points were. Basically he says we "should focus on the ideas that directly led to your final conceptual design." We can include pictures of actual prototypes we created as well as CAD models. This is a brief walk-through of our design selection process to show that we considered and pursued multiple design options. We want to basically back up our design choices with proofs and rational basis.

Main point: LOX compatibility was the main design challenge. PTFE was chosen as a liner material due to the inert nature and wide range of working temperatures of the material. The different designs focused on the manufacturing and geometry of the PTFE, how to incorporate the material into the established layup procedure, and how best to create a solid working seal between the liner and the aluminum end-caps. There was added difficulty due to the fact that all of these systems had to work together properly from an ambient loading temperature of roughly 80F down to a working temperature of about -297

Sheet Design

Main Point: An etched PTFE sheet was used/investigated since it was easier to obtain/manufacture. It was secured into cylindrical shape using Aluminum 'bridge' and then fitted into specially designed mating rings before performing the established layup procedure. The weaknesses of this design led directly to us exploring a more ideal design that included a few more manufacturing and procurement difficulties.

Included Pictures: Etched PTFE sheet, Aluminum bridge, and mating rings. (Layup steps, or pics from failed pressure tests?)

Tube Design

Main Point: The 'ideal' design, incorporates a tube of PTFE which provides a uniform liner surface with no seam in comparison to using a sheet. Due to the difficulty of obtaining material with the desired dimensions it was necessary to machine the material in house. With the removal of the seam and a slightly thicker liner material it was also possible to explore a shrink-fit design for the end-cap. This design allowed for the creation of a larger sealing surface by compressing the liner between the end-cap and the lapping portion of the mating ring.

Included Pictures: Machined tube, mating rings, and finished product ready for testing?

Subsystem Highlights: *3-5 pages for this one too. He suggests placing the Subsystem Decomp in this section and using CAD models and schematics to illustrate how they combine to create our entire system. Here is where we will directly compare the final subsystem choices with those we didn't go with. Again, think of the "crucial" choices and how some of the failed or unchosen designs led to our final choices. Don't go crazy with figures and pictures though. Refer to the Appendix for extra details and images that don't quite belong in the body of the report.*

Mating Rings

Main Point: Aluminum mating rings were incorporated in order to adhere and connect all subsystem components together. Two different designs were explored. One had a thin lapping portion allowing it to be easily sandwiched between two layers while the other contained a thicker lapping portion that was accommodated for by the use of an extra layer of the honeycomb material.

Included Pictures: Detail images of both mating ring designs

End-Caps

Main Point: Aluminum end-caps were incorporated using two different designs to match up with the respective PTFE liner designs. To be used with the sheet liner, a flat end cap secured into place with hex fasteners and a PTFE gasket was applied. For the tube design a shrink fit design was explored that provided a compression seal on the PTFE tube liner.

Included Pictures: Detail images of both end-cap designs

Structural Airframe Components

Main Point: Carbon fiber and Nomex honeycomb sandwich layering designs were incorporated based on the development and materials available from the 2014 LV3.0 Composite Airframe Capstone Team. Cytec Metlbond Adhesive was used to secure all material layers in place.

Included Pictures: Detail images of the components (process?), cross-sectional view of the practice tube model design?

Liner Materials

Main Point: PTFE was elected as the preferred liner material to use on the interior of the tank due to its chemical inertness (detailed as excellent in terms of LOX compatibility), weight, low permeability, and wide range of working temperatures. Two different PTFE designs were explored, one using an etched sheet, the other using a standard tube machined in-house to the desired dimensions.

Included Pictures: Charts/graphs comparing different material options? (I don't see a reason why we should include a second set of liner pics, but this seems a good place to include info-graphics)

Sealant/Fittings/Fasteners

Main Point: (Insert proper name) Cryo sealant 'caulking' was applied to all interior edges of the tank where leak paths may occur. This sealant is specified to operate at cryogenic temperatures to provide a secure seal to the interior of the tank. PTFE gaskets were also secured & compressed in between the end cap & mating rings (sheet design, possibly both depending on the results of some testing this week) to provide a seal. Both end-cap designs were secured in place with common hex head fasteners with Teflon tape applied to the threads.

Included Pictures: Caulking in place on a layup, gaskets, seals, and fasteners

Performance Summary: *3-5 pages here too. Measured and quantitative performance results. The goal is to show how well our design meets the client requirements. We are looking for the evidence of our successes. This is also where we will point out any shortcomings or failings of the design. Don't get overly detailed with test results and technical terminology here, use this section to highlight the key points and key results of experimentation and testing.*

Detail LOX Compatibility once we get data

Main Point: LOX compatibility testing will occur in the next 2 weeks in the form of spot testing the different component materials that LOX may come in contact with through normal operation. (*Reported data and results from LOX compatibility tests will be detailed here).* The behavior and strength of all construction materials was cryogenically tested using liquid nitrogen (LN2) and the results of those tests confirm that the tank will meet or exceed the desired FS of 2 in all critical metrics under operating temperatures.

Included Pictures: Stills from videos of the test procedures, details of failure conditions, and charts/graphs of the resulting data

Detail Analytical Models, FEA, and testing

Main Point: Analytical modeling of the components suggests that the tank will withstand an internal pressure of at least 6 atmosphere and a compressive loading of 4000 Newtons, providing the desired FS of 2. Upon testing of the physical prototypes the tank is shown to hold up to an internal pressure of ____ at ambient temperatures, as well as a compression loading of ___ at cryogenic temperatures. Using data provided concerning the expected loads during launch and operation these values were determined to provide a FS of at least 2 for the overall design of the rocket. (These values will be filled in when we have been able to conduct the various tests on the final model)

Included Pictures: FEA models(?), charts/tables of the results and analysis

Detail Scalability Analysis

Main Point: The Jupyter Notebook created during the course of this project predicts that the chosen proof-of-concept design should perform in a similarly when scaled up to the flight-ready dimensions of a 9"-11" diameter tank. (show numbers, analysis, etc)

Final Status: *1-2 pages here. For the most part this should be another high-level view section acting as a summary of the design, achievements, and current status of the project. Include what we've done with the final deliverables of the project.*

Main point: The tank was successful due to the following reasons:_______________ The tank was a failure due to the following reasons: ________ (Technically this is still an unknown for us at the moment).

A detailed account of the procedures, tests, and results has been compiled and delivered to PSAS to provide an information source for future teams who will work on this project. Along with this documentation, they have been provided the Jupyter Notebook as a stress calculation tool as well as all physical prototypes and any unused materials to allow for any future testing that may be desired. This information has also been compiled and stored on the open-source site GitHub so that it can be accessed and added to by other rocket enthusiasts in the community.

Conclusions/Recommendations for Moving Forward: *I added this one myself (Gerry suggests something similar as the second purpose for the preceding section, but I feel like separating it out might be appropriate given the nature of our project)... I'd say no more than 1 page for this. Take a little time to address some of the things we were unable to do (etching the tubes) due to time constraints. Point out some of the scalability calculation tools that we've put together, and take some time to address specific design suggestions for teams moving forward with this project including some of the things that might prove easier (and tougher) on the fully scaled up version of the tank.*

Main point: As this work will be continued by future teams, and will be scaled up by PSAS to incorporate into the LV4.0 Rocket, the following recommendations should be followed by any future teams addressing this project or duplicating the work (*list)*. Due to lead times and project deadlines, it was not feasible to have the tubes that were machined in-house etched. Where this did not seem to create any critical failures for the scaled down version, it is suggested to have this done. The lead time for the procedure is likely to be 3-4 weeks. The scaled up version of the manufacturing process for the PTFE liner is likely to include a few extra challenges due to the larger diameter, but it should be possible to follow a very similar process and achieve equally satisfactory results. (We will also include any other recommendations/warnings that come up as we finish this project and are more aware of the success/failure status of our final designs)