Spring 2019

Prototype Landing Gear Conceptual and Embodiment Design

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Honors Research Project

Submitted to

The Honors College

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ABSTRACT

Collin's Aerospace Mechanical systems engineering was tasked with designing a set of landing gear for an undisclosed project. The landing gear is required to comply with customer specifications, coordinate systems, and overall landing gear performance. The purpose of this project is to document the conceptual and embodiment design process for an articulated main landing gear system. Unfortunately, due to high expenses and high lead times required for 300M stainless steel components, no full size prototype can be produced within the timeframe of this report. Instead, this document should be viewed as a process mapping guide for initial landing gear design and sizing.

Based upon the specifications, it was quickly determined that an articulated landing gear with an oleo-pneumatic shock strut would be the most optimal design. Using the customer defined weights and landing gear coordinates, an amount of strut stroke required to dissipate the energy of a hard landing could be determined. Next, the landing gear can be solved statically at a number of points to determine the load transfer that occurs for any given load case. This data is then used for determining the overall initial sizing of the landing gear.

Based on the level of depth required to fully analyze the performance of landing gear, the scope of this report is restricted to ground and static load cases only. While not considering all cases required to fully design a landing gear, the static and ground handling cases are the first to be considered, and the entire process can be grueling based on the amount of non-automated iteration that is required to produce a design that fulfills all design requirements. Considerations must be made at this point in regards to material selection, seal sizing for struts and actuators, weight savings, retraction and locking mechanisms, and overall sizing to conform to required clearances. Any non-conformance could result in a total redesign.

Following the steps of the process outlined in this document, detail design can commence in conjunction with required analysis, especially in terms of shock strut landing performance and stress and weight analysis. The former is handled using extensive dynamic modelling, whereas the latter is currently not necessary given the simplistic geometry that was selected for this phase of the design. As the design becomes more complex, FEA analysis will need to be performed.

The process outlined within this report resulted in a preliminary design that fulfills the basic customer requirements.

Key Words: Aircraft, Landing Gear, Landing Gear Design

AKNOWLEDGEMENTS

Special thanks to the engineers at Collins Aerospace that have taken the time to assist in my learning of the landing gear design process.

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1.0 INTRODUCTION

Chuck Yeager once famously said in regards to aviation that “if you can walk away from a landing, it’s a good landing. If you can use the airplane the next day, it’s an outstanding landing.” The challenge of being able to safety dissipate the energy required to land an aircraft has been present since the dawn of flight, when the first aircraft employed skids and simple leaf-spring landing gear. Today, most large scale commercial, business, and military aircraft utilize complicated systems of landing gears with some form of energy damper to allow for high impact loads of heavy aircraft to be absorbed on touchdown. The strength and efficiency of these modern landing gear designs have advanced to the point that the maximum landing and ramp weights of an aircraft are limited by the strength of the runway surface, according to Collin’s Aerospace engineers.

Landing systems on aircraft fulfill three basic requirements of aircraft operations: take-off roll, landing, and ground handling operations. The first two are self-explanatory on a basic level and are generally more intensive in terms of forces seen by the aircraft, but it is the third mission by which the aircraft will live most of its life. As a matter of fact, commercial aircraft, on average, spend about 3000 hours per year in the air, which is only 34% of the time, which far eclipse that of most business jets and military aircraft. For this time on the ground, every aircraft experiences several different load cases given certain situations. Each of these load cases must be considered for the landing gear in order to design a robust system capable of maintaining integrity throughout its life.

Norman Currey, a Lockheed-Martin engineer and one of the foremost experts on landing gear design, explains in his book *Aircraft Landing Gear Design: Principles and Practices* that “landing gear design encompasses more engineering disciplines than any other aircraft design,” and must include a knowledge of “heavy forgings, machined parts, mechanisms, sheet metal parts, electrical systems, hydraulic systems, and a wide variety of materials… and today’s gear designer must also have a working knowledge of airfield strength calculations” [1]. Due to the complexity of landing gear design, this document serves primarily as process map for conceptual landing gear design and sizing, which encompasses the working knowledge of materials, stress calculations, manufacturability, and an advanced understanding of basic landing gear functions and performance.

1.1 Principles of Operation

The design for this main landing gear is based upon a specification supplied to Collin’s Aerospace for a proposed aircraft. The buyer and aircraft are currently undisclosed, and thus both shall hereby by referred to as the customer and Project 7426, respectively. Based on the intensive requirements of landing gear design and given the tight timeframe to present to the customer, the scope of this project is confined primarily to the conceptual and embodiment designs of the landing gear. Additionally, any production of parts at this point is nonexistent, and likely will not be accomplished soon due to long lead times often seen in the aerospace industry.

A full description of the customer specifications is listed in the following section. The goal of the design is to fulfill each requirement established while designing an optimal landing gear that is manufacturable, robust and reliable, and is as light as possible.

1.2 Product Definition

The following table displays the key coordinate points of the left-hand main landing gear. It is worth noting that the customer has already selected the main gear location. This selection is usually performed by the aircraft designers, as gear placement is crucial for overall aircraft performance. For instance, the center of gravity (CG) of an aircraft must by forward of the rearmost landing gear to prevent tip-back of the aircraft, but must not be too far forward to prevent rotation of the aircraft on takeoff.

KEY COORDINATES	FS	BL	WL
FWD TRUNNION ATTACH	652	-88	46
AFT TRUNNION ATTACH	670	-86	47
SIDE BRACE ATTACH	638	-36	51

Table 1 Key Coordinates

Note that the coordinate are in terms of the aircraft Fuselage Station, Butt Line, and Waterline. This terminology, however, is replaced with a standard x-y-z coordinate system from this point forward.

Max Landing Weight	**65000 lbs**
Max Ramp Weight	**78000 lbs**
Wheelbase (NLG to MLG)	**495.181 in.**
Forward CG Limit (x-dir)	**628 in**
Aft CG Limit (x-dir)	**645 in.**
CG Height (z-dir)	**98 in.**
Tires (2 per LG Leg)	**H34x4.25R18**

Table 2: Aircraft Parameters

Other specifications that affect the overall sizing of the landing gear are as follows:

- The main post shall incorporate trunnion attachment pins
- The main post shall incorporate a mounting for the Side Brace actuator assembly attachment
- The shock strut shall be removable without the need to remove the main landing gear from the aircraft
- The shock strut shall be removable without the need to remove the wheels, tires, and brakes

- Maximum pressure of the shock strut shall not exceed 2600 psi when the strut is compressed in the static ground condition at maximum ramp weight with aftmost CG location.

2.0 PROCESS DEFINITION AND FLOW CHART

Shown below is a general description of the process used for the design of the landing gear through both Conceptual and Embodiment design phases.

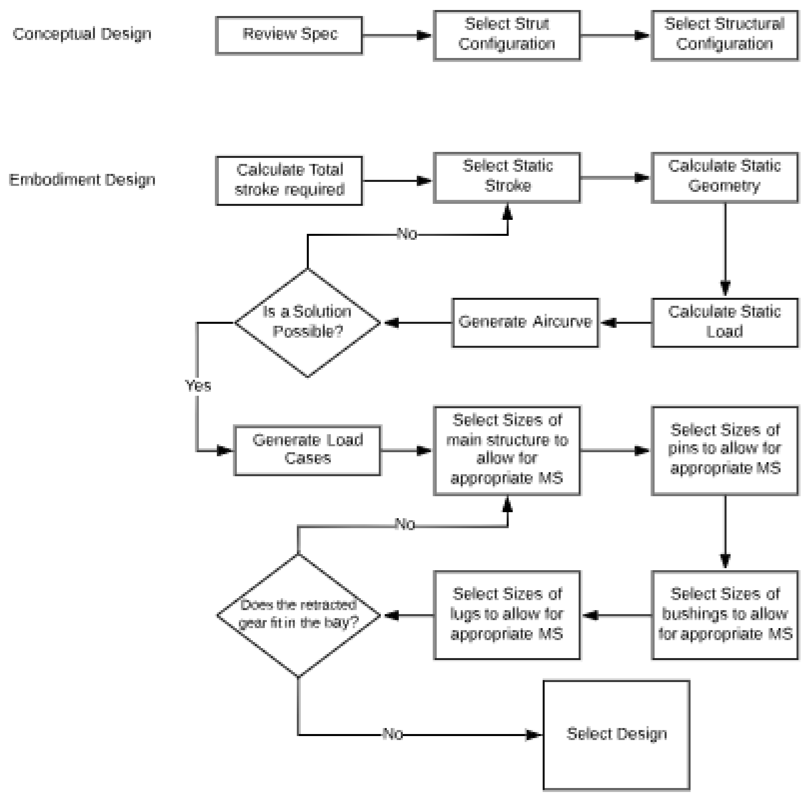


Figure 1 Design Flow Process

3.0 CONCEPTUAL DESIGN

Conceptual design begins with first analyzing the specifications outlined by the customer. The specification mentions a side brace actuator, meaning that the customer expects the brace to both support side loads experienced by the gear while also acting as a hydraulic actuator to retract the gear into the airplane. Another detail is that the customer does not specify an attach point for a shock strut, meaning that the strut most likely attaches to the main post that is explicitly mentioned. This is taken into consideration when selecting the initial configuration.

The first major decision was to design an oleo-pneumatic shock strut. Oleo-pneumatic shock struts utilize both oil and a gas (usually nitrogen) as means of energy dissipation. As the strut compresses, the oil is forced towards the top of the strut through an orifice plate and the gas is compressed, with the impact energy being dissipated as friction. Resistance increases as the gear strokes if the gear features a tapered metering pin, which effectively shrinks the orifice as the gear strokes. Once the force of the pressure inside the strut overcomes the force of landing, the oil is forced back down, but is instead forced through a recoil chamber, which slows the rate of extension to prevent the aircraft from bouncing off the runway. This design is the most widely used configuration of strut, as the design is the most efficient in terms of energy dissipation [1]. As a result, this is the most likely candidate for design.

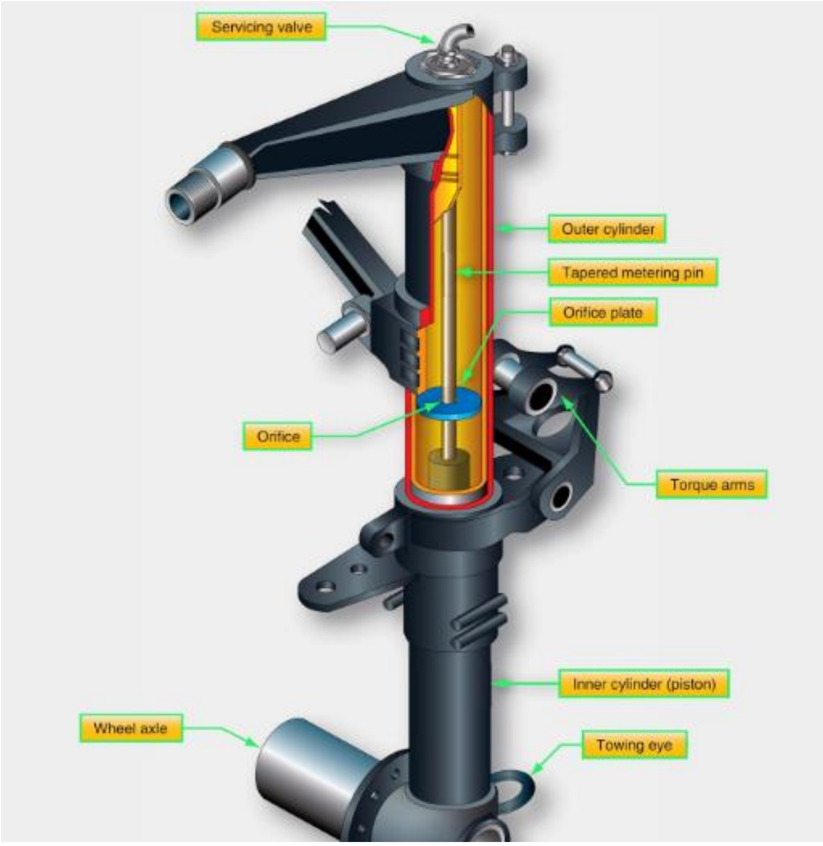


Figure 2 Oleo-Pneumatic Strut Configuration (Photo credit [1])

In terms of structural configuration, the landing gear can be one of two primary designs: cantilevered and articulated. Cantilevered gears typically consist of a shock strut that serves as the main structure that directly handles the ground loads. The gear shown in Figure 2 is a cantilevered landing gear. Conversely, an articulated landing gear features a shock strut attached to a brace, often known as a trailing arm, which places the axel further from the strut, creating a mechanical advantage. This allows for a smaller strut or a more compact gear depending on the design, which results in a smaller stowage space required. This, of course, comes with a trade-off that results in the gear being slightly heavier than a cantilevered beam.

Based on the specifications, there is no defined interface between the shock strut and the aircraft. This, coupled with the explicit use of the word “main post” indicated that an articulated landing gear is the best choice for the structure. This leads to the next phase of the design process, as the foundation has been laid for the sizing calculations.

4.0 EMBODIMENT DESIGN

4.1 Shock Strut Calculations

The first design consideration is the total stroke required for a landing gear to absorb the energy of a worst case scenario landing. The FAA defines a hard landing to be 12 ft/s for civil flight. This is considered to be a worst case landing, so coupled with the maximum landing weight, a maximum energy can be calculated. The total amount of stroke that is necessary to absorb the landing energy can be determined by balancing kinetic and potential energy.

$$S = \frac{\frac{w * v^2}{2g}}{w * \eta * n} + 1$$

S is the total stroke in inches, w is the max landing weight in pounds, v is the maximum velocity of landing in ft/s, g is the gravitational constant (32.2 ft/s^2), η is the metering pin efficiency (historically taken to be 0.85), and n is the load factor. The load factor is representative of how the strut handles the load, and is usually taken to be around 3, although a value to 2 was selected to reduce the overall length required by the shock strut. This gives a total stroke requirement of 16.662.

The static stroke of the strut is generally accepted to be about 75%-80% of the total stroke. A value of 80% was selected for this project. Next, the total load seen in the strut while in the static position must be calculated in order to determine the required gas pressure and piston area. This can be solved by solving the moment about the main post pivot.

Point	Description	X	Y	Z
A	Axel Location (Static)	683.7134089	-86	0.245293
B	MAIN POST LOWER (PIVOT)	658	-86	5
C	MAIN POST UPPER ATTACH	660	-86	46.5
E	FWD TRUNNION ATTACH	652	-88	46
F	AFT TRUNNION ATTACH	670	-86	47
G	LOWER OLEO ATTACH (Static)	681.0572	-86	8.060244

Table 3 Load Geometry

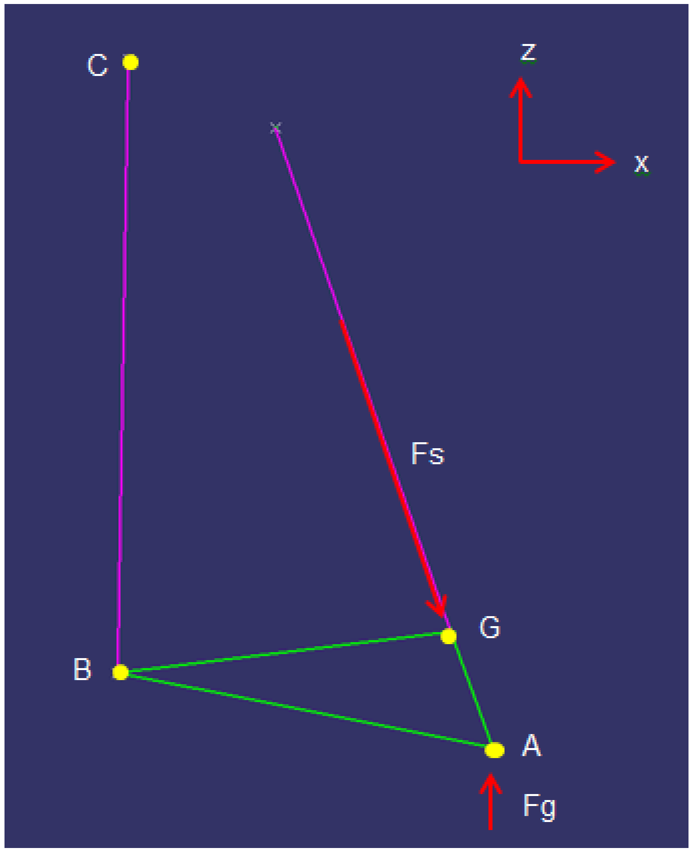


Figure 3 Free Body Diagram

This determines that the static load on the strut is approximately 40 kips. With the strut load calculated, a static pressure can be assumed and the piston area can be calculated. These values can in turn be inserted into a Collin's proprietary aircurve calculator, which returns a polytropic and isothermal aircurve of stroke versus load based on two input points. The points in this case were the static stroke and pressure and the compressed stroke and assumed pressure of 4500 psi.

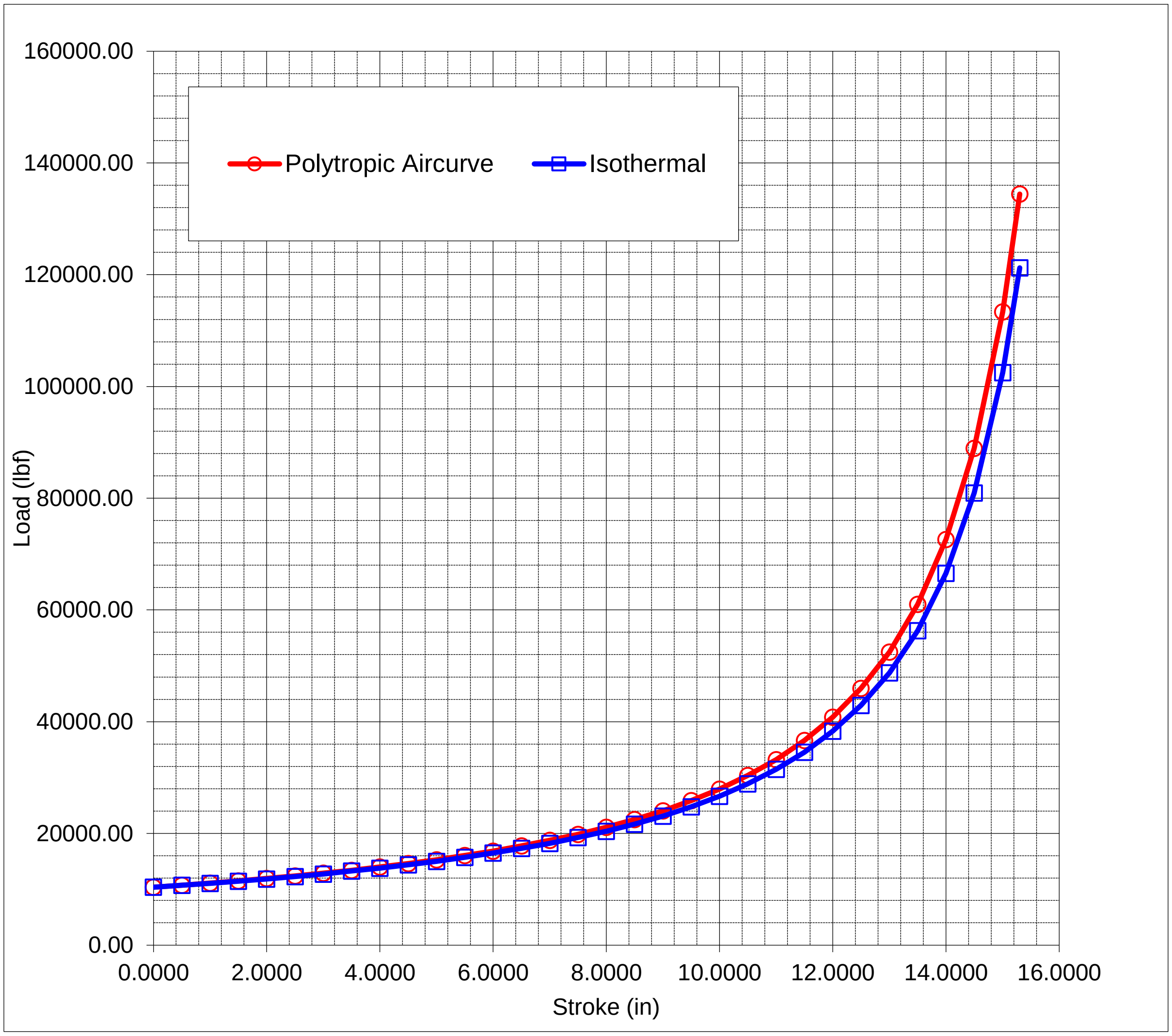


Figure 4 Aircurve

Since a reasonable aircurve was generated, it was acceptable to proceed with the design.

4.2 Load Cases and Structural Loading

In order to check the structural integrity of the gear design, a series of ground load cases were considered and detailed in Table 4. Each was calculated using standard Collin's internal engineering manuals, although each case is described in the corresponding specification.

Case	Tire Case	Vertical Factor	Vertical Load	Drag Factor	Drag Load	Side Factor (+/-)	Side Load
T-O Run, 2 pt FAR25.491	Normal	1.5	58500	0.2	11700	0.2	11700
	Flat Tire	1	35950.97	0.1	3595.096753	0.1	3595.096753
2 pt braked roll FJ25.491A	Normal	1.2	46800	0.8	37440	0	0
	Flat Tire	1	39000	0.4	15600	0	0
3 pt braked roll FJ25.491B	Normal	1	30510.55	0.8	24408.44	0	0
	Flat Tire	1	33313.75	0.4	13325.5	0	0
Turning: Left FJ25.495	Normal	1	13730.04	0.2	2746.008	0.5	-6865.02
	Flat Tire	1	24840.51	0.1	2484.051	0.25	-6210.1275
Turning: Right FJ25.495	Normal	1	58171.93	0.2	11634.386	0.5	29085.965
	Flat Tire	1	47061.43	0.1	4706.143	0.25	11765.3575
Nosewheel Yaw Part A Left Yaw FJ25.499	Normal	1	35950.97	0	0	-0.8	-2439.22598
	Flat Tire	1	35950.97	0	0	-0.4	-1219.61299
Nosewheel Yaw Part A Right Yaw FJ25.499	Normal	1	35950.97	0	0	0.8	2439.225977
	Flat Tire	1	35950.97	0	0	0.4	1219.612988
Nosewheel Yaw Part B Port Brake FJ25.499	Normal	1	35185.02	0.8	28148.016	-0.8	-1606.14953
	Flat Tire	1	36992.31	0.4	14796.924	-0.4	-803.074766
Nosewheel Yaw Part B STBD Brake FJ25.499	Normal	1	35185.02	0	0	0.8	1606.149532
	Flat Tire	1	36992.31	0	0	0.4	803.0747659
Reverse Braking FJ25.507	Normal	1	35950.97	-0.55	-19773.0335	0	0
	Flat Tire	1	35950.97	-0.275	-9886.51675	0	0
Jacking - 0 deg wrt nose FJ25.519B	N/A	1.33	47814.79	.33*	11863.8201	.33*	0
Jacking - 45 deg wrt nose FJ25.519B	N/A	1.33	47814.79	.33*	8388.987643	.33*	8388.987643
Jacking - 90 deg wrt nose FJ25.519B	N/A	1.33	47814.79	.33*	0	.33*	11863.8201
Jacking - 135 deg wrt nose FJ25.519B	N/A	1.33	47814.79	.33*	- 8388.987643	.33*	8388.987643
Jacking - 180 deg wrt nose FJ25.519B	N/A	1.33	47814.79	.33*	-11863.8201	.33*	0
Jacking - 225 deg wrt nose FJ25.519B	N/A	1.33	47814.79	.33*	- 8388.987643	.33*	-8388.98764
Jacking - 270 deg wrt nose FJ25.519B	N/A	1.33	47814.79	.33*	0	.33*	-11863.8201
Jacking - 315 deg wrt nose FJ25.519B	N/A	1.33	47814.79	.33*	8388.987643	.33*	-8388.98764

Table 4 Load Cases

Case	Tire Case	Vertical		Drag		Side	
		Factor	Load	Factor	Load	Factor (+/-)	Load
Towing FWD, par. To drag axis FJ25.509	Normal	1	35950.97	1	13114.28571	0	0
	Flat Tire	1	35950.97	0.6	7868.571429	0	0
Towing FWD, 30 deg To drag axis FJ25.509	Normal	1	35950.97	1	11357.30458	1	6557.142857
	Flat Tire	1	35950.97	0.6	6814.382749	0.6	3934.285714
Towing REV, par. To drag axis FJ25.509	Normal	1	35950.97	1	-13114.28571	0	0
	Flat Tire	1	35950.97	0.6	-13114.28571	0	0
Towing REV, 30 deg To drag axis FJ25.509	Normal	1	35950.97	1	-13114.28571	1	6557.142857
	Flat Tire	1	35950.97	0.6	-13114.28571	0.6	3934.285714

		Vertical		Torque (+=CCW, in*lb)	
Pivoting Left hand turn FJ25.503	N/A	1	35950.97	0.8	-230086.1922

Table 4 Load Cases (cont.)

From this point, each main point of the gear can be analyzed to find the reactions given each load case applied to the axel center line (point A). The results were compiled in a spreadsheet that contains controlled proprietary data and cannot be shared. These data points were then fed into the structural integrity calculator in order to find an appropriate size to yield an appropriate margin of safety.

4.3 <u>Side Brace Calculations</u>

To quickly determine the approximate sizing of the side brace, an attach point in about the middle of the main post was selected. The weight of the gear can be approximate to be about 1% of the total weight of the aircraft based on similar designs, and the CG of the gear can be placed at the axel since a high percentage of the total weight of the gear is from the wheels and brakes. This establishes a moment that resists retraction about the trunnion line. Summing the moments about the trunnion line gives the tensile force supplied by the side brace. Assuming that 2500 psi is supplied to the brace, an approximate bore area can be calculated. This results in a piston outer diameter of 3.2064.”

4.4 Structural Calculations

After the loads were calculated for each critical section of the structure, an appropriate stress calculation was applied for the given section. Four separate calculations were performed for a given part. For larger structural components, such as the main post, trailing arm, and shock strut, the combined loading equations were used:

Stresses at Section:

Axial: $ftu_i := \frac{(-FX1_{seas})_i}{Area}$ $\quad R_{t_i} := \frac{ftu_i}{F_{tu}}$

Bending: $fb_i := \frac{\sqrt{(MXs_i)^2 + (MYs_i)^2}}{Z}$ $\quad R_{b_i} := \frac{fb_i}{F_b}$

Shear: $fsavg_i := \frac{\sqrt{(FXs_i)^2 + (FYs_i)^2}}{Area}$ $\quad R_{savg_i} := \frac{fsavg_i}{F_{su}}$

$fsmax_i := Kshr \cdot fsavg_i$ $\quad R_{smax_i} := \frac{fsmax_i}{F_{su}}$

Torsion: $fstor_i := \frac{MZs_i}{2 \cdot Z}$ $\quad R_{tor_i} := \frac{fstor_i}{F_{su}}$

Hoop Tension: $fhoop_i := 0ksi$ $\quad R_{hoop_i} := \frac{fhoop_i}{F_{tu}}$

Tension side:

$$Ratio1_i := \sqrt{\left(R_{t_i} + R_{b_i}\right)^2 + \left(R_{hoop_i}\right)^2 - \left(R_{t_i} + R_{b_i}\right) \cdot R_{hoop_i} + \left(R_{savg_i} + R_{tor_i}\right)^2}$$

Compression side

$$Ratio2_i := \sqrt{\left(R_{t_i} - R_{b_i}\right)^2 + \left(R_{hoop_i}\right)^2 - \left(R_{t_i} - R_{b_i}\right) \cdot R_{hoop_i} + \left(R_{savg_i} + R_{tor_i}\right)^2}$$

Neutral of bending

$$Ratio3_i := \sqrt{\left(R_{t_i}\right)^2 + \left(R_{hoop_i}\right)^2 - R_{t_i} \cdot R_{hoop_i} + \left(R_{smax_i} + R_{tor_i}\right)^2}$$

$$MS_i := \begin{pmatrix} \frac{1}{Ratio1_i} - 1 \\ \frac{1}{Ratio2_i} - 1 \\ \frac{1}{Ratio3_i} - 1 \end{pmatrix} \qquad MS\_min_i := \min(MS_i)$$

Where F_{su}, F_{tu}, and F_b are material properties.

Next, pin joints could be calculated in a similar fashion:

Stresses:

$$f_t := \frac{Pax}{Area}$$

$$fshr := \frac{V_A}{Area}$$

$$fb := \frac{M_A}{Z}$$

$$fshr_{max} := \frac{V_A \cdot Kshr}{Area}$$

$$Rt := \frac{f_t}{F_{tu}}$$

$$Rshr := \frac{fshr}{F_{su}}$$

$$Rb := \frac{fb}{F_{bu}}$$

$$Rshr_{max} := \frac{fshr_{max}}{F_{su}}$$

Margin of Safety:

$$U := \begin{bmatrix} \left[Rshr^2 + (Rb + Rt)^2\right]^{0.5} \\ \left(Rshr_{max}{}^2 + Rt^2\right)^{0.5} \\ (Rb + Rt) \end{bmatrix}$$

$$MS := \frac{1}{\max(U)} - 1$$

The bushings and lugs for these pin joints were calculated using proprietary methods that accept a load vector, material, and sizing as inputs and outputs the corresponding margin of safety. 300M stainless steel was selected for each component due to its wide use in civilian landing gears. The ideal design point usually used by Collin's engineering this early in a project is for a margin of safety of 0.1, which would allow for growth of the components. Generally, each part is assumed to be cylindrical, so an outer radius was selected. An inner radius was solved for to result in a MS that was no less than 0.1. In some cases, such as the main post, the outer radius was calculated for a given inner radius to keep a consistent bore radius throughout. In some cases, MS of 0.2 was desired for critical components such as the shock strut. The results for each section are displayed in Table 5.

Component	R_I	R_O	MS
Trailing Arm	2.089889	2.5	0.100
Main Post (Upper Section)	2.5	3.513925	0.100
Main Post (Lower Section)	2.5	2.658244	0.100
FWD Trunnion Pin	1.20499	2.25	0.100
AFT Trunnion Pin	1.20499	2.25	0.103
Shock Strut Cylinder	2.928677	3.010112	0.200
Shock Strut Piston	2.847722	2.928677	0.200
Side Brace Cylinder	1.603224	1.643904	0.200
Side Brace Piston	1.55	1.603224	0.556
Main Post Pivot Pin	1.3387341	1.75	0.100
Main Post Pivot Bushing	1.75	2.031044	0.100
Main Post Lug	2.031044	3.125	20.766
Trailing Arm Pivot Lug	2.031044	3.25	23.772
Shock Strut Attach Pin	0.634412	0.75	0.100
Shock Strut Bushing	0.75	0.803858	0.100
Shock Strut Lugs	0.803858	1.25	3.423
Side Brace-Aircraft Lug	1	1.5	6.814
Side Brace Spindle	0.672374	1.125	0.100
Side Brace Spindle Bushing	1.125	1.1875	2.383
Side Brace Spindle Lug	1.1875	1.85	9.600
Side Brace Spindle Pin	0.779174	1.125	0.11

Table 5 Component Sizing

5.0 DETAIL DESIGN

With each component sized, each part could be modelled to create an assembly for retraction modelling. Each large part is intended to be custom forged at Collins or vendor manufacturing sites, and each small component can be custom made or can be found as an off-the-shelf standard part.

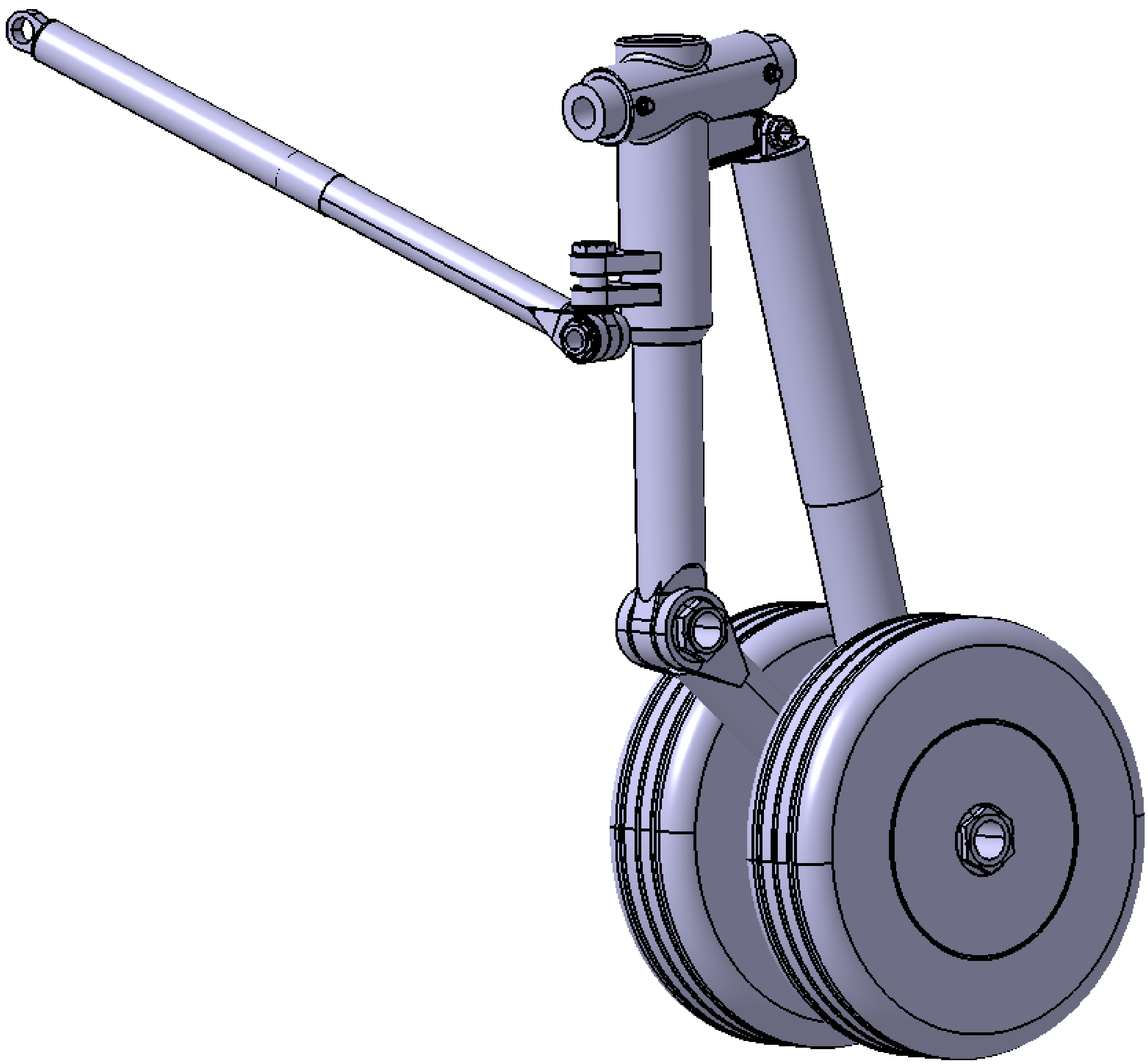
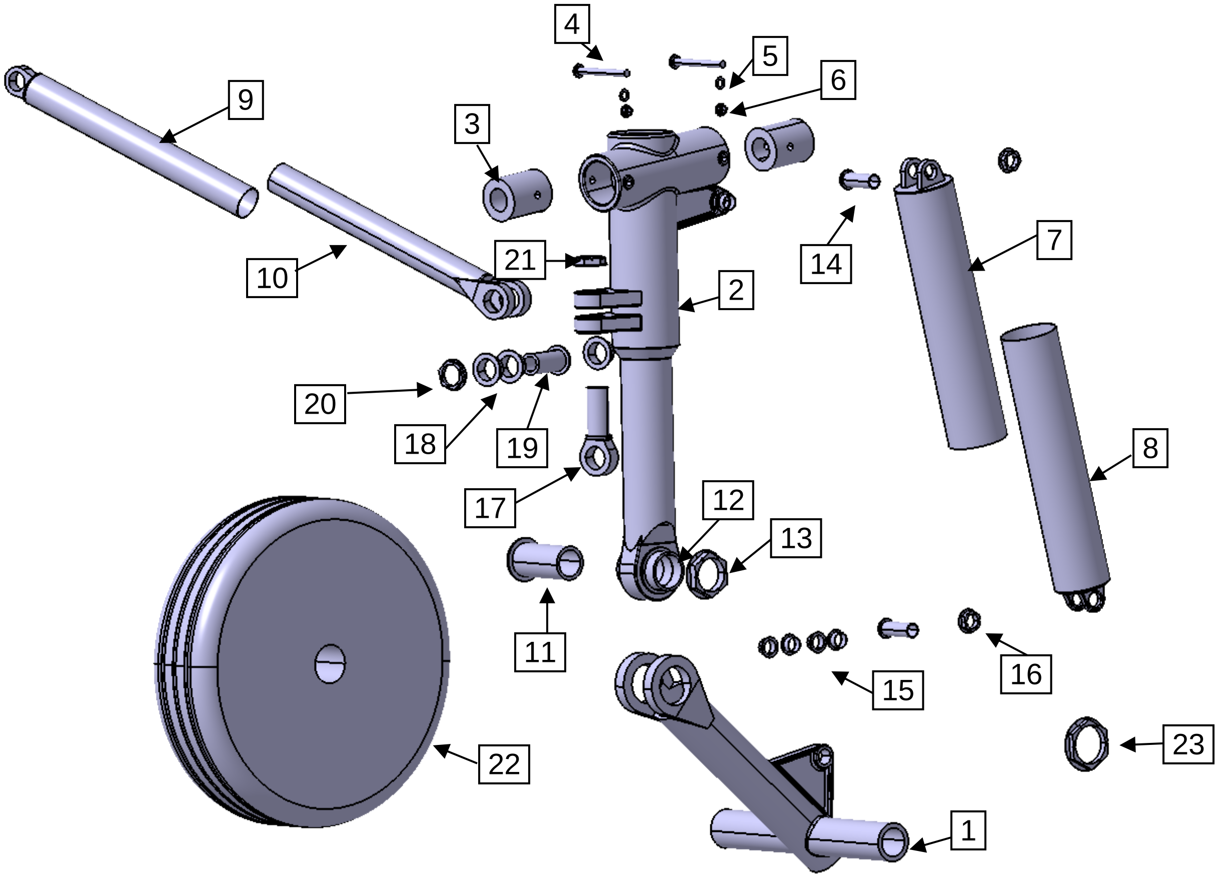


Figure 5 Full Assembly



Component	Description	QTY
1	Trailing Arm	1
2	Main Post	1
3	Trunnion Pin	2
4	Trunnion Crossbolt	2
5	Trunnion Crossbolt Washer	2
6	Trunnion Crossbolt Nut	2
7	Shock Strut Cylinder	1
8	Shock Strut Piston	1
9	Side Brace Cylinder	1
10	Side Brace Piston	1
11	Main Post Pivot Pin	1
12	Main Post Pivot Bushing	4
13	Main Post Pivot Nut	1
14	Shock Strut Attach Pin	2
15	Shock Strut Bushing	8
16	Shock Strut Attach Nut	2
17	Side Brace Spindle	1
18	Side Brace Spindle Bushing	3
19	Side Brace Spindle Pin	1
20	Side Brace Spindle Pin Nut	1
21	Side Brace Spindle	1
22	Wheel, Tire, and Brake Assembly	2
23	Wheel Nut	2

Figure 6 Exploded View and Bill of Materials

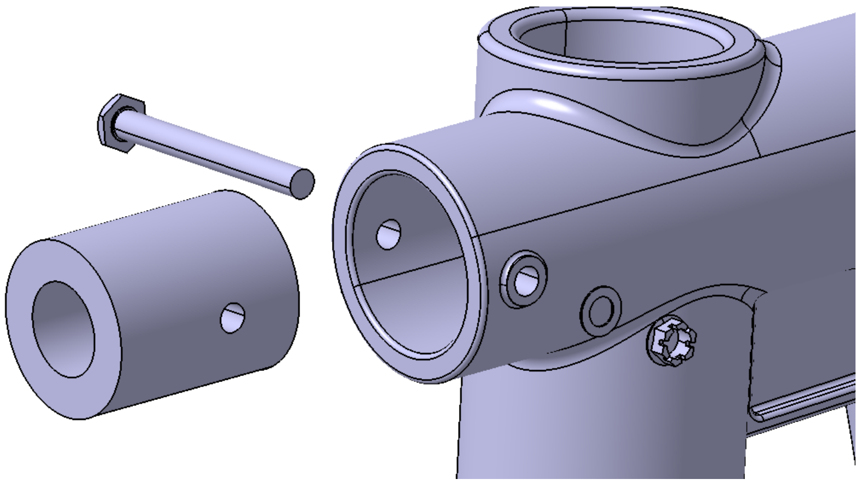


Figure 7 Trunnion Pin Attach Detail View

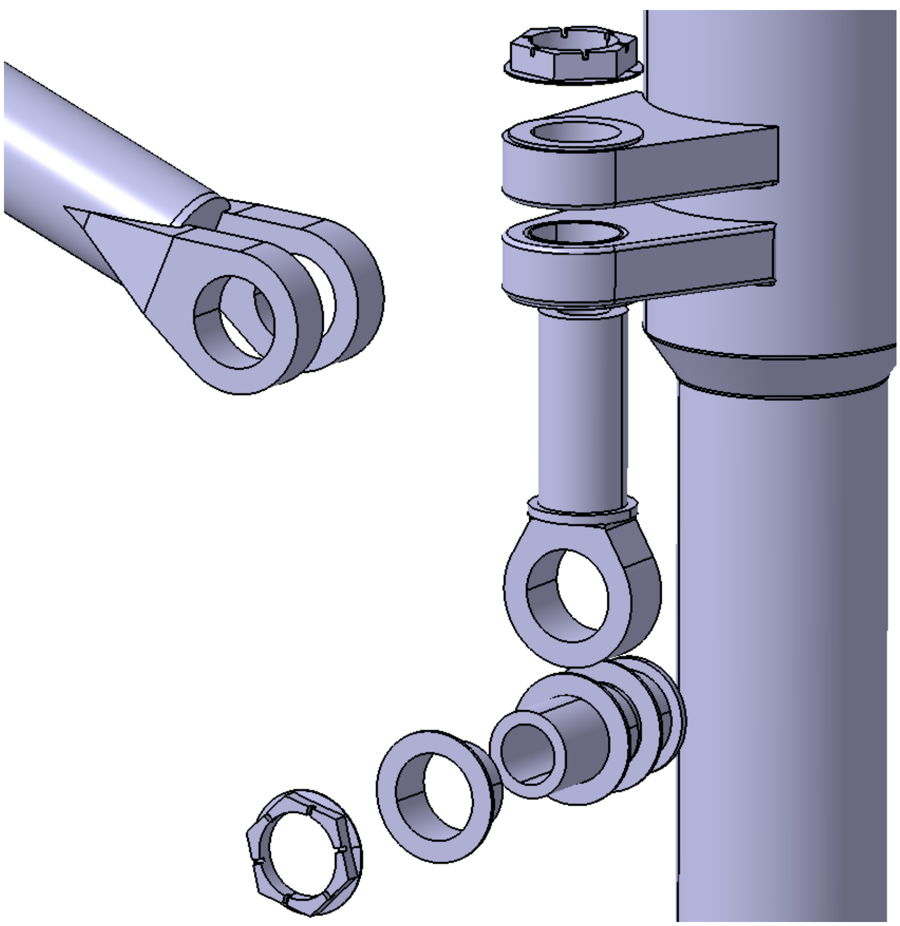


Figure 8 Side Brace Attach Detail View

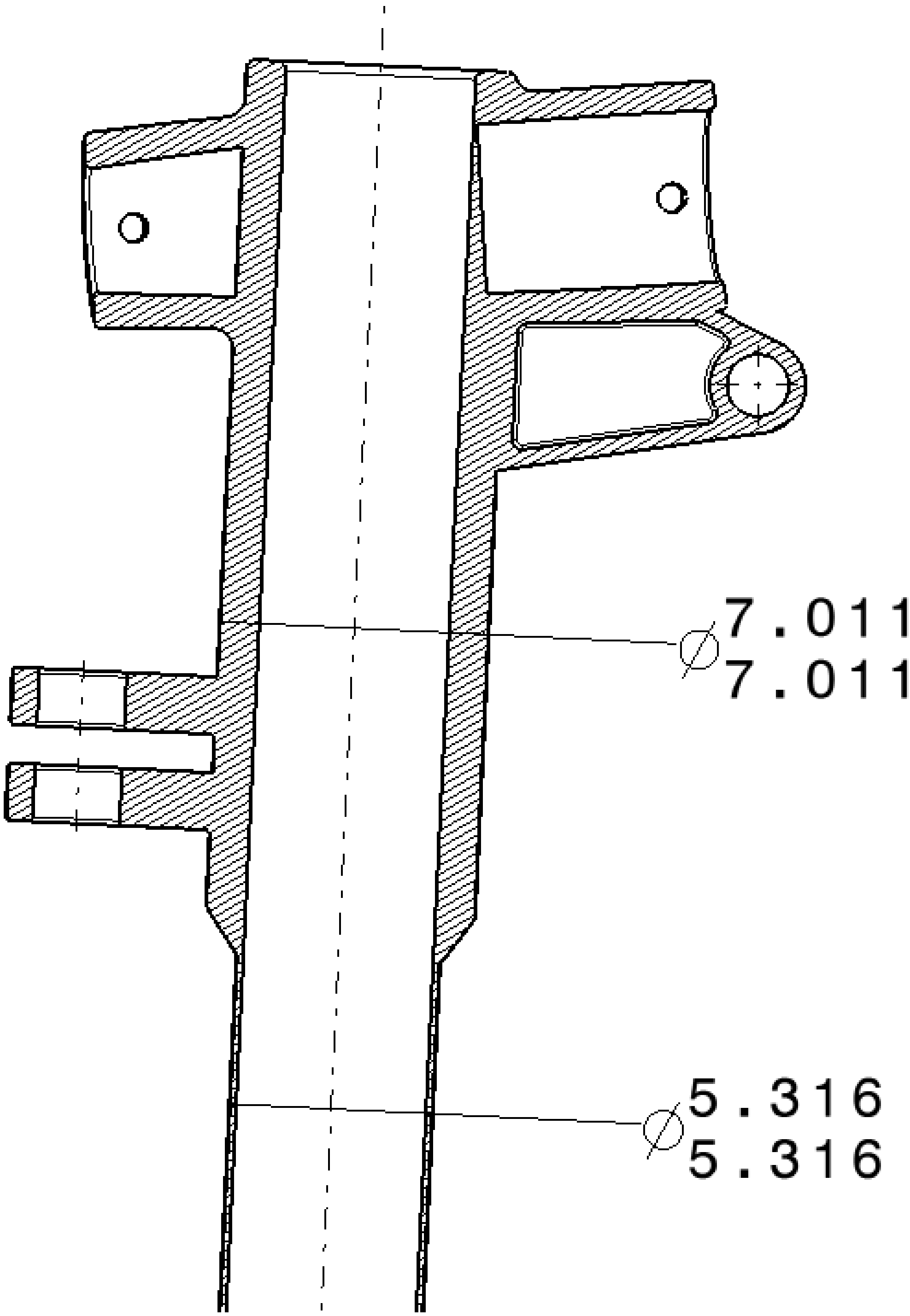


Figure 9 Main Post Section View

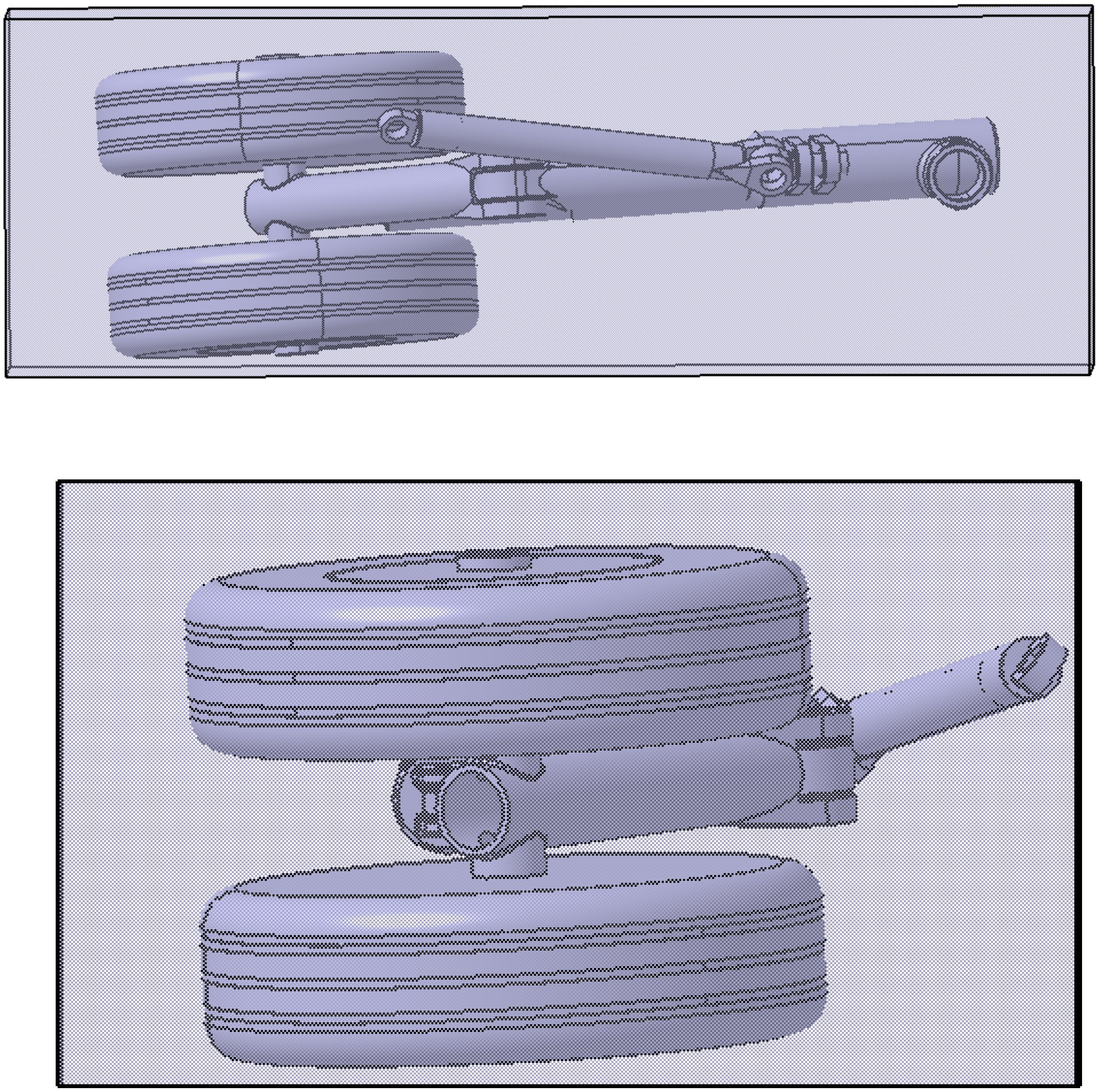


Figure 10 Gear Retracted into Bay

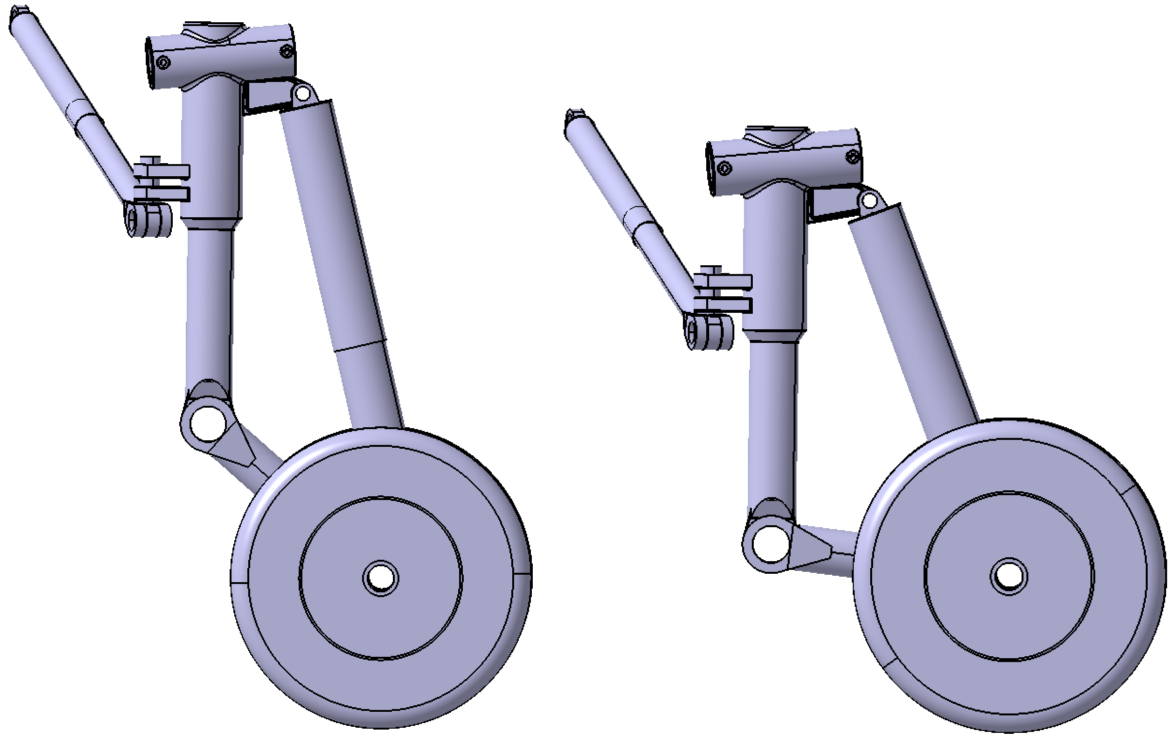


Figure 11 Extended vs Static Stroke

6.0 DISCUSSIONS

Upon modelling the Main Landing Gear Assembly and creating the kinematic model, the final iteration of the design was able to fit with the given bay dimensions, signifying a potential candidate for a final design. All design features were considered for the time being, including provisions to remove each component without needing to remove the entire landing gear assembly. While this concludes the preliminary sizing of the landing gear, the design is far from complete. The next phase of design would be to dynamically model the design to estimate shock strut fluid performance and to perform finite element analysis for various sections, such as the shock strut to main post attachment point. Fatigue analysis will also be necessary for every single component in the design to ensure full life of components. It is likely that all of these analyses would find that components are undersized for the higher loads seen on landing and aborted takeoffs. This would result in the process repeating again.

Many factors in the design are still left to be determined, such as hydraulic and electrical routings, transducer placement and functionality, and other specification-defined features and components. One particular issue that will need to be designed is the internals of the shock strut and side brace. These were omitted for the purpose of this external sizing exercise. However, the design of these components is among the most important for the purpose of the design. Another crucial task is to determine the locking mechanism for the side brace. Likely, the brace will have to be redesigned and made larger to accommodate seals and locking hardware. The

side brace must also include some form of downlock indicator and have some provisions for ground lock pins to prevent unintended retraction while the aircraft is on the ground. These all fall outside the scope of this venture.

Alternate materials should be investigated for weight savings or improved strength. 300M steel was considered only to simplify the process and create a viable means of analysis. Lastly, processing and manufacturing will need to be examined further. The components are intended to as simple as possible for analysis and manufacturing purposes; but of course the simplicity of the design will undoubtedly be disturbed by detail design, as material will likely be added or removed.

7.0 CONCLUSIONS

The process for designing landing gear, at least at conceptual, external level, is a fairly straightforward linear process. Iteration is inevitable, but the steps to achieve the design are sequential. Additionally, this whole project, besides the 3-Dimensional modelling, was completed using only excel spreadsheets. The sheets proved to be valuable for the whole process, as only changing a few cells could effectively alter the design without breaking the equations and logic around the data. This resulted in faster iteration each time that a component was required to change. The end result is a product that analytically fulfills each requirement that it faces at this point.

Landing gear design is indeed a very intensive discipline, requiring extensive knowledge in various areas that range from structural analysis to drafting and design to material science and beyond. On a project, often times dozens of individuals are required to provide input into the design. Each component must be intensely scrutinized in all aspects to ensure that the component will last an entire flight life. This is crucial since lives depend on the proper design and manufacturing of these systems.

Thousands of additional hours will be needed on design alone before this landing gear will even be ready for manufacturing and flight certification. Even then, physical testing will show any unexpected flaws within the design, and the design will be changed again. Landing gear design is a slow, often grueling process, but every analysis is absolutely crucial to ensure that the best, most safe product is delivered.

8.0 REFERENCES

[1] Currey, N.S. (1988). *Aircraft Landing Gear Design: Principles and Practices.* Washington, D.C.: American Institute of Aeronautics and Astronautics.

Photo Credits

(1) https://www.aircraftsystemstech.com/p/there-are-many-different-designsof.html