Spring 2023

Landing Gear Sealing Solution

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Landing Gear Sealing Solution

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Honors Research Project

Submitted to

The Williams Honors College
The University of Akron

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1.0 ABSTRACT

XYZ Landing Gear Solutions has been tasked with redesigning two internal components of the landing gears for the ABC-123 aircraft program. The customer, ABC Aeronautics, informed XYZ Landing Gear Solutions that a particular system of the landing gear does not meet the necessary performance requirements of the program. As a result, the entire system will have to be removed, facilitating the need for a redesign of the two components that the system interfaced with. The focus of this project will be completing the redesign process for both of these components. “Redesign” and “design” will be used interchangeably in this report.

The scope of this report will be limited to only the design of the new components and will not discuss, at least not in detail, the manufacturing and installation of the new components. Following the design process outlined in this report, a final detailed design of each component will be completed, while also following all requirements from ABC Aeronautics.

NOTE: Any and all proprietary/technical data has been excluded from this report. Many dimensions, calculations, and other quantities cannot be conveyed as a result. All models depicted will not have any true dimensions attached to them, nor any other revealing features.

2.0 ACKNOWLEDGEMENTS

I would like to thank my company for allowing me to use one of my tasks at work for my senior design project. Many engineers on the team have helped and guided me along the way, both on this project and in my development as a young engineer. While learning the design process of any landing gear is a long and complex one, I am grateful that all of my co-workers have provided (and continue to provide) me with any assistance necessary to ensure that I can become a great engineer on the team and make a meaningful impact.

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3.0 INTRODUCTION

3.1 Background

All ABC-123 landing gears feature an oleo-pneumatic shock strut as a way to damp the landing gear and reduce vertical oscillations on takeoff and landing. For the ABC-123 program, these shock struts are comprised of oil and a gas mixture. As the landing gear compresses, oil flows through an orifice, reducing the volume that the gas occupies. This reduction in volume increases the density of the gas, thus providing the damping required. In order to accurately measure the levels (or volume) of oil and gas in the landing gear, a Fluid Level Sensing System (FLSS) was created. This system utilizes fiber optics and is a component of the Prognostic and Health Management (PHM) assembly. The PHM assembly ensures that the landing gear is performing optimally and that all systems are functioning nominally. The FLSS requires the landing gear to be vertical and fully extended for a time period of several minutes to make the necessary fiber optic penetrations into the shock strut to record fluid levels.

Unfortunately, the PHM FLSS currently used on all ABC-123 landing gears does not meet the requirements of the ABC-123 program. In a typical ABC-123 flight the landing gear is never in the configuration needed for the FLSS, especially regarding the amount of time needed for the fluid measurements. This is a design flaw that cannot be overcome by any reasonable design changes to the FLSS. In addition, the fiber optic penetrations into the shock strut required for the FLSS have shown to be problematic as they are a common gas leak path requiring frequent maintenance actions to resolve resulting in increased aircraft downtime.

Given all of these shortcomings of the PHM FLSS on ABC-123 landing gears, ABC Aeronautics is requesting XYZ Landing Gear Solutions to remove the PHM FLSS from all ABC-123 landing gears. This project will encompass the research, analysis, and design of the new sealing system that will replace the one used with the FLSS.

3.2 Principles of Operation

Currently, the ABC-123 FLSS consists of the following hardware that will have to be redesigned to facilitate removal of the FLSS: an orifice support tube (OST) plug, a wire adapter retainer, an atmospheric sealing plug, and a fiber optic support tube. The atmospheric sealing plug and fiber optic support tube will be discussed first in the redesign process. The OST plug and wire adapter retainer will be discussed second. At the completion of this project, the new hardware and/or any new configurations must be able to hold an acceptable level of volume within the shock strut. They must also be able to provide an atmospheric seal for the bore in the cylinder of the shock strut where the FLSS used to reside. No performance metrics shall fall below acceptable levels as a result of the new hardware and/or any new configurations.

This project will focus on redesigning the OST plug and fiber optic support tube (also mentioned simply as “support tube”). The OST plug directly interacts with gas inside the landing gear, so a larger emphasis will be placed on the redesign of this component. The support tube will act as an atmospheric seal for the OST plug, where its main function will be to secure itself to the OST plug while also sealing off the atmospheric bore on the top of the shock strut cylinder. The interface between the OST plug and support tube will not change, as the FLSS removal does not facilitate changing the interaction between these two components.

The biggest challenge of this redesign will be ensuring that the OST plug retains the same amount of gas volume as the previous configuration. Increasing or decreasing the amount of oil in the shock strut will not affect the performance of the landing gear compared to the gas volume changing. An in-depth volume analysis of the internal oil and gas volumes in the landing gear will be completed as a result, which will be the bulk of the redesign effort. All top-level landing gear models in this report will be without hardware that is not necessary for the redesign effort.

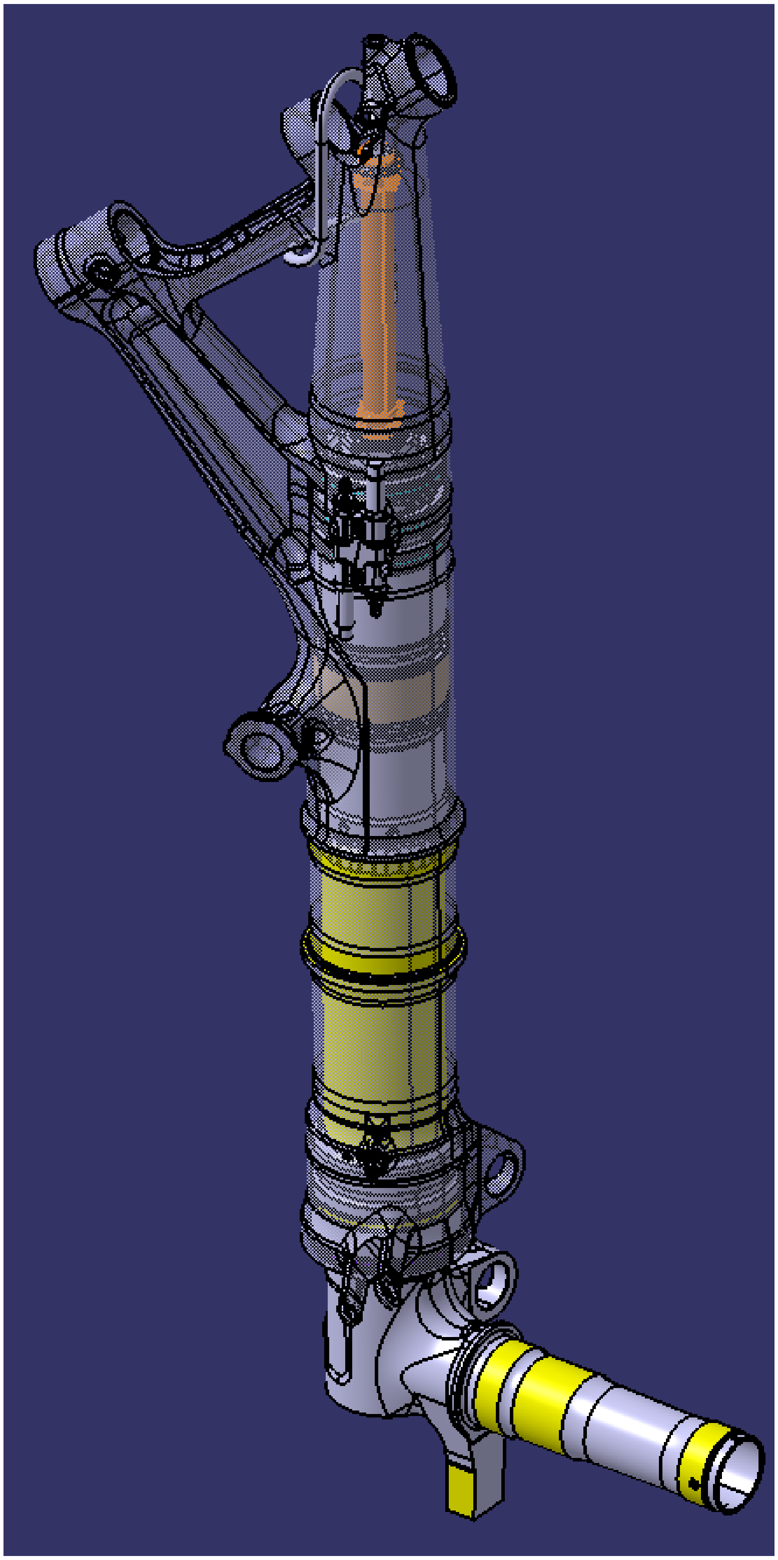

Figure 1: Current OST Plug and Fiber Optic Support Tube Assembled in Landing Gear

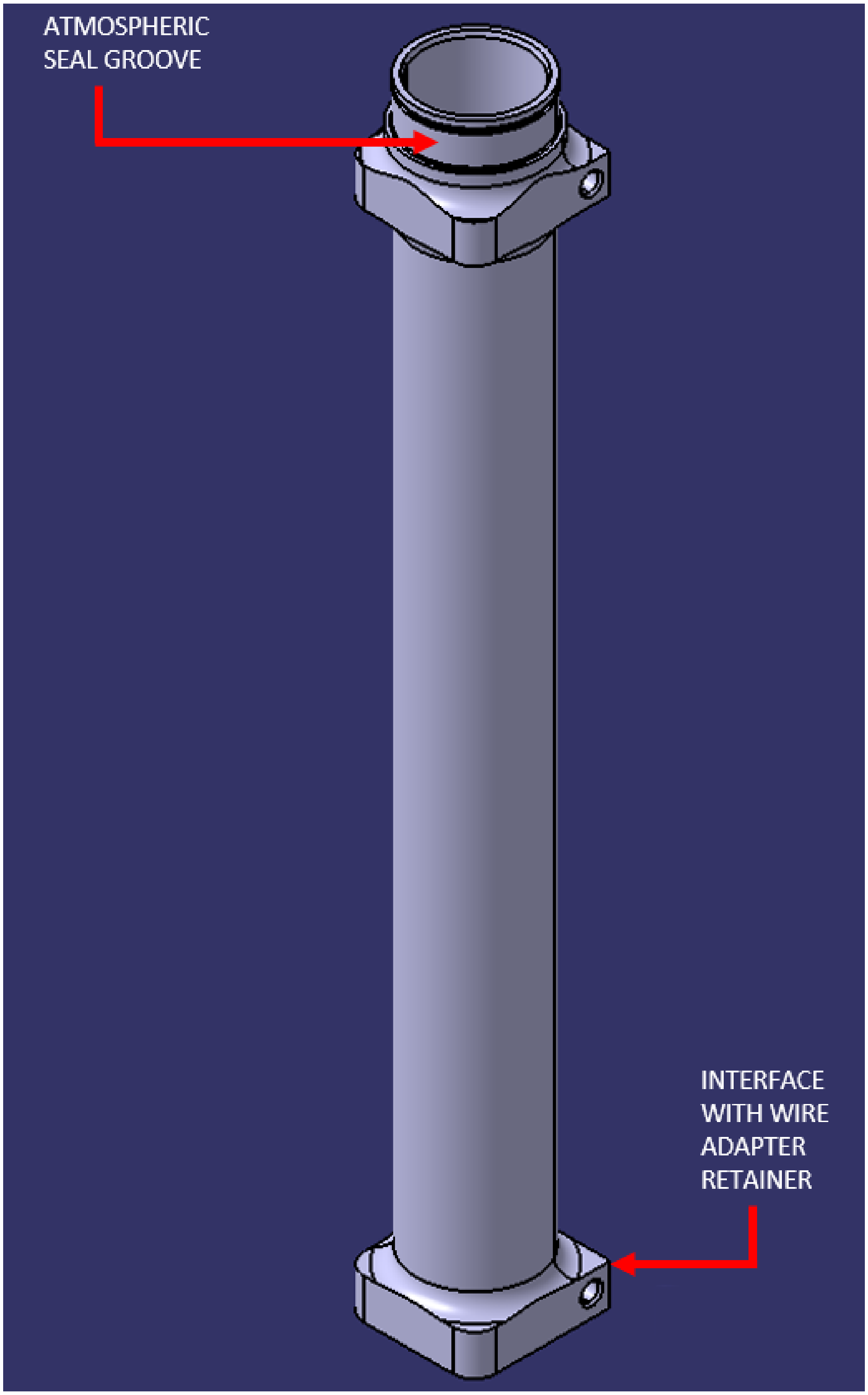

Figure 2: Current Fiber Optic Support Tube

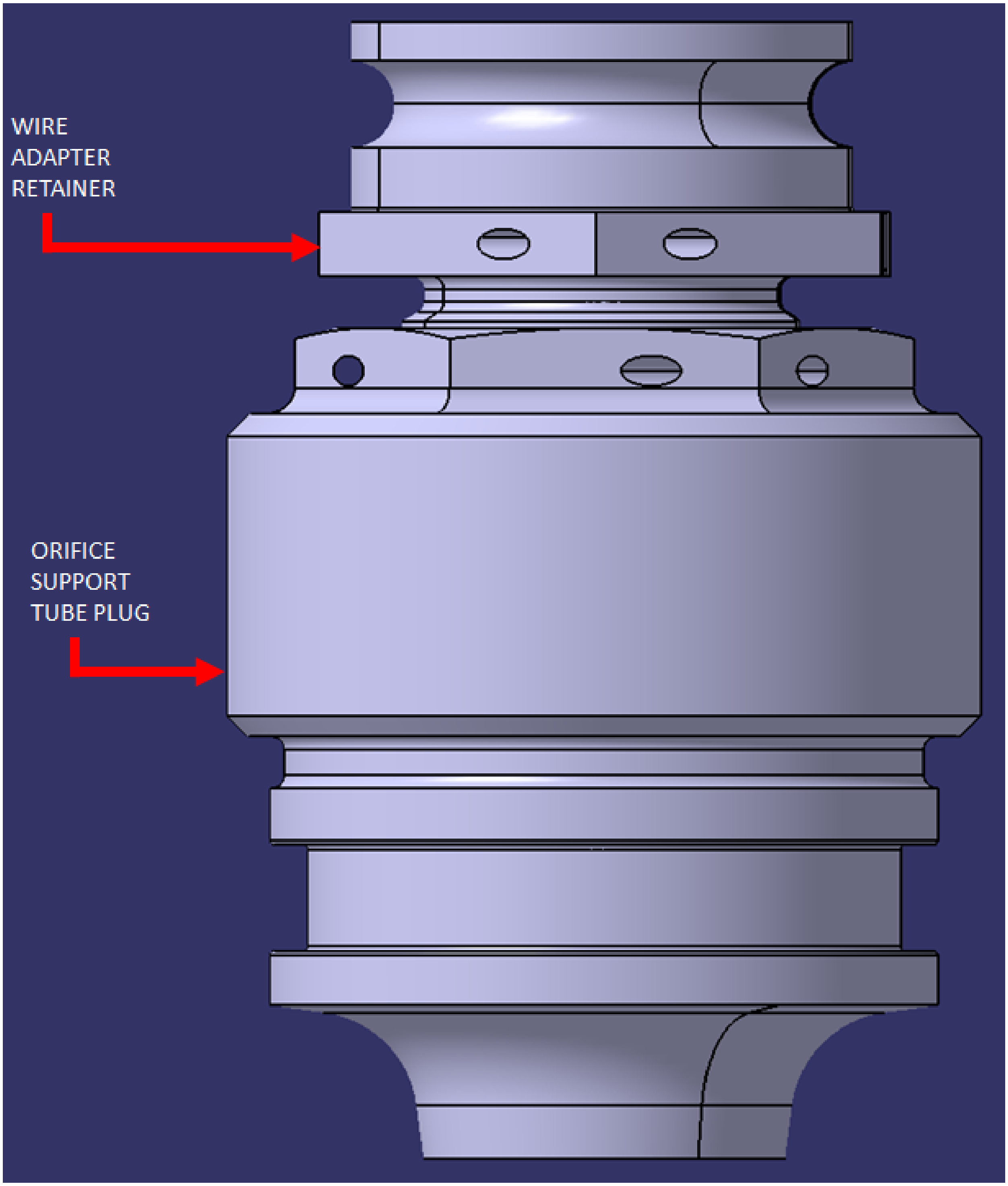

Figure 3: Current OST Plug and Wire Adapter Retainer

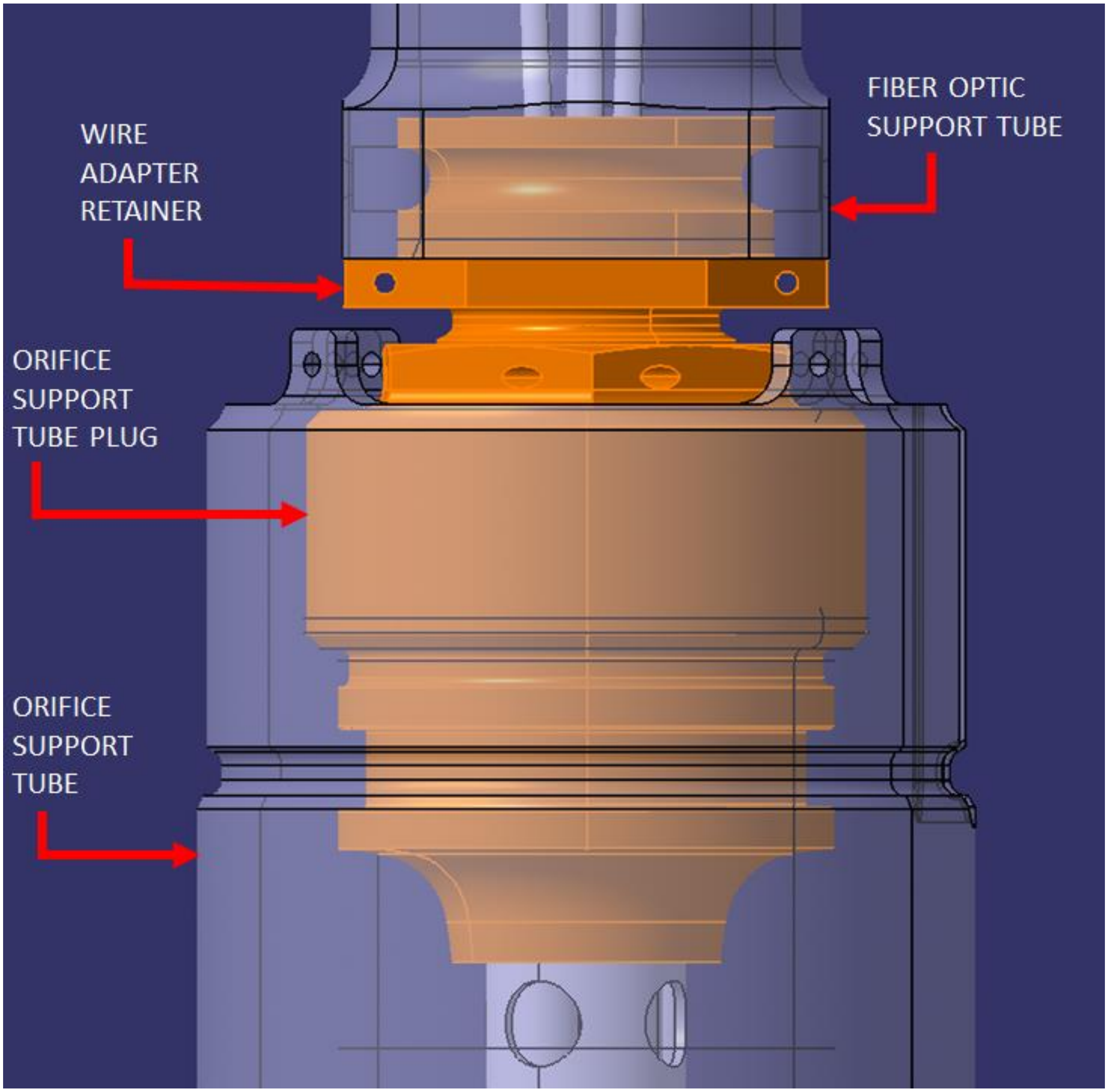

Figure 4: Current OST Plug, Wire Adapter Retainer, and Fiber Optic Support Tube Interface

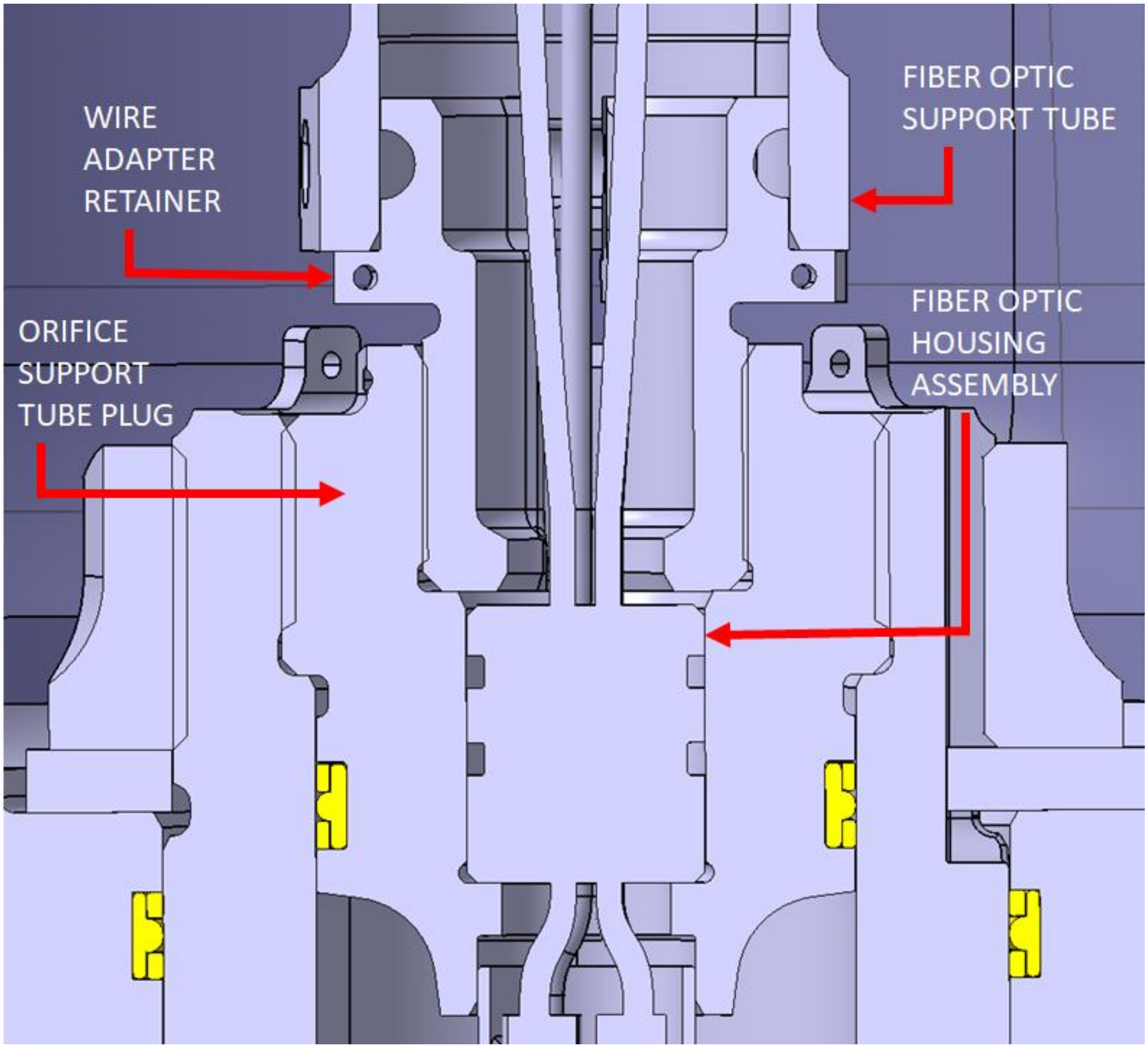

Figure 5: Section View of Current OST Plug, Wire Adapter Retainer, Fiber Optic Support Tube, and Fiber Optic Housing Assembly

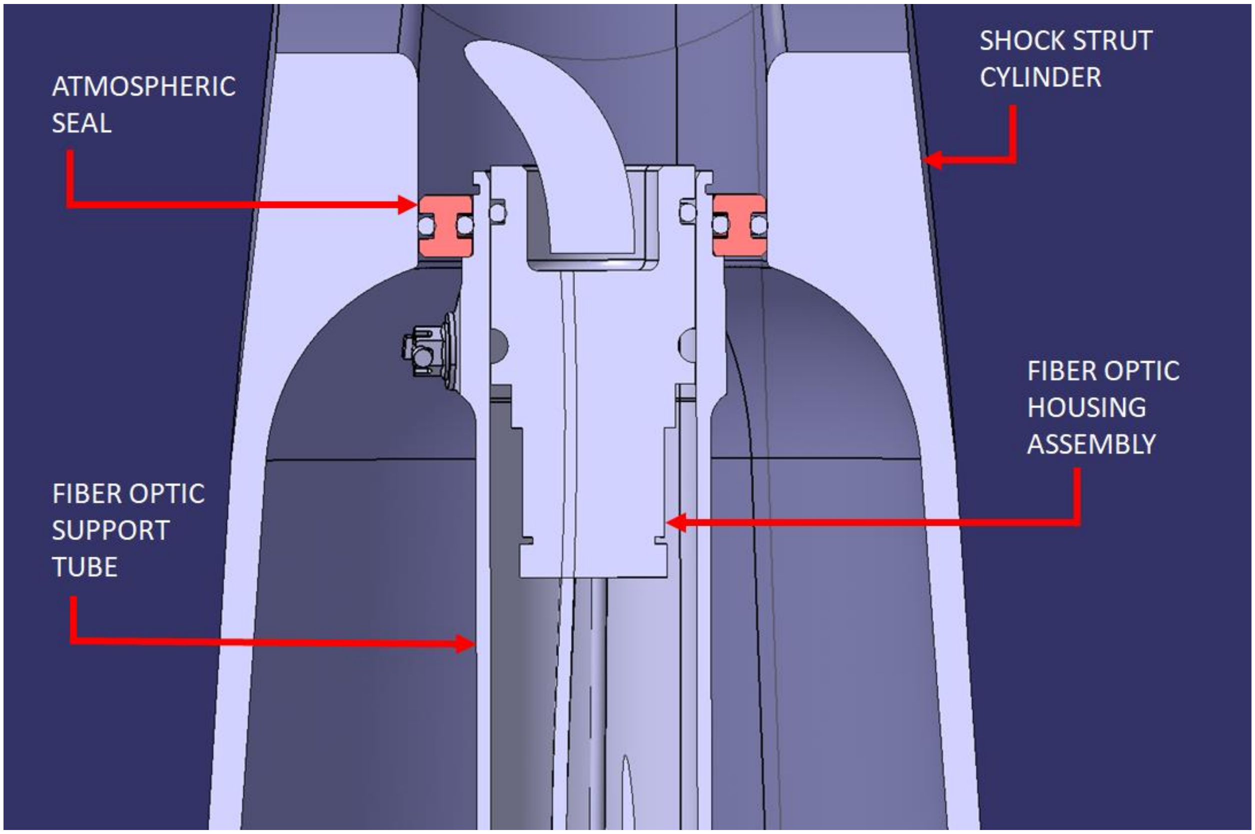

Figure 6: Section View of Current Fiber Optic Support Tube, Atmospheric Seal, and Fiber Optic Housing Assembly

Since the fiber optic housing assembly and fiber optics themselves are part of the FLSS, they will both have to be removed. This drives the need for a new OST plug and support tube design, as the current configuration does not allow the fiber optic housing assembly to be removed while keeping a seal. The fiber optic housing assembly acts as a seal for both the OST plug and support tube, so a new design will have to be made for each featuring their own sealing system. Previously known as the fiber optic support tube, the removal of the fiber optics from the landing gear will result in the redesigned component being referred to as just the "support tube" going forward.

4.0 PRODUCT DEFINITION

4.1 Simple Design Brief

There is a need to develop an easy and effective way to seal an internal and external chamber in a landing gear. The design should not allow any atmospheric gases to enter the landing gear while also containing all internal gases and fluids inside the landing gear. The internal gas volume must be equal to the volume from the old design.

4.2 Expanded Design Brief

There is a need to redesign a tube and plug seal internal to a landing gear shock strut. These designs should have minimal impact to the overall form and function of the components. The new designs should not adversely affect performance in any way. No testing shall be impacted by the design, including any quality or acceptance procedures. The design should be easy to manufacture while still including all the features necessary to facilitate the needs of the project and scope. Any and all documents relating to the components and assemblies being redesigned will have to be revised to reflect any changes that occurred. The final designs should not alter the amount of internal gas volume inside the shock strut. They should also prevent the possibility of any atmospheric gases entering the landing gear.

5.0 CONCEPTUAL DESIGN

The conceptual design of the support tube and atmospheric seal will be discussed first. While the bulk of the redesign effort will focus on the OST plug and wire adapter retainer due to the functionality of the components, the support tube and atmospheric seal are still important to consider. The support tube and atmospheric seal will be responsible for preventing atmospheric gases (and moisture) from entering the shock strut while also securing the OST plug in the landing gear. The OST plug will be responsible for containing the gas inside the internal shock strut chamber in the landing gear.

5.1 Support Tube

There were two main paths considered for the support tube redesign. Option 1 - keep the current support tube design but redesign the retention methods (plugs and seals). Option 2 – completely remodel the support tube to only feature one sealing feature (as opposed to 3). After consideration, option 2 was chosen for final implementation as this option presented the greatest number of benefits with virtually no drawbacks. By only having one seal path, components like extra plugs and seals can be eliminated, while also reducing the chance of a seal leakage, as there is only one seal now instead of multiple. Fewer components in the design will also likely cost less while being easier to manufacture and assemble in the landing gear.

Table 1: Support Tube Redesign Comparison Table

	PROS	CONS
OPTION 1	1. Similar to the current configuration	1. Does not eliminate any seal paths 2. Does not eliminate any components
OPTION 2	1. Eliminates two separate seal paths 2. Eliminates seal path components	

Option 1 will be briefly examined first. Then, Option 2's design will be discussed, where the benefits of the design will be highlighted.

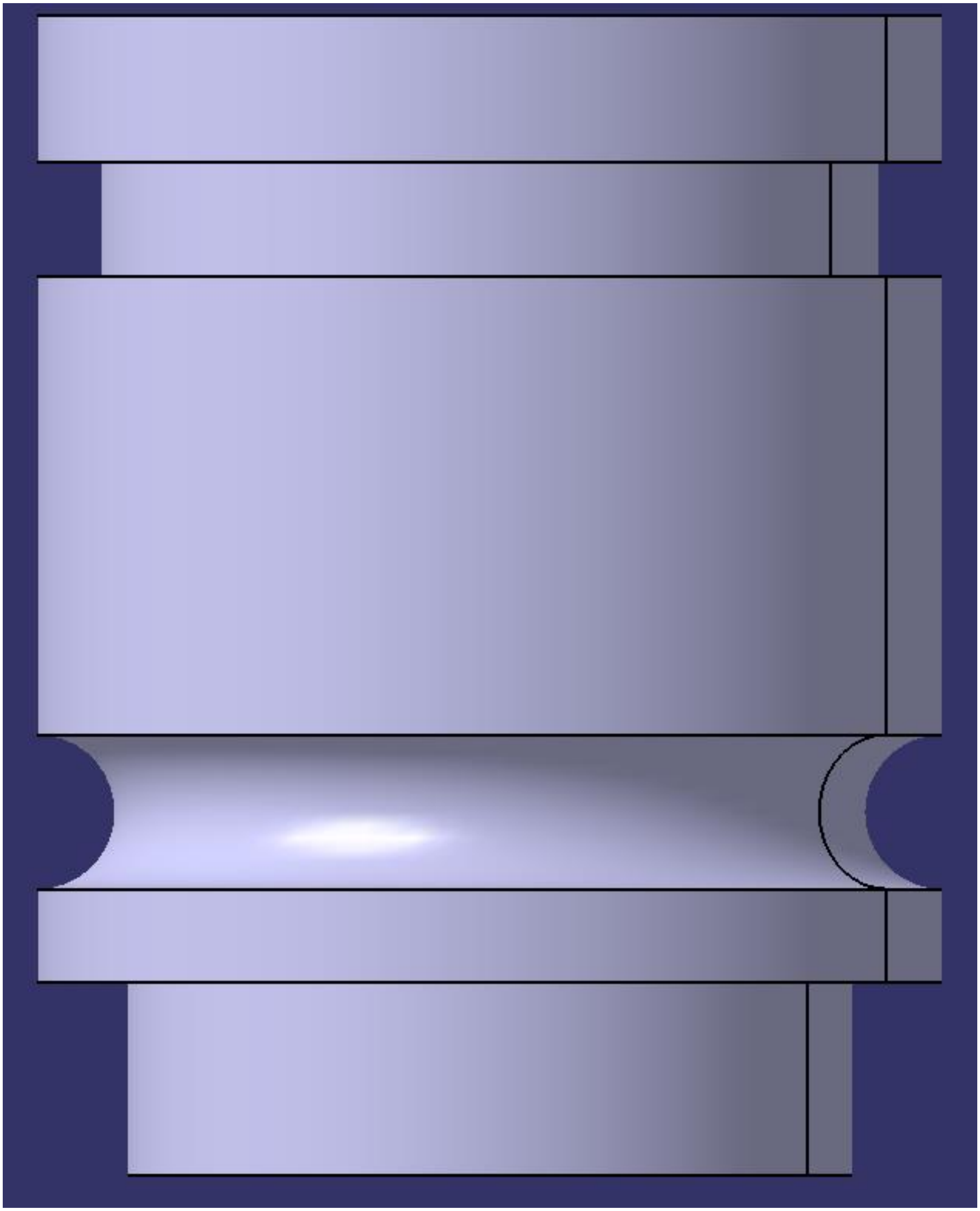

Figure 7: Option 1 Redesigned Support Tube Plug

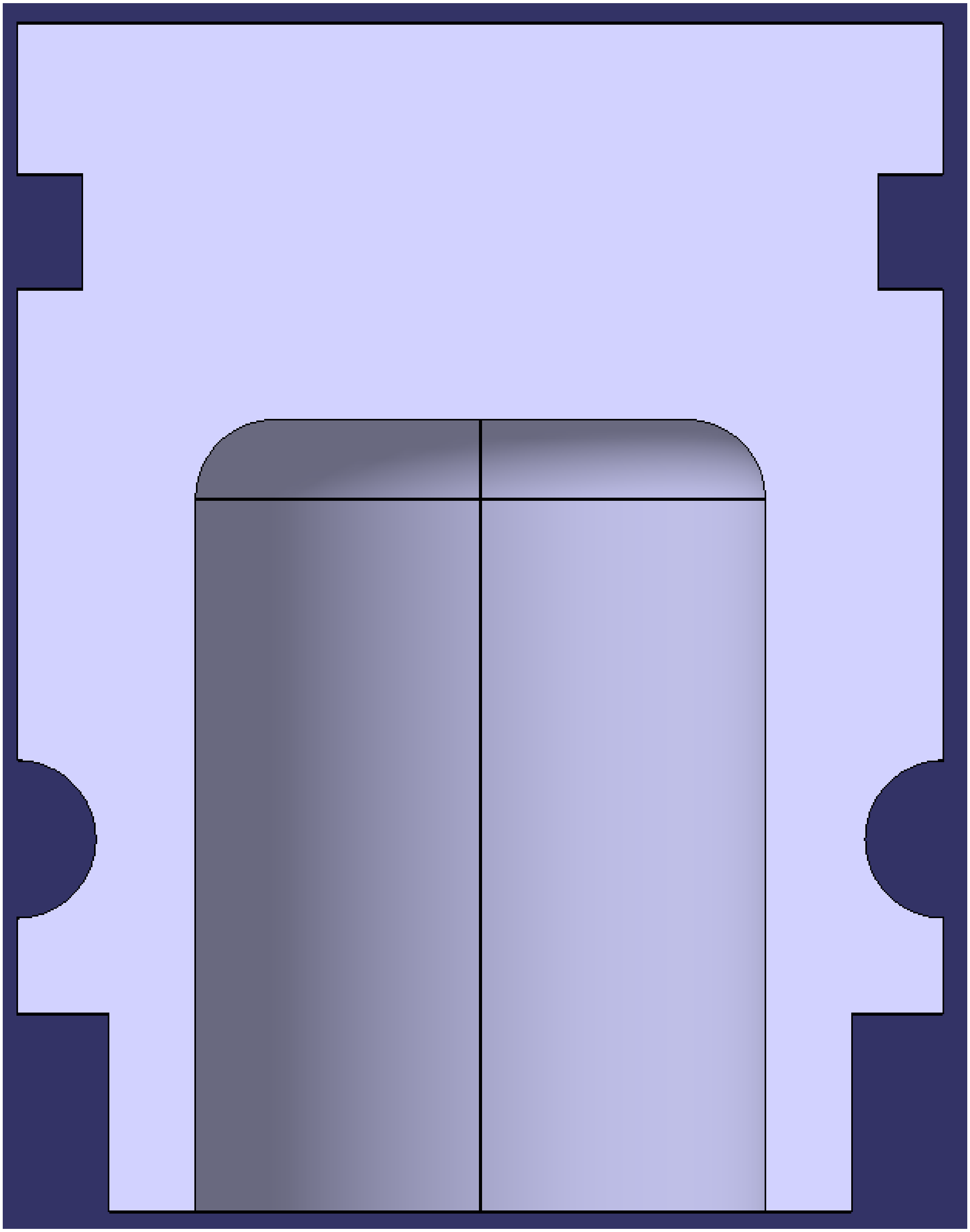

Figure 8: Section View of Option 1 Redesigned Support Tube Plug

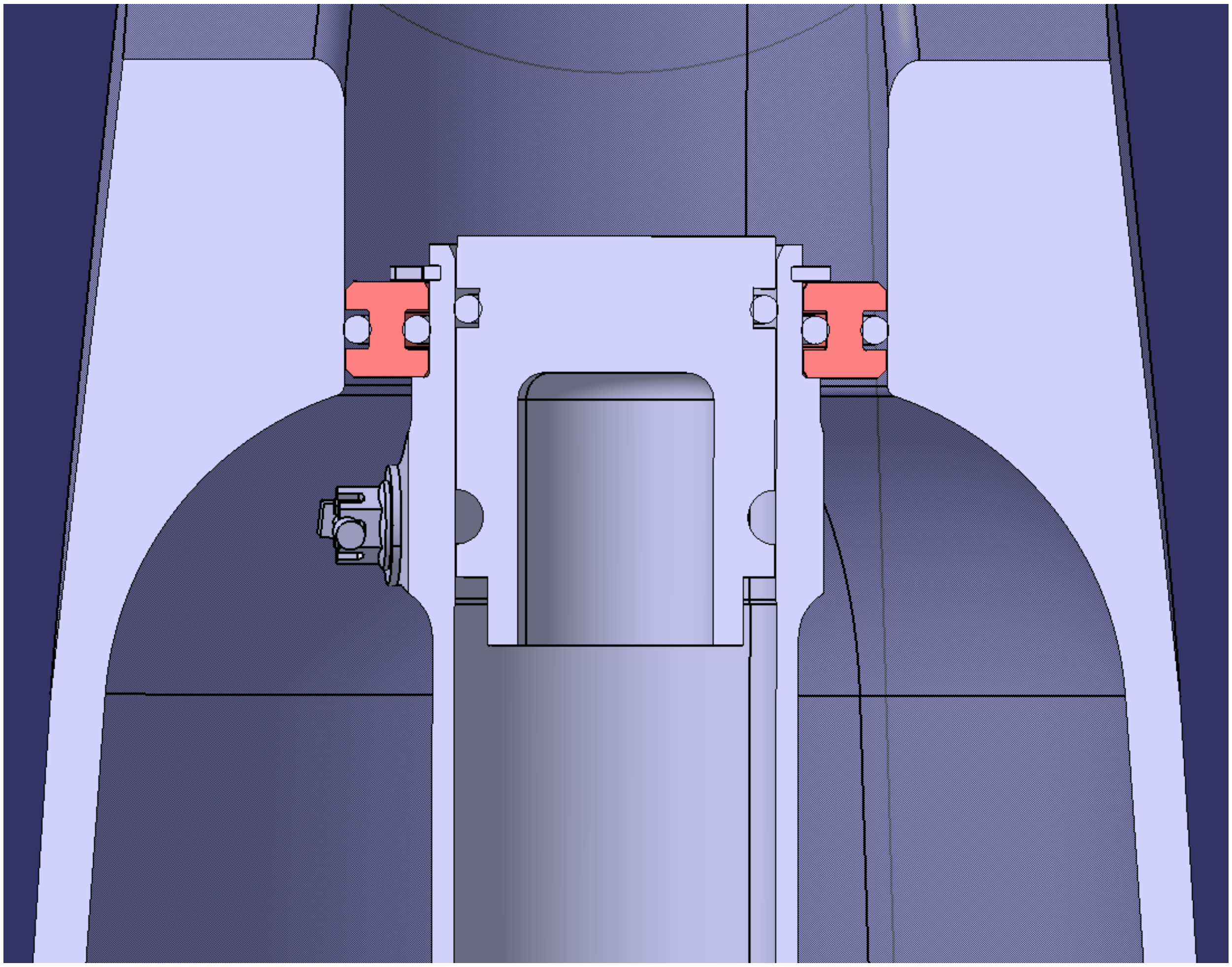

Figure 9: Option 1 Redesigned Support Tube Plug Interface with Support Tube

Option 1's design does not feature any of the benefits listed in option 2, while also not providing any benefits of its own (aside from keeping a similar design to the previous configuration). Having a similar design could help in a qualification by similarity report to ensure that the design will function the same as the previous configuration, but it would not give any other benefits. If this solution would have provided a performance increase compared to option 2, it may have been considered to a higher degree. However, since no performance gain could be observed between the design choices, its drawbacks prevented option 1 from being selected as the final design.

While option 2 facilitates a more in-depth redesign of the support tube, it simplifies the overall design and reduces the chance of a seal leakage.

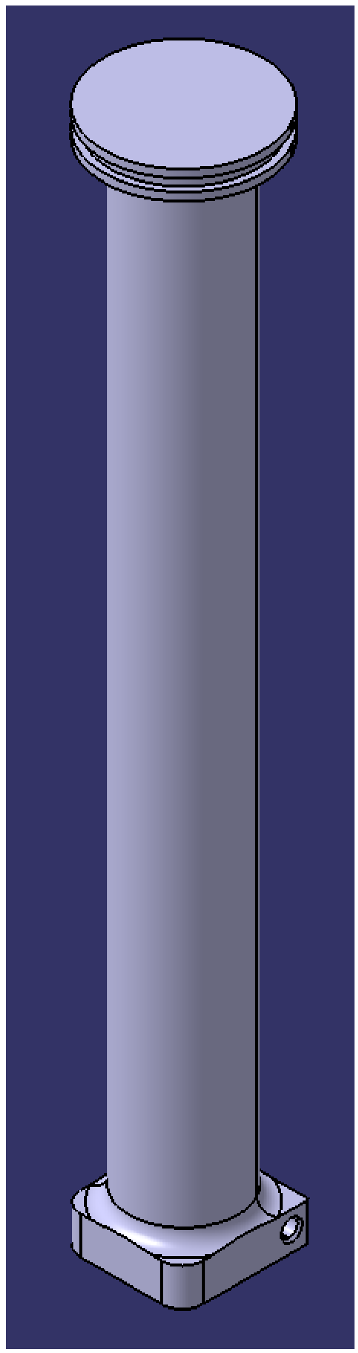

Figure 10: Option 2 Redesigned Support Tube

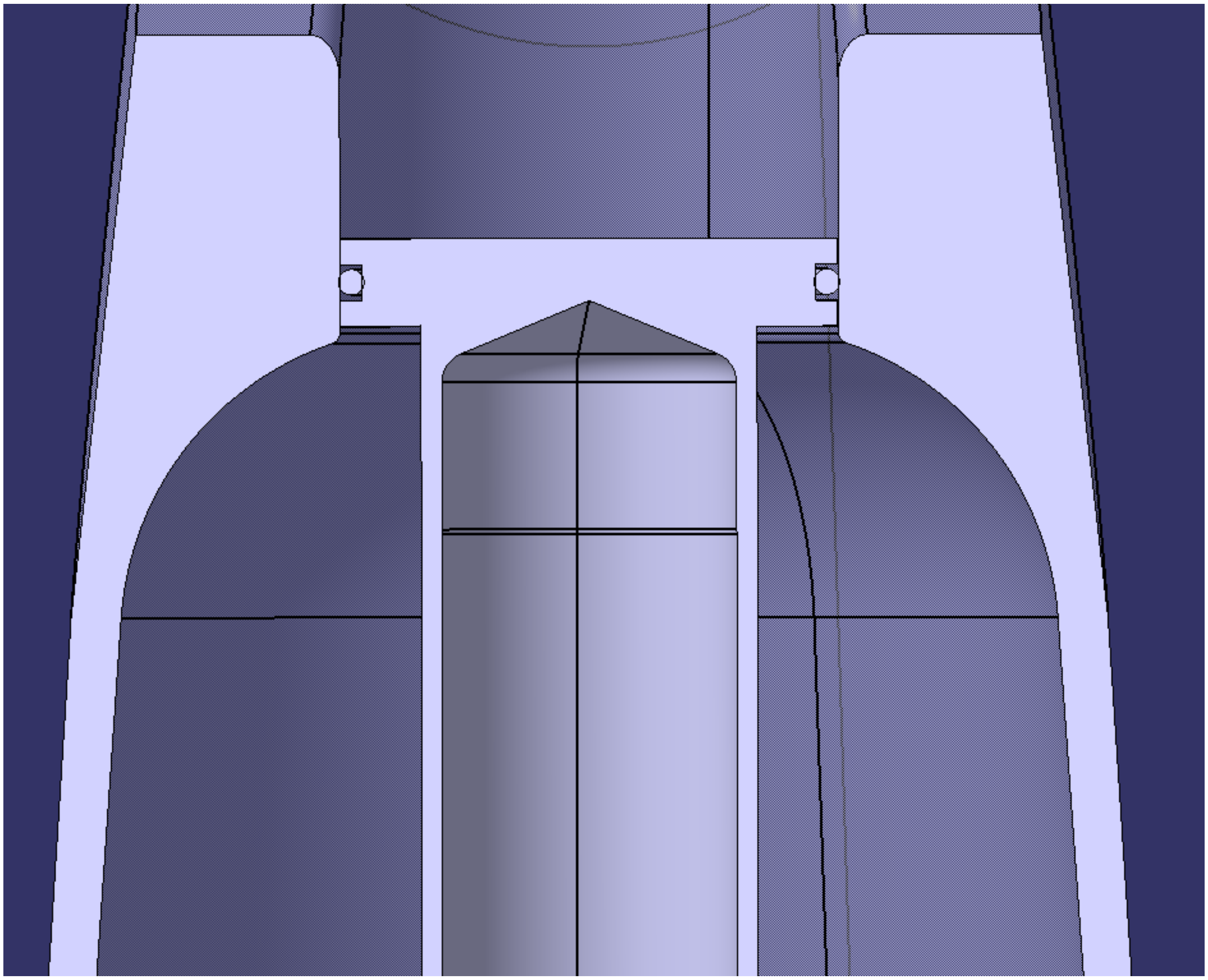

Figure 11: Section View of Option 2 Redesigned Support Tube

The design of the support tube will end here. With an initial design option chosen and a prototype made, the only remaining work will be to fully detail the part drawing. This will be accomplished with a computer-aided design program. After the drawing is released, it will be passed along to manufacturing. They will be responsible for fabricating the component to be installed on ABC-123 landing gears.

5.2 Orifice Support Tube Plug

Similarly to the support tube, the orifice support tube (OST) plug also had two main options to choose from. Option 1 – keep the wire adapter retainer and OST plug as separate components, except make the OST plug solid to seal off the gas in the shock strut. Option 2 – combine the wire adapter retainer and OST plug into one component, while also making the OST plug solid.

Table 2: Orifice Support Tube Plug Redesign Comparison Table

	PROS	CONS
OPTION 1	1. Similar to the current configuration 2. Easy to manufacture using current methods	1. Does not eliminate any components
OPTION 2	1. Eliminates extra component 2. Saves weight by reducing hardware	1. May require more time to manufacture

Both options are viable, as they will successfully eliminate the seal leakage path where the FLSS used to travel between. Since this plug is integral to the performance requirements of the landing gear, an objective tree and decision matrix will be created to compare the two options.

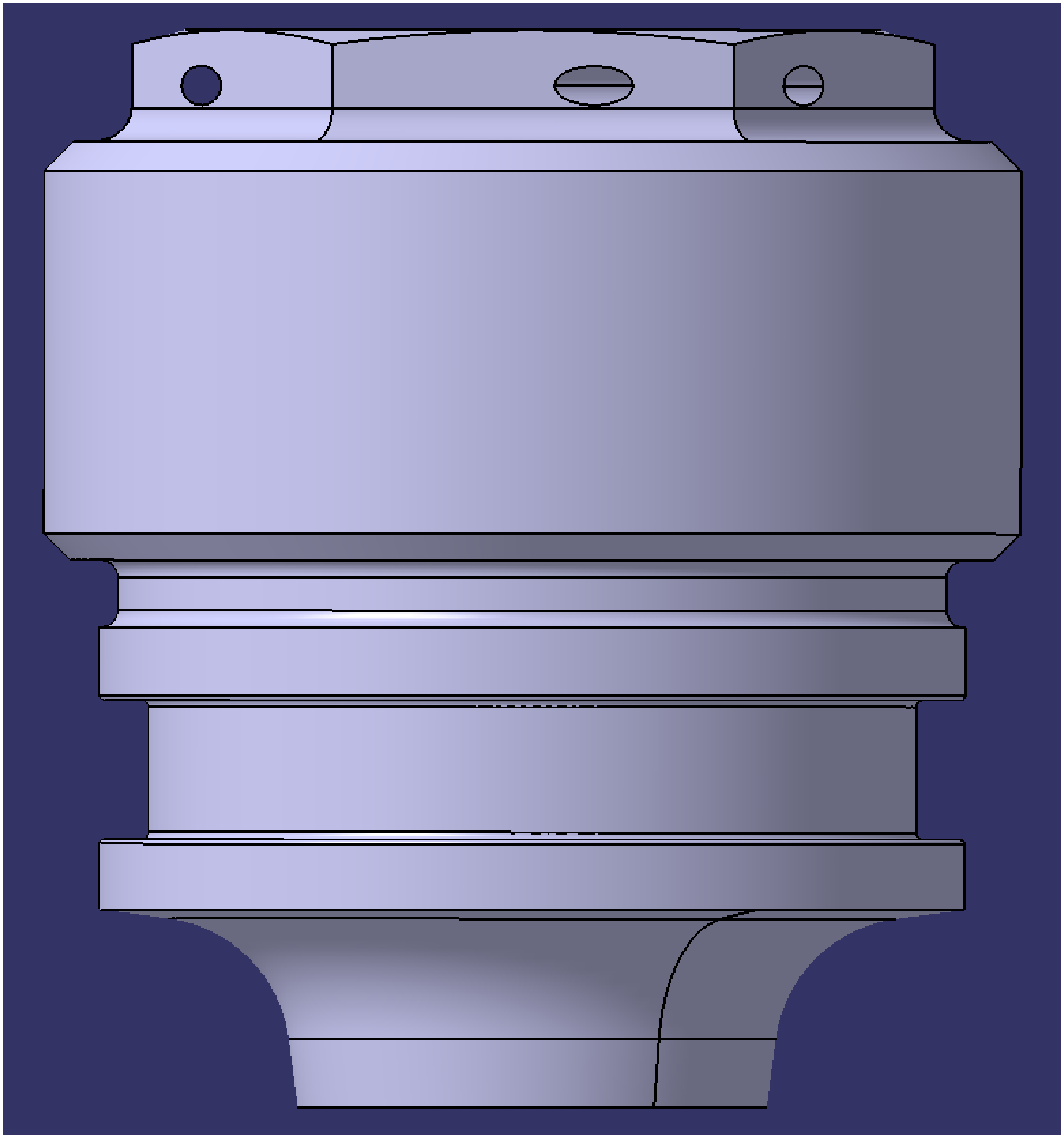

Figure 12: Option 1 OST Plug Redesign

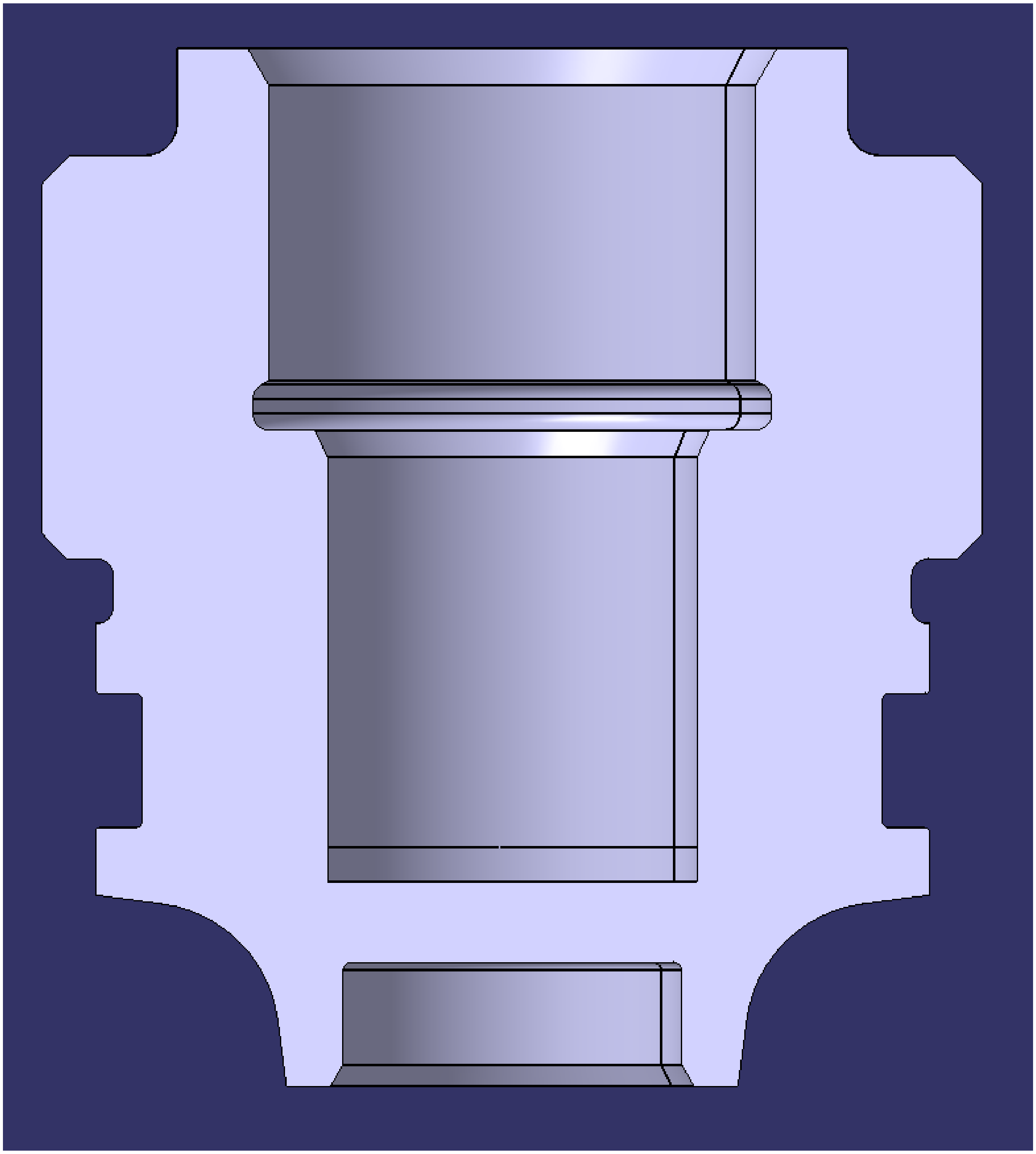

Figure 13: Section View of Option 1 OST Plug Redesign

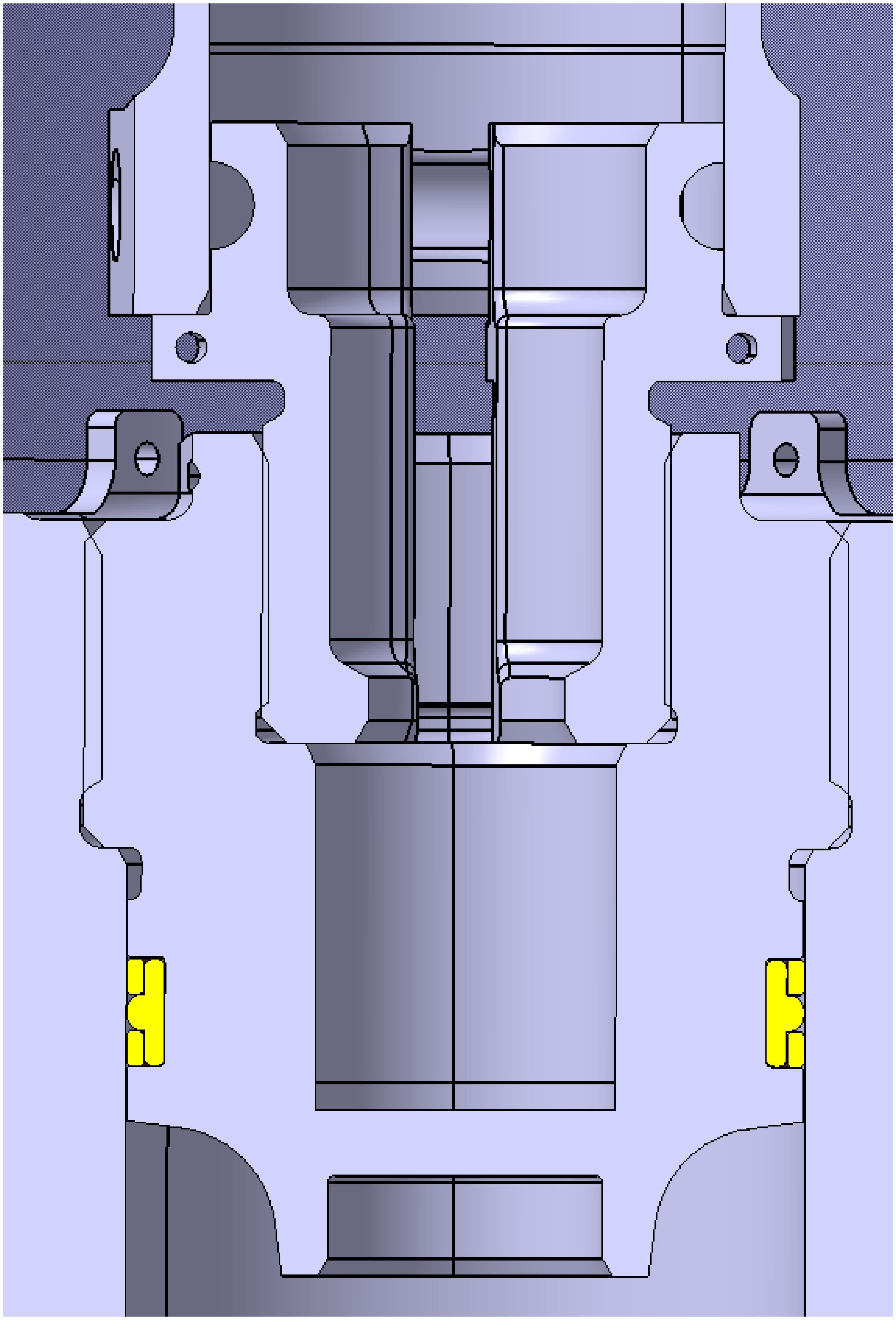

Figure 14: Section View of Option 1 OST Plug Redesign Interface

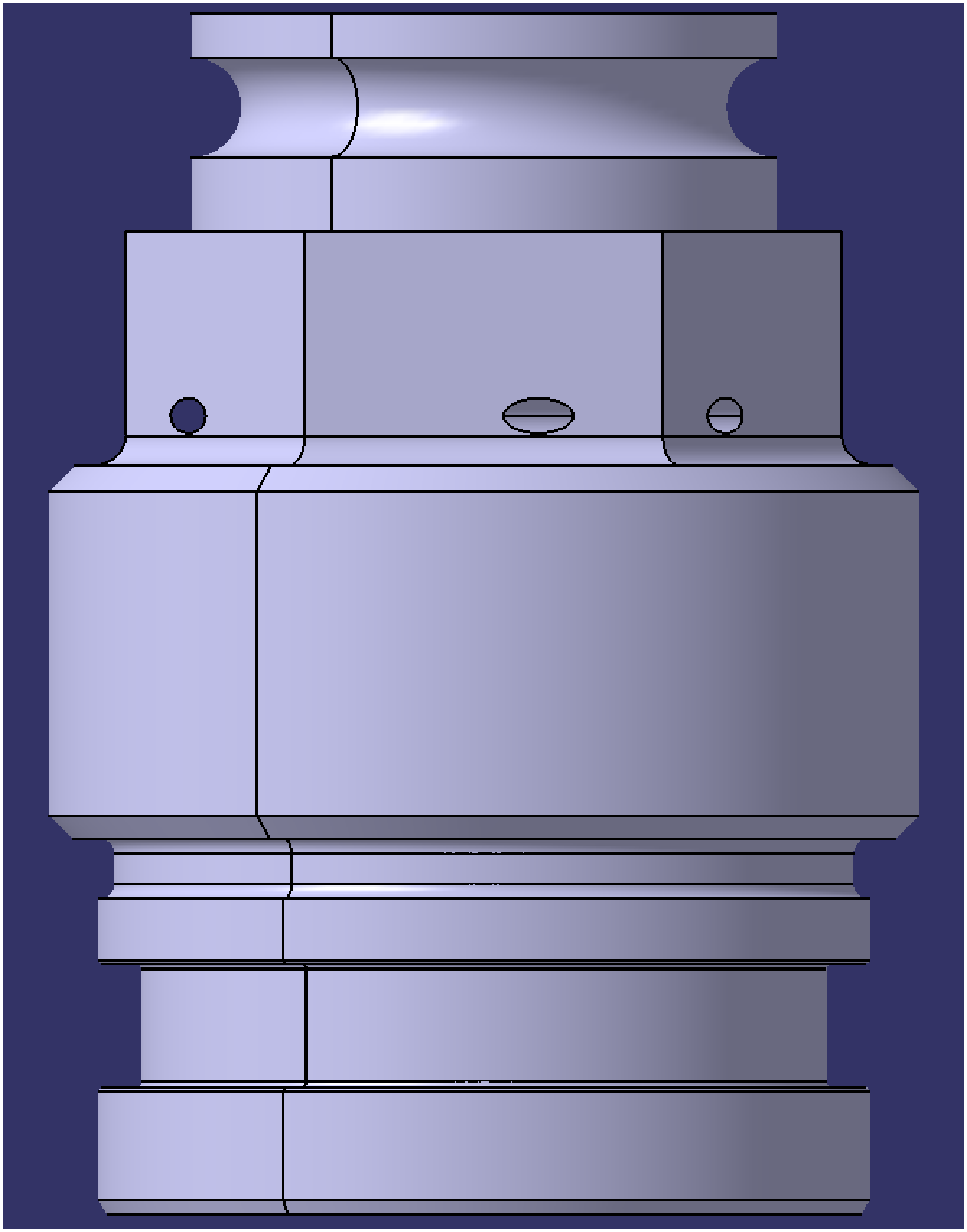

Figure 15: Option 2 OST Plug Redesign

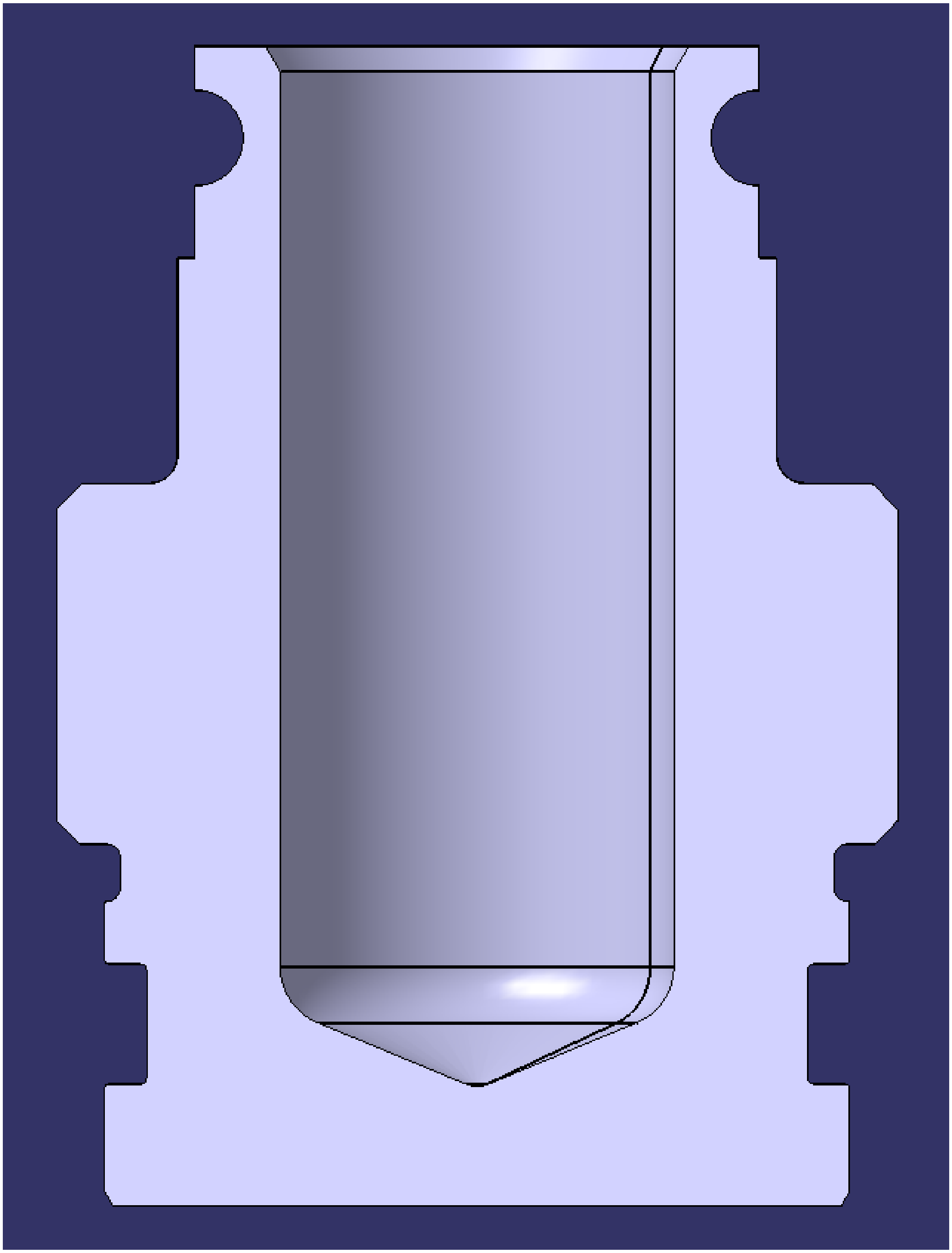

Figure 16: Section View of Option 2 OST Plug Redesign

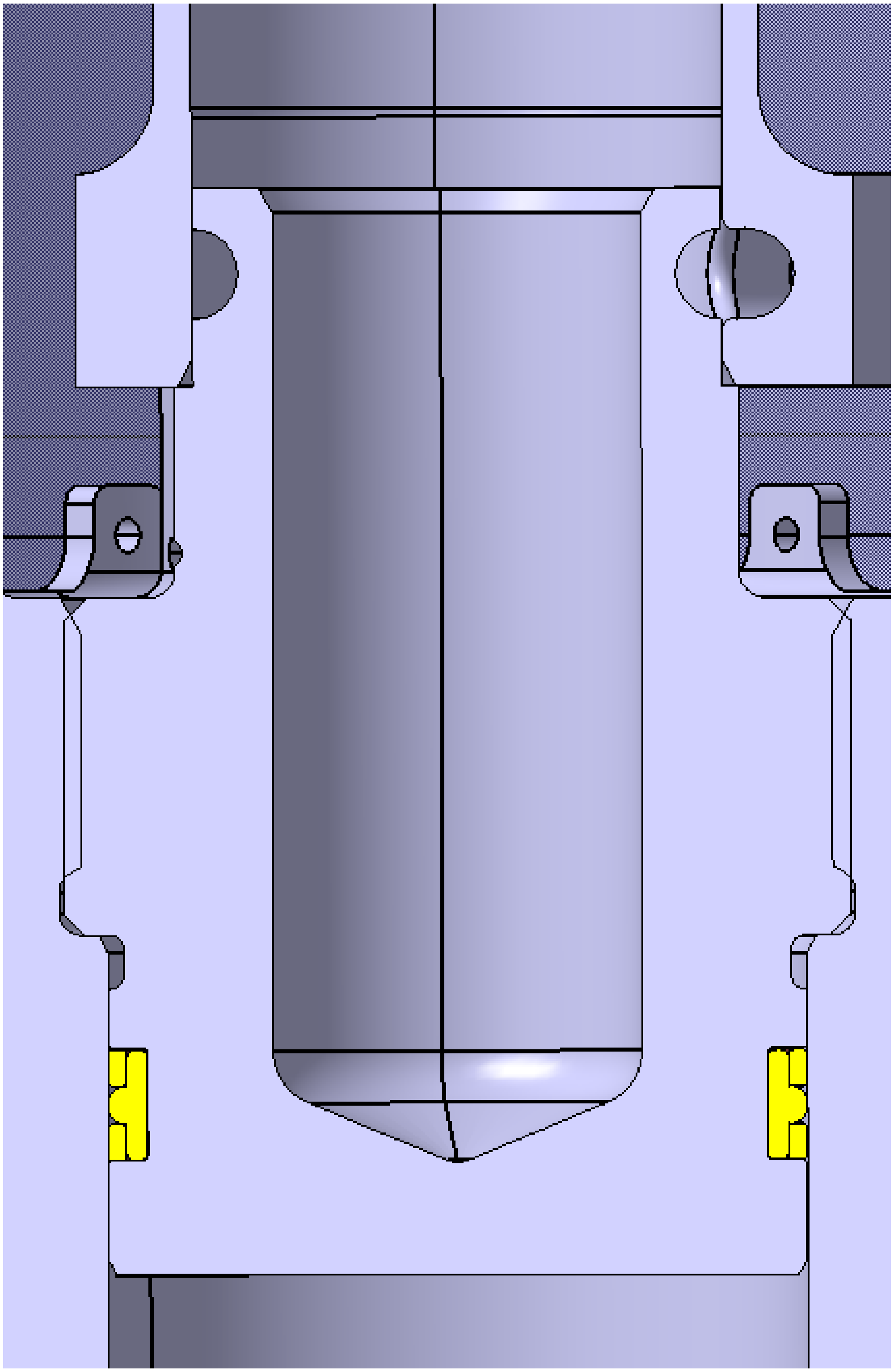

Figure 17: Section View of Option 2 OST Plug Redesign Interface

To decide which option is the best, an objective tree and decision matrix will be made with criteria to evaluate both options against. The objective tree and decision matrix will be evaluated against the following criteria: Assembly Procedure, Manufacturability, and Weight. Assembly Procedure involves the interfaces between each component and any other mating components after they are manufactured. It also considers the amount of time needed to assemble the products in the landing gear. Manufacturability is a measure of how easy it is to make each design option. Cost is also a factor of this criterion, as the price to manufacture increases greatly if a component is difficult to construct. Weight relates to the total mass in the design option. It also takes into account any extra components needed in each design option, such as extra seals or fastening cables.

Any other criteria that could have been chosen would have been similar enough between the two redesign options, so they were not considered. A rating of 1-3 was assigned to each criterion based on the importance of each, which could then be multiplied by each criteria score to give a "weighted" score. A higher rating is better and will give a larger weighted score.

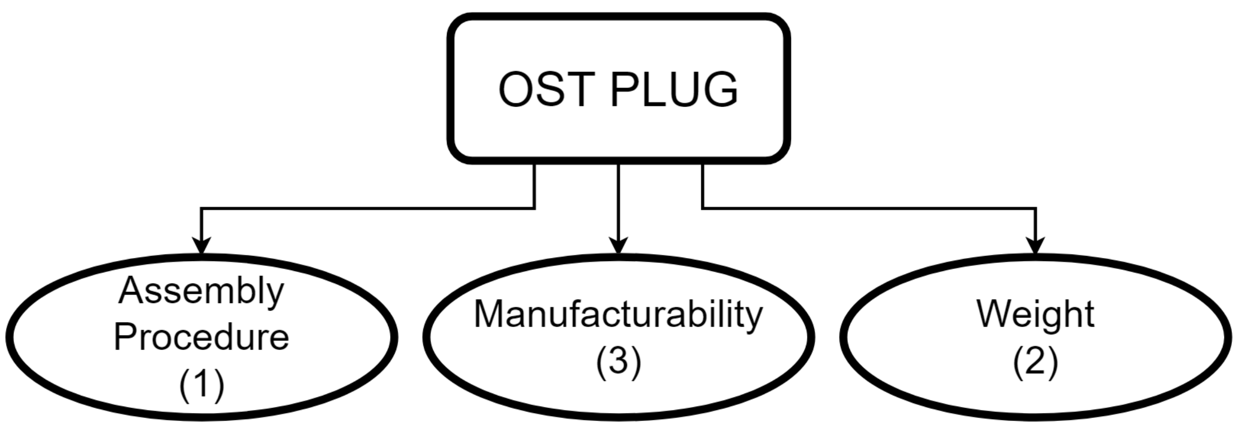

Figure 18: OST Plug Objective Tree

Table 3: OST Plug Redesign Decision Matrix

	Assembly Procedure	Manufacturability	Weight	Total
Rating	1	3	2	
Option 1	3	5	2	
Option 1 Weighted	3	15	4	22
Option 2	4	4	5	
Option 2 Weighted	4	12	10	26

As seen in Table 3, option 2 has a higher weighted score than option 1, meaning it will be chosen as the design option going forward. While option 1 is a viable candidate, option 2 provides the best metrics evaluated against the given criteria. A further look into the design of option 2 will be discussed in the next phase of the design process.

6.0 EMBODIMENT DESIGN

As discussed previously, the OST plug will be the only focus of the embodiment design. In order for the performance requirements of the landing gear to be satisfied, the gas volume inside the shock strut must remain unchanged from the previous configuration. To accomplish this, an in-depth volume analysis must be completed to ensure that the new OST plug will be acceptable. The volume analysis will include the total volume of fluid inside the shock strut, which is equal to the amount of oil and gas added together.

Before discussing the volume models, it is important to know how ABC-123 landing gear shock struts are serviced and where the oil and gas reside. Servicing the shock strut includes flowing oil throughout the entire shock strut, so this process is a great tool to use to follow the flow path of the oil. To begin servicing these shock struts, oil is slowly filled through the oil fill valve located on the bottom of the shock strut cylinder.

The valve continues to be filled until a bubble-free stream of oil flows out of the low-pressure air charging valve located on the top of the shock strut cylinder. Any excess air trapped in the shock strut oil is bled by exercising the shock strut, slightly rotating the shock strut back, or extending and compressing the shock strut several times.

ABC-123 landing gears are usually in two main states: compressed and extended. There will be a “volume model” made for each state to analyze. In this report, a larger focus will be placed on the compressed state volume model since it will be easier to see where the gas and oil levels sit in the shock strut. There is less internal volume in the shock strut at the compressed state of the landing gear compared to the extended state, reducing the amount of complexity in the volume model analysis.

Once a compressed volume model is made, it can easily be converted to an extended volume model by following the same process that will be discussed. In order to find the gas volume at the extended state, however, the compressed volume model must be analyzed first. This is because the oil volume from the compressed model is used to calculate the extended state gas volume. The compressed state oil volume can simply be subtracted from the total volume at the extended state to find the extended state gas volume. This can be accomplished by knowing that the amount of oil volume within the shock strut will not change between either state of the landing gear.

Starting with the current OST plug, a compressed volume model will be started by removing all unnecessary hardware not related to the internal volume within the landing gear. Any unrelated hardware that is not removed can skew the volume results, which could then give inaccurate data used to redesign the OST plug. After the current OST plug’s volume model is complete, the redesigned OST plug will be inserted into the landing gear to begin a new volume model of its own.

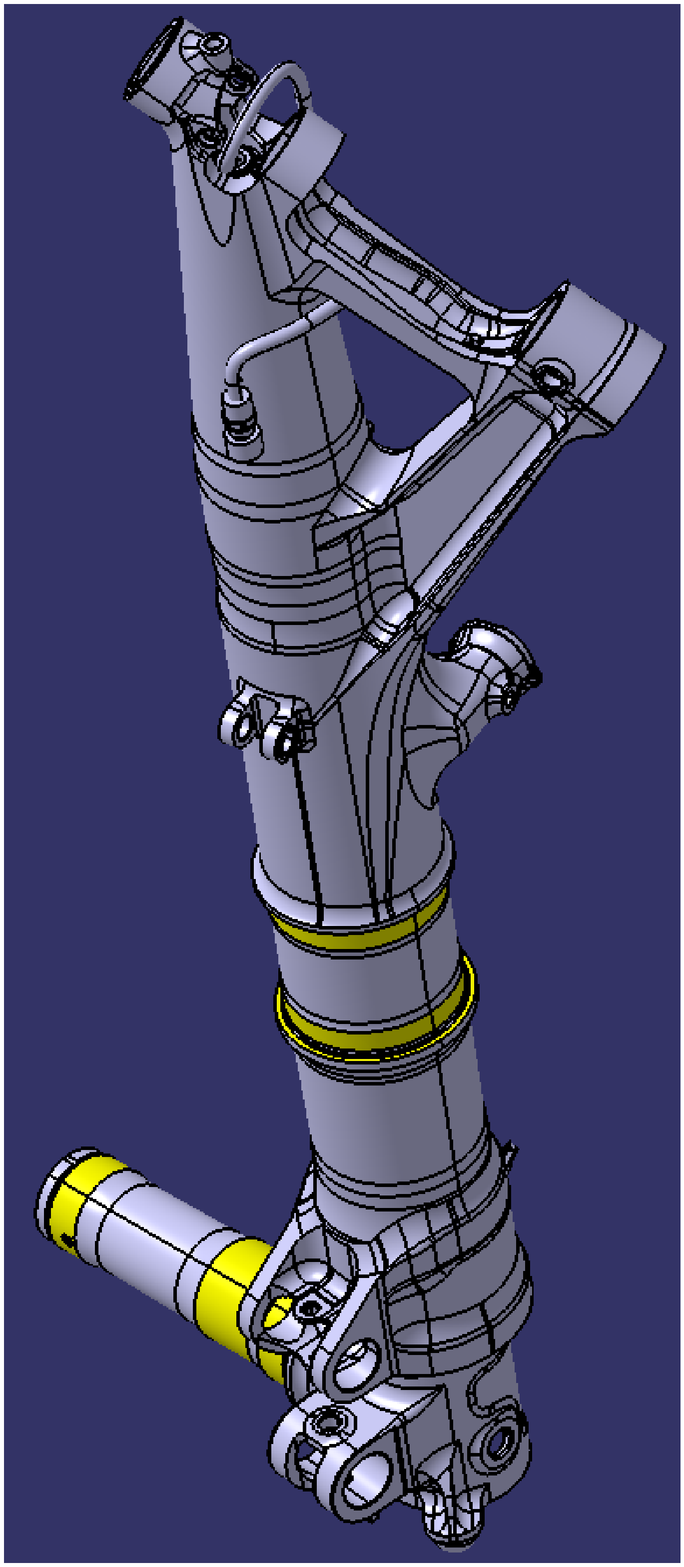

Figure 19: Compressed Volume Model Landing Gear Structure

Next, a sketch for revolution can be made on the mid-plane of the landing gear. This revolution will be the basis for the internal volume of the landing gear. It is important in this sketch to capture all necessary seals, whether they be static or dynamic, as they provide the barrier between the internal fluids (i.e. volume) inside the shock strut. A good place to start with the sketch is the interface between the secondary piston and OST bulkhead.

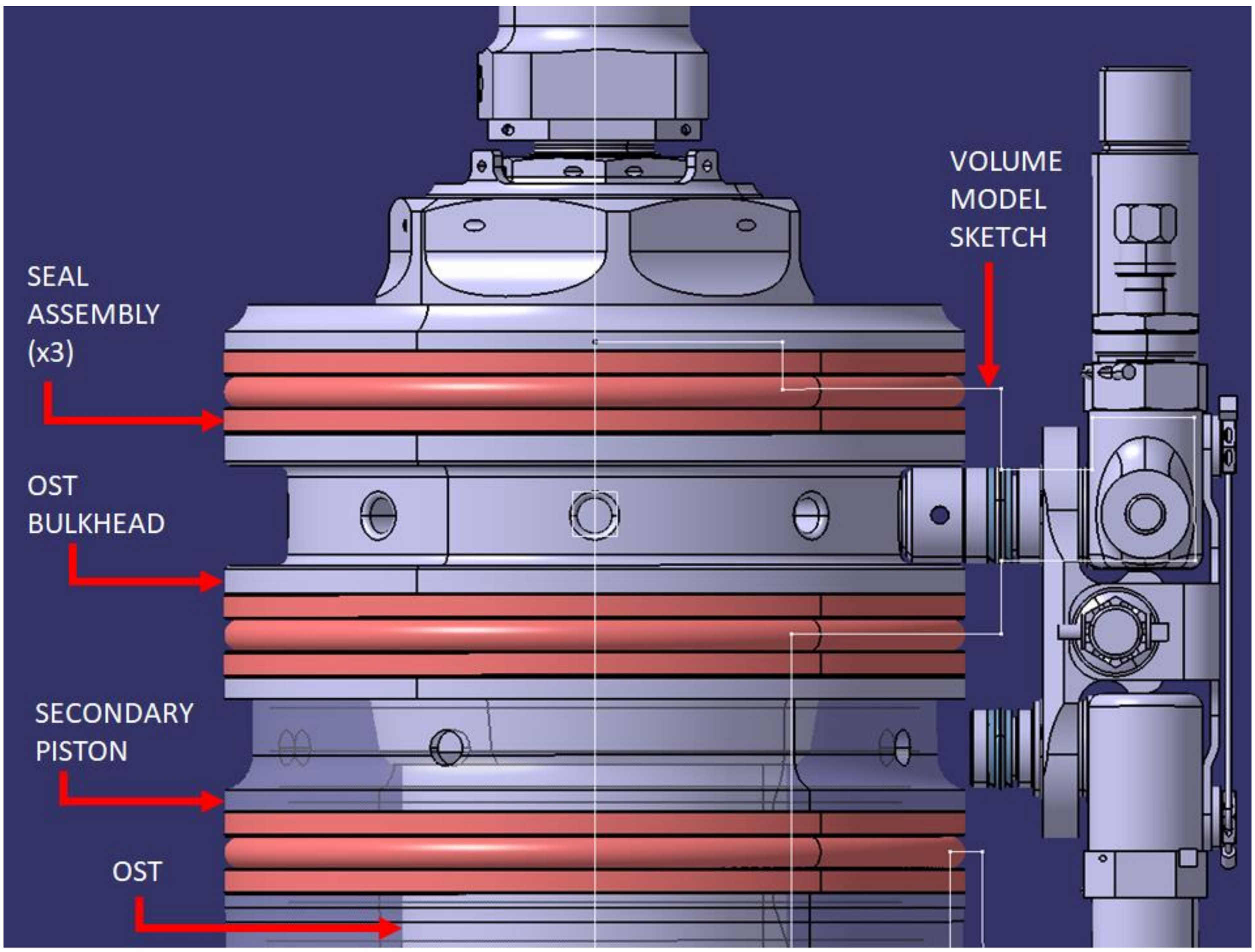

Figure 20: Compressed Volume Model Sketch Section

This sketch can be continued along the shock strut until it is fully defined and ready to be revolved. When revolved, this feature represents the internal volume within the shock strut. Next, a Boolean subtract operation can be performed on the revolution from the landing gear. Any unnecessary material left from the subtraction command, such as a section of a cylinder wall, can also be removed.

The final model represents an accurate depiction of the oil and gas levels within the shock strut. In order to determine the correct amount of volume of each fluid, however, some features will need to be tweaked on the initial volume model. This will be discussed next.

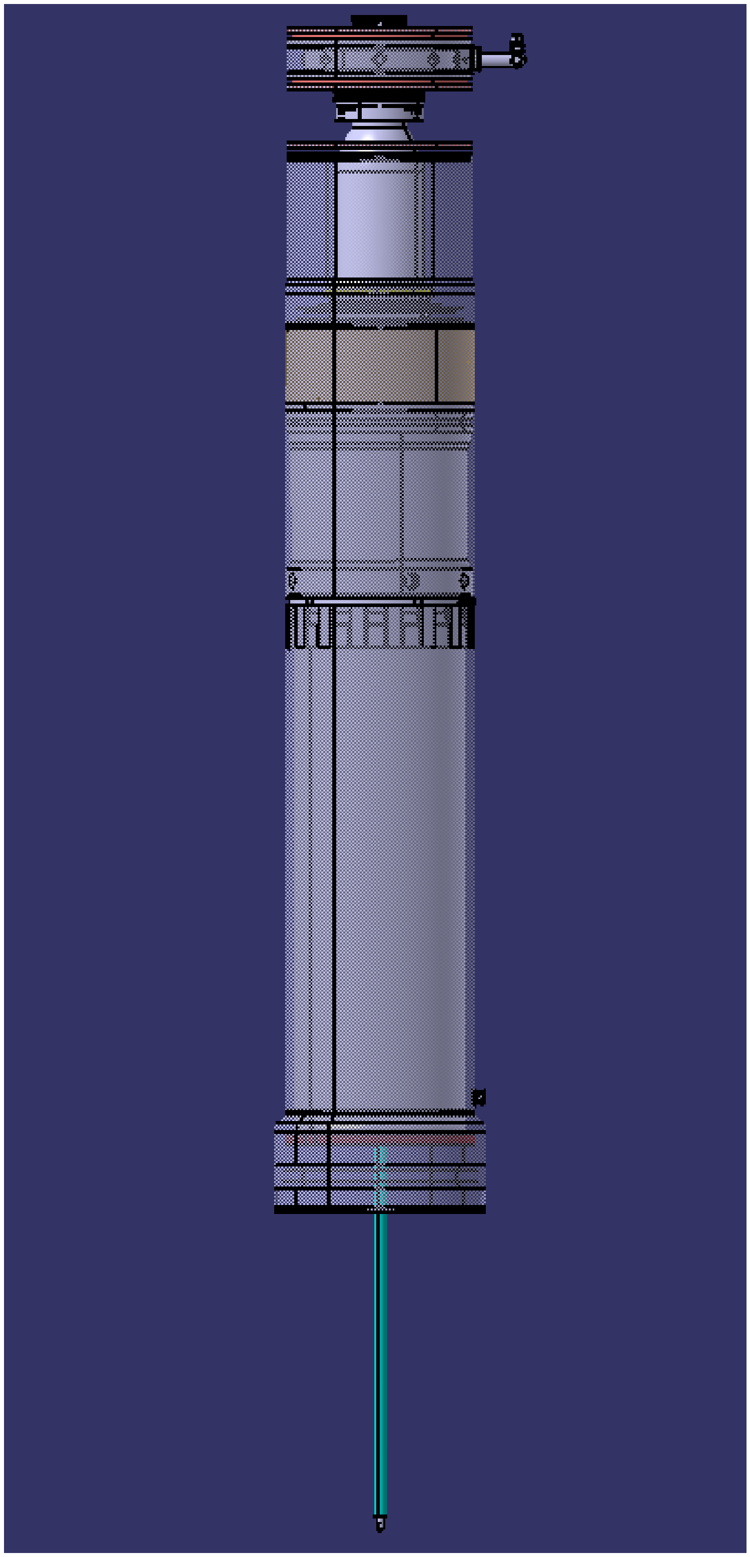

Figure 21: Initial Compressed Volume Model

As stated previously, in order to obtain an accurate measurement of both oil and gas in the shock strut, knowledge of the shock strut servicing procedure must be known. By following the flow of oil throughout the shock strut when it is being serviced, from the oil fill valve inlet to the air charging valve outlet, a direction of fluid movement can be observed. Following the flow of oil will also tell where the gas pockets are located in the shock strut.

Since the initial volume model does not contain any components of the landing gear itself, it will be overlayed with the landing gear structure to better understand where the volume is located inside the shock strut. Internal volume, whether oil or gas, will be highlighted green to provide clarity.

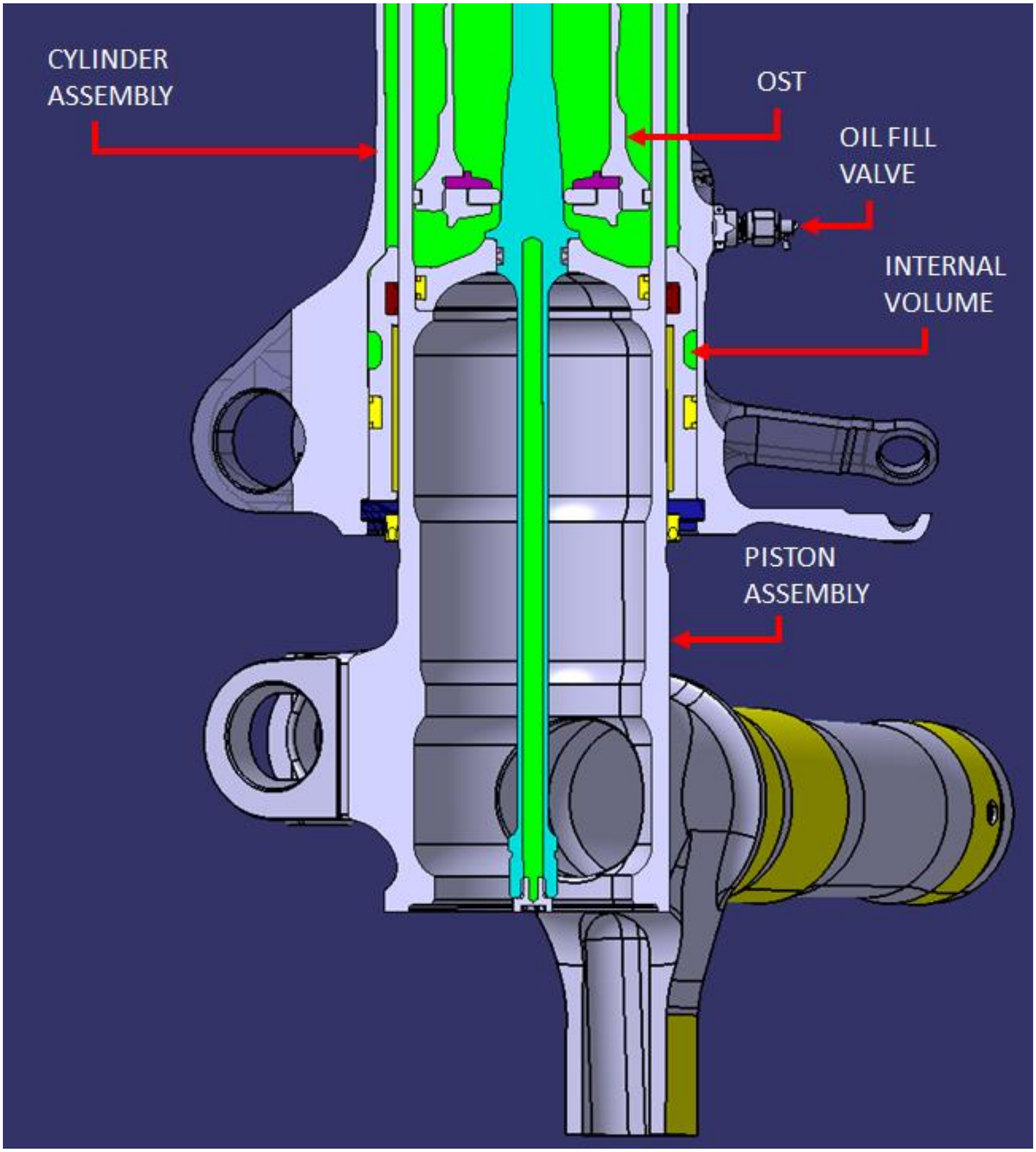

Figure 22: Compressed Volume Model (Volume Visualized)

Combing through the landing gear, the path of oil will be followed until it reaches a flow hole in a component. Anything above that flow hole is considered to be gas, as the oil cannot go above a flow hole due to gravity (remembering that the oil flows from the bottom to the top of the shock strut). For instance, when oil first enters the oil fill valve, it flows up until it reaches the flow hole in the piston assembly. All volume above this flow hole in the piston assembly is now considered gas. The gas will not be highlighted in the model anymore, it will now be transparent. Only the oil will be highlighted green now.

Then, the oil begins to fill up the piston assembly until it reaches the flow hole in the orifice support tube. This process is repeated until the oil path is traced up to the exit at the air charging valve.

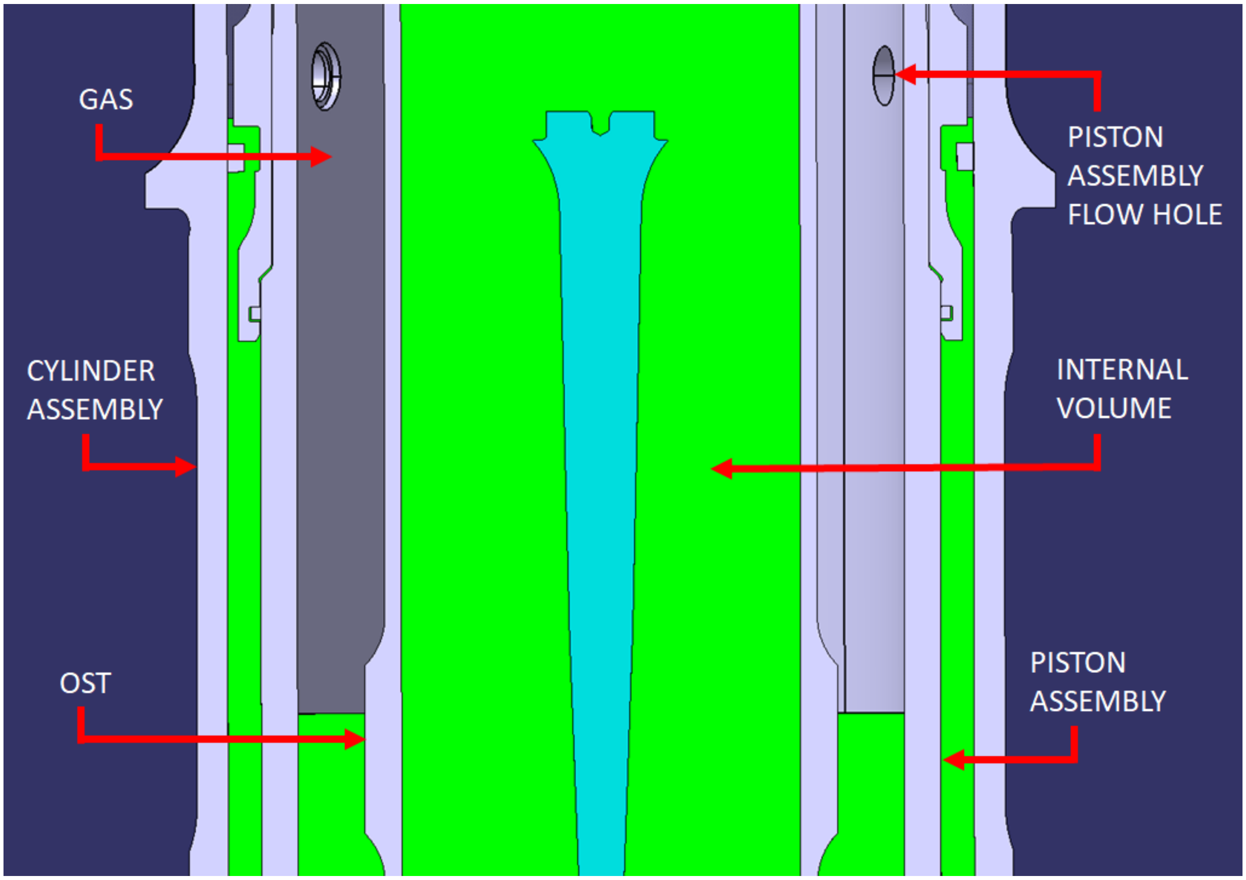

Figure 23: Compressed Volume Model Oil Flow Path

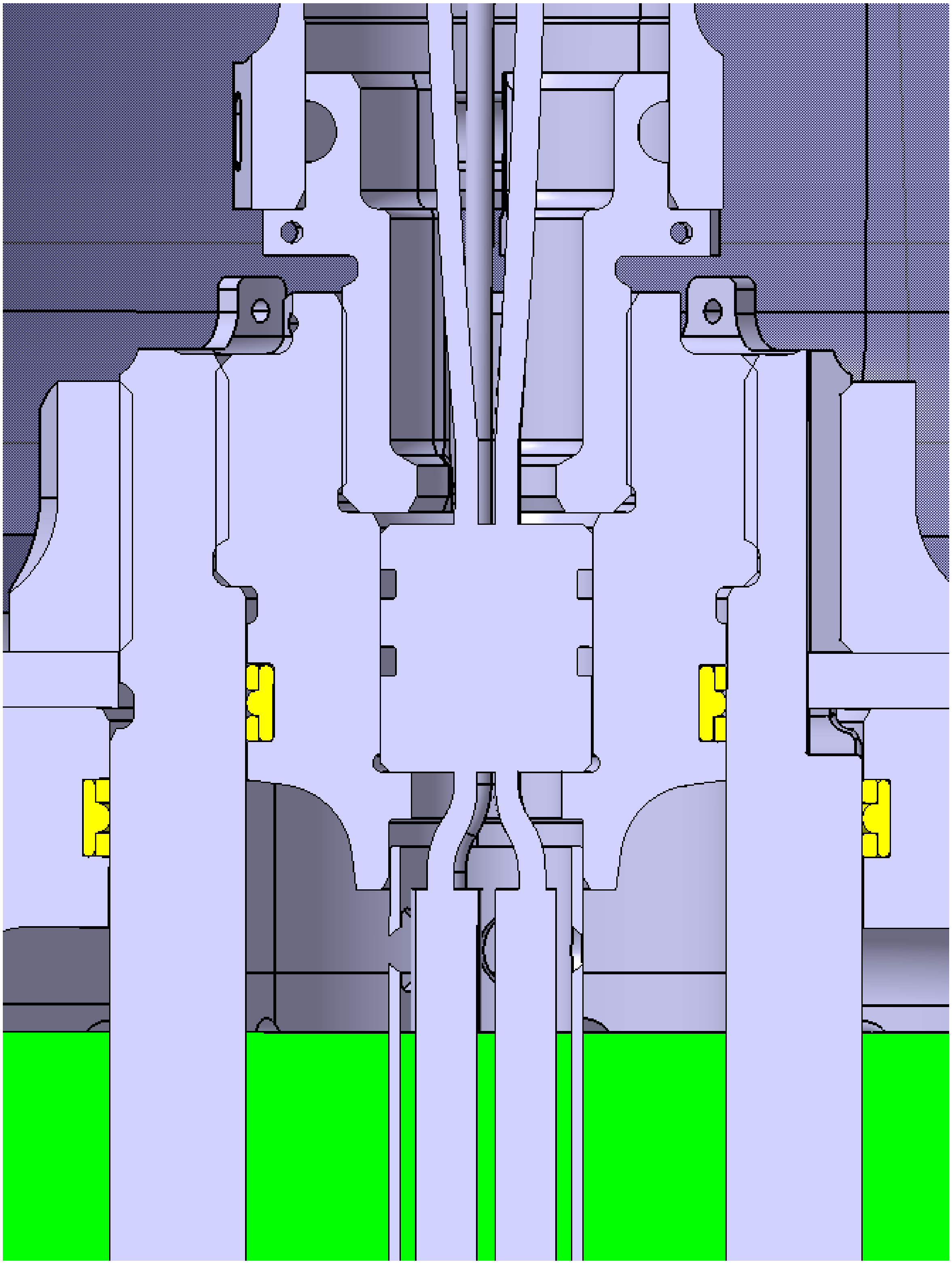

Figure 24: Current OST Plug Interface with OST Oil and Gas Levels

Once all of these gas pockets are captured, they can be integrated into the volume model through a series of sketches. These sketches can then be revolved and used to remove that material from the volume model, similar to an extruded cut or pocket feature. After this is complete, all that is left of the volume model is the total oil volume. If desired, gas volume can then be calculated by subtracting the oil volume from the total volume found in the initial volume model.

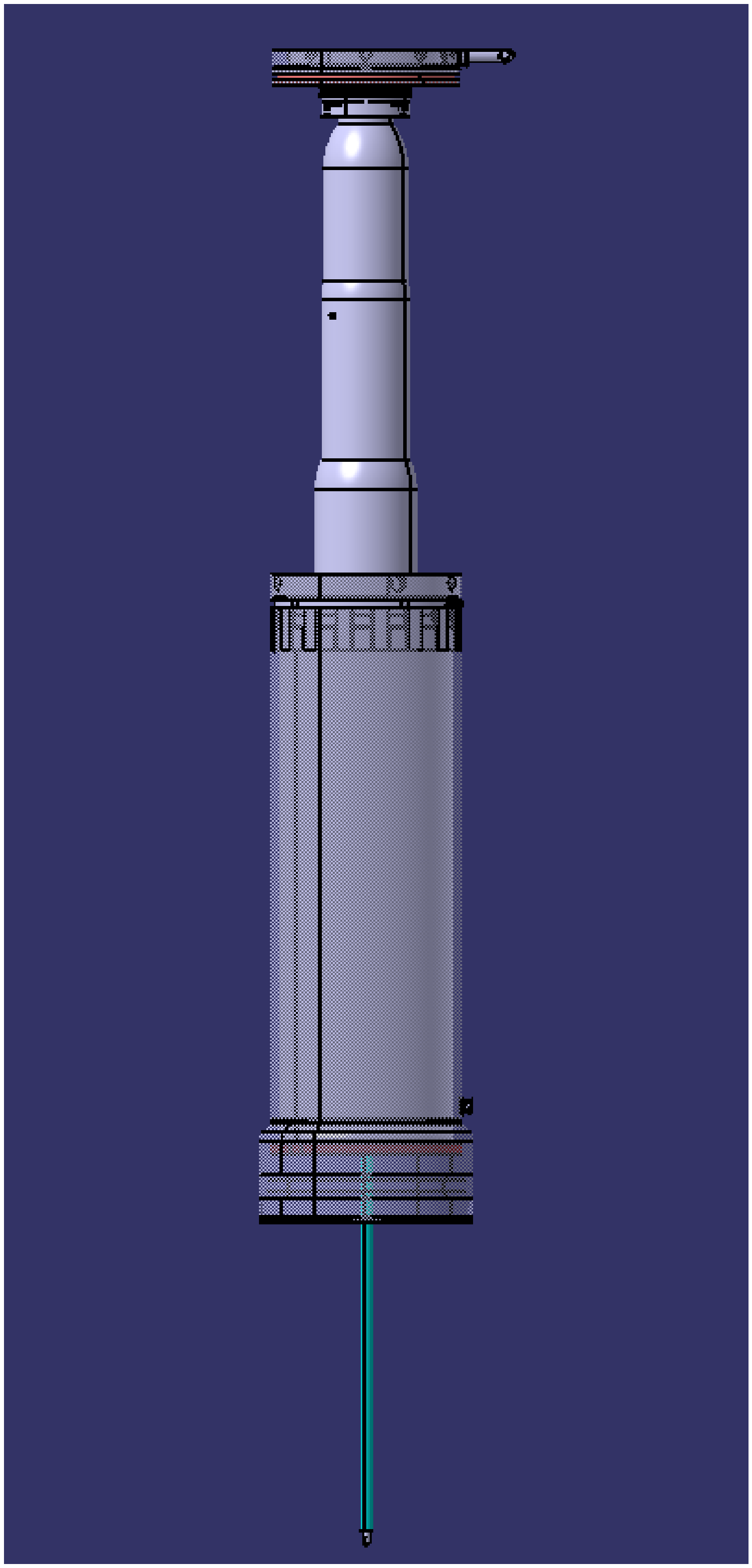

Figure 25: Compressed Volume Model (Oil Only)

This process will then be repeated for the new OST plug redesign in order to ensure that the volume of gas in the volume model remains the same. As stated before, the new OST plug must be designed so that the gas volume inside the shock strut will remain unchanged so as not to affect performance in any way. The only difference now is that the landing gear structure used for the volume model will feature the new OST plug.

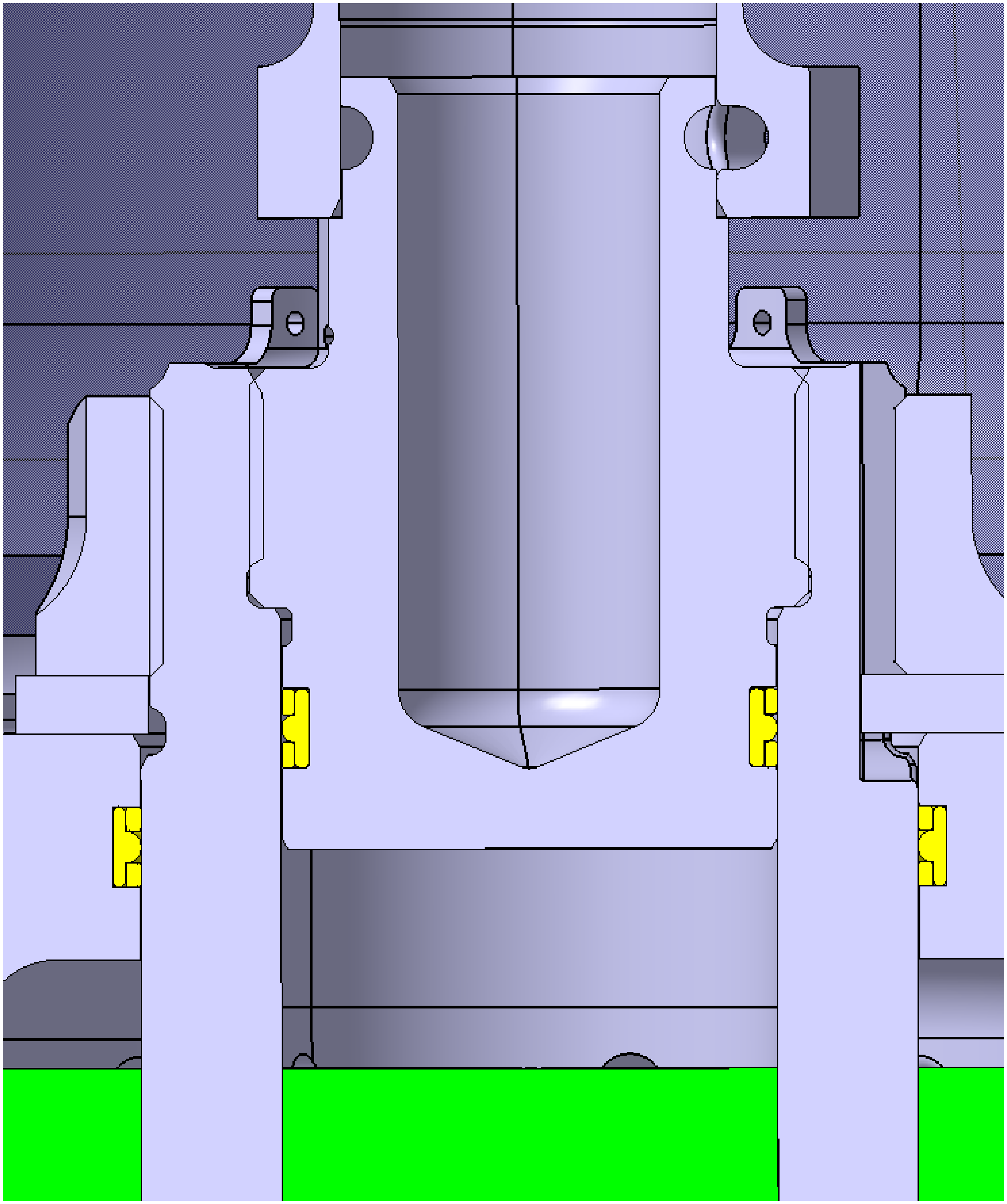

Figure 26: Redesigned OST Plug Interface with OST Oil and Gas Levels

The redesigned OST plug now features a flat, solid sealing feature on the bottom. Unlike the current OST plug, it does not feature the curvature radius or through hole, saving manufacturing time, complexity, and cost.

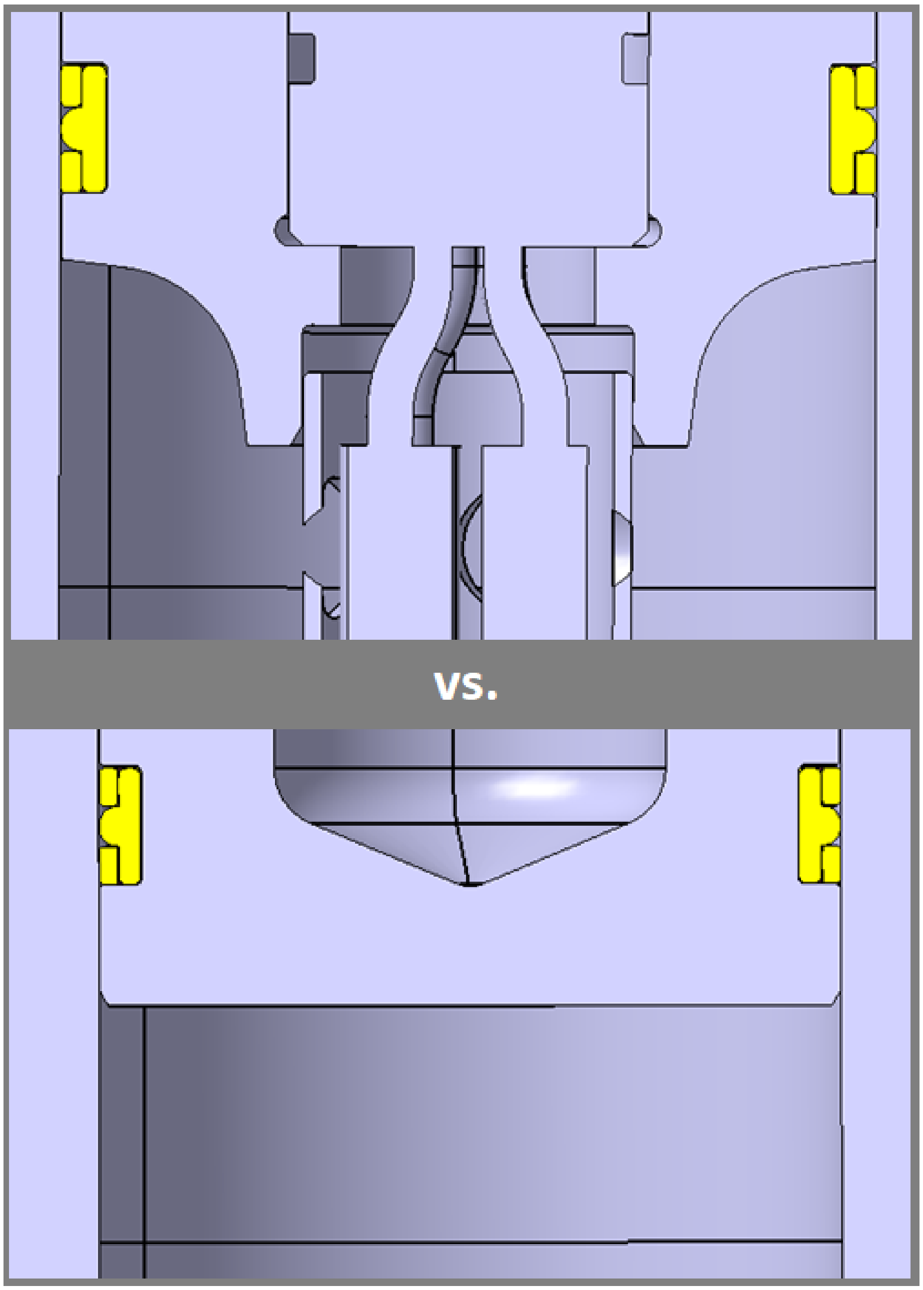

Figure 27: Redesigned OST Plug Sealing Feature (Current vs. Redesign)

An iterative method was used to calculate the length of the OST plug bottom sealing feature (extrusion). This length needs to guarantee that the gas volume inside the shock strut will remain unchanged.

First, by removing the radius and hole feature in the OST plug, a total volume can be found for the OST plug (this will be iteration "0"). The new OST plug design will use the following values to be used in the first iteration, or iteration 0: volume = *5.5in*^{3}, radius = *0.75in*. Since new material was technically "added" by removing the radius and hole feature, the redesigned OST plug volume will have to be subtracted from the current OST plug volume of *5in*^{3}. This way, a negative volume value will be calculated, meaning material must be removed from the redesigned OST plug in order to match the volume of the current OST plug.

The goal of doing this iteration (denoted with a subscript *1*) is to calculate the new length of the bottom extrusion of the redesigned OST plug to match the volume below the seal of the current OST plug.

$$Current\ OST\ Plug\ V - Redesigned\ OST\ Plug\ V = V_1 \rightarrow\ 5in^3 - 5.5in^3 = -0.5in^3$$

This calculated volume can then be used to find the new length needed for the redesigned OST plug using the equation for the volume of a cylinder.

$$V_1 = \pi r^2 L_1\ , where\ V_1 = -0.5in^3, r = 0.75in$$

$$L_1 = \frac{V_1}{\pi r^2} = \frac{-0.5in^3}{\pi(0.75in)^2}\ \rightarrow\ L_1 = -0.283in$$

This new value of L_1 means that the bottom extrusion on the redesigned OST plug will have to be reduced by *0.283in* in order to match the volume of the current OST plug. By interrogating the bottom extrusion of the redesigned OST plug model, it can be found that the total length is *0.5in* (L_0).

$$L_0 + L_1 = L_{iter\_1} \rightarrow 0.5in + (-0.283in) = 0.217in$$

The new value of *L* calculated gives a result of about half the distance of the proposed, redesigned OST plug's bottom extrusion. This iteration, however, does not take into account how the new bottom extrusion volume will affect the gas volume inside the shock strut. To accomplish this, a new iteration and volume model will have to be made with the reduced extrusion on the OST plug.

After analyzing the results from the new volume model, it was noted that the total gas volume was now slightly larger than previously. The current OST plug gave a total gas volume of *120*in^3, while the newly redesigned OST plug gave a total gas volume of *120.25*in^3.

A similar process will need to be completed to find a new value of *L* to use for the bottom extrusion. This time, instead of using the total OST plug volume to find the amount of new volume needed to be added or subtracted, the total gas volume will be used. This way, the new OST plug can be designed in such a way as to match the gas volume of the current OST plug. Since the redesigned OST plug gave a total volume of gas greater than the current OST plug, the current volume will need to be subtracted first to find the difference. This iteration will be denoted with a subscript *2*.

$$V_2 = Redesigned\ Gas\ V - Current\ Gas\ V \ \rightarrow\ 120.25in^3 - 120in^3 = 0.25in^3$$

Using the same process as before, this calculated volume can now be used to find the new distance of length needed for the redesigned OST plug using the equation for the volume of a cylinder.

$$V_2 = \pi r^2 L_2\ , where\ V_2 = 0.25in^3, r = 0.75in$$

$$L_2 = \frac{V_2}{\pi r^2} = \frac{0.25in^3}{\pi(0.75in)^2} \ \rightarrow\ L_2 = 0.141in = L_{iter\_2}$$

Recalling that the goal of this iteration is to reduce the total amount of gas volume to match the gas volume of the current configuration, more volume will have to be added to the OST plug bottom extrusion as a result. This new value of L_{iter_2} will be added to the value of L_{iter_1} found from the previous iteration. The new length, L_3, will give the total amount of volume necessary to the OST plug to ensure that the gas volume remains unchanged.

$$L_{iter\_1} + L_{iter\_2} = L_3 \rightarrow L_3 = 0.358in$$

After the iterative process is complete, a final length of *0.358in* is found for the length of the redesigned OST plug bottom extrusion. The final length needed to be smaller than the initial value of *0.5in* used in order to preserve the gas volume in the shock strut.

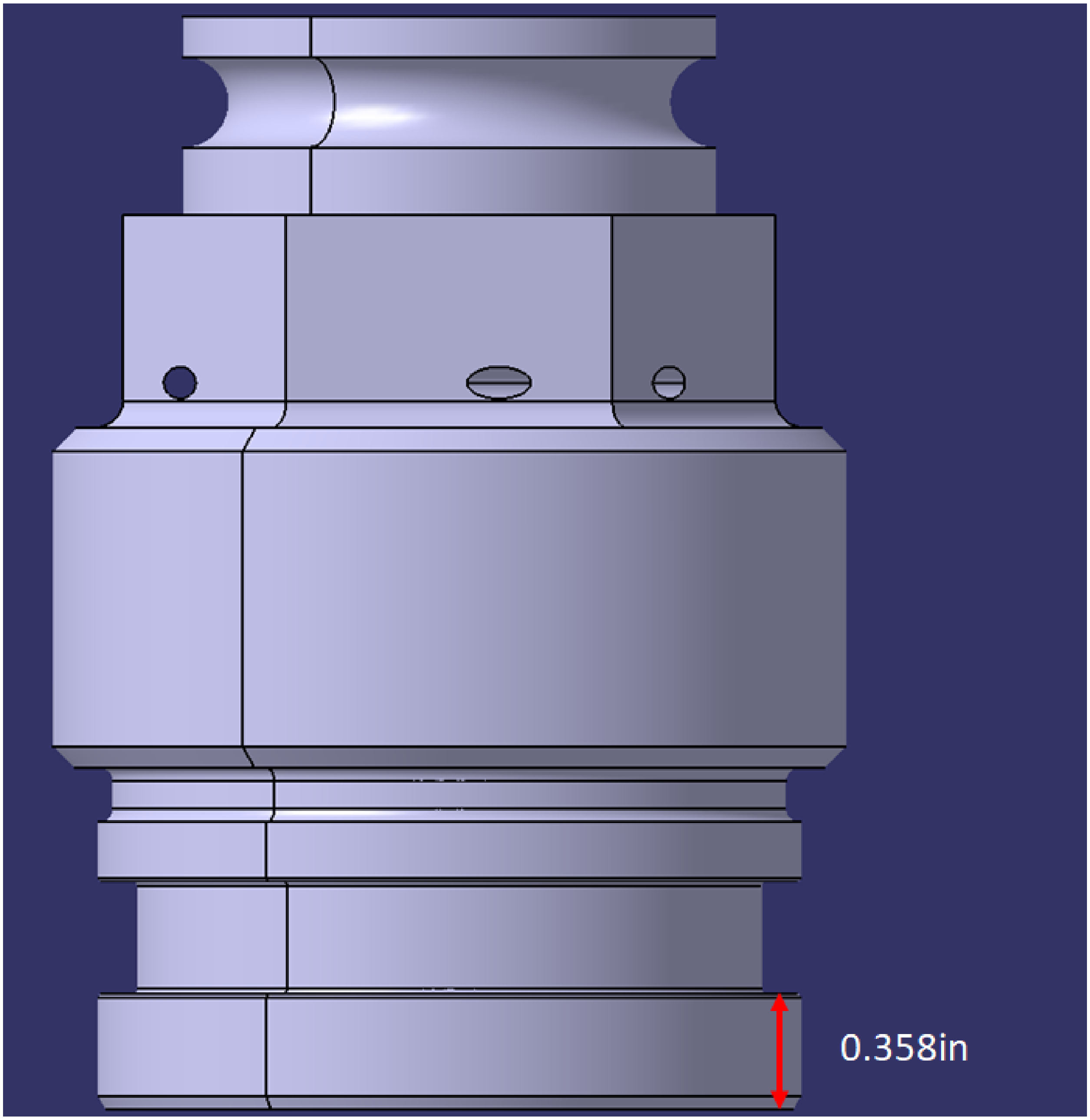

Figure 28: Final Iteration of Redesigned OST Plug (Simulated Value)

A table summarizing the different iterations and volumes at each helps to visualize how the OST plug changed throughout the span of the process.

Table 4: Redesigned OST Plug Iterative Volume Table (Simulated Values)

VOLUME WITH CURRENT OST PLUG (in^3)	VOLUME WITH REDESIGNED OST PLUG (ITERATION 0) (in^3)	VOLUME WITH REDESIGNED OST PLUG (ITERATION 1) (in^3)	VOLIME WITH REDESIGNED OST PLUG (ITERATION 2) (in^3)
TOTAL: 500	TOTAL: 514.875	TOTAL: 515	TOTAL: 514.75
OIL: 380	OIL: 394.75	OIL: 394.75	OIL: 394.75
GAS: 120	GAS: 120.125	GAS: 120.25	GAS: 120
PLUG: 4	PLUG: 5.5	PLUG: 5.75	PLUG: 5.6

This marks the end of the redesign process for the OST plug. A final design option was chosen and created through a prototype model. After the prototype undergoes any final touches, it will be ready to be implemented into ABC-123 landing gears.

7.0 DISCUSSION

Upon completion of the support tube and OST plug redesign, the best viable designs for each were chosen and implemented into the landing gear structure. Many considerations had to be included in the final selection of each design, including aspects of the manufacturability and overall simplicity. The designs chosen for each represented the best aspects of these considerations while also still performing at the level required for the ABC-123 program. This report only focused on the design of these components and not the final implementation of them in the landing gear (i.e. manufacturing and assembly).

The next phase of the design and implementation process of the new support tube and OST plug will be to begin manufacturing the components and installing them in the landing gears. While this process is ongoing, it is important to adhere to the guidelines and deadlines set forth by the customer, ABC Aeronautics. Since the design and implementation of these components must also follow a budget, it is key to follow the scope outlined in the statement of work given by ABC Aeronautics to XYZ Landing Gear Solutions. This includes only redesigning the specific number of components quantified, and not working on unrelated components that are not listed in the scope of the effort. The redesign of these components must also be completed within a certain timeframe, so the finished products will be driven by that date.

After the new support tube and OST plug have been successfully integrated into the landing gears within the set timeframe, performance metrics and in-flight characteristics will be monitored by XYZ Landing Gear Solutions to ensure that the components are performing optimally. Should any issues arise, the component(s) in question will need to be revised to correct them. From here, a decision will be made regarding all landing gears deployed and if they will need to be "retrofitted" to incorporate the new revision(s). This decision will depend mainly on how severe the issue is and how much it affects the landing gear.

8.0 CONCLUSION

Based on the problem identified of needing a new internal sealing system for ABC-123 landing gears, a redesign process was created. This redesign included all elements and phases of a standard design process, including the product definition, conceptual design, and embodiment design. After the redesign process was complete, two newly redesigned components (a support tube and an orifice support tube plug) were created to be manufactured and installed on all ABC-123 landing gears. The redesigned components successfully solved the issue given to XYZ Landing Gear Solutions from ABC Aeronautics. The new components also maintained all performance characteristics and adhered to all of the applicable requirements of the ABC-123 program.

Many different analyses were performed in order to determine the best configuration of each design, including utilizing internal volume models and an iterative process. Using these tools, an objective decision could be reached as to the best design path moving forward. Eventually, a final design decision was made for both the support tube and orifice support tube plug. These designs proved to be the best-performing components without any major flaws. These components, designed in this report, will be installed on all ABC-123 landing gears. The final designs are pictured below.

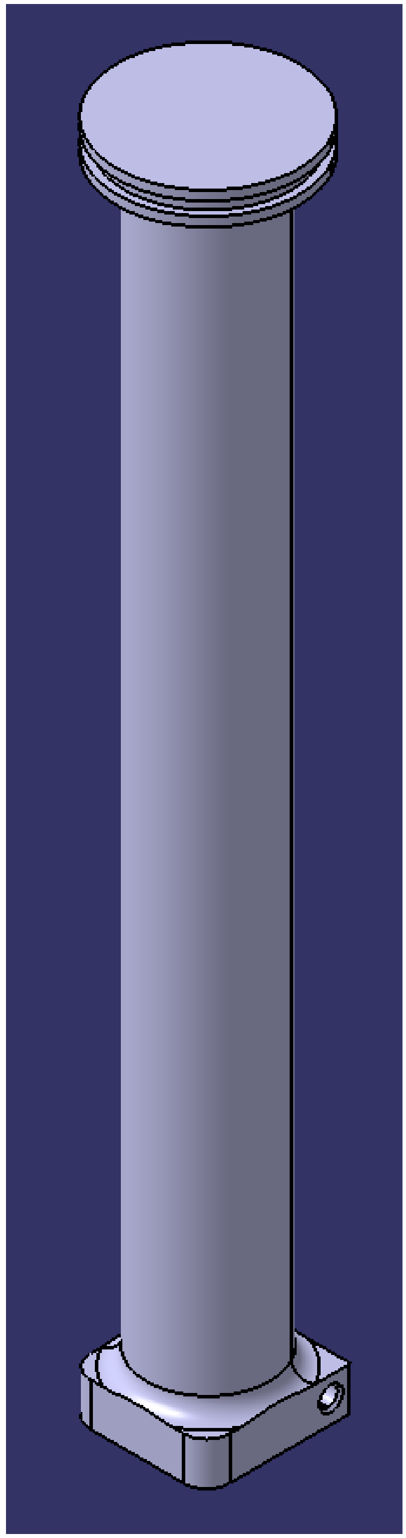

Figure 29: New Support Tube (Final Design)

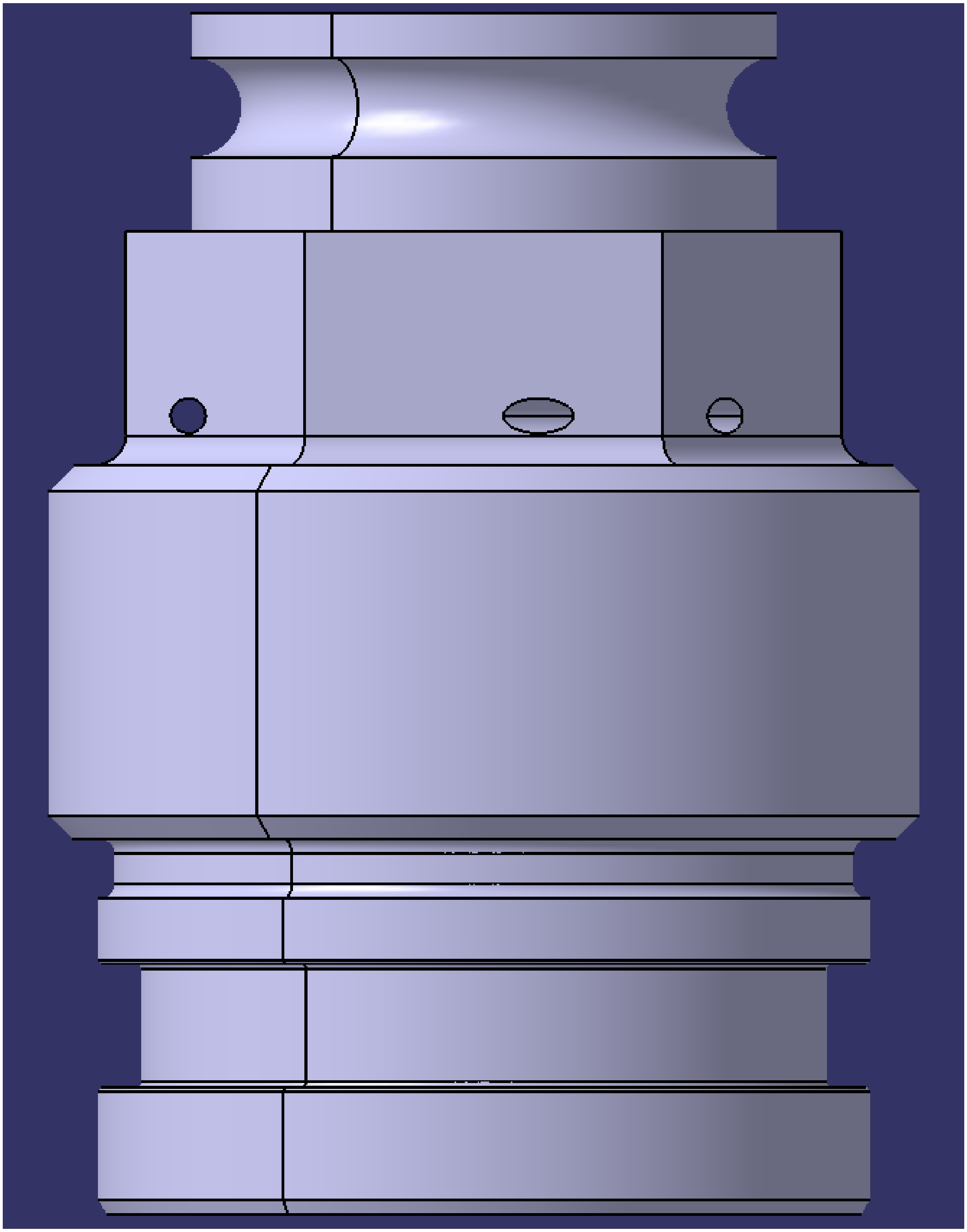

Figure 30: New OST Plug (Final Design)

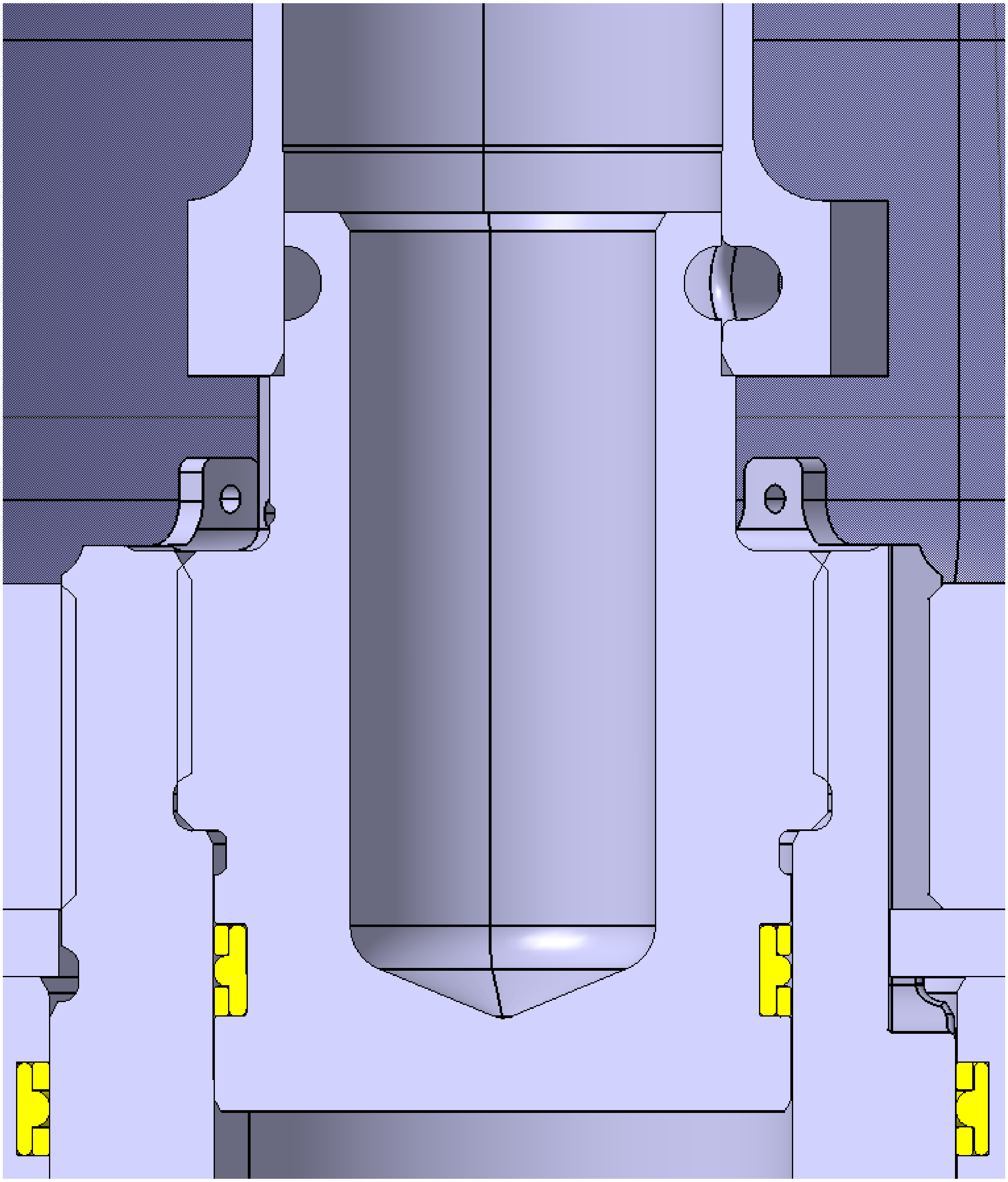

Figure 31: Section View of New OST Plug and New Support Tube Interface (Final Design)