Abstract

To load an off-road vehicle (ORV) into the bed of a pickup truck, the use of homemade or commercially produced ramps is common practice. This loading method can be dangerous and can cause serious injury for the operator. This outcome is almost certain if a ramp is inadequately rated for high loads. Atom-Jet Industries believes that there exists a market for a premium product with the ability to safely and conveniently load an ORV without the requirement for external power. Through the Mechanical Engineering Capstone course (MECH 4860) at the University of Manitoba, the student team, ORV Solutions was assigned to the Recreational Vehicle Lift project with Atom-Jet Industries. A three phased project plan including Phase I – Project Definition, Phase II – Concept Development, and Phase III – Detail Design, was employed to manage and successfully execute the project.

During Phase I, ORV Solutions were able to itemize the project scope through documenting of project requirements and specifications. Requirements with the highest priority included the capability to both load and unload the ORV, design compatibility with multiple ORVs, and powering of the concept through the ORV itself. The product requirements were then broken down to five key sections. These sections included compatibility, truck mounting, platform, power transmission, and loading/unloading methods. ORV Solutions was then able to generate several concepts by combining methods from each section. Following a screening, scoring, and review process, a concept was selected for development in the Detail Design phase.

The design of the self-powered recreational vehicle loader was finalized in phase III. To load an ORV in the final design, the ORV is driven up an inclined platform. This inclined platform then pivots to be parallel to the floor of the truck bed through spooling of a cable much like a winch. Power is transmitted from the ATV or snowmobile through a treadmill style track and roller system. A spool on the drive shaft is then able to reel in a cable attached to the truck bed and ultimately load the ORV. A v-belt system was introduced into the design to increase torque, this increased the loading capacity of the design. The platform is guided onto the truck bed through interference between a platform mounted rail and base frame structure bolted and mounted on the truck bed. From a list of 20 client needs and recommendations, 16 were met, two were partially developed, and two were not incorporated into the design. The total cost of purchasable and stock material (for manufacturing) for this design is estimated to be $1,718.00. While there is room for optimization and improvement in the design, ORV Solutions is confident that the design presented in this report is functional and achieves the design needs and requirements laid out and agreed upon during Phase I.

MECH 4860

Engineering Design

Design of a Self-Powered Recreational Vehicle Loader for Pickup Trucks

Final Report

Submitted to: Paul Labossiere, Atom Jet Industries, Nishant Balakrishnan

Submission Date: December 9, 2020

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Executive Summary

To load an off-road vehicle (ORV) into the bed of a pickup truck, the use of homemade or commercially produced ramps is common practice. This loading method can be dangerous and can cause serious injury for the operator. This outcome is almost certain if a ramp is inadequately rated for high loads. Atom-Jet Industries believes that there exists a market for a premium product with the ability to safely and conveniently load an ORV without the requirement for external power. Through the Mechanical Engineering Capstone course (MECH 4860) at the University of Manitoba, the student team, ORV Solutions was assigned to the Recreational Vehicle Lift project with Atom-Jet Industries. A three phased project plan including Phase I – Project Definition, Phase II – Concept Development, and Phase III – Detail Design, was employed to manage and successfully execute the project.

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1. Introduction

This final design report outlines the design that ORV Solutions developed to load ATVs and snowmobiles onto the bed of a pickup truck using power from the ORV as requested by the client, Atom Jet Industries. This report details how ORV Solutions developed the deliverables requested by Atom Jet including a working model, bill of materials, and power generation analysis. Also included are recommendations for future design and manufacturing considerations.

1.1. Company and Product Background

Based out of Brandon, Manitoba, Atom-Jet Industries is an international company serving agricultural and industrial markets [1]. Due to the seasonality of the products and services offered, Atom-Jet explored the opportunity to develop a product to ensure safe and convenient loading and unloading of Off-Road Vehicles (ORV). ORVs under consideration for the design include all-terrain vehicles (ATVs), snowmobiles, dirt bikes, and side by sides. Atom Jet Industries, in partnership with the University of Manitoba, requested a fully functional design, developed through three phases. By the end of the process, the product design is to be presented to both Atom Jet Industries and the University of Manitoba with the submission of this report.

1.2. Project Problem Statement and Business Case

ORV Solutions, formed by students in the Capstone program at the University of Manitoba, is a consulting team employed by Atom Jet Industries to envision, conceptualize, and design a fully functional product to lift an off-road vehicle into the bed of a pickup truck. The most common current practice consists of using homemade ramps which can be a source of major safety risks to the operator and vehicle. Providing a safer alternative to ramps for ORV loading ensures accessibility to a larger ORV-user market. This product is imagined to be a premium design aimed to greatly improve the safety, convenience, and ease ORV loading. The product is therefore anticipated to retail at $5,000 CAD.

1.3. Project Scope

This product is to be compatible with most unmodified snowmobiles and all-terrain vehicles (ATV's). This product is also be compatible with most unmodified half-ton trucks. Side by side (SxS) vehicles were omitted due to their size being incompatible with the inner dimensions of a truck bed. Motorcycles and dirt bikes were omitted due to the significant difference in wheel layout. Quarter ton trucks were omitted due to their size and weight capacity being unsuitable for the lift and an ATV or snowmobile.

1.4. Client Needs and Target Specifications

After discussing with Atom-Jet as well as several ORV users, ORV Solutions determined twenty client needs and prioritized each need on a scale of one to five, with five being the highest priority. The highest priority needs, highlighted in gold below, centered around the products ability to complete the task of loading and unloading in a safe and efficient manner, while being powered by the ORV itself. A full list of client needs can be found below in TABLE I.

TABLE I: CLIENT NEEDS

	Client Needs	Priority
1	The design must be compatible with different types and brands of ATV's and snowmobiles.	**5**
2	The design must be compatible with motorcycles and dirt bikes.	2
3	The design must be able to secure the ATV or snowmobile.	**5**
4	The design is capable of lifting the ATV/snowmobile and user at the same time.	**5**
5	The design is capable of loading and unloading an ATV or snowmobile from a truck bed.	**5**
6	The design can efficiently load and unload the ATV or snowmobile.	4
7	The design must be compatible with different truck beds.	4
8	The design must be safe in a roll-over.	4
9	The design has a high factor of safety when operating.	4
10	The design is ATV or snowmobile powered.	5
11	The design must have an alternate power source.	4
12	The design requires few steps to operate.	3
13	The design must be rugged.	4
14	The design must be simple to install.	3
15	The design must be able to operate on uneven ground.	2
16	The design must be simple to service.	3
17	The design must come in kit.	2
18	The design must be able to operate when dirty.	3
19	The design must be modular.	3
20	The design must be cost effective to manufacture.	4

After consulting with Atom-Jet, ORV Solutions developed twelve technical specifications to determine the product's ability to achieve the client needs. These technical specifications, along with their related client needs can be seen below in TABLE II.

TABLE II: TECHNICAL SPECIFICATIONS

	Specification	Corresponding Need	Unit of Measurement	Minimum Value	Ideal Value
1	Number of compatible ATV's and snowmobiles	1, 2, 3, 5, 8, 10	ATV's and snowmobiles	3	>3
2	Number of compatible truck beds	5, 7, 8, 14	Truck Models	3	>3
3	Weight capacity of the lift	4, 5, 6	lbs	2000	>2000
4	Total number of standard parts	14, 16	Percent	90	100
5	Total number of modular sections	14, 19	Sections	1	4-8
6	Loading speed	6, 9, 10	Minutes	10	3-5
7	Product is safe to operate	9, 13, 15, 18	Subjective	Subjective	Subjective
8	Material Cost	20	Dollars (CAD)	1500	<1500
9	Production Cost	17, 20	Dollars (CAD)	5000	<5000
10	Factor of Safety	9	-	2	>2
11	Operators required	6, 12, 19	People	2	1
12	Power system	10, 11	-	ATV, Truck, Battery, Hand	ATV, Hand

The number of compatible ATV's, snowmobiles, and truck beds, as well as the weight capacity are high priority technical specifications to focus on when determining concepts. After additional consultation with the client, the need for the lift to be ATV powered was subsequently deemed an additional high priority technical specification for market competitiveness [2].

1.5. Project Execution

The execution of this project followed a phased progression of project tasks. These three phases included Phase I – Project Definition, Phase II – Concept Development and Phase III – Detail Design. A concise timeline and brief introduction of generalized tasks accomplished in each phase is detailed in a simplified Work Breakdown Structure illustrated in Figure 1. The Work Breakdown Structure (WBS) is a hierarchical decomposition of the scope outlined by work packages that need to be completed by ORV Solutions. This tool will allow better itemization of the work to be performed and will also allow for better future planning. For simplicity, only elements to the second decomposition level are shown in Figure 1. In order to advance phases, a report outlining the work accomplished was to be formulaized and submitted to Atom-Jet and the University of Manitoba for each phase.

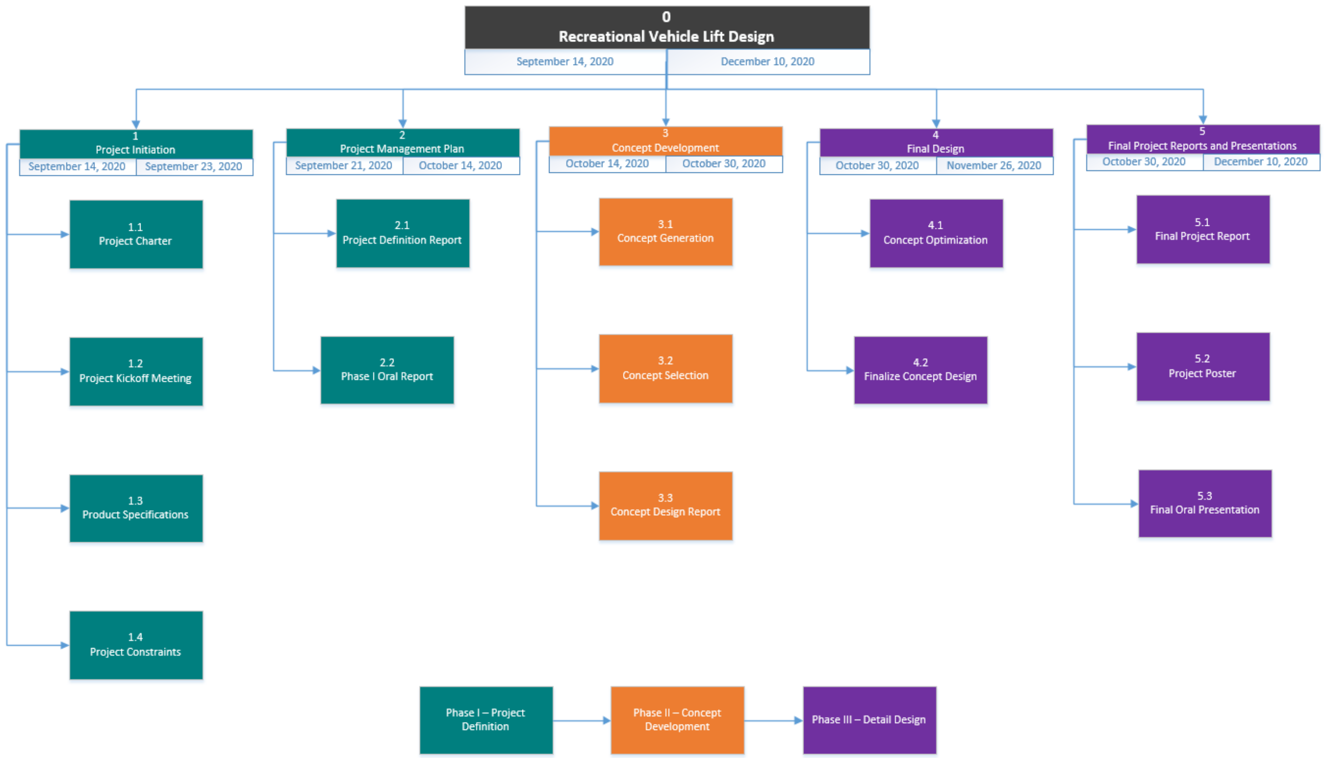


Figure 1: Simplified Work Breakdown Structure

2. Concept Development Process

To begin the concept development process, five distinct design sections were formed to break down possible concepts as identified in Figure 2. ORV Solutions then worked to develop various options capable of achieving the individual design goals. The breakdown of the needs and specification into design sections and subsequent method review is illustrated in a schematic diagram in

Figure 2.

Prior to incorporating the various options for each section into a full concept, a scoring system was used to determine the strengths and weaknesses of the various alternatives for each section. The scores for each option helped in the development of concepts by allowing the options to be ranked against each other. This identified potentially stronger options to be implemented in the concept generation.

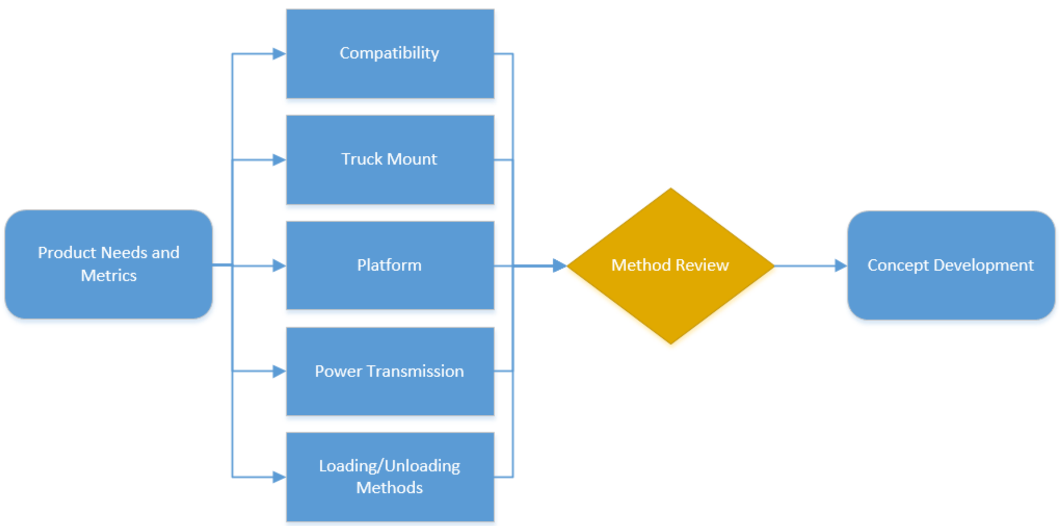


Figure 2: Concept Problem Breakdown

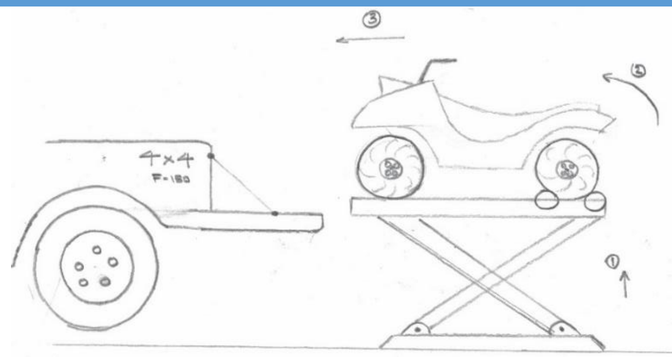
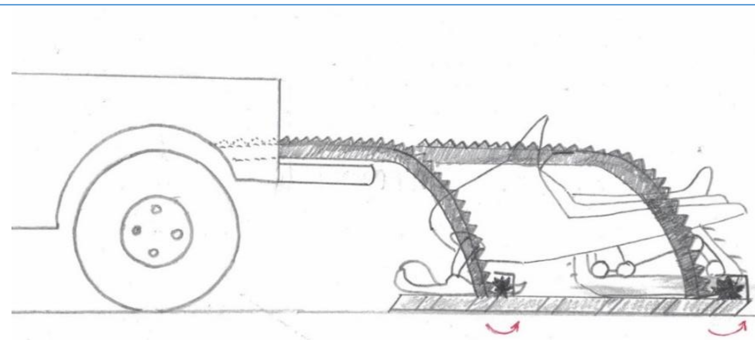
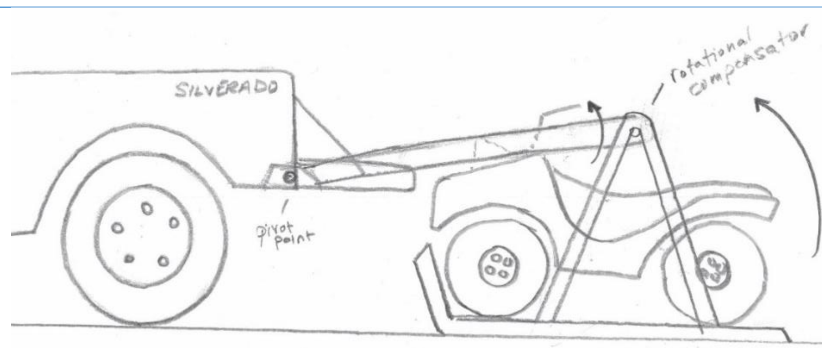
2.1. Revisiting Client Needs

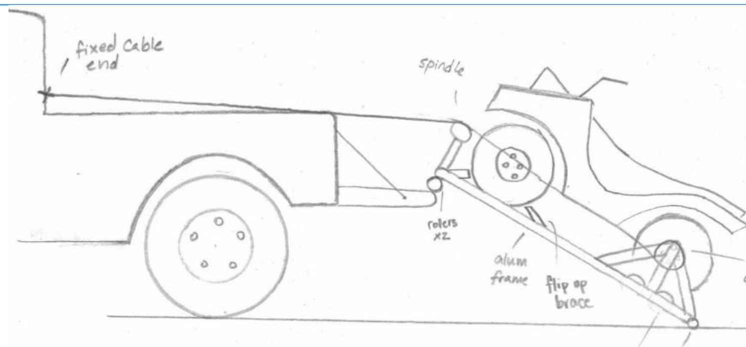
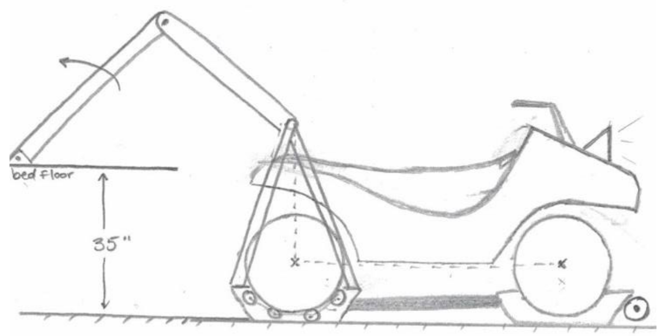
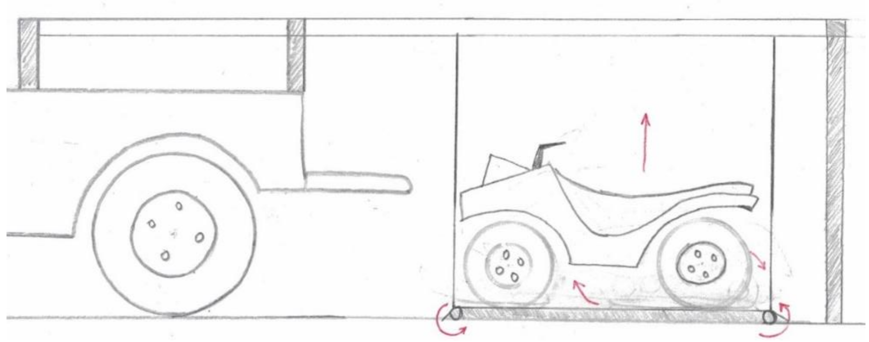
Throughout the development of concepts, contrasting client needs became evident. Through further communication with the client, the most important need was established; the vehicle lift must be powered by the ORV in some capacity while the importance of motorcycle and dirt bike compatibility was reduced.

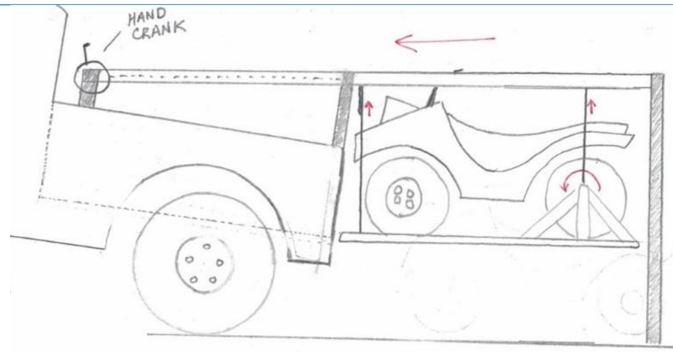
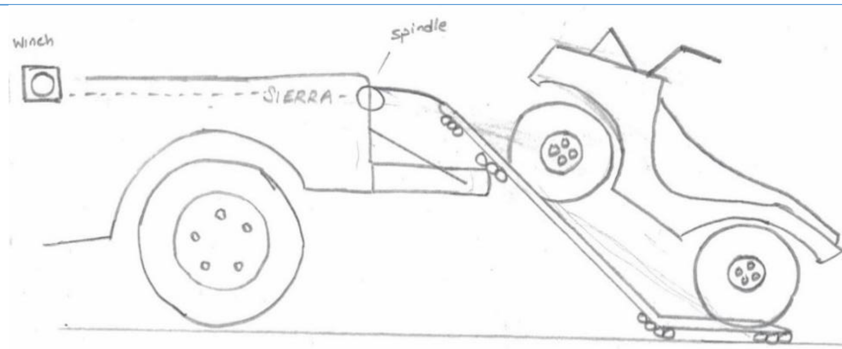
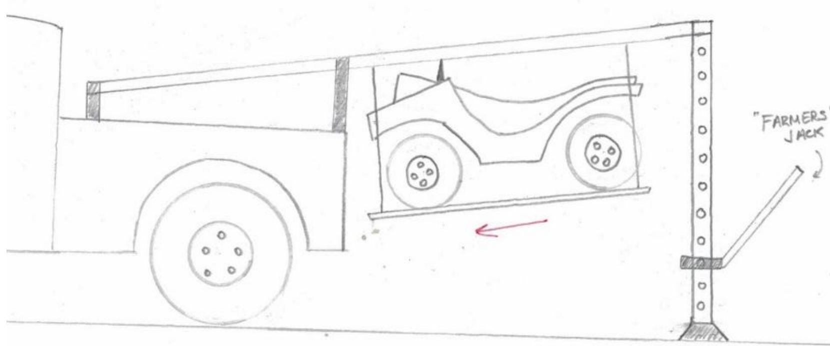
2.2. Generated Concepts

TABLE III presents all concepts developed during the concept generation. ORV Solutions strove to have each concept satisfy as many client needs as possible, allowing for several high quality concepts to be considered for development in the final phase.

TABLE III: CONCEPTS

CONCEPT	SKETCH
Scissor Jack Lift	 Platform that raises the vehicle off the ground, placing the upper platform on the bed of the pickup truck, then folding the ground level base platform upward into the truck bed.
Gear Rack Lift	 Gears attached to the platform and powered by the vehicle roll along the gear rack up and into the pickup truck bed. Once the ORV is in the pickup truck, the gear racks are disassembled and placed alongside the ORV in the pickup truck.
Crane Platform	 A swinging arm mechanism powered via pulleys in turn powered by the vehicle, swing the ORV into the truck bed. Compensator ensures the platform is balanced.

Partial Ramp	 The ramp/platform is placed on the edge of the pickup truck. The ORV is driven up the ramp and secured in place. Rotational movement of the rear ORV wheels wind up the non-fixed end of the cable, effectively dragging the platform into the bed.
Segmented Crane Platform	 Modification of the crane design. ORV is loaded backwards to minimize the distance between the crane mechanism and the generated power. Front and rear wheel supports connected by a bar (no platform).
Cable Supported Platform	 Design 'scaffolding'/framing to raise ATV off the ground. Framing must be assembled prior to loading and unloading. ATV tire rotational movement contracts the cables and lifts the platform up. Platform is pushed into truck bed.

Segmented Angled Bed Cable Platform	 Modification of cable supported platform. Pickup truck is propped up on ramps to angle the truck bed closer to the ground, reducing the necessary lift. A hand crank drags the platform into the truck bed.
Electric Winch Partial Ramp	 ORV is driven partially up the platform, secured in place, and an electric winch drags the platform onto the truck bed.
Farmer Jack Cable Platform	 Alternative design to cable supported concept. Rear support of frame is propped up using farmers' jack. Platform relies on gravity to slide onto the truck bed. When offloading, the method is reversed (rear frame lowered for platform to slide down).

2.3. Selection Methodology for the Initial Concepts

The initial concepts entered a preliminary screening process before a more intensive concept scoring where a final concept was selected for the final design development in this report. A metric importance matrix was used to determine various metrics for concept selection and assign weights for each criterion. The concepts are then scored on a scale from 1-5 in a weighted decision matrix. The concepts and concept scores were then reviewed with Atom-Jet prior to selection of the final concept for detail design. On October 28, 2020, the "Scissor Jack Lift" concept was selected for development in the Detail Design phase.

2.4. Project Redirection

Following Phase II, ORV Solutions began developing and designing a "scissor jack lift". As decided at that point in time, the design was to be compatible with ATVs only. Two weeks into Phase III (13 Nov. 2020), the client requested that the project be redirected based on internal correspondence at Atom Jet Industries. The major elements of the redirection included the compatibility for both ATV's and snowmobiles. The client also requested that ORV Solutions create a product like the concept in Figure 3.

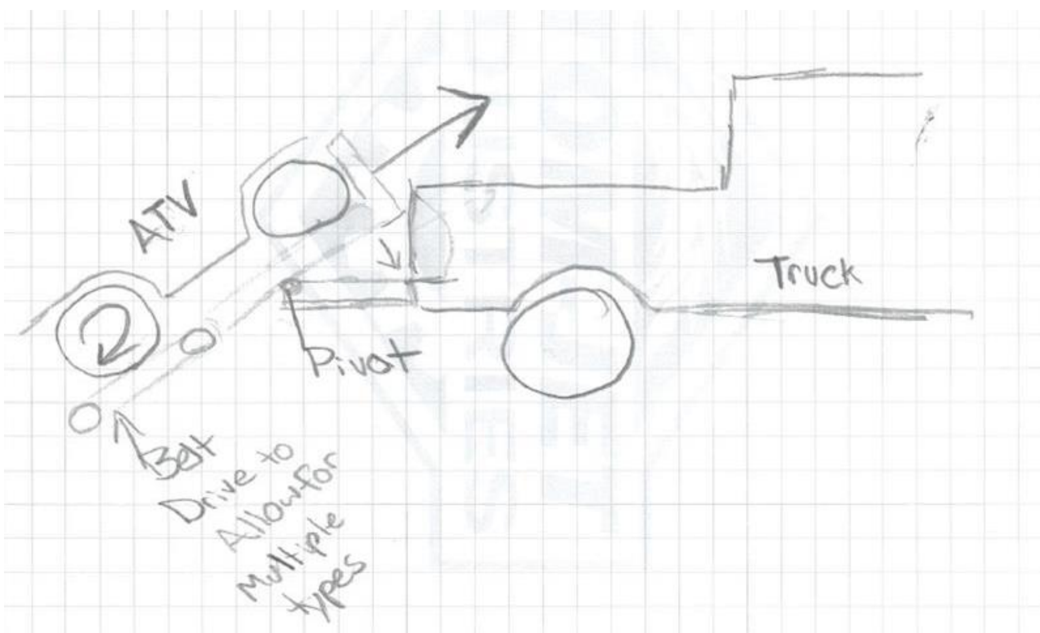


Figure 3: Proposed Concept Submitted from Atom-Jet

The redirected proposed concept was accepted by ORV solutions on November 15, 2020 and the timeline was adjusted for Phase III as outlined in Figure 4. Grey bars on the timeline illustrate the baseline schedule prior to project redirection.

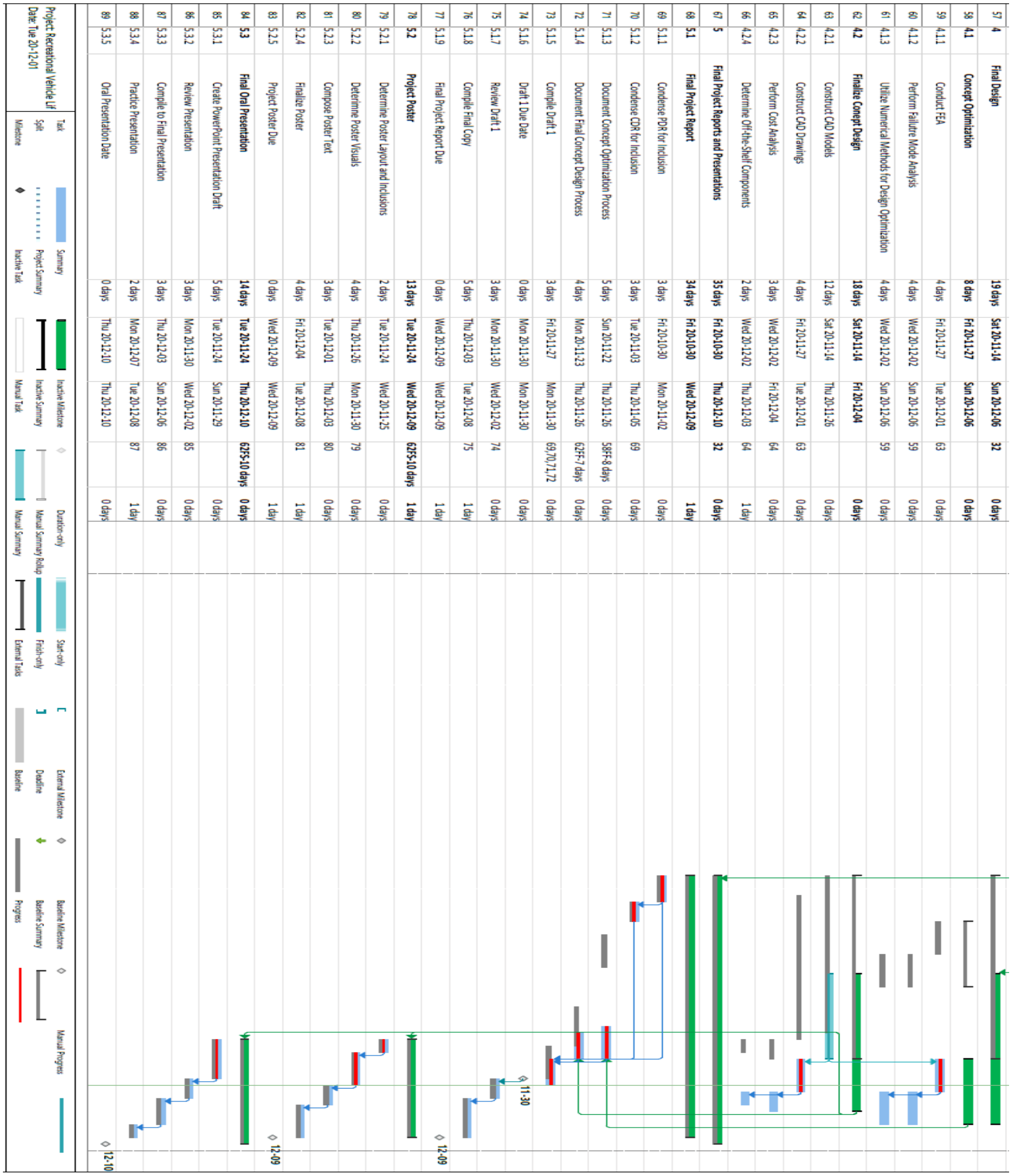


Figure 4: Phase III Timeline Adjustment

3. Final Design: Self-Powered Recreational Vehicle Loader

This section details the design and components of the concept fully developed by ORV Solutions for Atom Jet Industries, conclusively named “Self-Powered Recreational Vehicle Loader”. The following is an overview of the various subsections to facilitate the complete documentation of the design, in a systematic approach flowing from the ‘bigger picture’ (how the design functions), to a focus on various subassemblies and their own function, to elemental aspects of the design. The flow of contents within Section 3 follows the thought process of the designer and the subsequent development of the project.

The client needs and requirements developed at the beginning of the project kept are also demonstrated throughout this section, highlighting the most important aspects of the design that fulfill requests made by Atom Jet Industries. The final design model is pictured below as Figure 5.

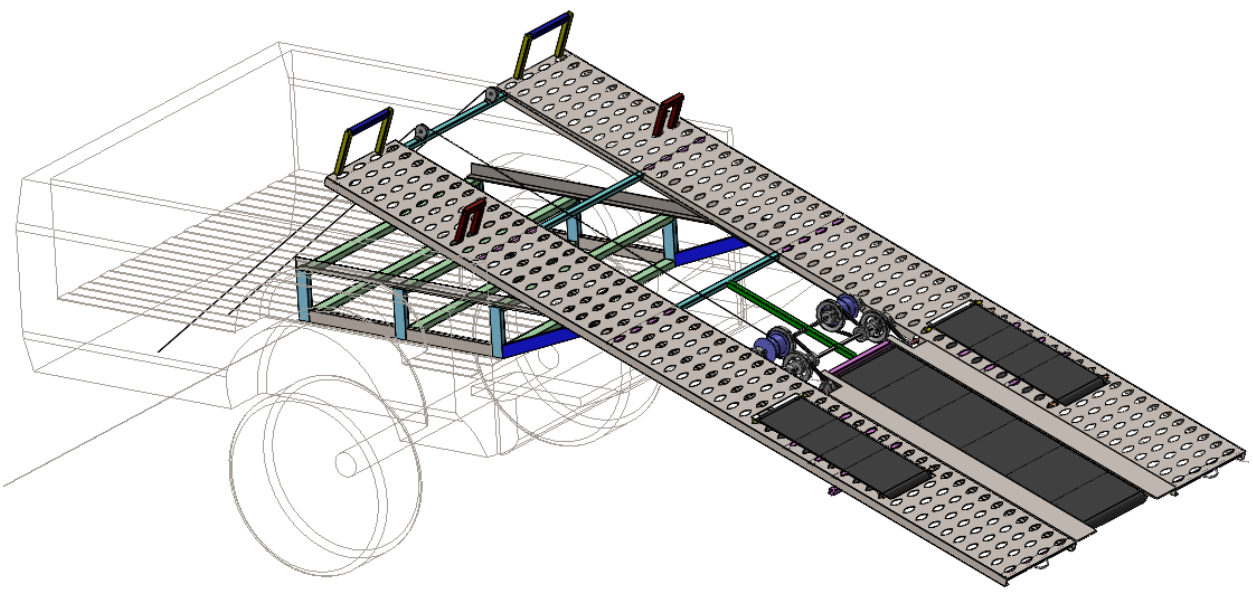


Figure 5: Final Design Model

The final rendered design in Figure 6 is the complete design presented to Atom Jet Industries. In light of the challenges faced during the concept development phase, ORV Solutions strove to align their own vision for the completion of the project to Atom Jet’s vision, with the result being the figure below.

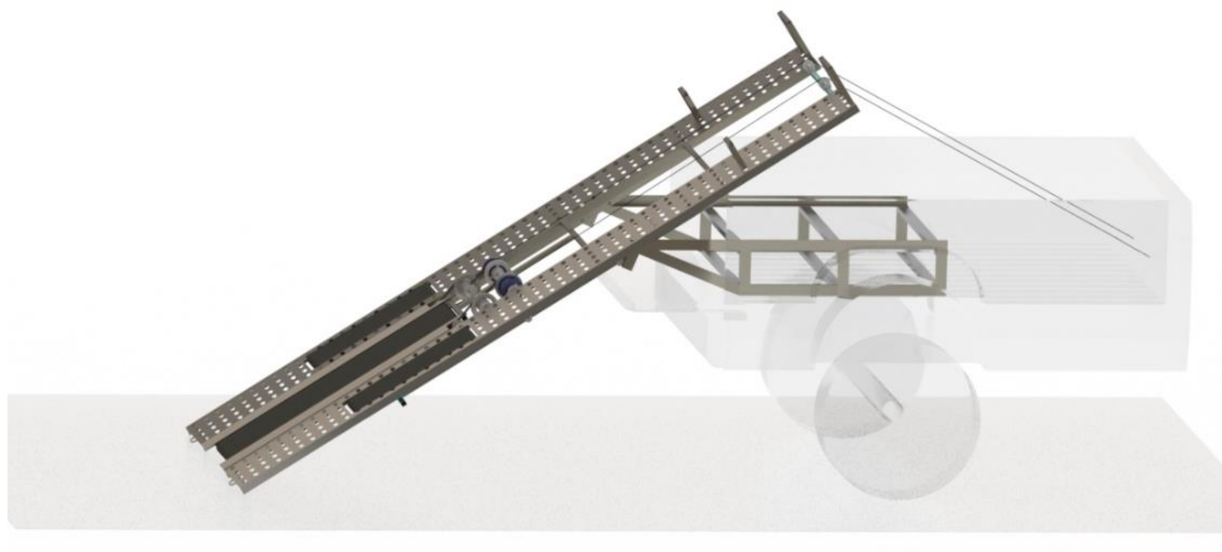


Figure 6: Self-Powered Recreational Vehicle Loader

This section of the report is dedicated to the design process from the beginning as a concept to the completion as a fully functional off-road vehicle loader. As far as Atom Jet Industries provided feedback and a change in design direction, certain elements of the design found their roots in product compatibility. The first sub-section of this report concerning the design outlines the role that compatibility played within the development of the final design.

3.1. Compatibility

From the beginning of the project, it was evident that for the design to be well-received by Atom Jet, it had to be compatible with as many off-road vehicles as possible, and with the most popular selling pickup trucks on the market. This requirement aided in the development process by setting definitive sizing restrictions for the design. The following subsections outline the compatibility of each of the associated vehicles.

3.1.1. Pickup Truck Compatibility

One foundational requirement was for the design to be seamlessly incorporated with the most popular pickup trucks currently available. The vehicles identified for compatibility were the Ford F-150, the Chevrolet Silverado, the Dodge Ram, and the GMC Sierra, notably all half-ton pickup trucks. Although these trucks differ in various aspects, the qualities of interest to this project are generalized across the truck models.

The critical pickup truck specifications of interest to the design include maximum payload, bed length, absolute width, and wheel well width. Since the former three attributes are generally constrained to three types across all pickup truck models (short bed, regular bed, long bed), a model of a regular bed was designed to provide further developmental context for the platform. The following Figure 7 illustrates the modelled truck bed.

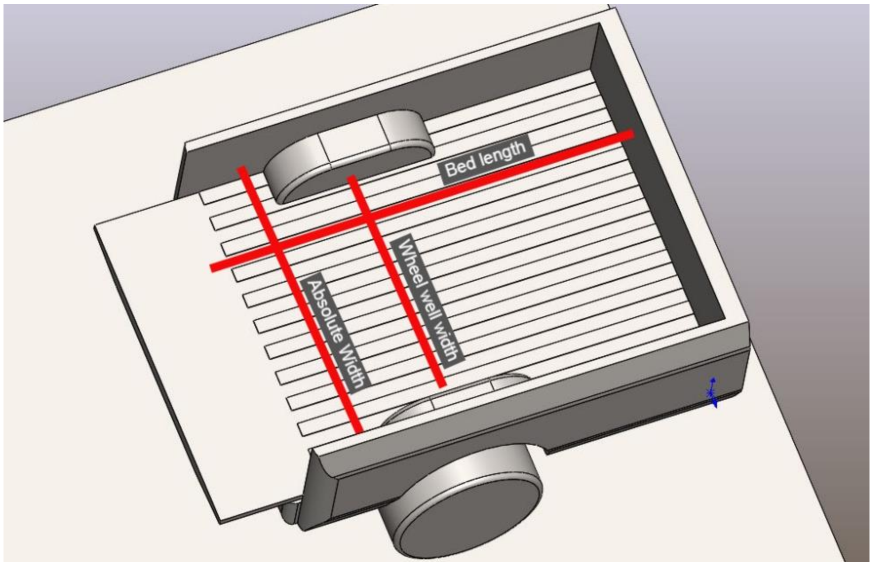


Figure 7: Pickup truck bed model

This model was used throughout the design process, providing both a quick quantifiable reference to the designers without checking a table as well as providing context to the overall completed design. With a truck bed as reference, it was possible to move onto the next compatibility matter, off-road vehicles.

3.1.2. Off-Road Vehicle Compatibility

As mentioned, the desire for multi-vehicle compatibility proposed by Atom Jet Industries was on the table during Phase I, taken off the table during Phase II and returned to consideration for Phase III. As such, both a snowmobile model and an ATV model were necessary. These references were required strictly for the design of the ORV ramp itself.

Evidently, a single SolidWorks ORV model cannot achieve both objectives as the pickup truck model does since ATV and snowmobile measurements vary significantly based on selected model. Figure 8 provides a minimalistic representation of the key aspects of compatibility with the final design, namely wheel spacings and tire size.

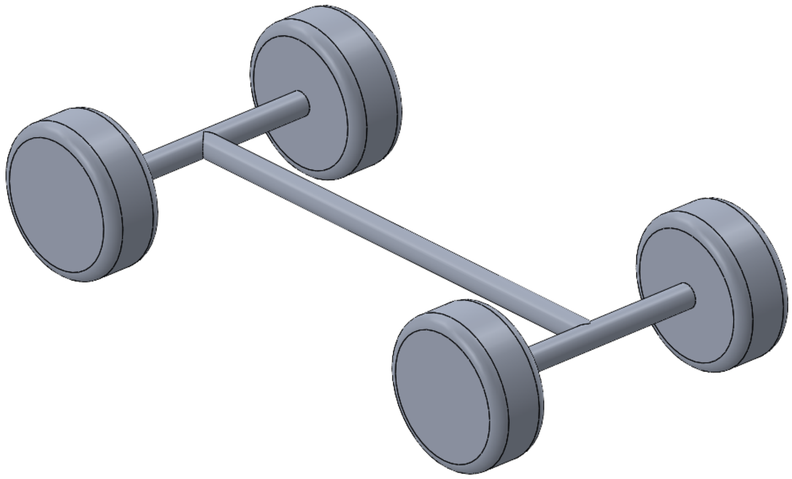


Figure 8: ATV SolidWorks model

Clearly, the above model is not mechanically correct, but it serves its purpose in the overall design. Similarly, with Figure 9, only the elements of a snowmobile that would interact with the ORV platform are modelled. These elements include the two skis, drawn at maximum manufacturer's stock width, and the snowmobile belt, drawn at standard width and regular belt length.

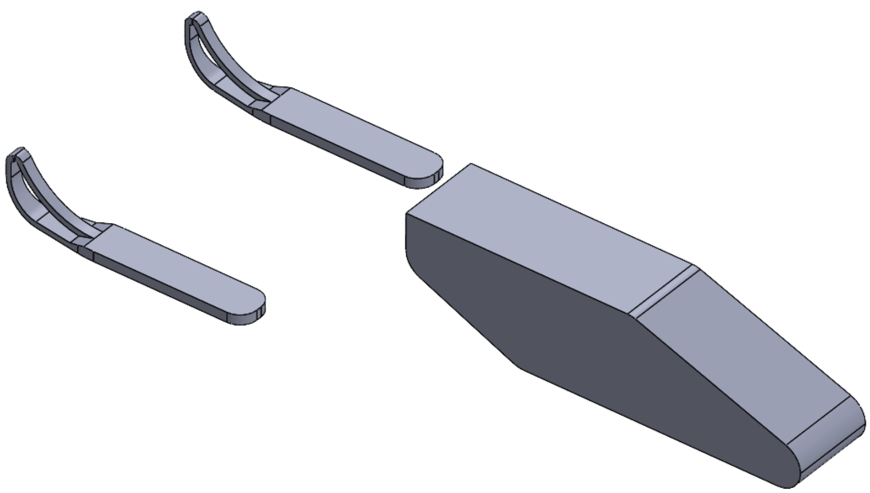


Figure 9: Snowmobile SolidWorks model

Both Figure 8 and Figure 9 are featured prominently throughout the design to have visual representations of measurements. As mentioned however, the above two models provide contextual reference to the SolidWorks models and renders, but a more extensive approach was required to ensure multi-vehicle compatibility on the ORV ramp. This began the design of one of the two main subassemblies of the final design. Figure 10 illustrates the measurements of the largest and smallest adult ATVs currently on the market, as well as a standard sized, regular track length snowmobile.

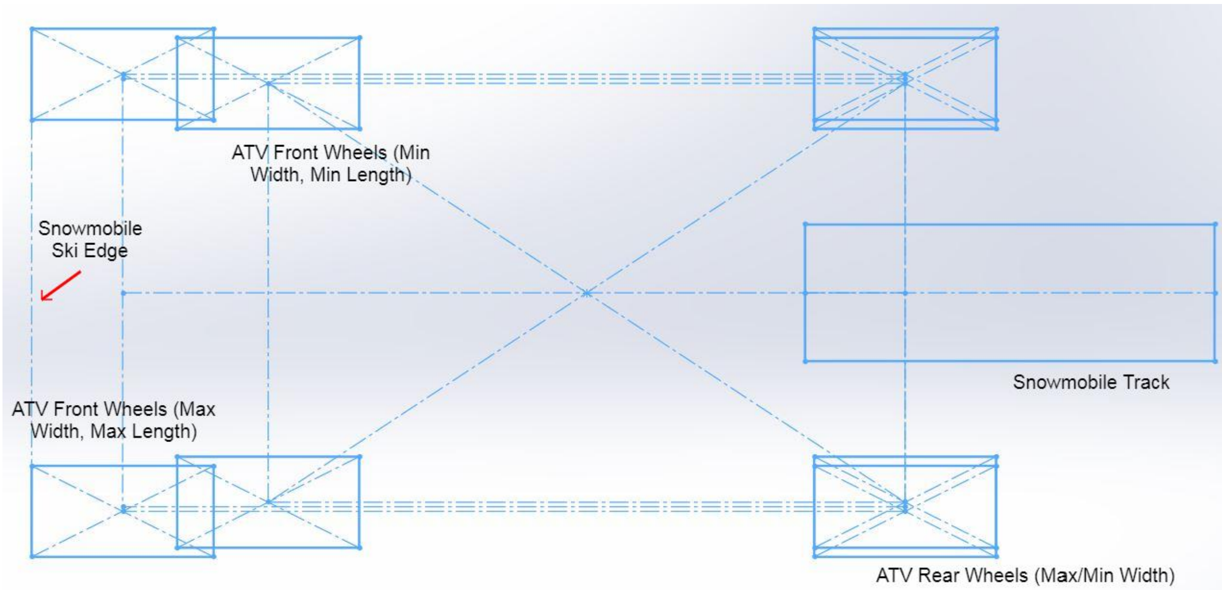


Figure 10: Initial platform sketch with ORVs

The entire final design platform subassembly was built around this line sketch to encompass as many ATVs and as many snowmobiles as possible. Fortunately, the maximum outside width of the largest ATV or snowmobile were still within the constraint of the pickup truck absolute width (Figure 7), but neither the minimum width ATV, nor the maximum width ATV or any snowmobile would fit within the pickup truck wheel well spacing.

3.1.3. Wheel Well Compatibility

The wheel wells restricting the loading of the ORV onto the base of the truck required a major design decision. The two alternatives were to rest the ORV platform above the wheel wells at all times, maximizing the truck bed width into the absolute width, or engineering a sort of flexible frontal platform that would allow the front ATV tires to roll over top of the wheel wells and rest on the truck bed platform. Both of these had their accompanying challenges. In the former, the overall center of gravity of the pickup truck would increase by a minimum height of the wheel wells. In the latter, snowmobile skis would not work as well as tires would in riding over the wheel wells, as well as the complexity of the design would significantly increase. Figure 11 illustrates the path required in the former described scenario as a five-step process.

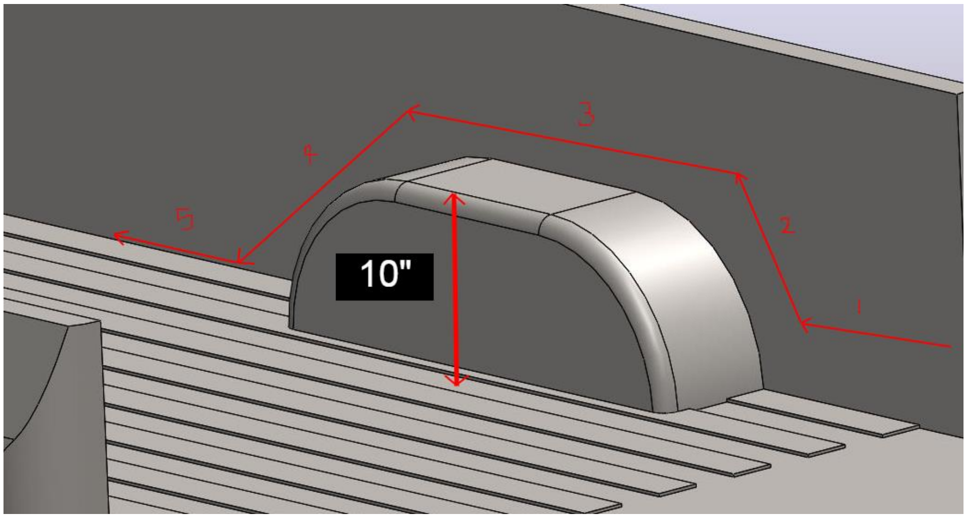


Figure 11: Wheel well path

Since the wheel wells are protruding at a minimum of 10 inches in every pickup truck model, the final decision was to lift the entire design above the wheel wells. One contributing factor was the subsequent opportunity to create a bed frame within the pickup truck bed that would aid in the loading process. The next section details the design and development of the truck bed frame.

3.2. Base Frame

Developing the concept in Figure 3 clearly required an additional feature to the design to aid in the loading sequence. In the concept drawing, that element is introduced by a pivot point on the pickup truck tailgate. Although the bed itself is rated for a certain load, tailgates are not rated and hence applying any load to the tailgate should be avoided. Based on the integral premise that the concept requires a point over which to pivot, a permanent structure mounted to the bed frame itself was proposed.

3.2.1. Base Frame Structure

Introducing a frame that is permanently mounted to the frame of a pickup solved two issues at once. It is clear that the full weight of the design, plus the weight of ORV along with the user on the ORV will be applied to the pivot point during the loading sequence. A tailgate supported by two cables would be unable to support the full applied load. Hence the two issues that are solved by introducing a permanent mount to the truck are: (1) a frame can act as both a pivot point and a railing system for the platform, and (2) the frame lifts the platform storage height above the wheel wells (refer to Section 3.1.3).

The following Figure 12 presents the frame itself, including two additional design elements. In dark gray, angle iron is utilized in place of strut channels. Using angle iron instead of strut channels allowed for a greater selection of materials (thicker gauge and more suitable widths) as well as decreasing costs. The green, light and dark blue as well as light gray members are all structurally supporting. The shorter gray members to the left of the image assist in the loading sequence. (Refer to Section 3.3.2.3)

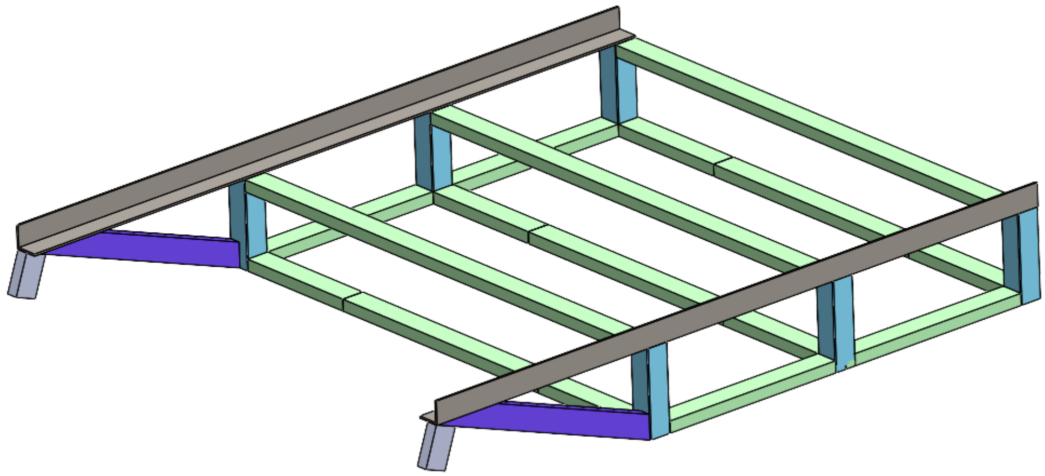


Figure 12: Base frame

Initially intended to be fabricated from aluminum components, a decision was made to swap all components in the frame to rectangular steel tubing components, welded together to create a frame. This decision was based on the structural integrity of the platform, considering that the weights described above (ORV, user, platform) are all supported. Figure 13 presents assembly component 1006 as seen in the above Figure 12, acting as a vertical support beam.

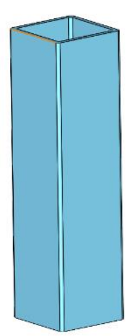


Figure 13: Frame component 1006

The assembly components 1005 (illustrated dark blue in Figure 12) are miter cut for ease of welding purposes. All dimensions, lengths, and gauges of the components in the truck frame can be located in Appendix A for reference. As a visual, Figure 14 illustrates how the frame assembly would fit in the bed of a regular bed length pickup truck.

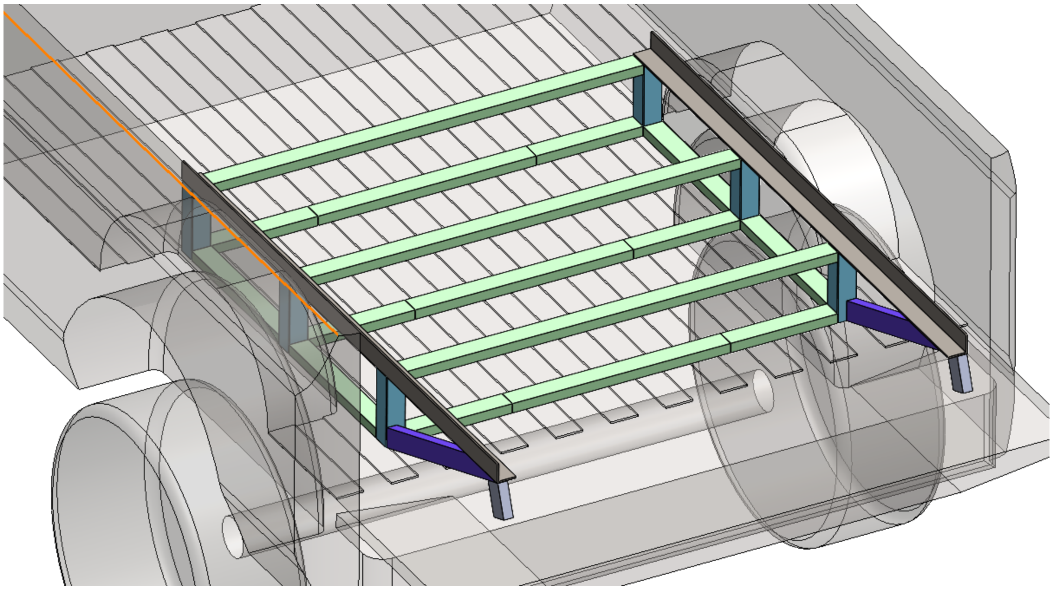


Figure 14: Permanent frame in bed of pickup truck

As the platform must be essentially ‘dragged’ onto the pickup truck bed, roller elements help smoothen out the loading sequence. The roller elements (explained in sections below) glide along the angle iron, which act as strut channels. At this point in the development process, the key elements of this structure are its ability to bear the full load required, and its assistance in the loading sequence. Since these more intricate aspects of the frame design are intertwined with the platform, they will be explained in further detail in the following sections.

3.2.2. Attachment to Pickup Truck

The safest method to mount the design truck frame to the pickup truck itself is by permanently attaching the design to the pickup truck bed frame. This ensures the safest possible loading and unloading sequence. Since each truck varies slightly, there are no mounting through-holes in any of the design frame. Depending on where the cross members are in the pickup truck bed, it is expected that the design frame would be professionally installed, drilling holes as necessary.

3.3. ORV Platform

The platform design continued using aspects of the truck frame design. The two main aspects of the platform design were the material used for the platform itself and the positioning of the off-road vehicles on the platform. Figure 10 provided a line sketch of all of the possible ORVs used in conjunction with the overall design and was the steppingstone for the design of the platform subassembly.

The platform and frame components give a body to the design, houses the power transmission system, and provides a base for the ATV or snowmobile to be secured to during loading and transportation. The design goal for this component was for it to be lightweight and cost effective, while being rigid enough to allow the rollers to travel smoothly in their channels.

3.3.1. Platform Design

The design of the platform was approached from two different perspectives. The first perspective was the incorporating of a self-powered system into the platform subassembly while the second perspective was basing the design on available and cost-effective materials from which to manufacture the platform. It was clear from early in the project that the platform would need to have high grip elements.

As a reminder, this section does not explain in detail the rationale behind several design decision unless absolutely critical to the understanding of the development process. The consensus on many issues was reached either by the group at ORV Solutions, through consultation with Atom Jet Industries, with the project advisor, or by the designer himself.

It was determined that incorporating a self-powered system into the design was a larger task and hence took precedence over material considerations. In simpler terms, the platform design would begin from a power generation perspective, while then incorporating the additional platform elements as an amalgamated design. After extensive consultation, a treadmill-like system, as illustrated in Figure 15 was identified as the clearest path to achieving a self-powered design.

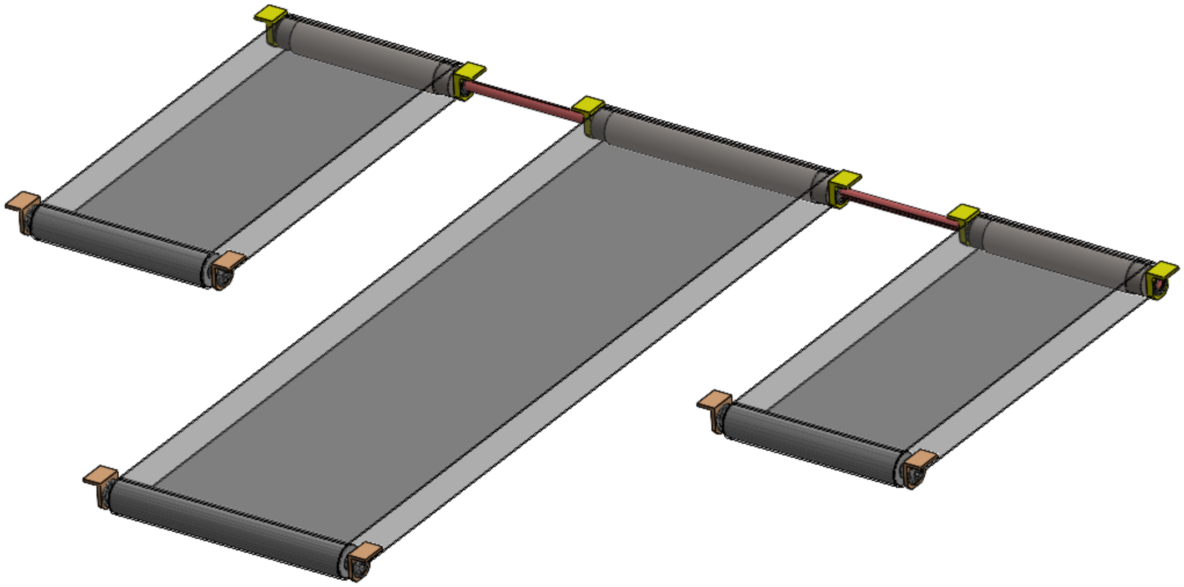


Figure 15: Treadmill-like belting and rollers

Similar in function to a regular treadmill, this set up of rollers and belting transmit torque generated by the snowmobile tread or the ATV tires to the red shaft in Figure 15. Although the intricate details of how this powered belting system is covered in Section 3.4. The key features of this belting system that permitted the design to continue was the overall shape, arrangement, and configuration. Notably, the center belting is 15.56” wide, and the outer ATV beltings are 11.60” wide. These dimensions dictate the rest of the platform design.

With the self-powered system incorporated into the beginnings of the platform, the second design consideration, namely the material selection, could be incorporated into the design. The use of high-grip perforated grating both provides traction and allows residual water, mud, or snow to fall through the grating. Figure 16 illustrates the rollers and belting with the added grating and grating reinforcement members.

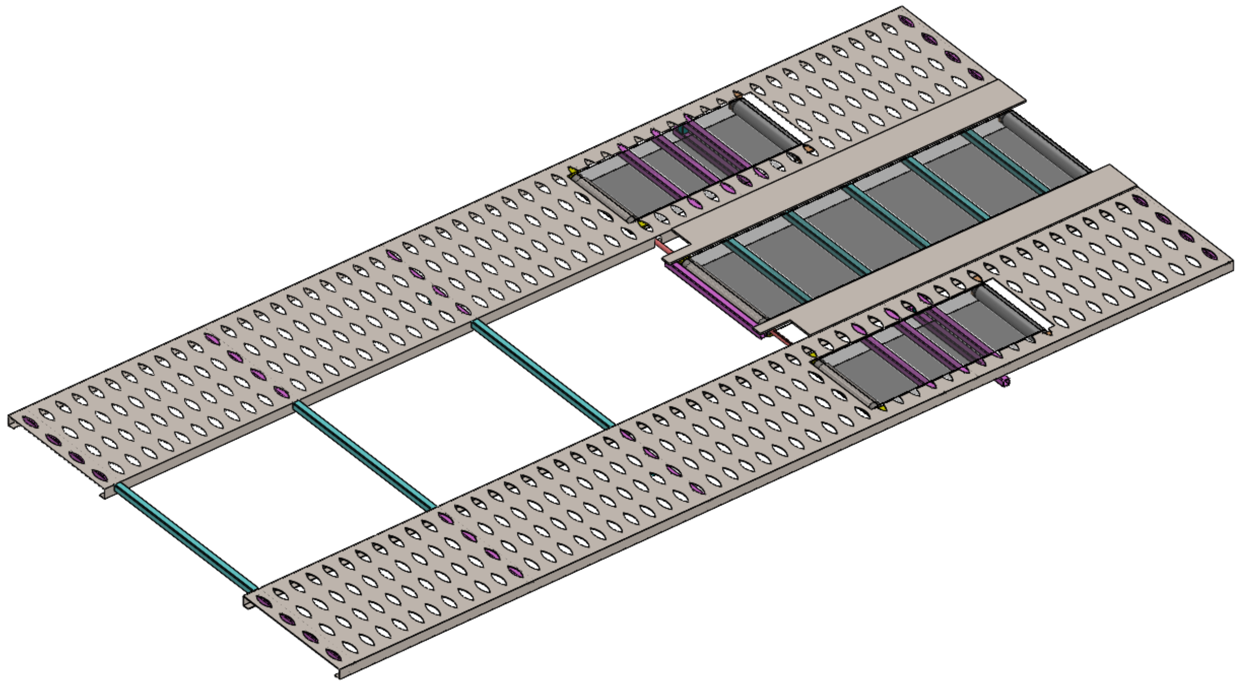


Figure 16: Belting and grating

The platform is constructed of two pieces of 12-gauge steel safety grating, reinforced horizontally with 1", 1/8" wall square steel tubing every two feet as per manufacturer requirements [3]. Safety grating was selected because of the high friction it offers with the wheels, this ultimately aids with the ATV or snowmobile traveling up the initial incline of 32°. The two pieces of safety grating are 18 ¾" wide and 11 feet 3 inches long. They are spaced 27 inches apart which gives room for the center snowmobile driven belt. The grating is connected by steel ribs every two feet. For the ATV driven belts, a 12" wide section is cut out from each piece of grating to allow the rear wheels of the ATV to make contact.

Six-inch-wide pieces of ¼" steel cover the opening to prevent falling through or getting caught between the belting and grating. Additional ribs were added to support the snowmobile track on the belt such that the two sides of the belt would not touch while in operation.

3.3.2. Rail System

The use of rails in the design allow for the movement of the frame during the loading and unloading sequences. The rail system connects the two major subassemblies (platform and truck frame) together. Track rollers and platform frame beams are attached to the platform itself, while the roller channels are part of the pickup truck bed frame. Introduced as angle iron and strut channels in Section 3.2, they are referred to from this section on as roller channels.

3.3.2.1. Track Rollers

Based on the overall design configuration, the rollers would be subjected to a large and sustained load, especially during the loading and unloading sequence. Instead of a pivot point, the load is transmitted through the track roller. The rollers were selected based on their loading capacity to ensure that they do not fail during the largest load application. Considering the viable options based on capacity and cost, steel track rollers (Figure 17) with a 2" roller diameter and a 1 5/8" roller width were selected.

Figure 17: Track Rollers [4]

These rollers were chosen as they individually have a radial load capacity of 1,600 pounds and 1,400 pounds for static and dynamic load conditions, respectively. The track rollers also have a stud measuring 2" in length, which allows for it to attach to the frame. As designed, the platform did not have any additional support in achieving the tipping over the pivot point. Hence, a bracket was added to the Base Frame in Figure 12 to force the desired motion. The pivot bracket and roller are pictured in Figure 18.

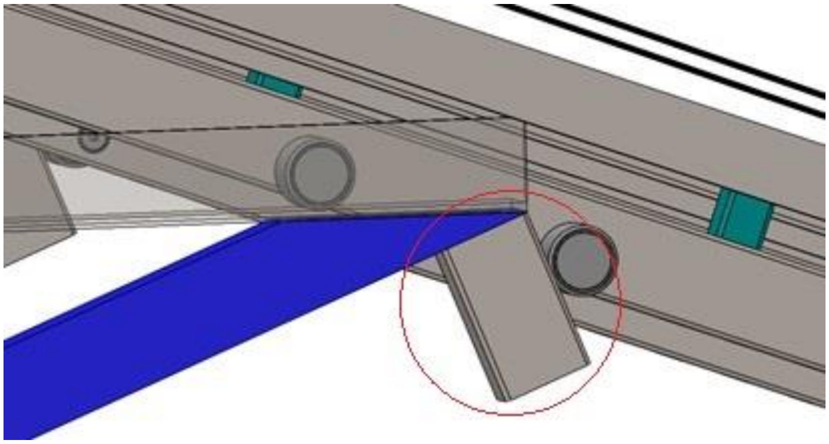


Figure 18: Pivot bracket

The bracket, circled in red in the above figure, prevents the second roller from linearly advancing, and forces the whole platform to rotate (pivot). Without this feature, as the cable spools in, the platform would not pivot, and the edge of the pickup bed frame would come into contact with the grating, seizing all motion.

3.3.2.2. Platform Frame Beams

The rollers required a mounting method to the platform itself. Pictured in Figure 19 as part of the platform design, beams provide the structural integrity along the length of the platform for smooth rolling during the loading and unloading of the off-road vehicle.

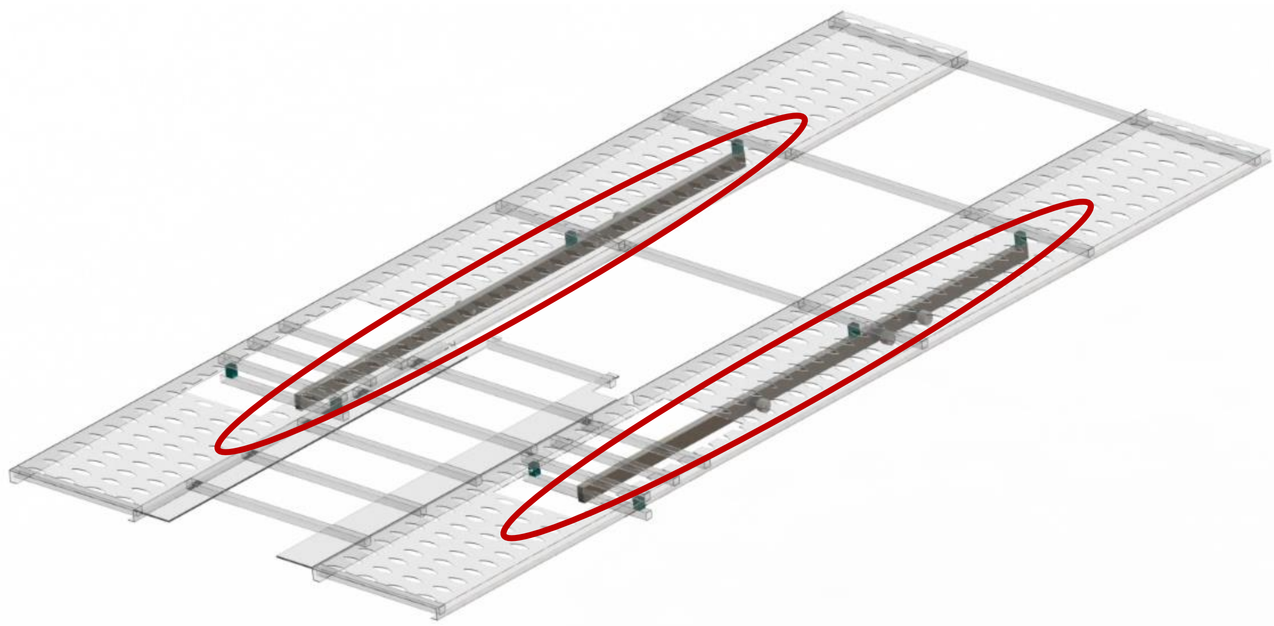


Figure 19: Platform Rails

The selected beams were 1” x 2”, 1/8 wall rectangular steel tubes. Since the cross members described in Section 3.3.1 provide transverse rigidity, the beams assist in axial rigidity.

3.3.2.3. Roller Channels

This design was considered, but was later switched to angle iron, as it was determined that only 2 walls would be needed to restrain the track rollers. The final configuration for the angle iron chosen was 2” A36 steel with 3/16 walls. Figure 20 illustrates the isometric and cross-sectional views of the angle iron being used as a roller channel.

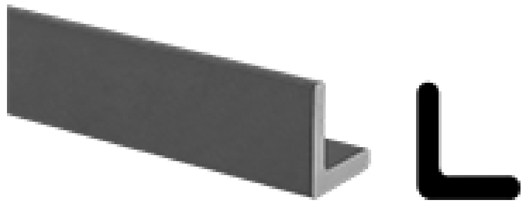


Figure 20: Angle Iron Geometry [5]

3.3.3. Vehicle Positioning and Mounting

For the design to function properly, the rear tires of the ATV or the tread of the snowmobile must be positioned accurately on their respective belting. Figure 21 demonstrates the positioning of an ATV, with the frontal tires within the bumpers.

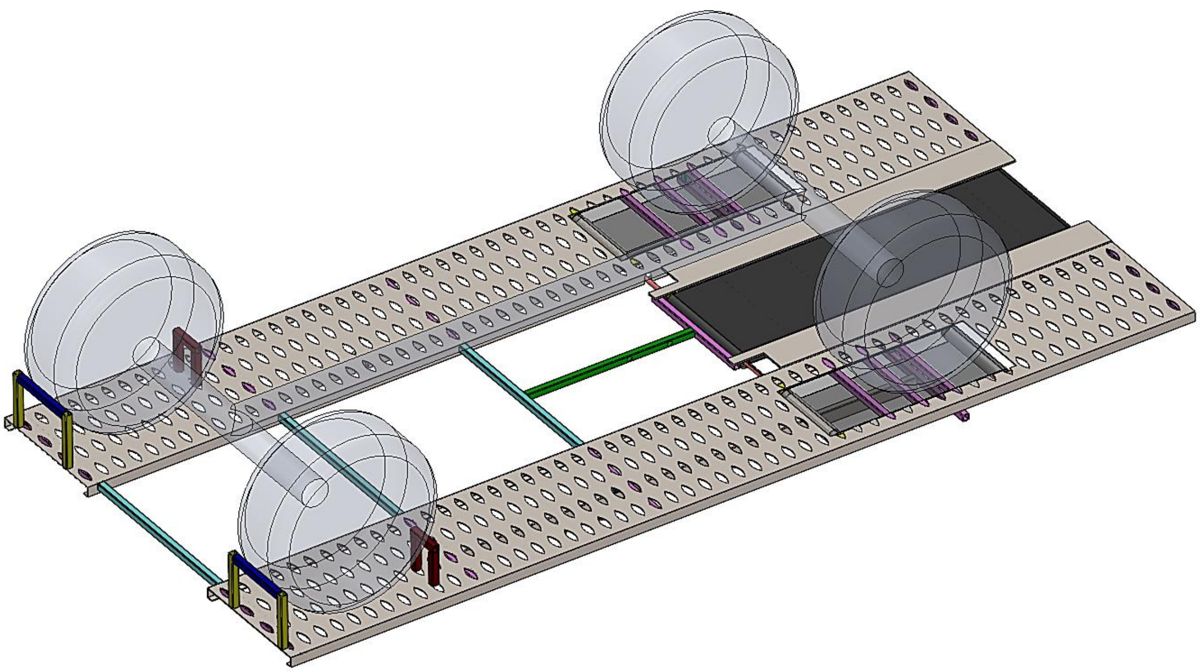


Figure 21: Platform with positioned ORV

The platform bumpers on the leftmost part of the grating doubles in function. During the loading sequence, the bumpers indicate that the ATV is in position, while also providing a chock to restrict movement. The rear ‘chocks’ are narrower than the front tire chocks because a snowmobile would not manage to ride over the rear chocks and fall in place between the bumpers, such as the ATV does. In the case of snowmobile loading, the rear chocks are positioned such that the snowmobile skis pass along beside. The frontal bumper then provides a stop, indicating that the snowmobile is in position.

The mounting of the recreational vehicle is extremely versatile and up to the dimensions of the ATV or snowmobile. Perforated safety grating does allow additional cords or rachet straps to secure the ORV in place. Since the default position for loading is seen in Figure 22, the bumpers provide some added safety to the loading. The height distance from the top of the bumper to the ground is 2.3 m and can vary based on raised pickup truck suspensions. Completely securing the ORV at this stage may not be possible for shorter users.

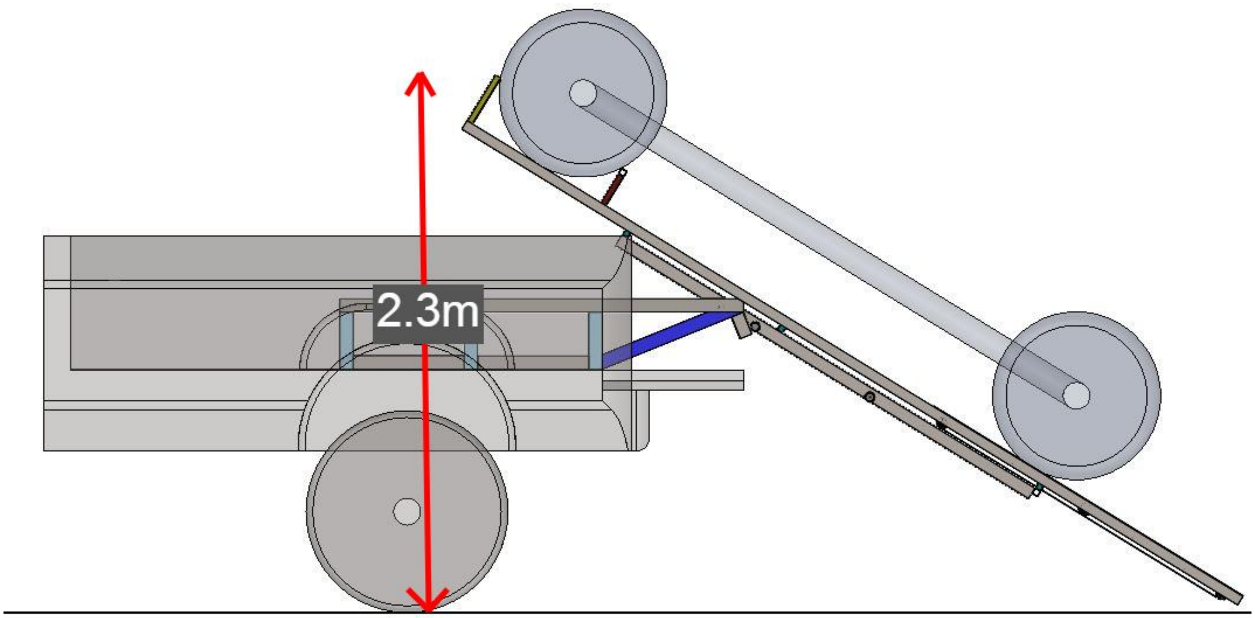


Figure 22: Platform during loading sequence

Once the vehicle is loaded into the pickup truck bed, it is possible to completely fasten the ORV to the platform, or to any hooking points located within the pickup truck bed.

3.4. Power Transmission

Briefly discussed in previous sections to convey insight in the design process, this section details each aspect of the power transmission system. Winch powered platforms similar to the design outlined in this report are currently available on the market, however they require high-capacity winches and electrical reworking to power the winch. A self-powered vehicle lift is revolutionary for the market, and this design requires several components to power the loading and unloading sequences. This section outlines each of the components of the power transmission for a fully functional design.

3.4.1. Roller Elements

This subsection details all the rotational elements (aside from the v-belts covered in a subsequent section) within the design that make up the power transmission. Starting from the basic setup in Figure 15, the power is generated by the rotation of the belting, relying on friction. The rollers near the rear of the platform are all idler rollers, providing tension and general shape for the belting material. Since the power system works similar to a conveyor belt, the frontal rollers could not be idler rollers.

The sequence of power generation from ORV to a useable shaft is as follows: the ORV applies throttle, subsequently rotating the rear tires of an ATV or the track of a snowmobile. The belting, upon which the tires/tread rests, rotate. The rear idler roller rotates, as does the frontal powered roller. The idle rollers were chosen because of their load rating of 300 lbs. Since the idle roller (pictured below in are not required to transmit torque, they are not required to be a keyed connection.

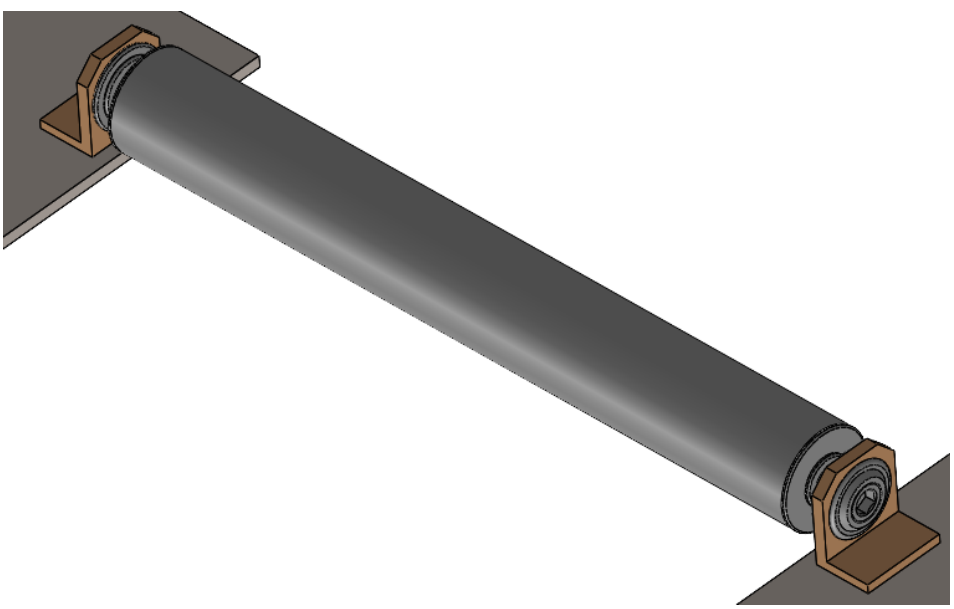


Figure 23: Idler rollers and bearings

The frontal roller cannot be an idler roller (torque must be extracted from it). A custom 'powered' roller takes the rotational power from the belt, spinning the roller axial shaft. The powered rollers were made from 2”, 3/16” wall steeling tubing. All rollers, both powered and idler had an outer-diameter of 2”. Figure 24 illustrates the components of the powered roller at the edge of the platform.

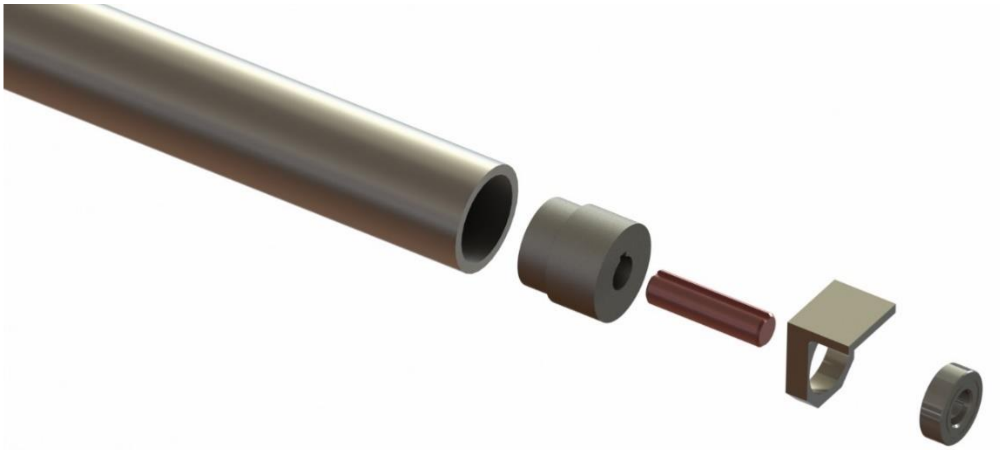


Figure 24: Bearings and shaft components

Hollow steel tubing acts as the roller outer surface that contacts the belting material and a weld on hub is welded to the steel tubing. While regular idler rollers are free to rotate with a fixed shaft, this design rotates as one element: if the tubing rotates, so does the weld-on hub, and the subsequent red shaft. The shaft is connected to the weld-on hub by machined key as well as a set screw. The shaft is free to rotate in the bearing and hence the bearing housing.

3.4.1.1. Bearings

Bearings were required in the design to allow the driven shaft to rotate while also supporting the shaft to the frame of the platform. In turn, this will allow for the spool on the shaft to reel in the cable and ultimately load the platform. Two different types of bearings are employed in this design depending on the ‘conveyor’ rollers (powered or idler). The drive shaft bearing, (pictured in Figure 24, alongside the powered roller) is a high capacity, light duty shielded ball bearing for a 5/8” shaft. The radial load capacity is 940lbs and 850lbs for dynamic and static loading, respectively. The second bearing type is used in conjunction with the idler rollers. No shaft is required since these rollers roll freely. The idler rollers must simply be held in place. Since 2” idler rollers (sourced from McMaster-Carr at a competitive price) are available only in hexagonal shaft configurations, the accompanying hexagonal bearings must be purchased with the rollers. These ‘for hex shaft’ bearings have a rating of 300lbs each. Seemingly insufficient, in the ATV configuration, the maximum weight is distributed on two rollers, each with two bearings. The maximum snowmobile weight (along with user) is much lower than the ATV configuration, and so the bearings are sufficient.

3.4.1.2. Forward Shaft

The forward shaft (drive shaft, pictured in red in Figure 15) connects all powered rollers and the two cable spools indirectly. If one belt turns, the other belts and spools turn at the same rate. This was achieved by having the front of the belts sit in-line with each other and simplified the power transmission system as a whole. On either side of each roller is a ball bearing installed in a housing that is welded to the top platform to provide support for the shaft and roller. Since this shaft is delivering large amount of torque to different components, anything mounted onto the shaft will be required to be a keyed and set-screw connection.

3.4.2. Belting

The power transmission system consists of three belts (two ATV driven belts, one snowmobile driven) connected to the same shaft. The middle (snowmobile) belt is longer than the ATV belts to accommodate for the length of a snowmobile and to maximize contact of the belt with the snowmobile track. Each belt runs between the power roller and the idler roller. The front shaft connects all the belts and uses two spools to wind metal cables, pulling the entire platform up. As the ATV tires/snowmobile track move the belt, the shaft rotates, reeling in the cable, pulling the platform up and into the truck bed.

3.4.3. V-Belt and Pulleys

The torque requirement to pull the platform, the user, and the vehicle up onto the pickup truck bed was certainly lacking based on the weight, but also based on the issue discovered later in development, namely the cable spool. The cable is detailed in full in a following section, but a challenge was the required size of the spool. The amount of toque produced would struggle to rotate the spool, and so a v-belt system was introduced into the design to overcome this obstacle.

3.4.3.1. V-Belt Analysis

Before implementing a v-belt system in the design, equations of machine elements, specifically v-belt pulleys and sheaves provide useful insight for the design. First, a sheave ratio must be selected. It was preferred for the sheaves to produce a 4:1 reduction in angular rotation done in two passes as a 2:1 and again as a 2:1 reduction. Upon sourcing sheaves from suppliers, the two sheaves selected were 2.5” x 5/8” bore single groove pulley and a 5” x 5/8” bore single groove pulley.

The two following equations, while variations of each other, can solve for either C (the center-to-center distances of the sheaves) or L_p (the pitch length) [6]. Since space was not limited, the value for C was solved based on L_p, which corresponds to standard belt sizes.

$$C = 0.25\left\{\left[L_p - \frac{\pi}{2}(D+d)\right] + \sqrt{\left[L_p - \frac{\pi}{2}(D+d)\right]^2 - 2(D-d)^2}\right\} \tag{1}$$

$$L_p = 2C + \frac{\pi(D+d)}{2} + \frac{(D-d)^2}{4C} \tag{2}$$

An A19 grade v-belt was selected based on its medium-to-heavy duty application [7]. An A19 belt has a 19" pitch length and a 21" outer circumference. Additional information concerning 'A' sheaves include *D = 4.4"* (pitch diameter of the large pulley) and *d =1.7"* (pitch diameter of the small pulley). Solving for the center-to-center distances of the sheaves resulted in:

$$C = 0.25\left\{\left[19 - \frac{\pi}{2}(4.4+1.7)\right] + \sqrt{\left[19 - \frac{\pi}{2}(4.4+1.7)\right]^2 - 2(4.4-1.7)^2}\right\} = 4.5068 \tag{3}$$

Hence using the above sheaves and a A19 v-belt, the center-to-center distances of the sheaves must be 4.5068 inches. The diametral pitch also results in a two 4.4:1.7 reductions, leading to a total reduction of 6.7:1.

3.4.3.2. Implementing V-Belts into the Design

With the sheave sizes and v-belts selected, as well as knowing the center-to-center distance of the sheaves, implementing the v-belt system becomes a matter of modelling. Figure 25 illustrates the double pass reduction, including the intermediate shafts and the spool on the final shaft.

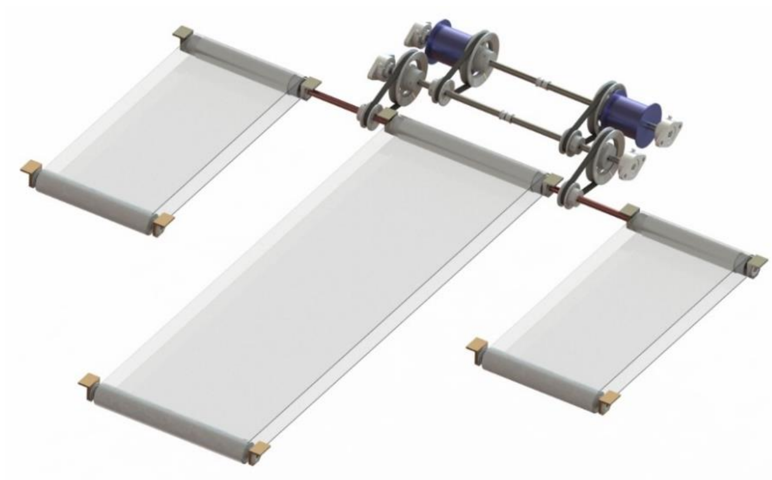


Figure 25: Belt and Power Transmission

As modeled, when the main power shaft (in red) rotates, the spool will rotate at about one sixth the speed. A larger radius spool will pull in more cable with each rotation. With a sheave and belt system, the ORV will be able to operate at higher revolutions during the loading and unloading phase, without the torque on the spool rapidly increasing. Figure 26 provides a close-up view of the v-belt transmission.

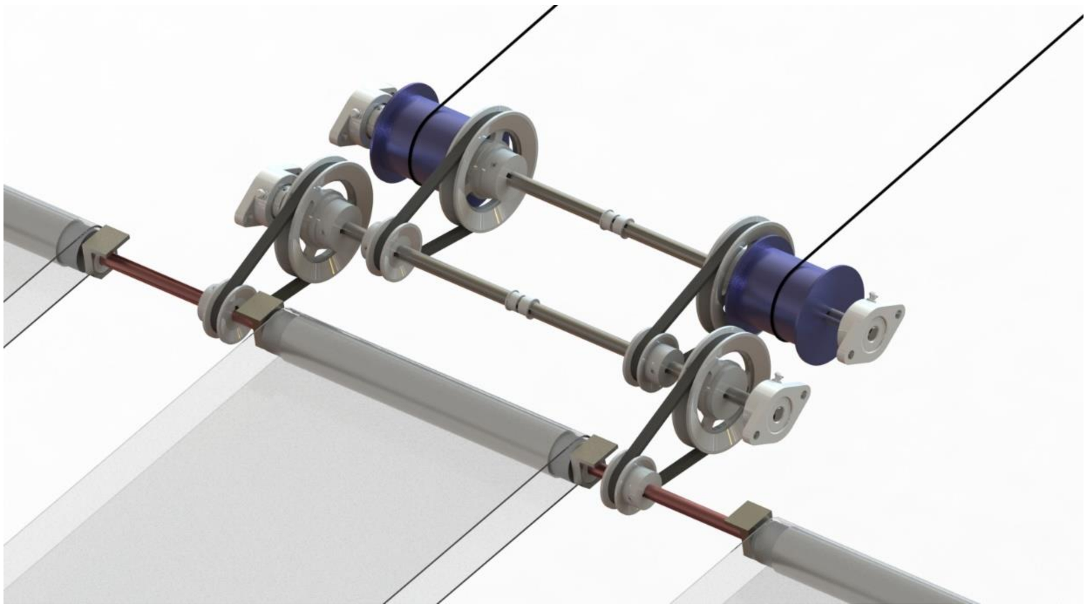


Figure 26: V-belt assembly closeup

The major components of the v-belt include the large and small sheaves, the A19 v-belts, machine key stock used as the main shafts for the two passes, pillow blocks to secure the shafts in place, Oilite bushings to prevent bending in the shafts, and finally the cable spools, which acts as the focal point for the movement of the platform design into the pickup truck.

3.4.4. Power Generation Analysis

This power generation analysis is a key deliverable requested by Atom Jet. Applying some basic physics, the following hand calculations are performed showing that both ATV's and snowmobiles can operate the design developed by ORV Solutions.

For the power generation analysis, the engine specifications for the Polaris Sportsman 450 were chosen due to its small engine displacement. The weights used will be from one of the largest ATV's available on the market, the Polaris Sportsman 800 X2 EFI, weighing in at 840 pounds [8]. ORV solutions decided that if a small engine could power a lift with the heaviest ATV, the widest range of compatibility would be achieved.

The Polaris Sportsman 450 has an engine torque of 15 ft-lbf with a gearing ratio of 24:1 while in the low gear. [9] This gives the rear axle a torque of 360 ft-lbf. The tires on a Sportsman 450 are 25 inches in diameter (radius of 1.04 feet) [9]. From section 3.4.1, the front roller is 2 inches in diameter (radius of 0.0833 feet). The diametral pitch of the small pulleys are 1.7 inches (radius of 0.0708 feet) with the large pulleys diametral pitch being 4.4 inches (radius of 0.183 feet). With 2 reductions, the total reduction between the gears becomes 6.7:1. The minimum pulley diameter of the selected cable is 3.25 inches (radius of 0.135 feet). The below equations show the calculations used to determine the required tension to begin rotating the platform off the ground and into the truck bed.

$$\tau = F \cdot d \;\rightarrow F = \frac{\tau}{d} \tag{4}$$

$$F_{tire\ edge} = \frac{\tau}{d} = \frac{360\ ft\ lbf}{1.04\ ft} = 346\ lbs \tag{5}$$

$$\tau_{roller} = F \cdot d = 346\ lbf\ \cdot 0.0833 ft = 28.8\ ft\ lbs \tag{6}$$

$$F_{1st\ pulley\ edge} = \frac{\tau}{d} = \frac{28.8\ ft\ lbf}{0.0708\ ft} = 407\ lbf = 2 \cdot T_{belt} \tag{7}$$

$$406\ lbf\ x\ 6.7{:}1 = 2729\ lbf \tag{8}$$

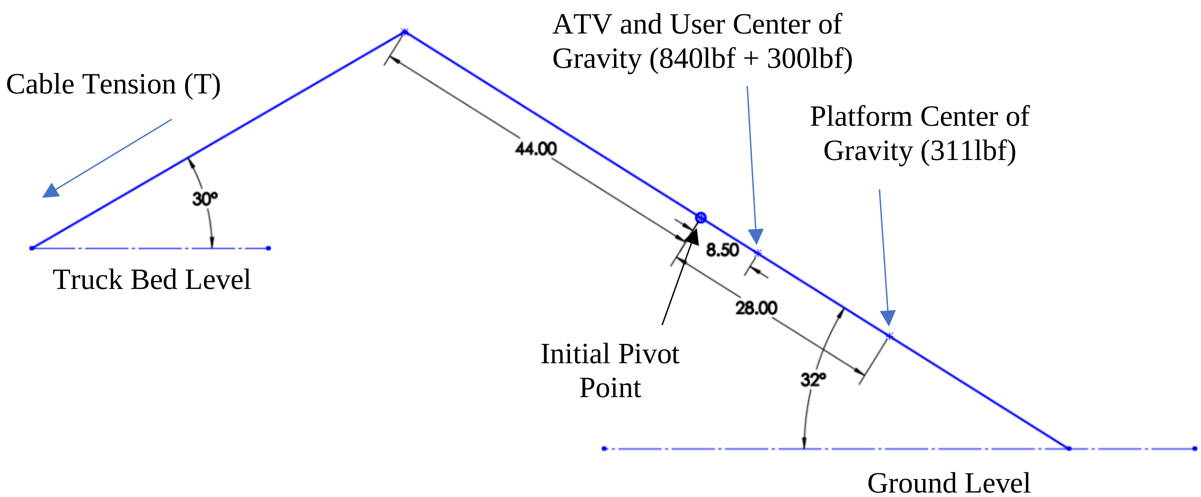
$$\tau_{final\ shaft=} F_{last\ pulley\ edge} \cdot d_{big\ pulley} = 2720 lbf\ \cdot 0.183 ft = 499 ft\ lbs \tag{9}$$

$$F_{spool} = \frac{\tau_{final\ shaft}}{d_{spool}} = \frac{498 ft\ lbs}{0.135\ ft} = 3699\ lbf = 2 \cdot T_{cable} \tag{10}$$

In the above equations, τ is the torque being considered, F is the force at the outer diameter, and d is the radius of the part being considered. In the last equation, the force on the spools is also equal to double the tension (T) of the cable since 2 cables are used.

With the belt reductions, the amount of force that an ATV or snowmobile can apply to pull the platform into the truck is significantly increased. The belt reduction system described in section 3.4.3.2 employs two sets of four pulleys, increasing the pulling force by a factor of 6.7. This increases the total force that can be used to pull up the platform to 3699 lbf.

The next part of the analysis involves determining the force needed to rotate and pull the platform. The maximum ATV weight of 840 lbf with a center of gravity located 8.5 inches along the grating behind the initial pivot point was chosen because of the placement of the engine in the largest ATV considered. The weight of the platform was estimated to be about 311 lbf with the weight of the user assumed to be 300 lbf as well. The center of gravity for the user is assumed to be the same as the ATV. The platform center of gravity is located at 28 inches behind the initial pivot point. The initial platform angle of 32° from the horizontal was used with an initial cable angle of 30° from the horizontal. The cable connected to the platform is 44 inches ahead of the initial pivot point. These angles, distances, and forces are illustrated below. A moment analysis was first completed in the below equations. The equations first determine if enough tension in the cable was available to begin rotating the platform. A force analysis was then carried out to determine the amount of cable tension required to pull the platform into the truck bed. Since rollers are employed to reduce friction between the roller rails, friction was not considered in this analysis. The maximum required force occurs at the initial loading moment, hence any frictional loses are well below the calculated requirements.



$$M_{cable} = T \cdot \cos(30°) \cdot 44 \cdot \sin(30°) + T \cdot \sin(30°) \cdot 44 \cdot \cos(30°) = 38.105 \cdot T \tag{11}$$

$$\begin{aligned} M_{platform} &= (Mass_{ATV} + Mass_{User}) \cdot 8.5 \cdot \cos(32°) + Mass_{platform} \cdot 28 \cdot \cos(32°) \\ &= 1140 \cdot 8.5 \cdot \cos(32°) + 311 \cdot 28 \cdot \cos(32°) = 15602\ lb \cdot in \end{aligned} \tag{12}$$

$$38.104 \cdot T = 15602\ \rightarrow T = 409.45\ lbf \tag{13}$$

The above equations show that the required cable tension to begin rotating the platform is 410 lbf at the top of the platform. Much less than the maximum achievable tension.

3.5. Cable

Both aircraft grade metal and polymer cables were under consideration to decide which would be best suited to a platform and cable design. While metal cables have a much higher tensile strength with smaller cross-sectional diameters, the minimum pulley diameter (corresponding to the minimum bend radius of the cable) increases rapidly as the cross-sectional diameter increases. As mentioned previously, a larger spool will pull in more cable with each rotation, increasing the torque requirement of the spool shaft. The relationship between the selected steel cable and the spool diameter is:

$$Minimum\ Spool\ diameter = 26 * Cable\ Diameter \tag{14}$$

Minimum pulley diameter was a critical factor in the decision between aircraft grade metal cables and braided polypropylene cable, as was the space constraint when implementing the spools into the overall design. Ultimately, it was decided to use a metal cable over the braided cable. The selected cable used in the design is a 7x19 carbon steel hot dip galvanized preformed aircraft cable with a 1/8" cross-sectional diameter. Based on the cross section, the corresponding spool diameter must be at a minimum 3.25" [10]. The minimum breaking strength for this cable is 2000lbs [11].

3.6. Attainment of Client Needs and Requirements

This section revisits the client needs and scores them based on the presented design. A brief explanation of the achievements is discussed below. This section is aptly placed at the end of the entire design section once the design portion of this project is concluded.

TABLE IV: ATTAINMENT OF CLIENT NEEDS

	Client Needs	Priority	Achieved?
1	The design must be compatible with different types and brands of ATV's and snowmobiles	**5**	**Yes**
2	The design must be compatible with motorcycles and dirt bikes	2	No
3	The design must be able to secure the ATV or snowmobile	**5**	**Yes**
4	The design is capable of lifting the ATV and user at the same time	**5**	**Yes**
5	The design is capable of loading and unloading an ATV or snowmobile from a truck bed	**5**	**Yes**
6	The design can efficiently load and unload the ATV or snowmobile	4	Yes
7	The design must be compatible with different truck beds	4	Yes
8	The design must be safe in a roll-over	4	Yes
9	The design has a high factor of safety when operating	4	Yes
10	The design is ATV or snowmobile powered	**5**	**Yes**
11	The design must have an alternate power source	4	No
12	The design requires few steps to operate	3	Yes
13	The design must be rugged	4	Yes
14	The design must be simple to install	3	Yes
15	The design must be able to operate on uneven ground	2	Yes
16	The design must be simple to service	3	Developing
17	The design must come in kit	2	Yes
18	The design must be able to operate when dirty	3	Yes
19	The design must be modular	3	Yes
20	The design must be cost effective to manufacture	4	Developing

The rating system in the above table, based on if the client needs or requirement is met is based on the following scale:

Yes – the design accomplishes this need fully in its present form

No – This requirement was not met by the design in its present form

Developing – While the design does not fully achieve this requirement to the satisfaction of ORV Solutions or the client, there are elements within the design partially fulfilling the need.

The following grading based on the weights of the requirements is presented to achieve an understanding numerically as to how well ORV Solutions managed to incorporate all the needs into the design. The two developing needs are quantified as percentages to their incorporation into the design, where 0% indicated it is not incorporated at all and 100% signifies complete incorporation into the design.

The design must be simple to service – 33% (1/3)

Explanation: Although all components are easily accessible, certain shaft elements (shafts, bearings) may be complicated to service

The design must be cost effective to manufacture – 75% (3/4)

Explanation: Described in full detail in Section 0, the budget was over the agreed upon value of $1,500 CAD

TABLE V: QUANTIFICATION AND GRADING OF ATTAINED CLIENT NEEDS

	Quantity of Needs	Available Score from Needs	Achieved Score from Needs	Total
All Requirements	**20**	**69**	**-**	**69**
'Yes' (full marks)	16	56	56	56
'No' (no marks)	2	6	0	0
'Developing' (partial marks)	2	7	4	4
			Total	**60**
			Difference	**9**

From TABLE V, with the client needs quantified based on their importance, and summed to a total, ORV Solutions scored 60 from a possible 69; a 9-point difference. From a list of 20 needs and recommendations, 16 were met, two were partially developed and two were not incorporated into the design.

3.7. Final Design Concluding Remarks

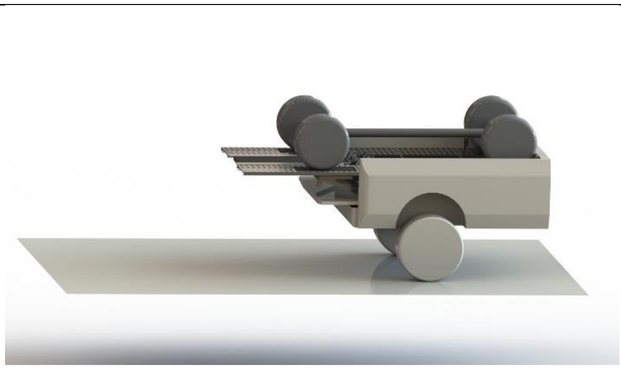
ORV Solutions strove to envision, characterize, and develop a final design in accordance with their engineering proficiency while at the same time adhering as close to Atom Jet Industries' vision for a final design. While there is room for optimization and improvement in the design, ORV Solutions is entirely confident that the design presented in this report is functional and achieves the design needs and requirements laid out and agreed upon during Phase I.

4. Loading and Unloading Sequence

The loading procedure for the design occurs in the following three distinct steps summarized in TABLE VI.

TABLE VI: LOADING SEQUENCE

Loading Step	Image
1. The ATV or snowmobile is driven up onto the ramp such that the rear wheels/snowmobile belt are stopped on top of the corresponding belt. The brakes on the ATV or snowmobile are then locked and the vehicle is strapped down.	 Figure 27: Loading Step 1
2. The brakes of the ATV and snowmobile are unlocked, and the throttle is then applied. The throttle then turns the rear wheels of the ATV or belt of the snowmobile, rotating the platform up and parallel to the truck bed.	 Figure 28: Loading Step 2

3. Continuous throttle to the ATV or Snowmobile will slide the platform into the truck bed. An additional push from the user may be required. The platform can then be secured in place.	 Figure 29: Loading Step 3

The unloading procedure for this concept occurs in the following three distinct steps summarized in TABLE VII.

TABLE VII: UNLOADING SEQUENCE

Unloading Step	Image
1. One user will ensure the ATV or snowmobile is in reverse and apply the throttle to unwind the cable while a second user pulls the platform out of the truck bed until the platform reaches the tipping point.	 Figure 30: Unloading Step 1

2. The user on the ATV or snowmobile will then continue to apply throttle until the platform is touching the ground.	 Figure 31: Unloading Step 2
3. The user will lock the brakes on the ATV or snowmobile and unstrap the machine from the platform. The user can then drive the ATV or snowmobile off of the ramp and enjoy their machine.	 Figure 32: Unloading Step 3 [24]

During the unloading sequence and perhaps during the loading sequence, the platform must be rolled along the railing system from just past the pivot point to the completely stowed position or vice-versa., Two handles (circled in red in Figure 33) were added to assist the user in this process.

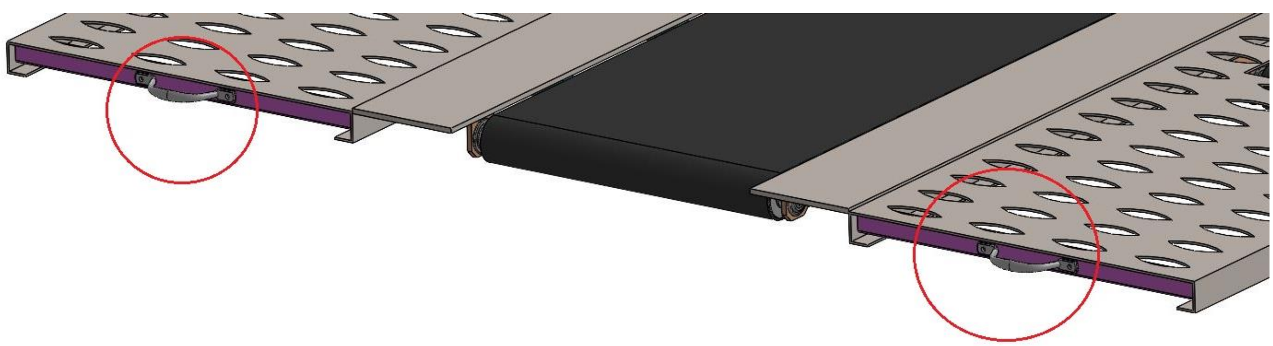


Figure 33: Platform handles

5. Numerical Analysis

Numerical Analysis was performed on the design to ensure that it would be able to withstand the different loads that it would be operating under. This section details the different loads expected from each of the operating steps as well the results from the numerical analysis performed to verify the design.

Two positions of the loading were examined, the position where the ORV is being loaded and the position where the ORV is fully loaded into the truck bed.

5.1. Setup

A tally of the assembly and device weights were compiled together and can be found in TABLE VIII . Weights used for the analysis were taken from the SolidWorks models and rounded up to have a higher factor of safety.

TABLE VIII: WEIGHTS

Assembly/Device	Weight
User	300 lbs
ORV	840 lbs*
TOTAL (USER)	**1,200 lbs**
Platform Assembly	320 lbs
Truck Frame	160 lbs
TOTAL (DESIGN)	**480 lbs**
TOTAL (ABS)	**1,680 lbs**

*Represents maximum ORV weight based on available models

The total mass used for the analysis included the weight of the user, the ORV and the platform assembly since they would be directly transferred into the base frame.

The analysis used a weight of 300lbs for the user. This represents the weight of the 96th percentile of males [12]. The weight of a 96th percentile male was chosen as it would also cover female weight (estimated to generally be 75% of male weight [13]) and would encompass a large amount of the consumer market expected for this device.

With the bed frame being constructed of steel tubing, it was determined that the analysis could be performed as a beam element analysis. This helped simplify the process by reducing the complexity while still providing accurate results.

In order to properly simulate the base frame being attached to the truck, nodes were placed in the middle of the bottom cross beams (red circles in Figure 34) and then were constrained as fixed geometry.

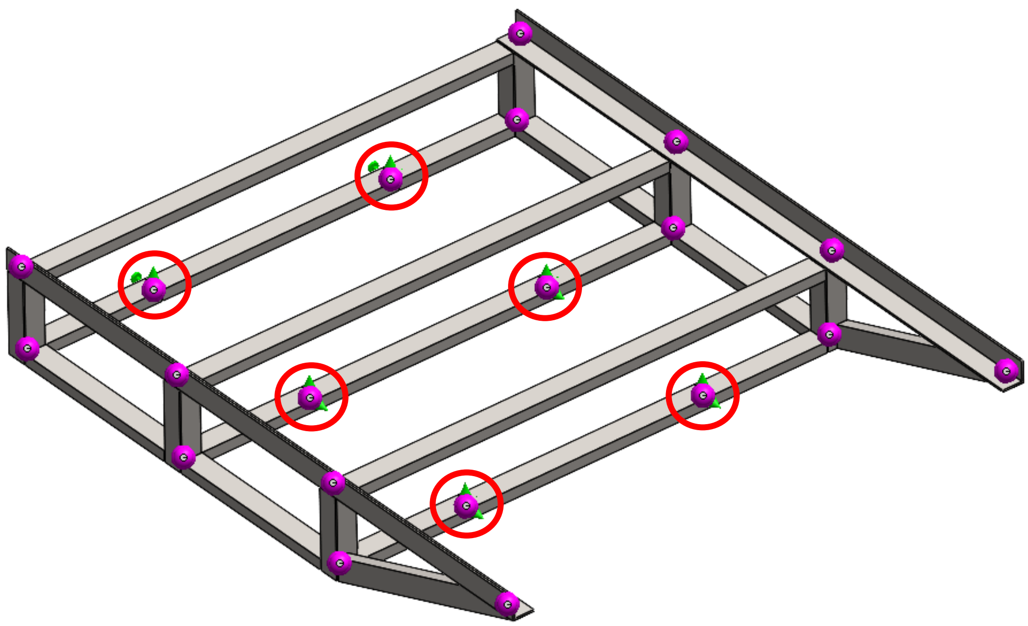


Figure 34: Fixed Nodes

This simulates the base frame being bolted to the chassis of the truck. The spacing of the between a pair of nodes was set to 24 inches [14] in spacing for the analysis, as to be representative of the spacing of the chassis frame rails half ton truck. Repositioning and reanalysis of these nodes would need to be done for each model of truck that may have a different chassis frame rail position. Along with the position needing be examined for the final configuration being used in a truck, the reactionary forces at the fixed geometry locations would need to be considered in order to determine the bolts required.

Nodes of the outer perimeter of the Base Frame (circled in green inFigure 35) were set to allow for lateral movement and movement upwards out of the truck bed, but restricted movement into the truck bed. This simulated these the bottom beams on the side resting on truck bed without being fully constrained as if they were bolted.

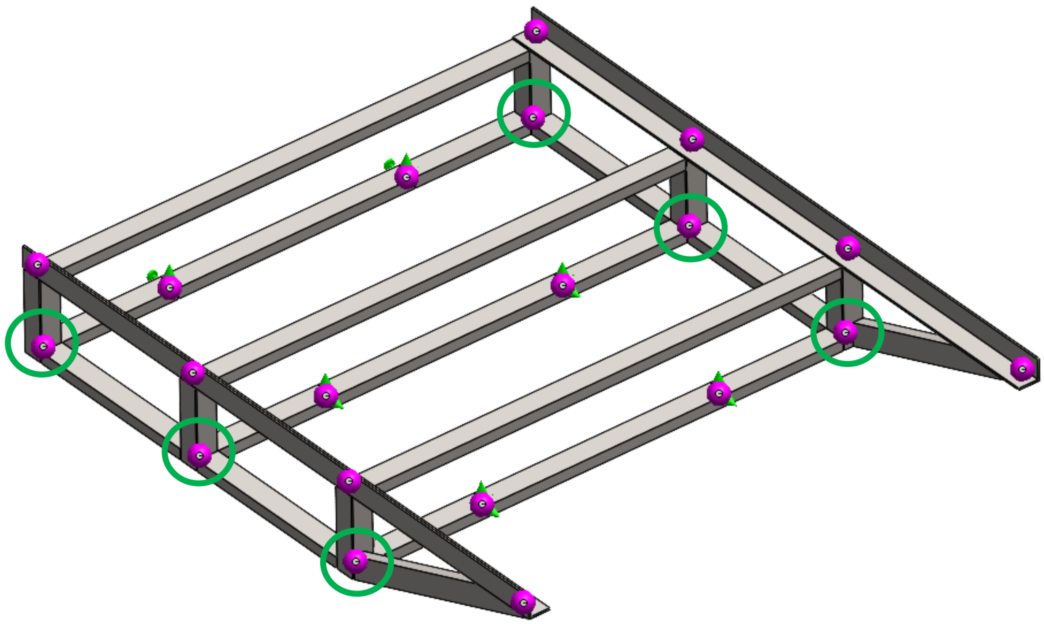


Figure 35: Outer Perimeter Nodes

Meshing was automatically generated by SolidWorks and only needed to be refined by increasing the number of elements for the vertical 2”x2” legs (circled in blue in Figure 36) to be consistent with the entire model.

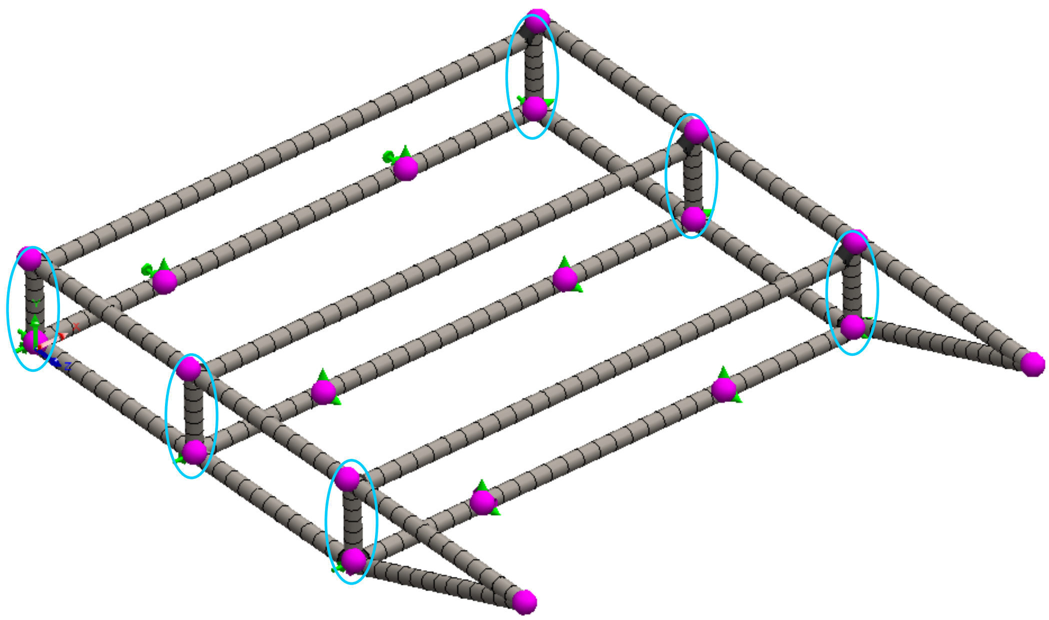


Figure 36: Mesh for base frame

5.2. Scenario 1 - Loading

The first analysis that was looked at is when the ORV has just started being loaded and is no longer touching the ground. The case was determined to be one of the highest stress loading situations that the design would be subjected to. This case also represents when the ORV is being unloaded and is a moment away from touching the ground.

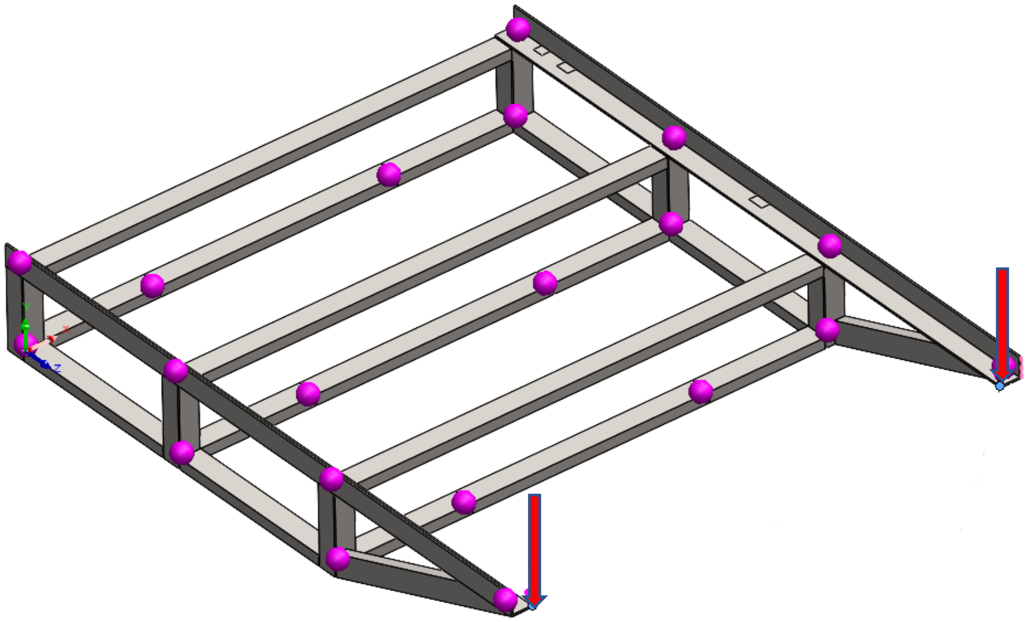


Figure 37: Loads for Loading Position

The results of this study showed that the maximum amount of stress would be 29.84 ksi located in the first upper joint positions (as seen in Figure 38).

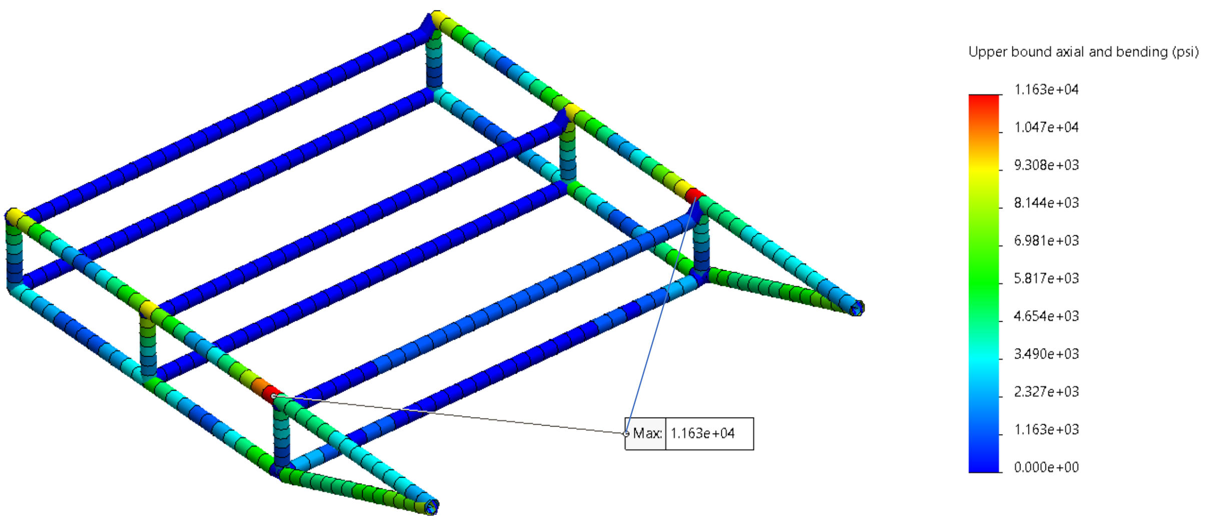


Figure 38: Stress in Truck Bed Frame during Loading

The maximum stress was well below the yield strength of the material and had a factor of safety (FOS) of 1.7 in the maximum stress location.

For the displacement during the loading process, the maximum amount of displacement was determined to be 0.03025in and was located right at the front of the base frame. This was expected as it is in the truss portion of the design, which is more susceptible to deflection at the end where the load is being applied.

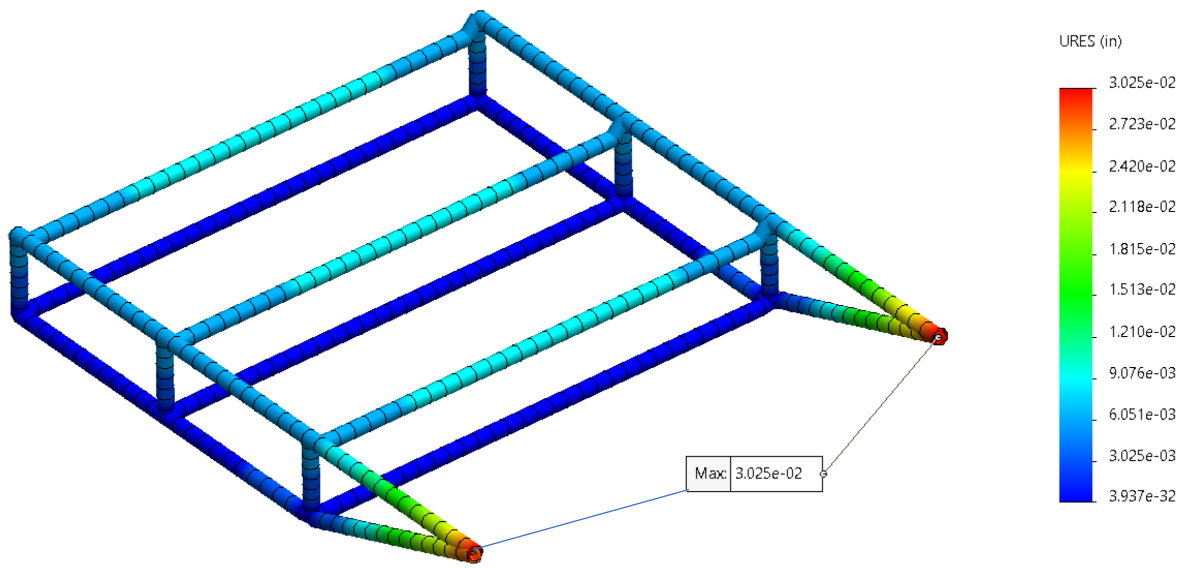


Figure 39: Displacement in Truck Bed Frame during Loading

The maximum displacement in the loading configuration determined by analysis was considered by ORV Solutions to be moderate for the design and application. As part of the recommendations to the client (Section 7.2), ORV Solutions has recommended that the base frame be optimized to help reduce the deflection in this configuration.

5.3. Scenario 2 – Fully Loaded

The second scenario examined was the position which the platform and ORV were fully loaded into the truck. The loading of the forces was determined to be distributed through the track rollers onto the platform.

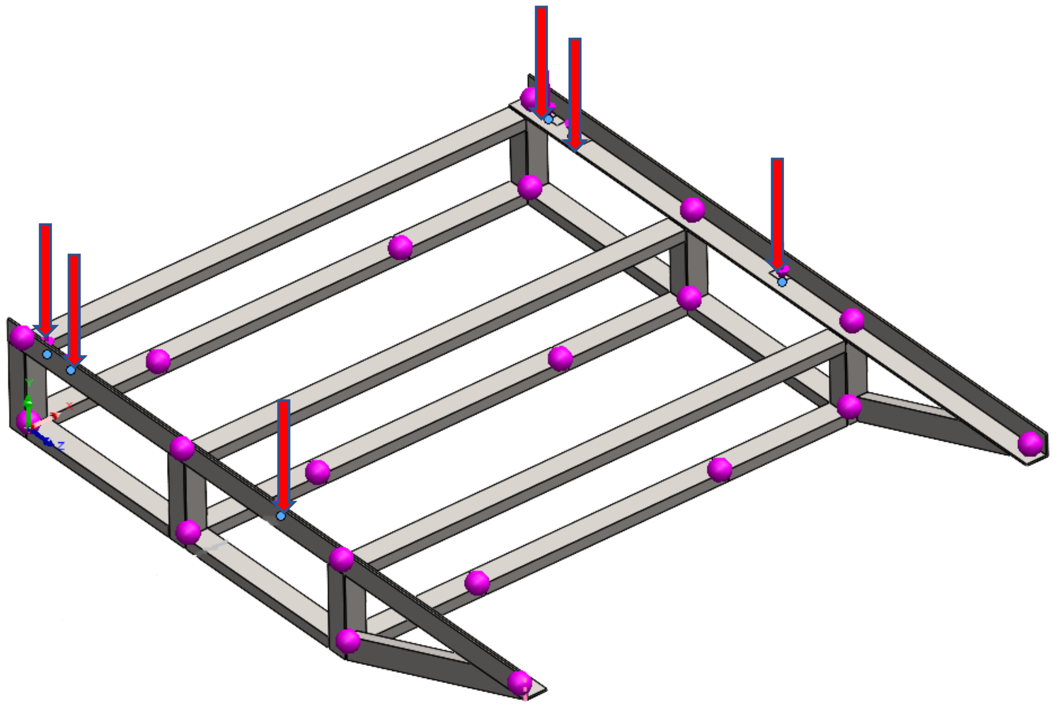


Figure 40: Loads Applied in Fully Loaded Position

The max stress in the scenario of fully loaded was determined to be 1.46 ksi. The stress in this scenario was more spread out across the base frame compared to Scenario 1 as the loads were distributed across the entirety of the frame.

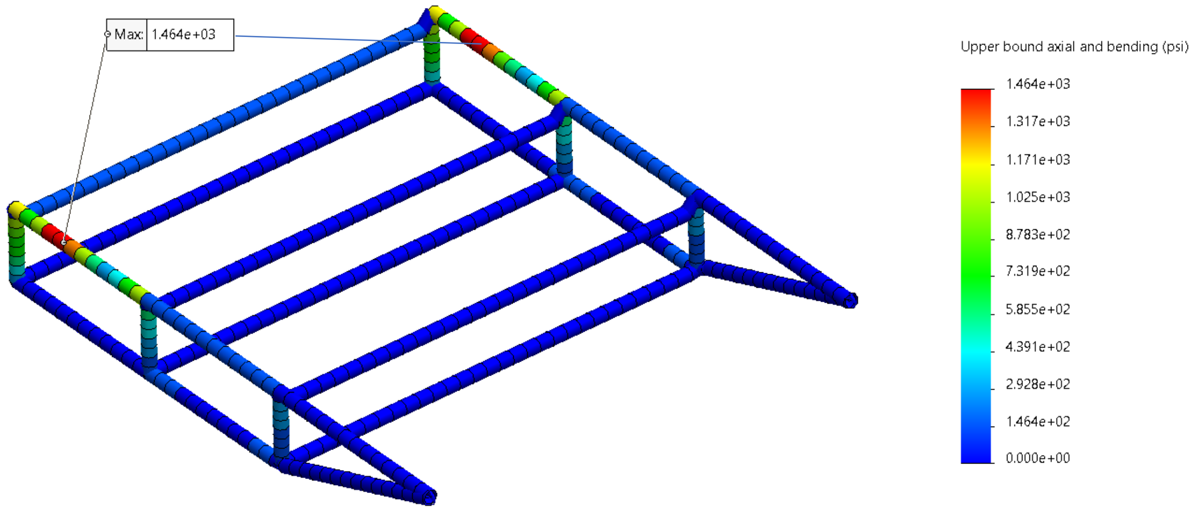


Figure 41: Stress in Fully Loaded Position

By having the load distributed across the frame, the factor of safety rose to 7 for the higher stress regions. The maximum displacement was in the rear of the mounting frame with a value of 0.0007723in and was in the rear of the angle iron. (Figure 42).

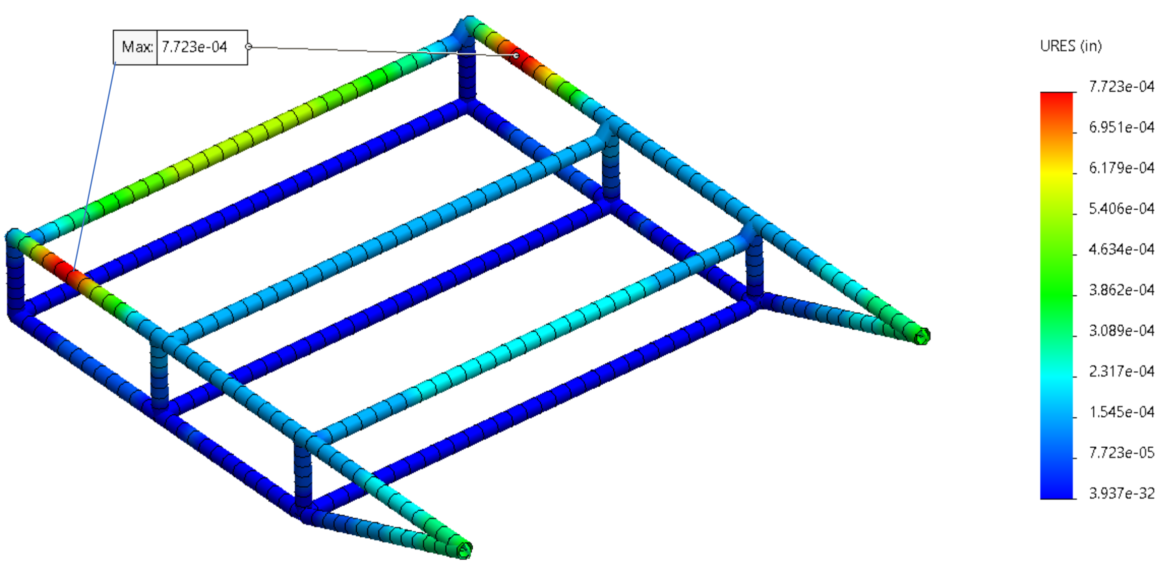


Figure 42: Deflection in Fully Loaded Position

5.4. Weld Analysis

With the base frame being welded together, a weld analysis on different joints of concern were performed to ensure that the design would not fail at the welds.

Due to the high variability that is involved with the process of welding, a very conservative approach was taken for determining the stress at the weld locations where the interface was a T-butt joint with sharp corners. Section 7.2 includes recommendations for improving the weld analysis.

The assumptions made for the weld analysis were as follows:

- External loading is to be carried by shear forces on the throat area of the weld. These shear stresses are inflated sufficiently to be able to ignore the normal forces. [7]
- The welds performed were consistent across all areas without any variability between each other.
- There exists a groove between the two bodies being welded which allows for the filler material to interface consistently with each body.
- Weld material and component material have similar strength properties.

The following Figure 43 illustrates the welding of two bodies, and the resulting shear stress. The weld itself is colored red, pointed towards using a weld symbol.

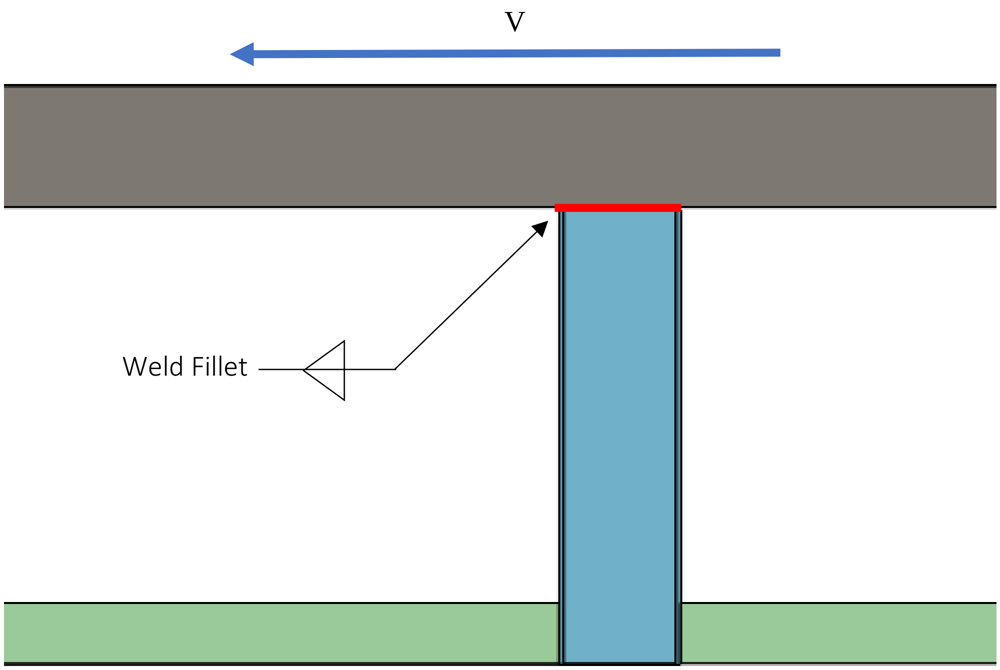


Figure 43: Shear on Welded Joints

The calculation of the shear stress that would be observed in the weld is done by using equation 15 where *F* is the force, *L* is the length of the weld and *h* is the weld throat [7].

$$\tau = \frac{F}{0.707hl} \tag{15}$$

As per the Canadian Institute of Steel Construction, it is recommended that a weld size of 1/8in to be used for the material thickness of 1/8in [15]. With a weld size of 1/8, the throat size *h* is determined to be 0.088in.

The force being applied to the frame causing shear was determined to be at its maximum when the loading was just beginning and was starting to pivot downwards to lower the platform. At this point, the maximum amount of force would be that of the cable pulling, which was determined to the 410lbf. (Section 3.4.4)

With a bead length of 2in, the total maximum amount of shear stress was determined to be 3.219 ksi, seen in equation 16.

$$\tau = \frac{409.45}{0.707(0.088)(2)} = 3.219\ ksi \tag{16}$$

6. Bill of Materials

Per the client's requirement, the design budget for components was set at $1500 CAD. To meet this requirement, a bill of materials was produced to help keep track of the purchased parts as well as stock material for parts that would be manufactured.

The bill of materials (BOM) lists all the required material and their individual costs. The BOM was broken into two sections, purchased components and manufactured components. For the purchased components, pricing was determined by the supplier of the component. For manufactured components, only the stock material required for each component was priced, as manufacturing capabilities would be dependent on the client.

6.1. Purchased Components

Components were sourced from various suppliers, based on the availability of the desired product and the lowest price. Most stock steel was sourced from Russel Metals. The safety grating was sourced from UBS-Unistrut, and most v-belt components were sourced from Princess Auto. Other components were sourced from McMaster-Carr as required. Although it was desired to find purchasable component sources other than McMaster due to cost, for several items McMaster-Carr provided reasonable prices. A list of each component and the designated supplier is in the following

TABLE IX. The bill of purchased components also includes the total cost, which represents the overall cost of material for the design. The total tally for the entire design was 158 components, 55 of which were ready to implement, purchasable components, and 103 components that would require manufacturing.

TABLE IX: BILL OF PURCHASED COMPONENTS

	Supplier	DESC.	QTY	COST/UNIT.	TOT
1	Russell Metals	0.25x4'x8' Steel price per sq ft	6	$ 4.99	$ 29.94
2	Russell Metals	1"x1" 1/8" sq. tubing per ft	53	$ 1.28	$ 67.84
3	Russell Metals	2" x3/16" Round Tube	3	$ 3.28	$ 9.84
4	Metal Depot	2"x1" Rect. Steel Tubing	1	$ 163.38	$ 163.38
5	UBS-Unistrut	18.75" wide Grating	2	$ 115.58	$ 231.16
6	Ben-Mor	1/8 S. Steel 304 cable 7x19	48	$ 0.22	$ 10.56
7	V-Belt Supply	V-belt (A19)	4	$ 1.06	$ 4.24
8	McMaster-Carr	Threaded Track Roller-2	2	$ 36.54	$ 73.08
9	McMaster-Carr	12"x2" Roller	4	$ 12.47	$ 49.88
10	McMaster-Carr	16"x2" Roller	2	$ 14.61	$ 29.22
11	McMaster-Carr	Drive Shaft Bearing	6	$ 12.14	$ 72.84
12	McMaster-Carr	Hex Bearing	6	$ 3.36	$ 20.16
13	McMaster-Carr	0.12", 1x2in Tube	2	$ 40.19	$ 80.38
14	McMaster-Carr	Angle Iron	2	$ 22.47	$ 44.94
15	McMaster-Carr	Threaded Track Roller	4	$ 59.62	$ 238.48
16	McMaster-Carr	18" Rough Surface Belt	9	$ 11.11	$ 99.99
17	McMaster-Carr	12" Rough Surface Belt	10	$ 7.42	$ 74.20
18	McMaster-Carr	2.5x2.5x0.5 Angle Iron	1	$ 18.89	$ 18.89
19	McMaster-Carr	2x1.5x0.25 Angle Iron	1	$ 7.64	$ 7.64
20	McMaster-Carr	0.75OD 0.5ID 0.5' Round Tube	1	$ 4.15	$ 4.15
21	McMaster-Carr	0.25x6x24 Steel Bar	1	$ 43.34	$ 43.34
22	McMaster-Carr	Cable Pulley	2	$ 7.38	$ 14.76
23	McMaster-Carr	Handles	2	$ 2.15	$ 4.30
24	McMaster-Carr	Machine Key	1	$ 3.04	$ 3.04
25	McMaster-Carr	5/8"s, 3/4" S Olite Bushings	4	$ 1.49	$ 5.96
26	Princess Auto	Weld-on Hub	6	$ 6.99	$ 41.94
27	Princess Auto	5/8" x 3ft Keyed Shaft	3	$ 29.99	$ 89.97
28	Princess Auto	5/8" Mounted Bearing	4	$ 11.99	$ 47.96
29	Princess Auto	2.5" x 5/8" V-Belt Pulley	4	$ 11.99	$ 47.96
30	Princess Auto	5" x 5/8" V-Belt Pulley	4	$ 21.99	$ 87.96
				TOTAL:	$1,718.00
				DIFFERENCE:	-$218.00

Note that the quantities in TABLE IX does not tally to the total number of components in the modelled design. Material stock components were purchased in units, and more than one unit of stock was often required to satisfy the total stock in the final design.

6.2. Manufactured Components

Components that were designed which required some form of manufacturing (i.e., additional processing after being purchased to be implemented into the design) all have engineering drawings supplied to the client, located in Appendix A of this report. These engineering drawings, while providing measurements of all components also help the client determine what kind of manufacturing processes would be needed to produce the parts.

6.3. Total Costs

The total cost of all the non-manufactured purchasable components as well as all the manufactured components is $1,718.00. Evidently, this is $218.00 over the project budget goal.

7. Limitations and Future Recommendations

ORV Solutions worked to ensure the best product was developed to submit to the client. Every product has limitations, while some limits were identified in the scope, other limitations were discovered as the product was developed. While ORV Solutions were able to develop a working product, we have formed a list of limits and recommendations to further improve the product for both the end user and the manufacturer. For many of the limits, ORV Solutions also developed a corresponding recommendation to aid the client.

7.1. Limitations

- The ATV cannot be excessively loaded with weight during the loading process. While the Self-Powered Recreational Vehicle Loader was designed to withstand a weight larger than the recommended operating weight of 1200 lbs (which represents the weight of the ATV and rider), it should not be loaded with other items during use. This could result in failure in the Auto-Ramp and potential injury to the user.
- Manufacturability was not considered in the design of this product. While it is possible to manufacture, the process would be arduous. This limitation would also encompass home repairs, in that they would be difficult to accomplish.
- A frictional analysis was not carried out; therefore, it is unknown if the static friction between the belt and the ATV tires/snowmobile track is sufficient to pull the loaded platform into the truck.
- To unload the platform, the ATV or snowmobile is required to rotate its wheels/track in reverse to unspool cable, before manually pulling the platform to its tipping point.
- The platform is not compatible with ATV's that are always or 'stuck' in four-wheel-drive.
- The platform cannot operate if the ATV or snowmobile in inoperable.

7.2. Recommendations

The following recommendations were developed by ORV Solutions to help with future designs of the product and reduce its limitations.

- To increase the safety of the overall design, ORV Solutions recommends analyzing the effects of eccentric loading and temperature effects on all components of the product.

- To increase the safety of the overall design, ORV Solutions recommends implementing guards around the cable to protect the user from potential recoil of a snapped cable. ORV Solutions also recommends researching a method to “catch” should the cables snap.

- This report did not investigate fasteners for the cables, as such, ORV Solutions recommends the client investigate methods for attaching the cable to the truck bed and spool without reducing the cable’s strength.

- To increase the accuracy of the test results, ORV Solutions recommends doing a more thorough weld analysis on the construction of the frame and platform.

- To better aid in the manufacturing process and maintenance, the bearing houses that are welded in the design could be bolted to allow the shafts to be placed and removed without having to break any welds. This would also aid in the changing of belts as they wear out over time from usage.

- To combat the wearing of the belts and allow for a longer life of belt, it is recommended that a tensioner be incorporated into the bearing housings of each idle roller. This will allow for the tension of the belt to be maintained even as they stretch and wear.

- To increase the amount of traction that can be achieved by the snowmobile on the belt, it is recommended to incorporate flaps/panels into the belt. This could be accomplished by drilling two or three holes in a horizontal line on the belt and then using those wholes to screw a piece of rubber that sticks out about an inch. This would be repeated for the circumference of the snowmobile belt. Each of these flaps/panels would be able to interlock with the flaps/panels found on a snowmobile belt. Both the belts would then interact similar to cogs, pushing each other rather than relying on friction.

- To aid in the unloading process and securing the platform, the incorporation of a clutch system is recommended. This system would allow the spool that wind the cable to spin freely (for unloading) or to lock all movement (while transporting). This system would increase the safety of the design and increase the speed at which the platform can be unloaded.

- To help with the loading of a broken ATV for transport either out of the field or to the mechanic, the incorporation of a hand-crank is recommended. This would allow the user to safely load and unload an inoperable machine by themselves.

- To reduce the wear of the cable and help with preventing kinks in the system, it is recommended to incorporate a spool guide. This would allow the cable to wind up and take up the least amount of space, allowing for a decrease in the height of the walls of the spools.

- To improve the marketability of this design, it is recommended to incorporate a system that allows for easy removability. This could be accomplished by bolting sleeves to the frame of the truck (through the truck bed) that the base of the platform can slide and lock into. This would permit customers to have additional space in their truck bed should they desire. This feature could also make the design compatible with more truck beds, requiring only the bolting pattern on the sleeves to be modified for each truck type.

- To increase the compatibility of the platform to older ATV's that may only operate in four-wheel-drive, a dolly style lift such as those used in formula 1 could be incorporated into the platform. This lift would raise the front wheels off the grating while the rear wheels maintain contact and turn the belt.

- To increase the strength of the section bolted to the truck bed, incorporating triangles such as those found in a truss would increase the strength. This increase in strength would allow for larger ATV's and snowmobiles to become compatible with the platform. The increase in strength could also allow for a reduction of material, reducing the load on the truck suspension.

8. Conclusion

The Self Powered Recreational Vehicle Loader is the final product designed by ORV Solutions to safely load and unload ATV's and snowmobiles onto the bed of a pickup truck. The main requirements for the product included the ability to execute both loading and unloading of the ORV, design compatibility with multiple ORVs, and powering of the product through the ORV itself.

The final design produced by ORV Solutions utilizes a platform in which its unloaded configuration is situated in an inclined position leading into the truck bed. An ORV can drive up the ramp and be secured to the platform. Through spooling of a cable onto a drive shaft on the platform, the ORV and platform are loaded into the pickup truck.

A robust power transmission system was required to ensure enough torque is produced to load the ORV. Power is transmitted from an ATV or snowmobile through a treadmill style track and roller system. A v-belt system was introduced into the design to increase the torque applied to the cable and therefore the loading capacity of the design. Using the Polaris Sportsman 450, due to its low engine displacement as the driving ORV, a power generated analysis showed that total force that can be used to pull up the platform is equal to 3699 lbf. The required torque to rotate the Platform and ATV was a much lower value of 410 lbf showing that most ORVs should be capable of producing enough torque to operate the design.

From a list of 20 needs and recommendations, 16 were met, two were partially developed, and two were not incorporated into the design. The total manufactured cost of this design is estimated to be $1,718. While there is room for optimization and improvement in the design, ORV Solutions is confident that the design presented in this report is functional and achieves the design needs and requirements laid out and agreed upon during Phase I.

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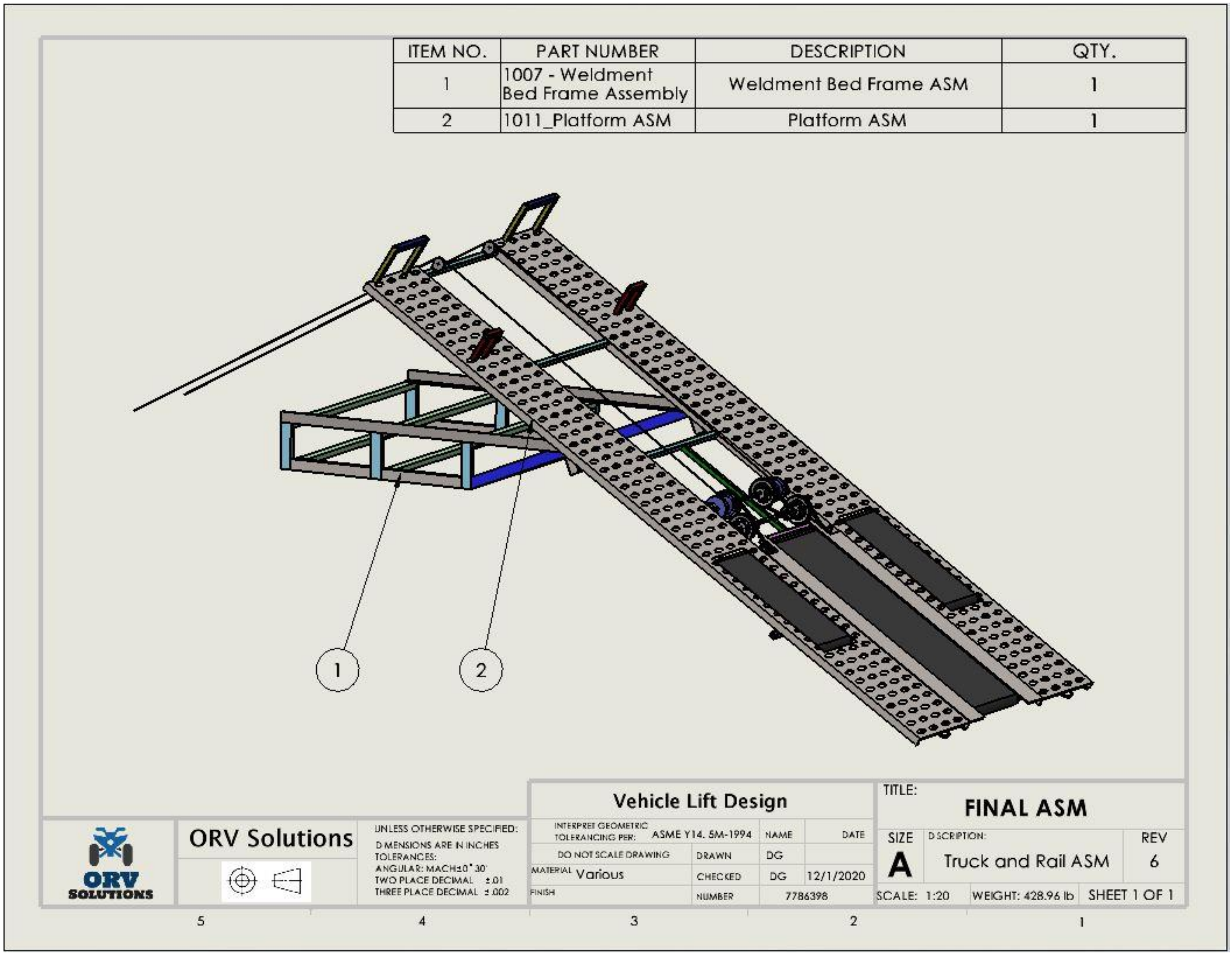
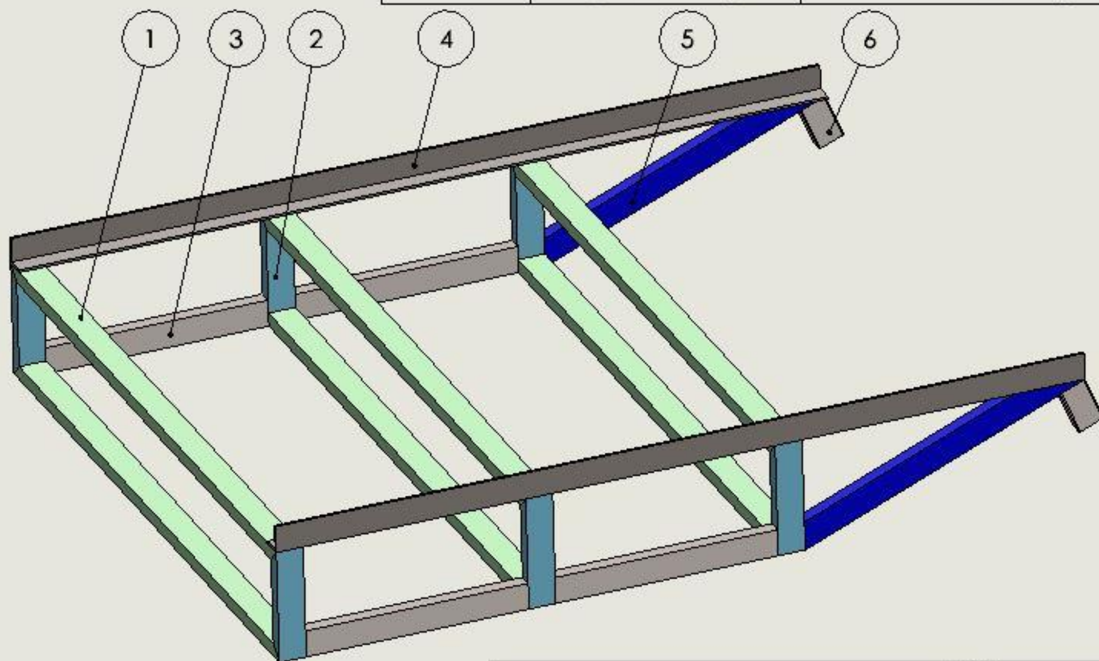
Figures in Appendices

Tables in Appendices

Appendix A: Engineering Drawings



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	1004 - Long Beam	Long Beam	6
2	1006 - Side Brace	Side Brace	6
3	1038_Small Bottom Brace	Small Bottom Brace	4
4	1008_Angle Iron Rails	Angle Iron Rails	2
5	1005 - Angled Truss Member	Angled Truss Member	2
6	1040_Roller Angle	Roller Angle	2



ORV SOLUTIONS

ORV Solutions

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: MACH ±0°30
TWO PLACE DECIMAL ±.01
THREE PLACE DECIMAL ±.002

Vehicle Lift Design

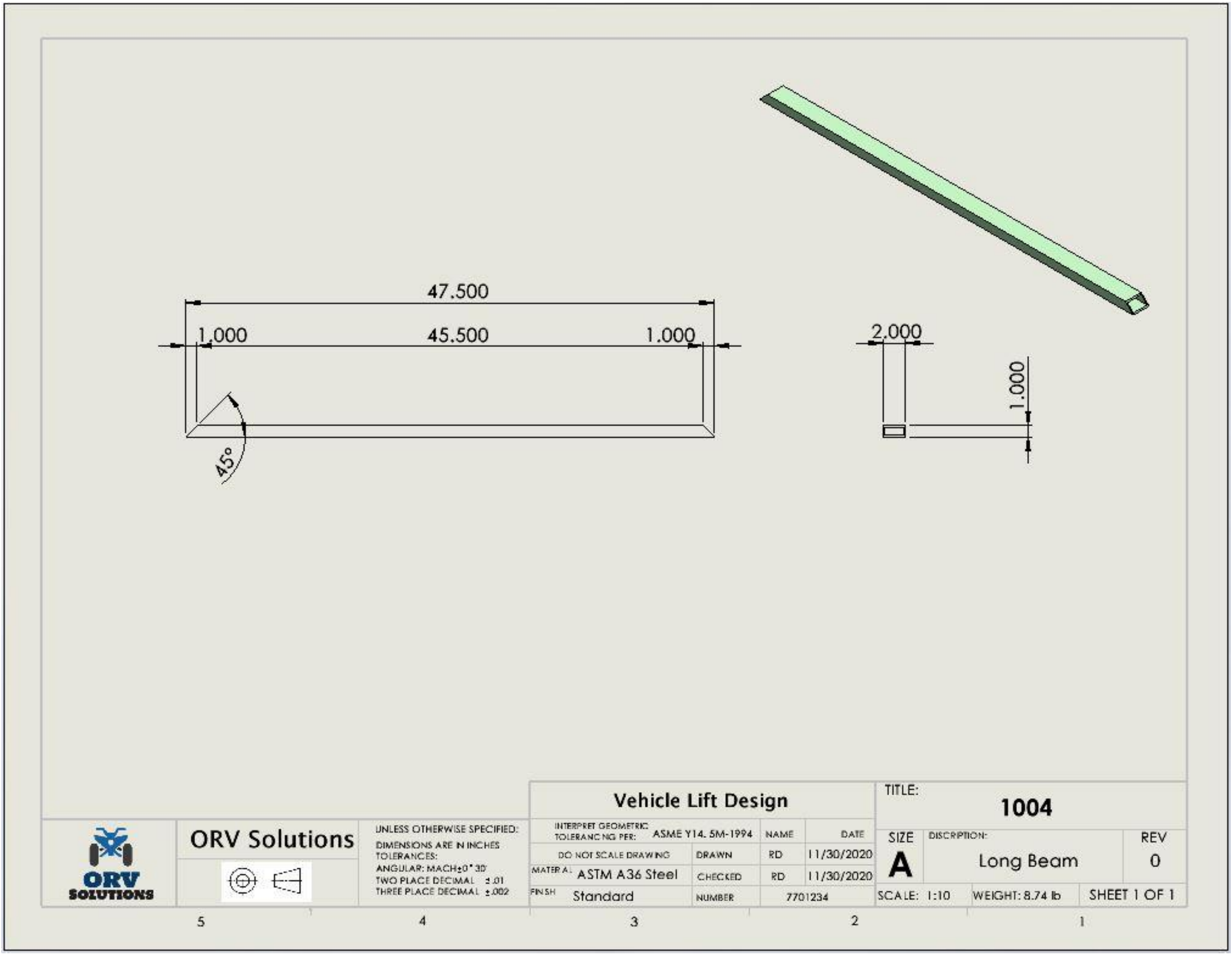
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14. 5M-1994		NAME	DATE
DO NOT SCALE DRAWING	DRAWN	RD	11/30/2020
MATERIAL Various	CHECKED	DG	11/30/2020
FINISH	NUMBER	7701234	

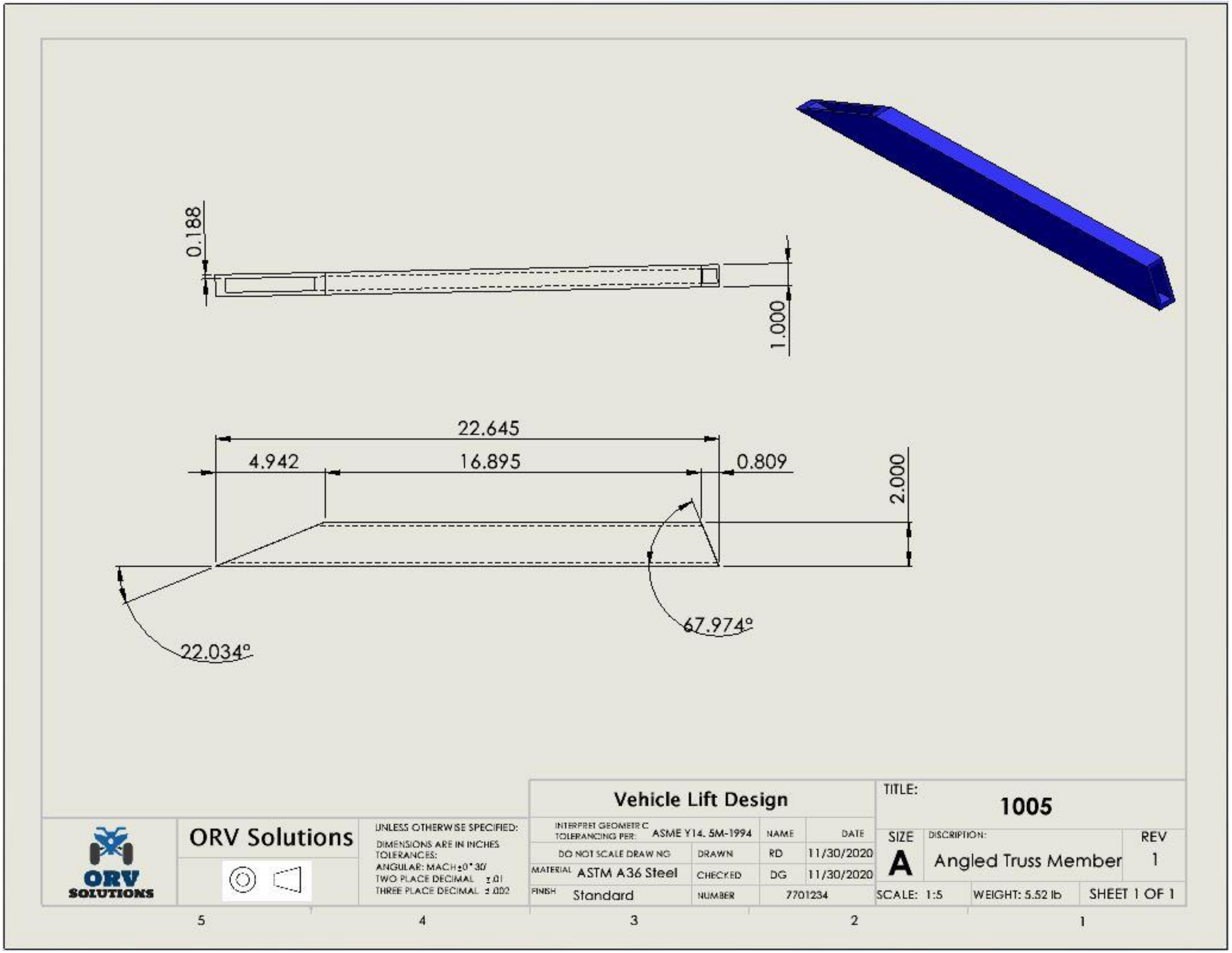
TITLE: 1007

SIZE	DISCRPTION:	REV
A	Weldment Bed Frame ASM	2

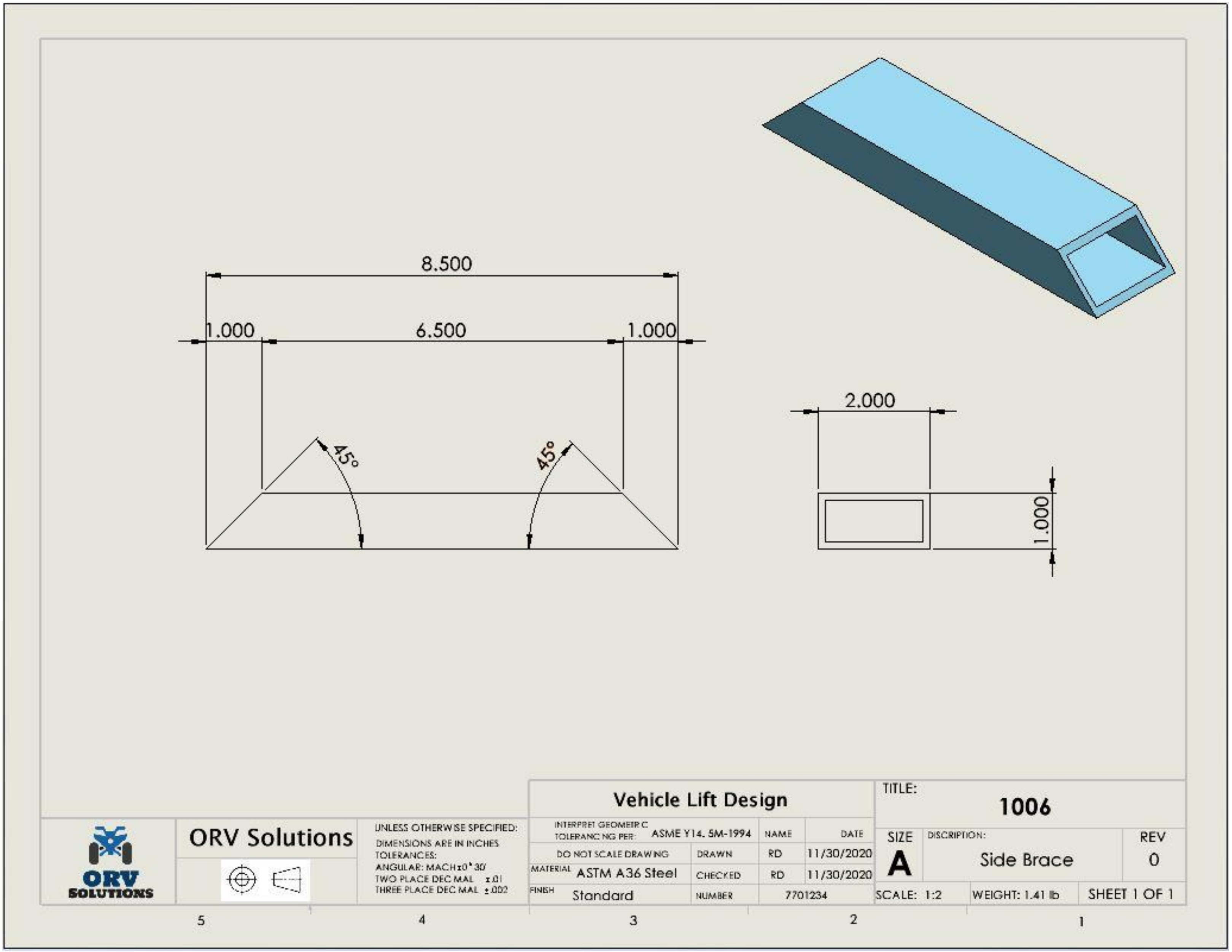
SCALE: 1:10 WEIGHT: 106.28 lb SHEET 1 OF 1

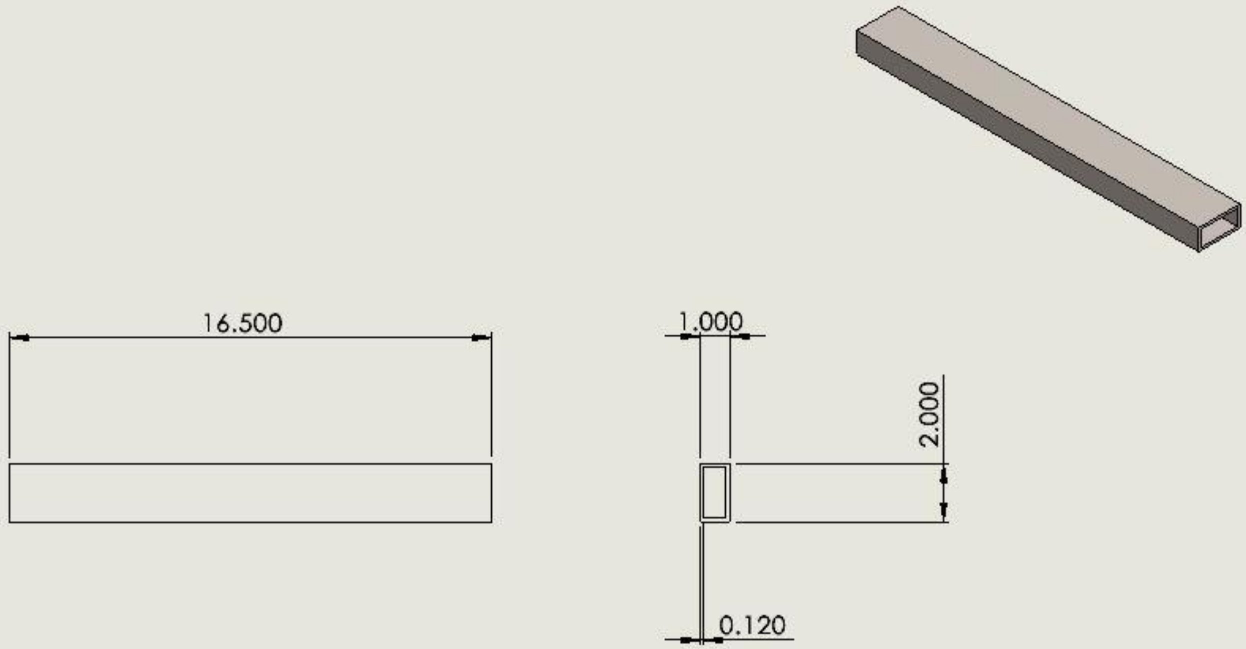
5 4 3 2 1


47.500
1.000
45.500
1.000
45°
2.000
1.000
ORV SOLUTIONS
ORV Solutions
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: MACH±0°30'
TWO PLACE DECIMAL ±.01
THREE PLACE DECIMAL ±.002
Vehicle Lift Design
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5M-1994
NAME
DATE
DO NOT SCALE DRAWING
DRAWN RD 11/30/2020
MATERIAL ASTM A36 Steel
CHECKED RD 11/30/2020
FINISH Standard
NUMBER 7701234
TITLE:
1004
SIZE A
DISCRIPTION:
Long Beam
REV 0
SCALE: 1:10
WEIGHT: 8.74 lb
SHEET 1 OF 1
5
4
3
2
1



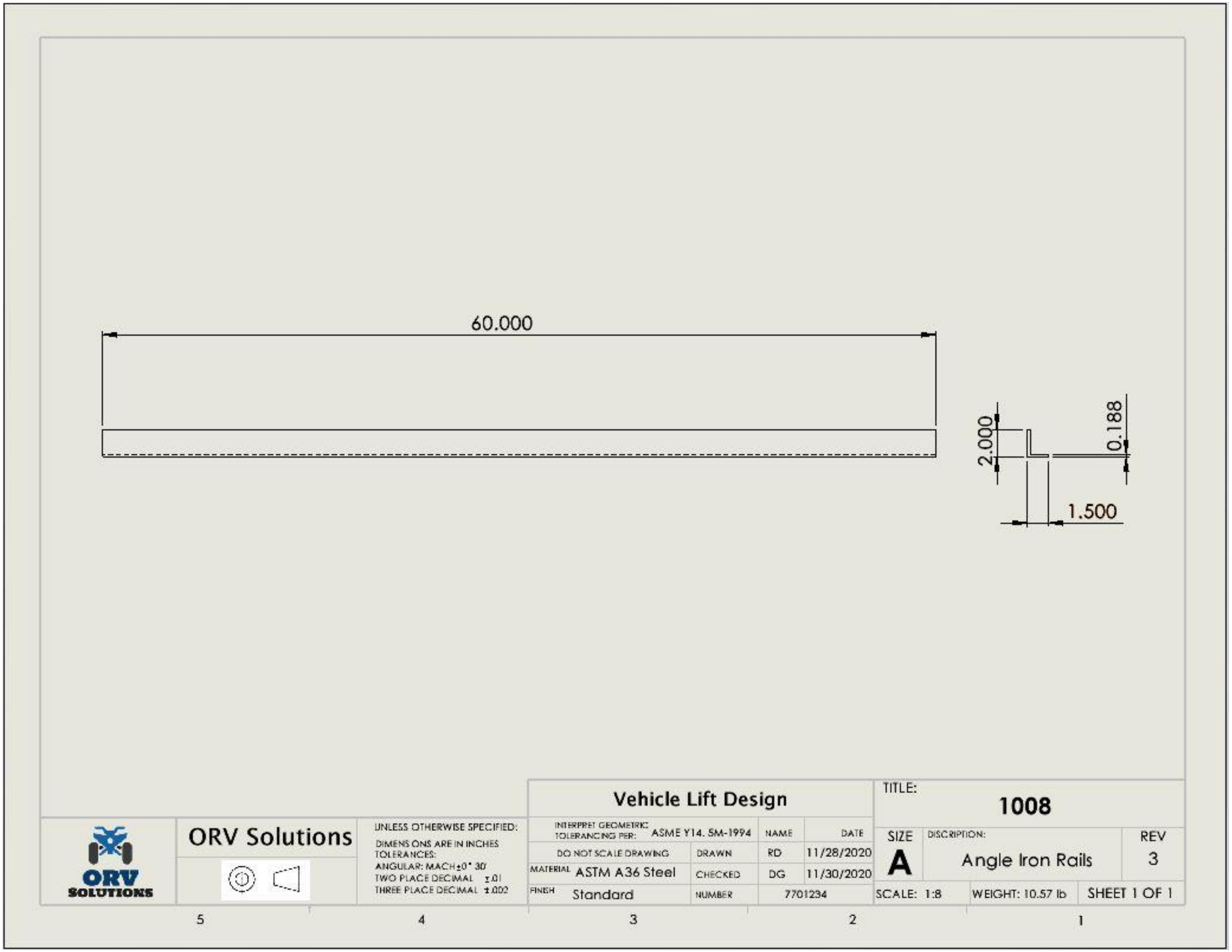
0.188
1.000
22.645
4.942
16.895
0.809
2.000
22.034°
67.974°
Vehicle Lift Design
TITLE:
1005
ORV SOLUTIONS
ORV Solutions
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: MACH±0°30'
TWO PLACE DECIMAL ±.01
THREE PLACE DECIMAL ±.002
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5M-1994
DO NOT SCALE DRAWING
MATERIAL ASTM A36 Steel
FINISH Standard
NAME
DATE
DRAWN RD 11/30/2020
CHECKED DG 11/30/2020
NUMBER 7701234
SIZE
A
DISCRIPTION:
Angled Truss Member
REV
1
SCALE: 1:5
WEIGHT: 5.52 lb
SHEET 1 OF 1
5
4
3
2
1

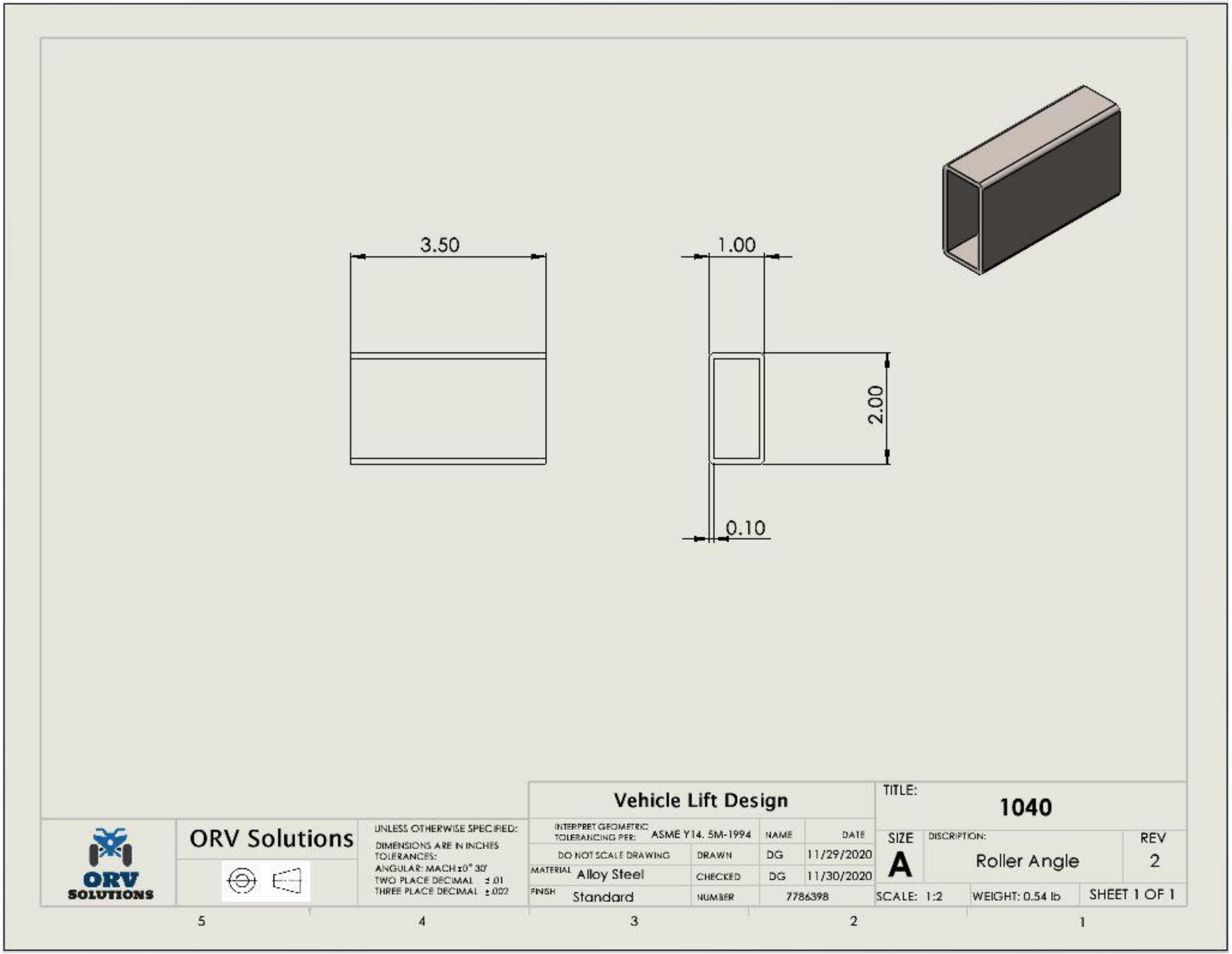

8.500
1.000
6.500
1.000
45°
45°
2.000
1.000
ORV SOLUTIONS
ORV Solutions
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: MACH ±0° 30'
TWO PLACE DECIMAL ±.01
THREE PLACE DECIMAL ±.002
Vehicle Lift Design
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14. 5M-1994
NAME
DATE
DO NOT SCALE DRAWING
DRAWN RD 11/30/2020
MATERIAL ASTM A36 Steel
CHECKED RD 11/30/2020
FINISH Standard
NUMBER 7701234
TITLE:
1006
SIZE
A
DISCRIPTION:
Side Brace
REV
0
SCALE: 1:2
WEIGHT: 1.41 lb
SHEET 1 OF 1
5
4
3
2
1

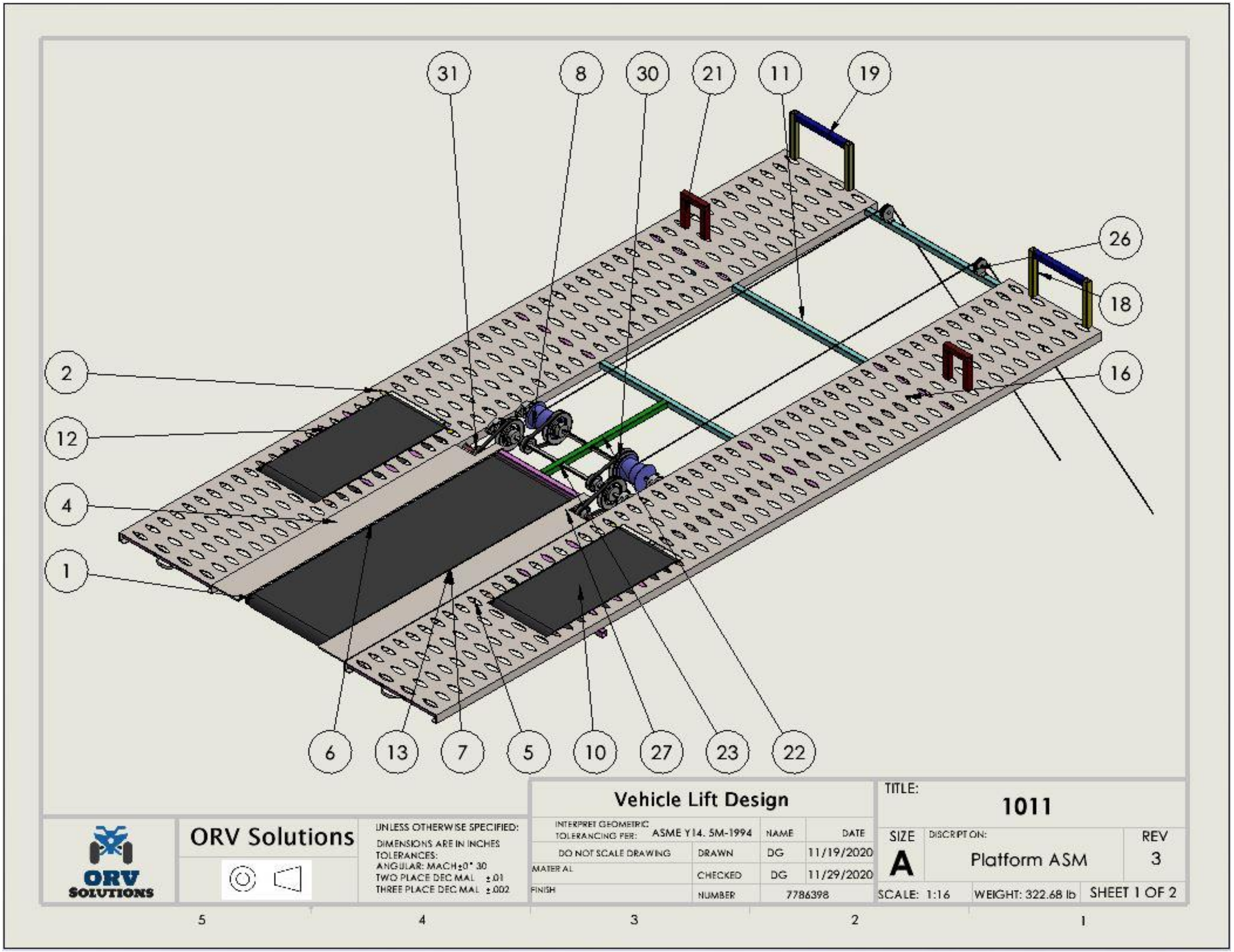


ORV SOLUTIONS	ORV Solutions	UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES TOLERANCES: ANGULAR: MACH ±0° 30' TWO PLACE DECIMAL ±.01 THREE PLACE DECIMAL ±.002	Vehicle Lift Design			TITLE: 1038	
			INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14. 5M-1994	NAME	DATE	SIZE A	DISCRIPTION: Small Bottom Brace	REV 1
			DO NOT SCALE DRAWING	DRAWN RD	11/28/2020		
			MATERIAL Alloy Steel	CHECKED DG	11/30/2020		
			FINISH Standard	NUMBER	7786398	SCALE: 1:5	WEIGHT: 3.04 lb	SHEET 1 OF 1

5 4 3 2 1


60.000
2.000
0.188
1.500
Vehicle Lift Design
TITLE:
1008
ORV Solutions
ORV SOLUTIONS
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: MACH±0° 30'
TWO PLACE DECIMAL ±.01
THREE PLACE DECIMAL ±.002
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14. 5M-1994
NAME
DATE
DO NOT SCALE DRAWING
DRAWN
RD
11/28/2020
MATERIAL ASTM A36 Steel
CHECKED
DG
11/30/2020
FINISH Standard
NUMBER
7701234
SIZE
A
DISCRIPTION:
Angle Iron Rails
REV
3
SCALE: 1:8
WEIGHT: 10.57 lb
SHEET 1 OF 1
5
4
3
2
1


3.50
1.00
2.00
0.10
Vehicle Lift Design
TITLE:
1040
ORV SOLUTIONS
ORV Solutions
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: MACH ±0° 30'
TWO PLACE DECIMAL ±.01
THREE PLACE DECIMAL ±.002
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14. 5M-1994
DO NOT SCALE DRAWING
MATERIAL Alloy Steel
FINISH Standard
NAME
DATE
DRAWN DG 11/29/2020
CHECKED DG 11/30/2020
NUMBER 7786398
SIZE
A
DISCRIPTION:
Roller Angle
REV
2
SCALE: 1:2
WEIGHT: 0.54 lb
SHEET 1 OF 1
5
4
3
2
1


31
8
30
21
11
19
26
18
16
2
12
4
1
6
13
7
5
10
27
23
22
Vehicle Lift Design
ORV Solutions
ORV SOLUTIONS
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: MACH±0° 30
TWO PLACE DECIMAL ±.01
THREE PLACE DECIMAL ±.002
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14. 5M-1994
DO NOT SCALE DRAWING
MATERIAL
FINISH
NAME
DATE
DRAWN
DG
11/19/2020
CHECKED
DG
11/29/2020
NUMBER
7786398
TITLE:
1011
SIZE
A
DISCRIPTION:
Platform ASM
REV
3
SCALE: 1:16
WEIGHT: 322.68 lb
SHEET 1 OF 2
5
4
3
2
1

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	1012_Rollers ASM		1
2	1009_Bearing Housing	Bearing Housing	2
3	1497K42	Drive Shaft	2
4	1013_Left Grating	Outer Grating	1
5	1014_Right Grating	Right Grating	1
6	1015_Center Left Grating	Center Right Grating	1
7	1016_Center Right Grating	Center Right Grating	1
8	1019_Spool ASM	Spool ASM	2
9	1497K42	Drive Shaft-2	2
10	1022_Outer Cross Brace	Outer Cross Brace	17
11	1023_Inner Cross Brace	Inner Cross Brace	8
12	1024_Outer Belt	Outer Belt	2
13	1025_Inner Belt	Inner Belt	1
14	1027_Platfrom Rail-Rollers L	Platform Rail-Rollers L	1
15	1028_Platfrom Rail-Rollers R	Platform Rail-Rollers R	1
16	1030_Rail Risers	Rail Risers	8
17	1031_Steel Roller	Belt Powered Roller	2
18	1032_Bumper-1	Bumper-1	4
19	1033_Bumper-2	Outer Cross Brace	2
20	1034_Steel Roller Center	Steel Roller Center	1
21	1035_Bumper-3	Bumper-3	6
22	1036_Cross Shaft Support	Cross Shaft Support	1
23	1497K42	Sheave Shaft	2
24	14895A41	Handles	2
25	6384K65	Drive Shaft Bearings	2
26	3099T34	Cable Pulley	2
27	3845179_WELD ON HUB PA	3/4 in. Bore W-Series Weld-On Hub	6
28	6338K575	Olite Bushings	4
29	6494K38	Mounted Ball Bearing With Two-Bolt Flange	4

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
30	6204K272	5" OD 5/8" Bore Pulley	4
31	6204K133	2.5" OD 5/8" Bore Pulley	4
32	1029_VBelt	A19 V-Belt	4
33	1039_Cable	Cable	2

Vehicle Lift Design

ORV Solutions

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: MACH ±0° 30'
TWO PLACE DECIMAL ±.01
THREE PLACE DECIMAL ±.002

INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5M-1994
DO NOT SCALE DRAWING
MATERIAL
FINISH

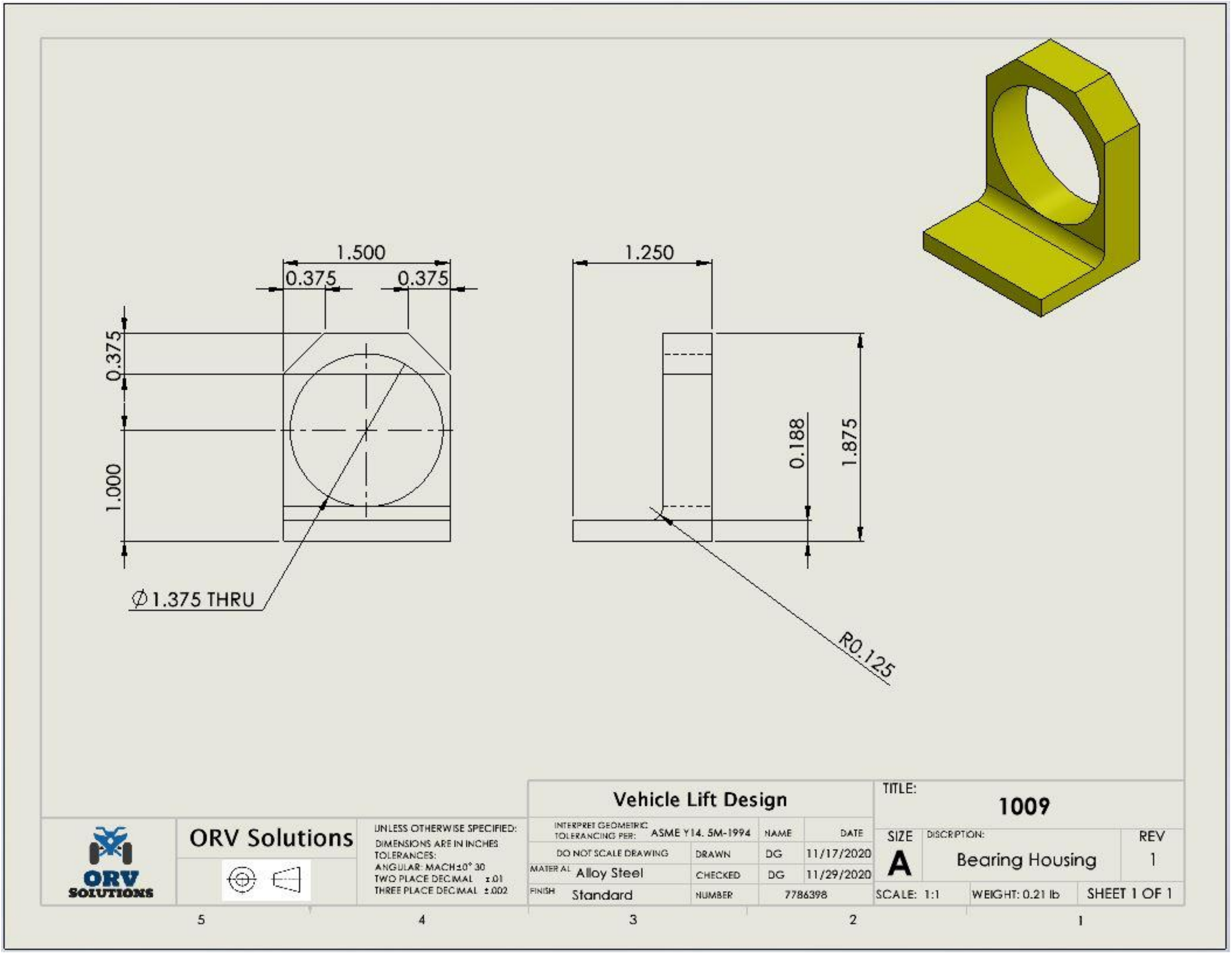
	NAME	DATE
DRAWN	DG	11/19/2020
CHECKED	DG	11/29/2020
NUMBER	7786398	

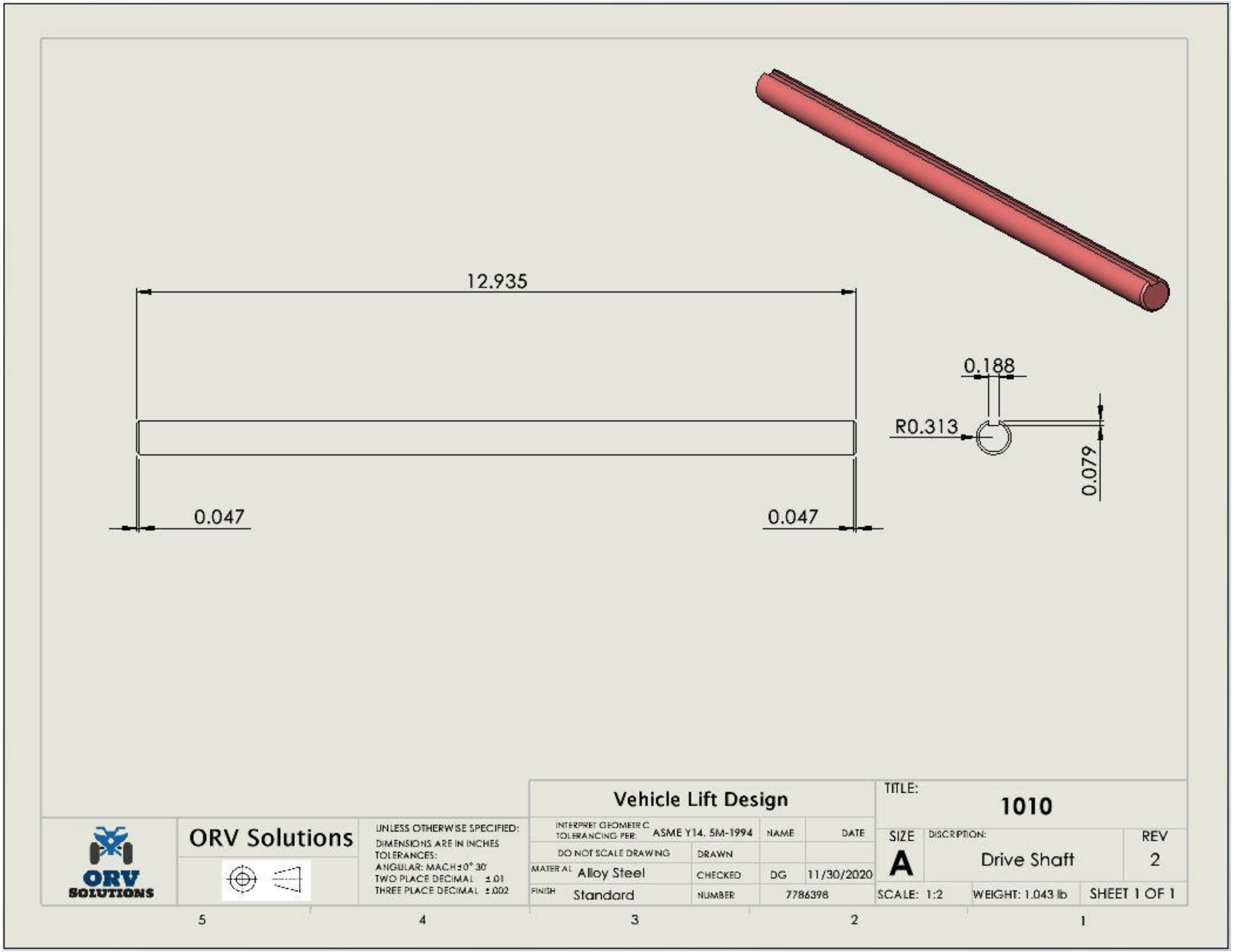
TITLE: **1011**

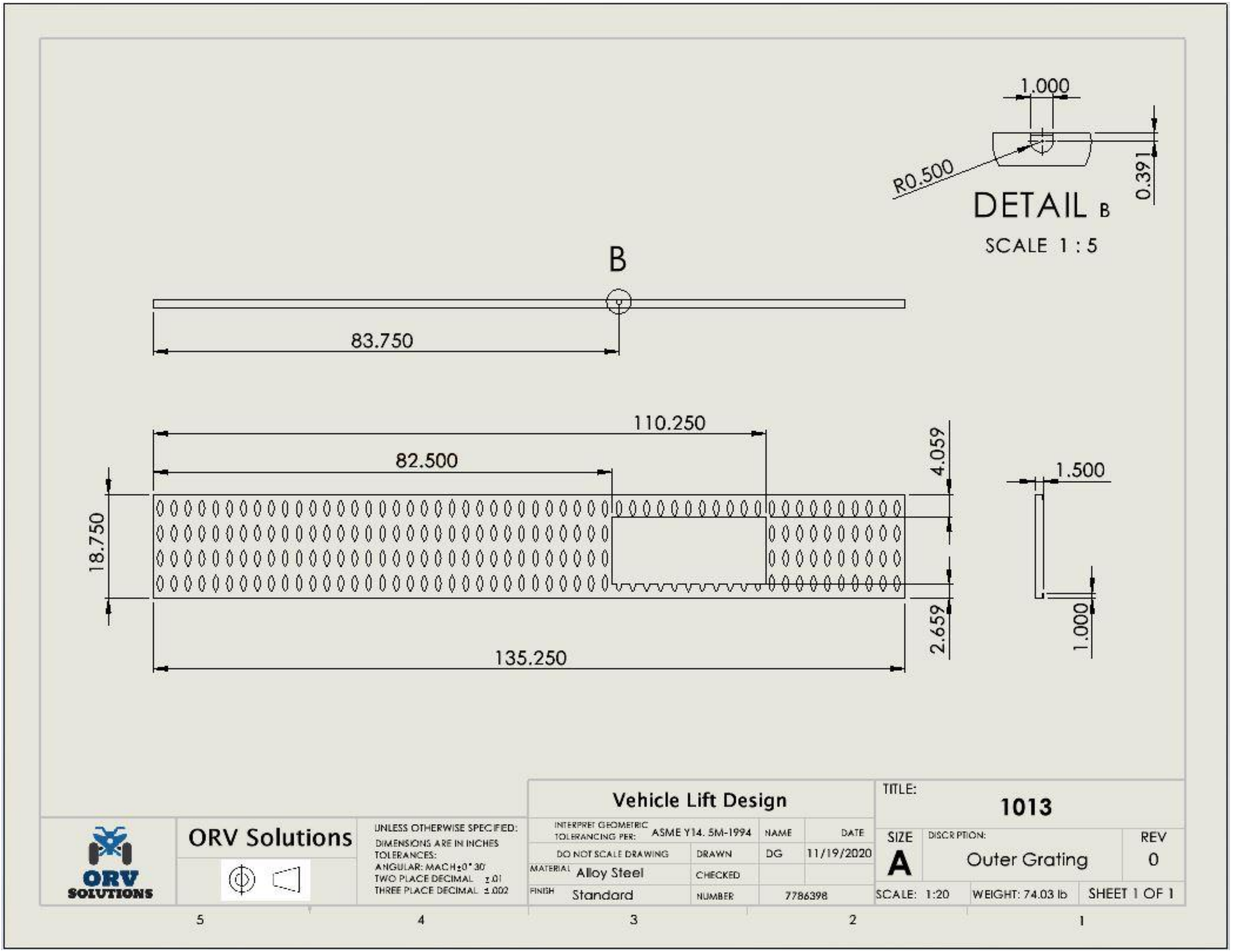
SIZE: A
DESCRIPTION: Platform ASM
REV: 3

SCALE: 1:16 WEIGHT: 322.68 lb SHEET 2 OF 2

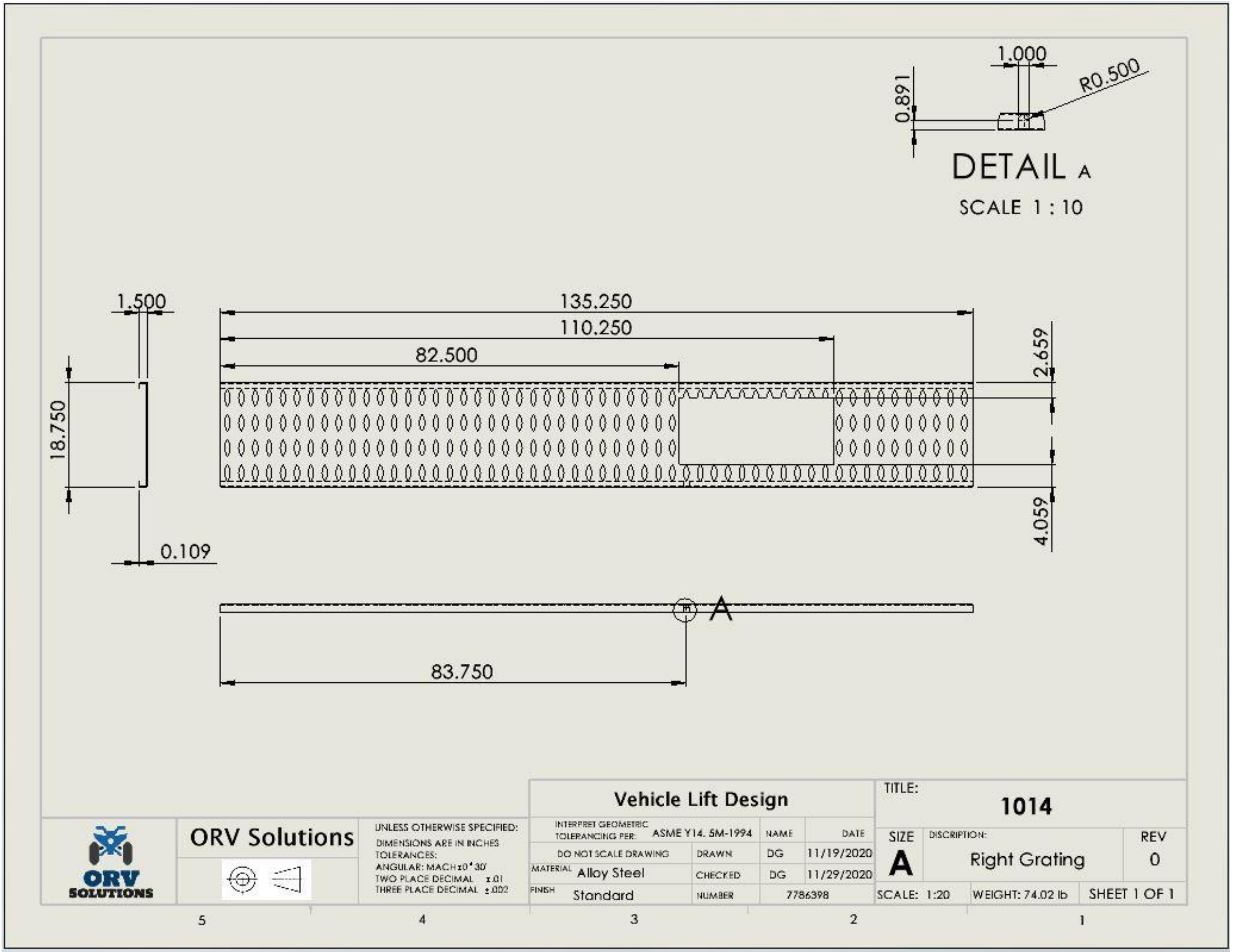
5 4 3 2 1


1.500
0.375
0.375
0.375
1.000
Ø1.375 THRU
1.250
0.188
1.875
R0.125
Vehicle Lift Design
TITLE:
1009
ORV SOLUTIONS
ORV Solutions
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: MACH±0° 30
TWO PLACE DECIMAL ±.01
THREE PLACE DECIMAL ±.002
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14. 5M-1994
NAME
DATE
DO NOT SCALE DRAWING
DRAWN DG 11/17/2020
MATERIAL Alloy Steel
CHECKED DG 11/29/2020
FINISH Standard
NUMBER 7786398
SIZE
A
DISCRIPTION:
Bearing Housing
REV
1
SCALE: 1:1
WEIGHT: 0.21 lb
SHEET 1 OF 1
5
4
3
2
1

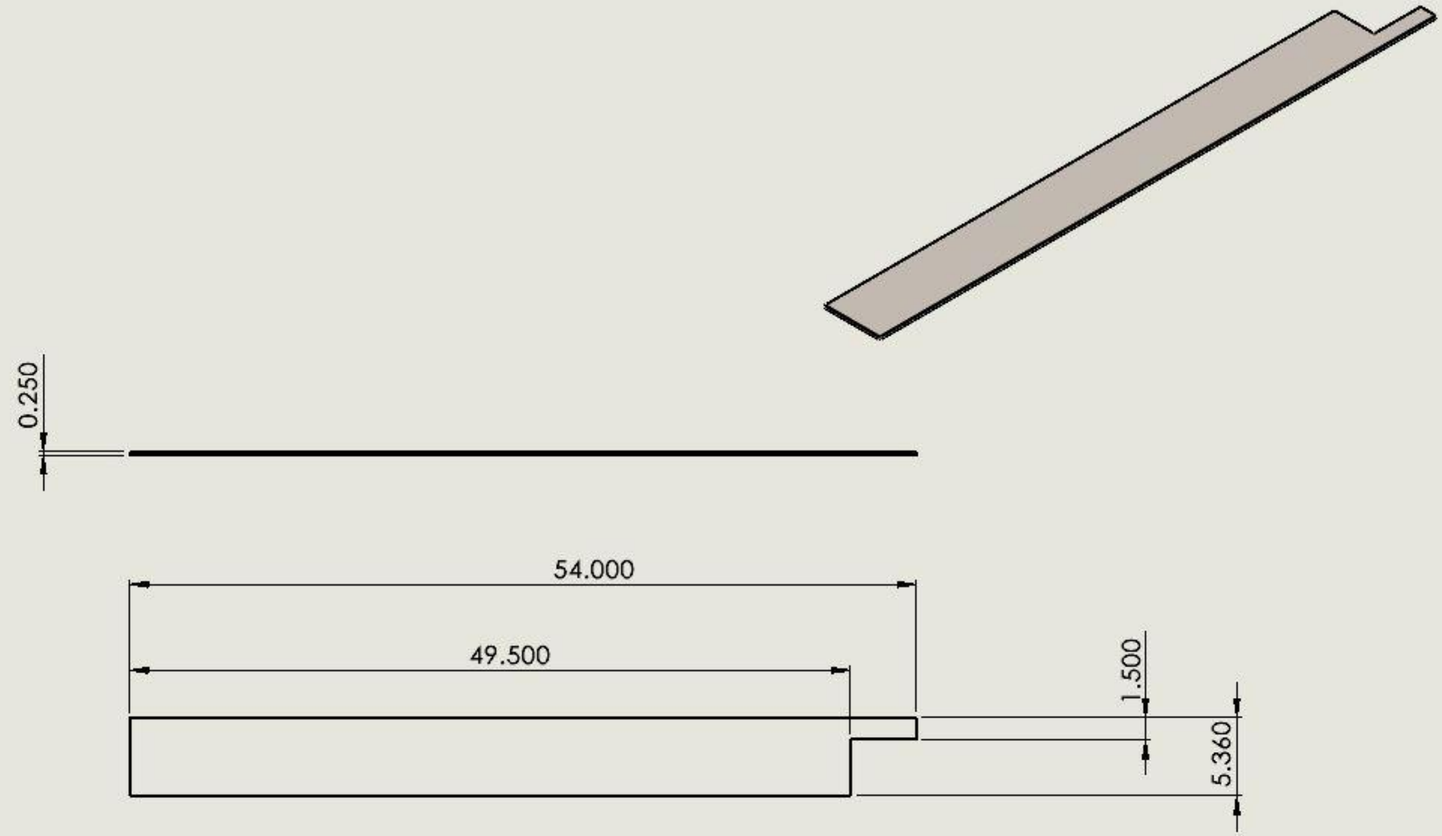

12.935
0.188
R0.313
0.079
0.047
0.047
Vehicle Lift Design
TITLE:
1010
ORV Solutions
ORV SOLUTIONS
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: MACH±0° 30'
TWO PLACE DECIMAL ±.01
THREE PLACE DECIMAL ±.002
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14. 5M-1994
NAME
DATE
DO NOT SCALE DRAWING
DRAWN
MATERIAL Alloy Steel
CHECKED DG 11/30/2020
FINISH Standard
NUMBER 7786398
SIZE A
DISCRIPTION: Drive Shaft
REV 2
SCALE: 1:2
WEIGHT: 1.043 lb
SHEET 1 OF 1
5
4
3
2
1



1.000
R0.500
0.391
DETAIL B
SCALE 1 : 5
B
83.750
110.250
82.500
4.059
1.500
18.750
2.659
1.000
135.250
Vehicle Lift Design
TITLE:
1013
ORV Solutions
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: MACH±0°30'
TWO PLACE DECIMAL ±.01
THREE PLACE DECIMAL ±.002
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5M-1994
NAME
DATE
DO NOT SCALE DRAWING
DRAWN DG 11/19/2020
MATERIAL Alloy Steel
CHECKED
FINISH Standard
NUMBER 7786398
SIZE A
DESCRIPTION: Outer Grating
REV 0
SCALE: 1:20
WEIGHT: 74.03 lb
SHEET 1 OF 1
5
4
3
2
1

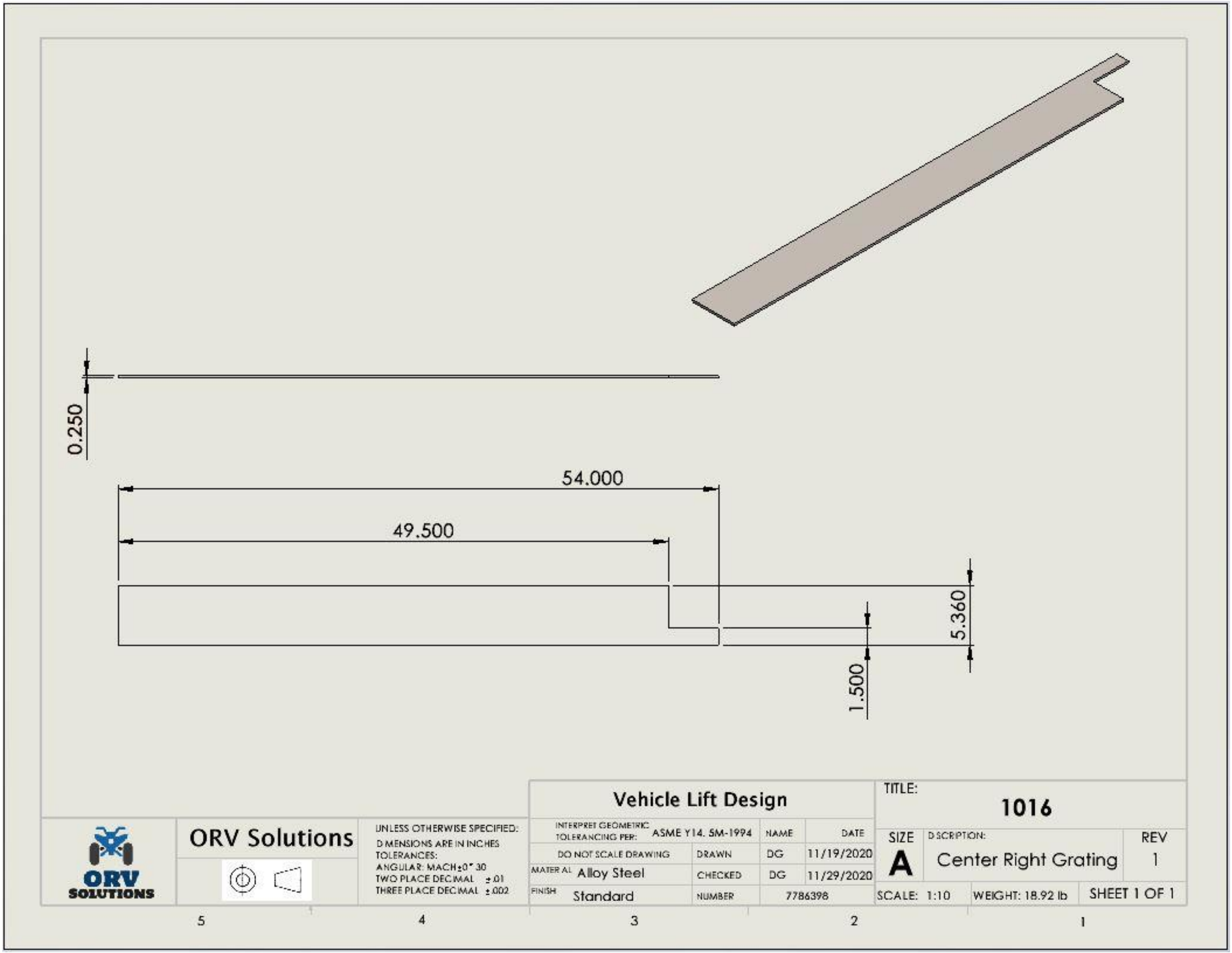


1.000
R0.500
0.891
DETAIL A
SCALE 1 : 10
1.500
135.250
110.250
82.500
2.659
18.750
4.059
0.109
A
83.750
Vehicle Lift Design
TITLE:
1014
ORV Solutions
ORV SOLUTIONS
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: MACH±0°30'
TWO PLACE DECIMAL ±.01
THREE PLACE DECIMAL ±.002
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14. 5M-1994
NAME
DATE
DO NOT SCALE DRAWING
DRAWN DG 11/19/2020
MATERIAL Alloy Steel
CHECKED DG 11/29/2020
FINISH Standard
NUMBER 7786398
SIZE A
DISCRIPTION:
Right Grating
REV 0
SCALE: 1:20
WEIGHT: 74.02 lb
SHEET 1 OF 1
5
4
3
2
1

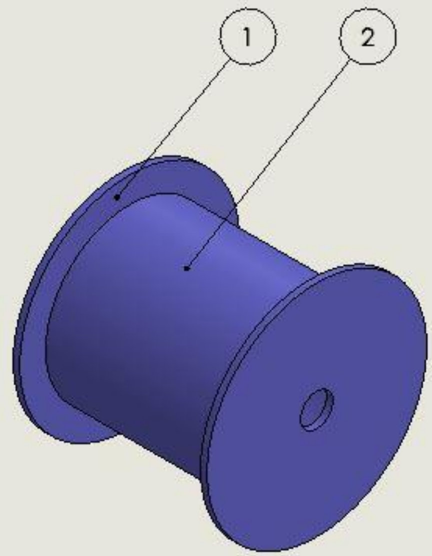


ORV SOLUTIONS	ORV Solutions	UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES TOLERANCES: ANGULAR: MACH ±0° 30' TWO PLACE DECIMAL ±.01 THREE PLACE DECIMAL ±.002	Vehicle Lift Design		TITLE: 1015
			INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14. 5M-1994	NAME / DATE	SIZE A — DESCRIPTION: Center Right Grating — REV 1
			DO NOT SCALE DRAWING	DRAWN DG 11/19/2020	
			MATERIAL Alloy Steel	CHECKED DG 11/29/2020	
			FINISH Standard	NUMBER 7786398	SCALE: 1:10 — WEIGHT: 18.92 lb — SHEET 1 OF 1

5 4 3 2 1

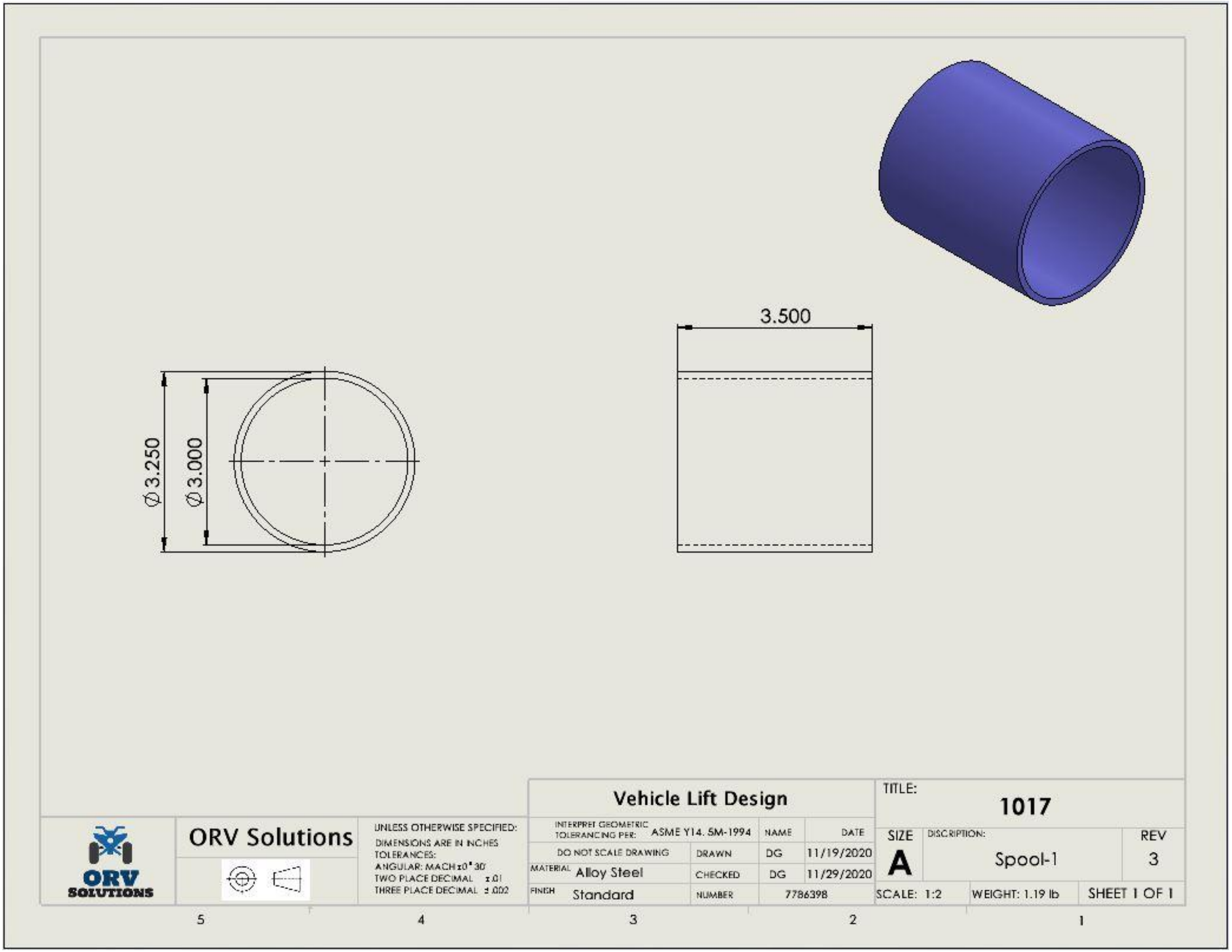

0.250
54.000
49.500
5.360
1.500
ORV SOLUTIONS
ORV Solutions
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: MACH±0° 30
TWO PLACE DECIMAL ±.01
THREE PLACE DECIMAL ±.002
Vehicle Lift Design
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14. 5M-1994
NAME
DATE
DO NOT SCALE DRAWING
DRAWN DG 11/19/2020
MATERIAL Alloy Steel
CHECKED DG 11/29/2020
FINISH Standard
NUMBER 7786398
TITLE:
1016
SIZE A
DESCRIPTION: Center Right Grating
REV 1
SCALE: 1:10
WEIGHT: 18.92 lb
SHEET 1 OF 1
5
4
3
2
1

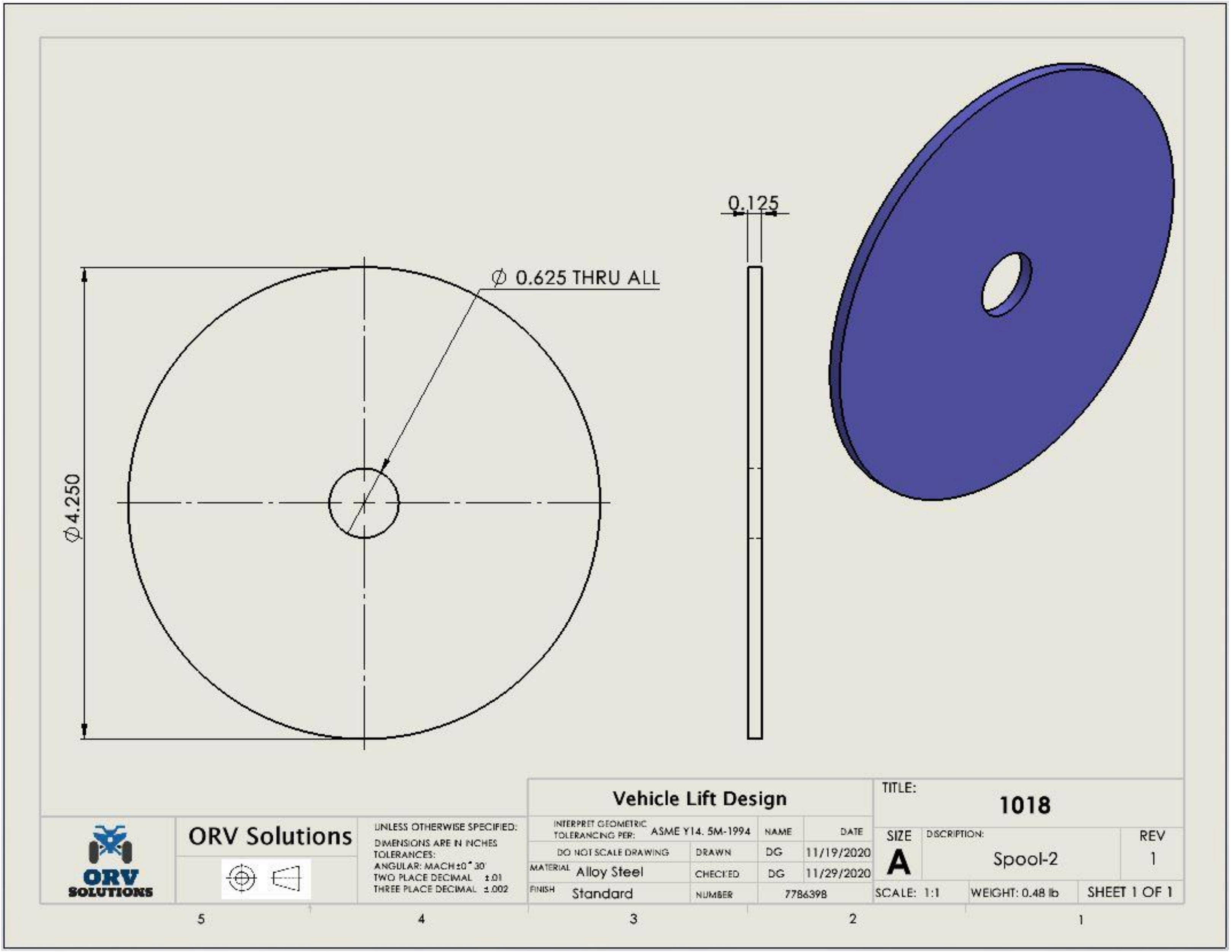
ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	1018_Spool-2	Spool-2	2
2	1017_Spool-1	Spool-1	1

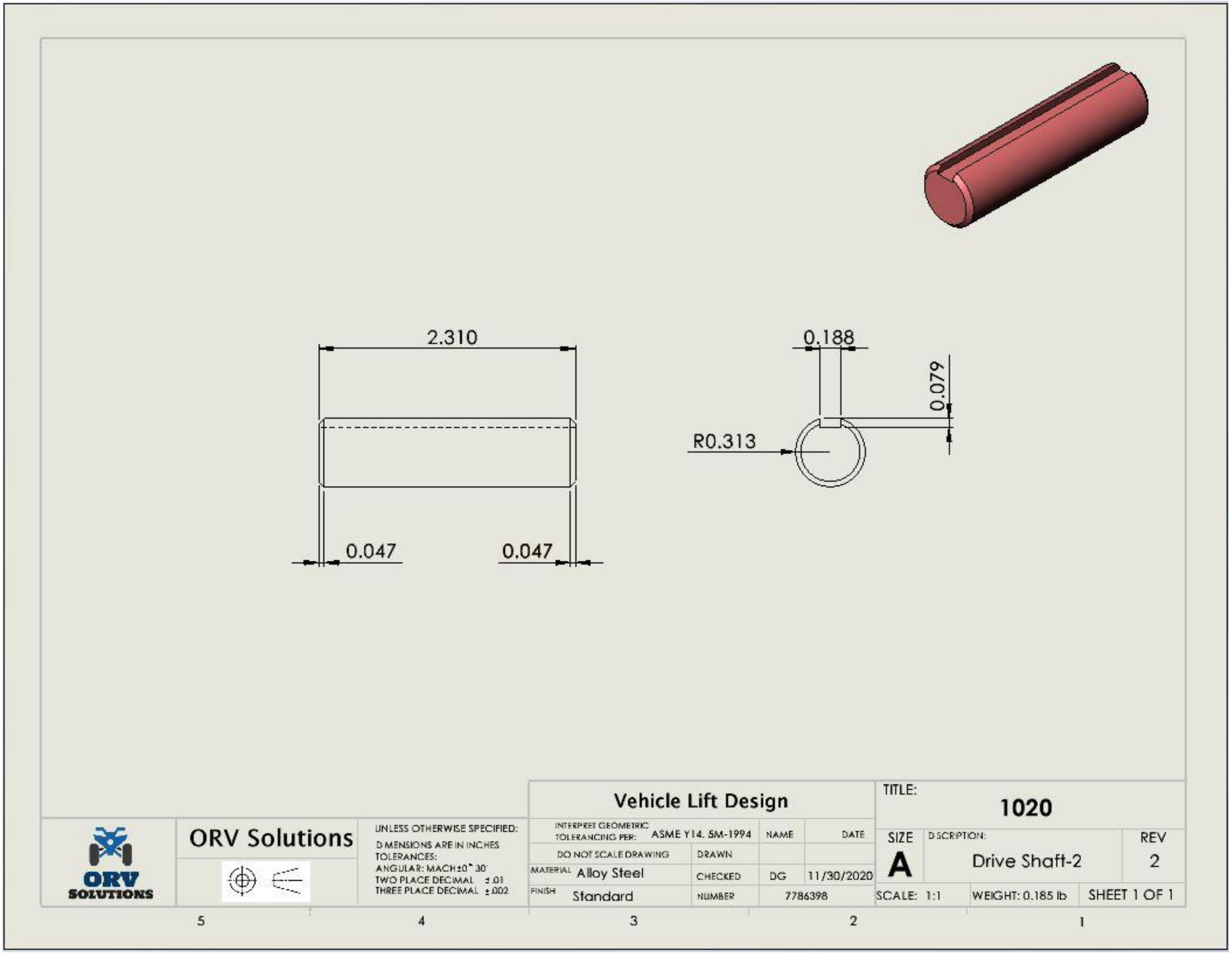


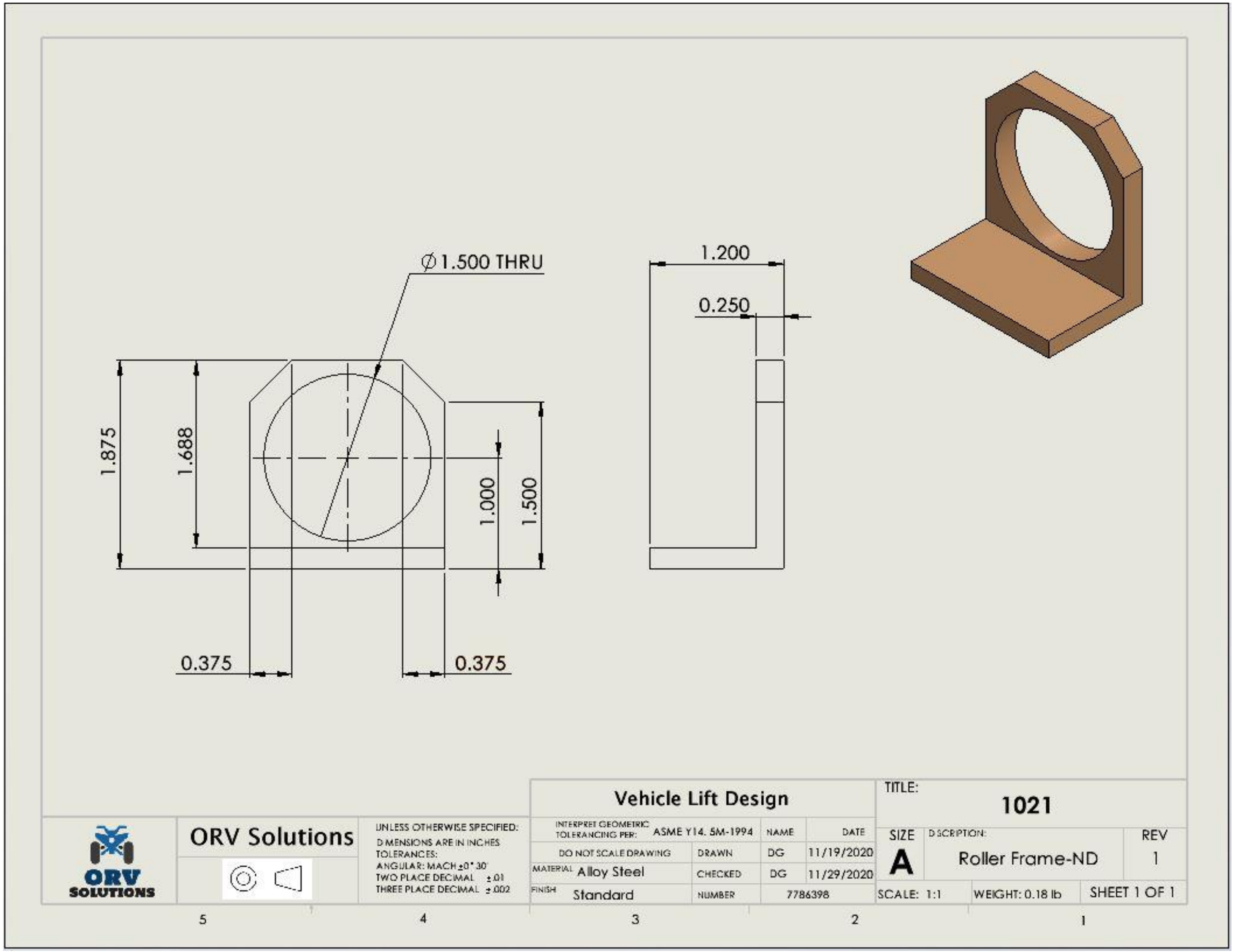
ORV SOLUTIONS	ORV Solutions	UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES TOLERANCES: ANGULAR: MACH ±0° 30' TWO PLACE DECIMAL ±.01 THREE PLACE DECIMAL ±.002	Vehicle Lift Design		TITLE: 1019
			INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14. 5M-1994	NAME / DATE	SIZE A — DISCRIPTION: Spool ASM — REV 0
			DO NOT SCALE DRAWING	DRAWN DG 11/17/2020	
			MATERIAL	CHECKED DG 11/29/2020	
			FINISH	NUMBER 7786398	SCALE: 1:2 — WEIGHT: 2.16 lb — SHEET 1 OF 1

5 4 3 2 1

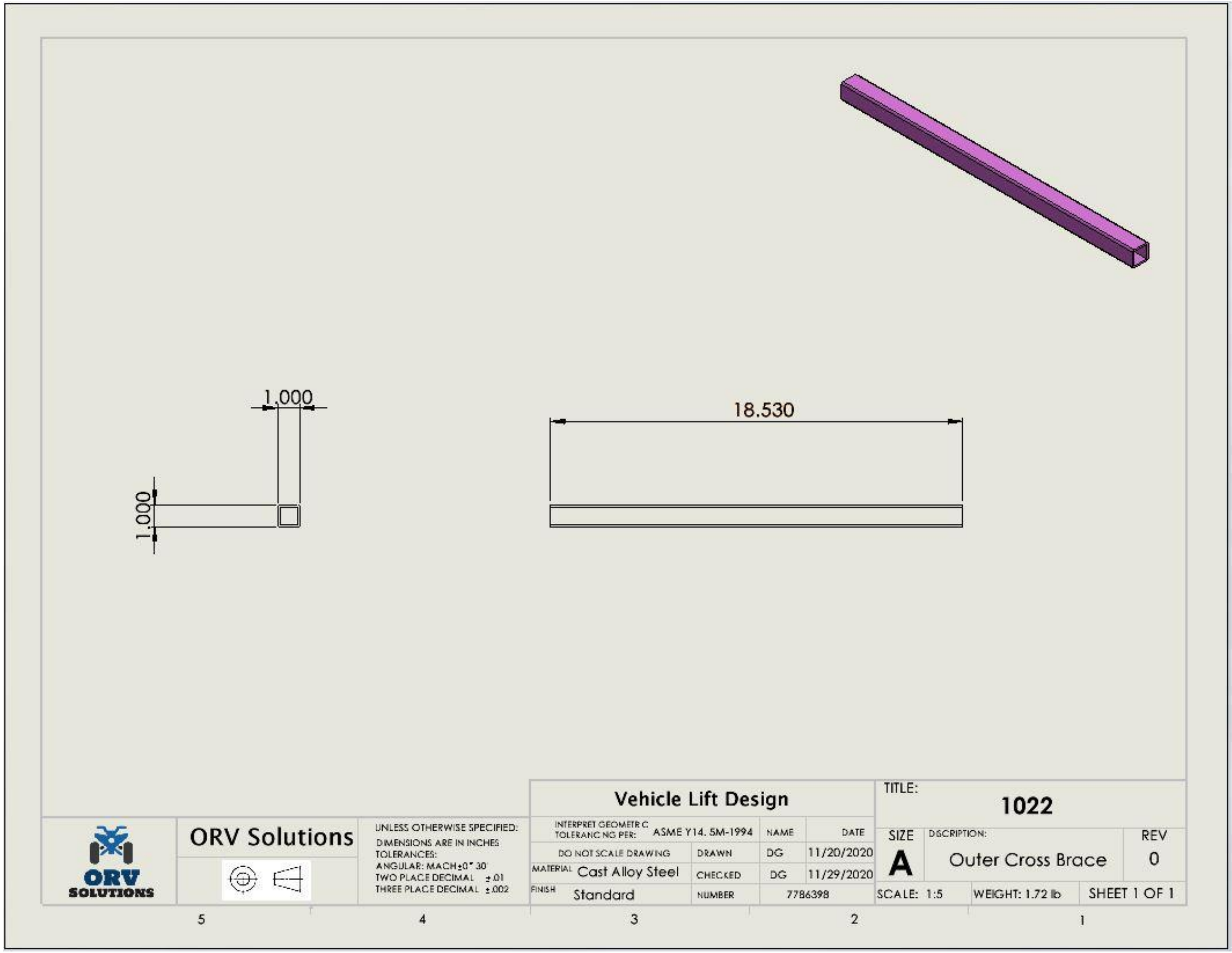

3.500
Ø3.250
Ø3.000
Vehicle Lift Design
ORV Solutions
ORV SOLUTIONS
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: MACH ±0° 30'
TWO PLACE DECIMAL ±.01
THREE PLACE DECIMAL ±.002
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14. 5M-1994
NAME
DATE
DO NOT SCALE DRAWING
DRAWN DG 11/19/2020
MATERIAL Alloy Steel
CHECKED DG 11/29/2020
FINISH Standard
NUMBER 7786398
TITLE:
1017
SIZE
A
DISCRIPTION:
Spool-1
REV
3
SCALE: 1:2
WEIGHT: 1.19 lb
SHEET 1 OF 1
5
4
3
2
1


0.125
⌀ 0.625 THRU ALL
⌀4.250
Vehicle Lift Design
TITLE:
1018
ORV SOLUTIONS
ORV Solutions
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: MACH±0°30'
TWO PLACE DECIMAL ±.01
THREE PLACE DECIMAL ±.002
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5M-1994
NAME
DATE
DO NOT SCALE DRAWING
DRAWN DG 11/19/2020
MATERIAL Alloy Steel
CHECKED DG 11/29/2020
FINISH Standard
NUMBER 7786398
SIZE A
DESCRIPTION: Spool-2
REV 1
SCALE: 1:1
WEIGHT: 0.48 lb
SHEET 1 OF 1
5 4 3 2 1


2.310
0.047
0.047
0.188
0.079
R0.313
Vehicle Lift Design
TITLE:
1020
ORV Solutions
ORV SOLUTIONS
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: MACH±0° 30'
TWO PLACE DECIMAL ±.01
THREE PLACE DECIMAL ±.002
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14. 5M-1994
NAME
DATE
DO NOT SCALE DRAWING
DRAWN
MATERIAL Alloy Steel
CHECKED DG 11/30/2020
FINISH Standard
NUMBER 7786398
SIZE
A
DESCRIPTION:
Drive Shaft-2
REV
2
SCALE: 1:1
WEIGHT: 0.185 lb
SHEET 1 OF 1
5
4
3
2
1



∅1.500 THRU
1.875
1.688
1.000
1.500
0.375
0.375
1.200
0.250
Vehicle Lift Design
TITLE:
1021
ORV Solutions
ORV SOLUTIONS
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: MACH ±0° 30'
TWO PLACE DECIMAL ±.01
THREE PLACE DECIMAL ±.002
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14. 5M-1994
NAME
DATE
DO NOT SCALE DRAWING
DRAWN DG 11/19/2020
MATERIAL Alloy Steel
CHECKED DG 11/29/2020
FINISH Standard
NUMBER 7786398
SIZE A
DESCRIPTION: Roller Frame-ND
REV 1
SCALE: 1:1
WEIGHT: 0.18 lb
SHEET 1 OF 1
5
4
3
2
1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THREE PLACE DECIMAL ±.002
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14. 5M-1994
NAME
DATE
DO NOT SCALE DRAWING
DRAWN DG 11/20/2020
MATERIAL Cast Alloy Steel
CHECKED DG 11/29/2020
FINISH Standard
NUMBER 7786398
SIZE A
DESCRIPTION: Outer Cross Brace
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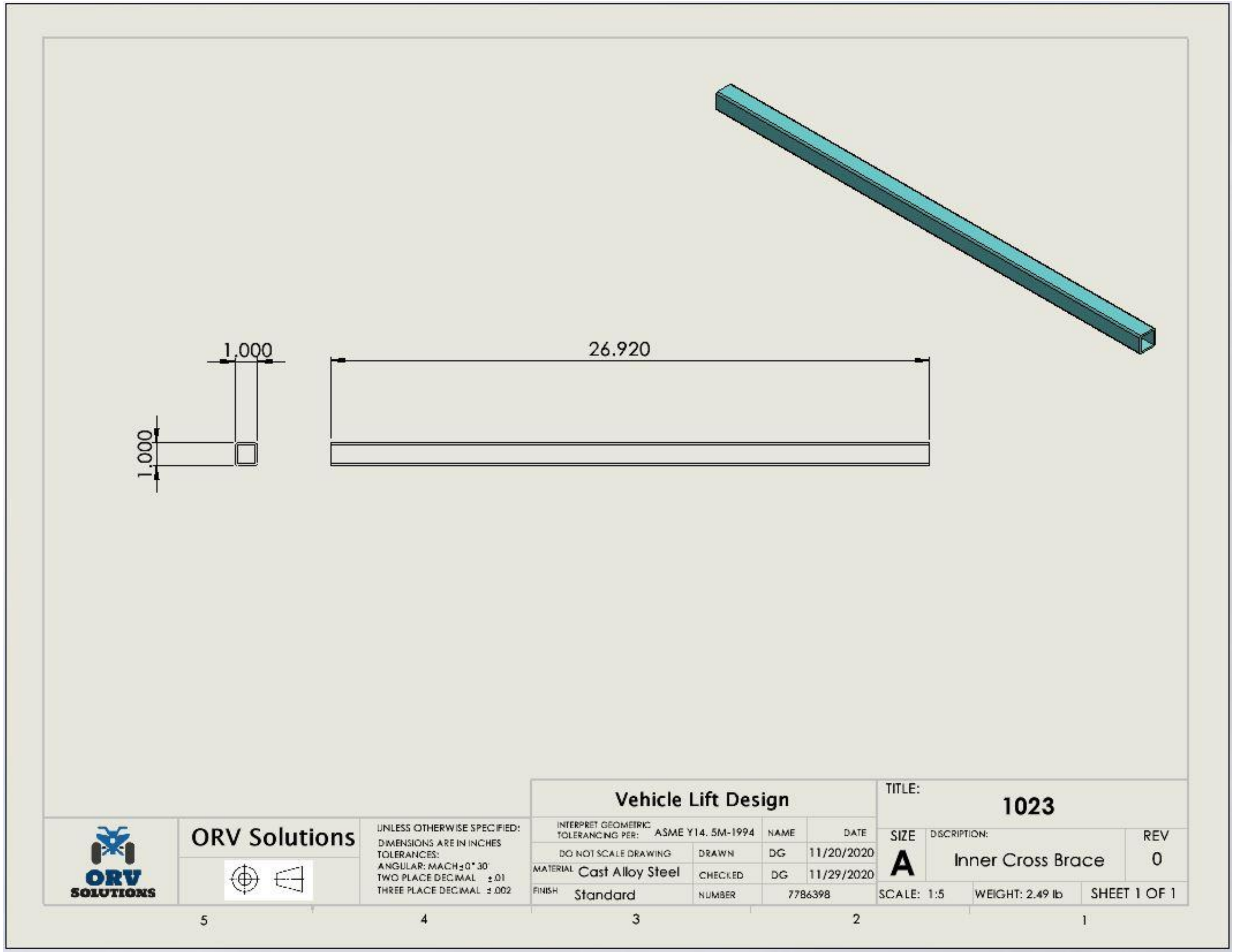
SCALE: 1:5
WEIGHT: 1.72 lb
SHEET 1 OF 1
ORV SOLUTIONS
5
4
3
2
1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ORV Solutions
ORV SOLUTIONS
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TOLERANCES:
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NAME
DATE
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MATERIAL Cast Alloy Steel
CHECKED DG 11/29/2020
FINISH Standard
NUMBER 7786398
SIZE
A
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REV
0
SCALE: 1:5
WEIGHT: 2.49 lb
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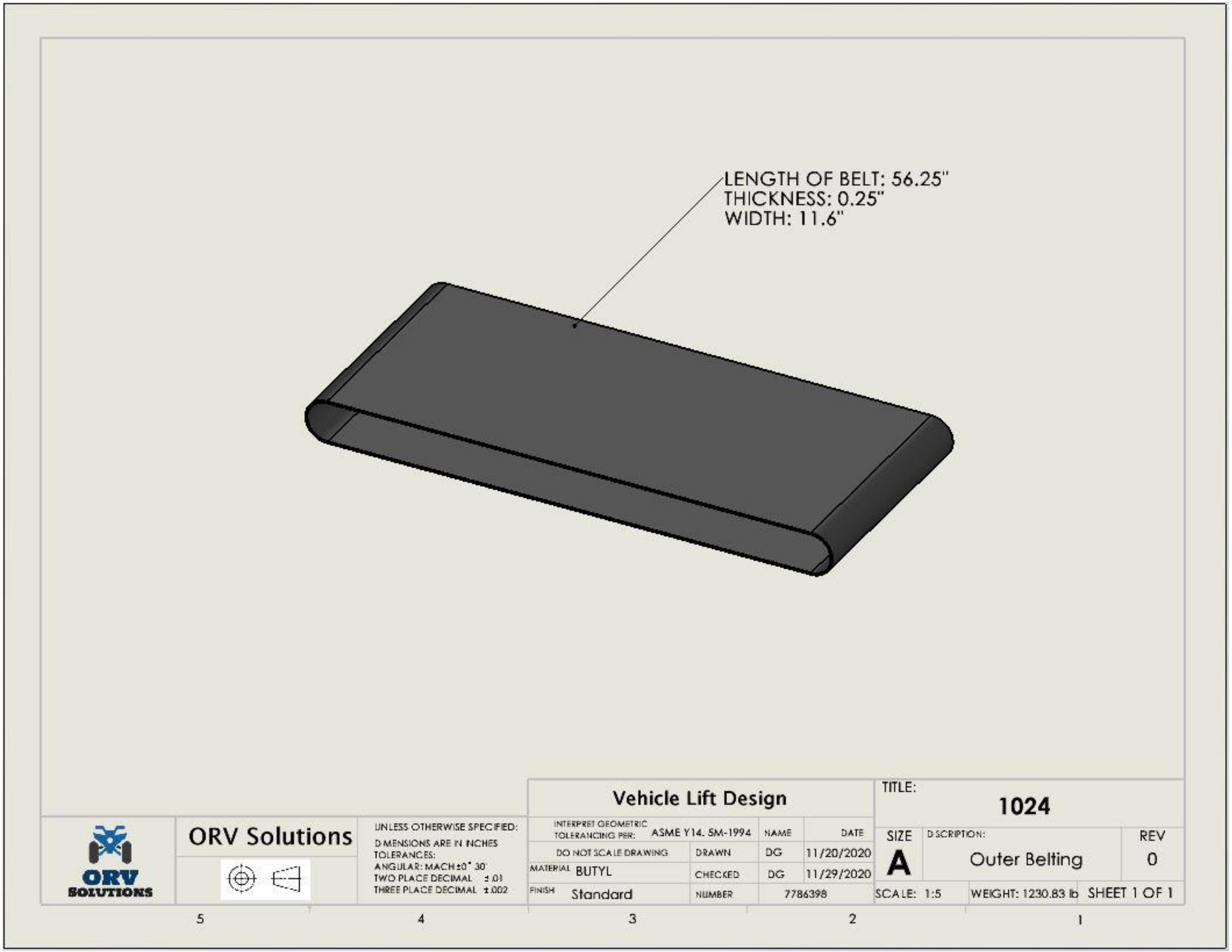
5
4
3
2
1



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WIDTH: 11.6"
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ORV Solutions
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TWO PLACE DECIMAL ±.01
THREE PLACE DECIMAL ±.002
Vehicle Lift Design
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5M-1994
NAME
DATE
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MATERIAL BUTYL
CHECKED DG 11/29/2020
FINISH Standard
NUMBER 7786398
TITLE:
1024
SIZE
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DESCRIPTION:
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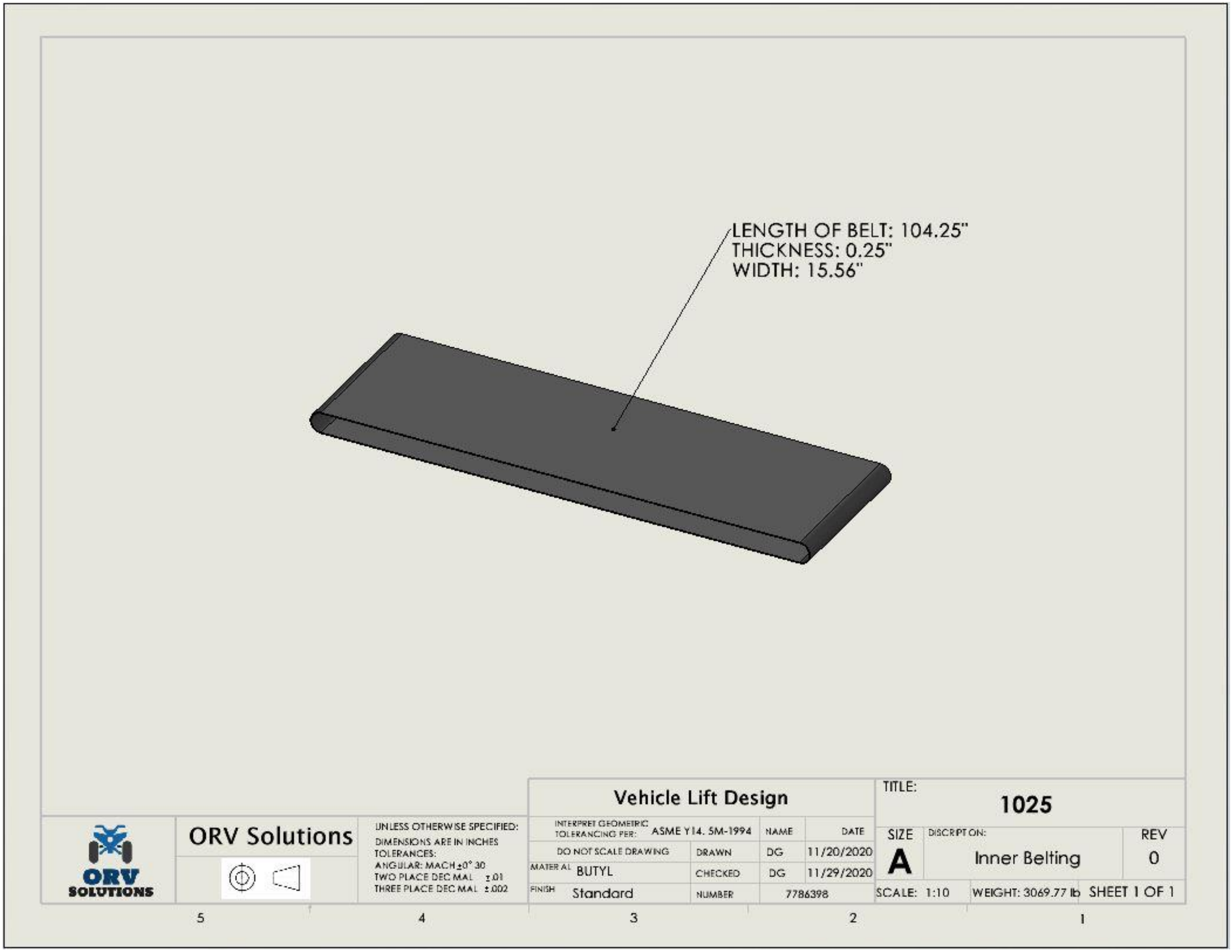
SCALE: 1:5
WEIGHT: 1230.83 lb
SHEET 1 OF 1
5
4
3
2
1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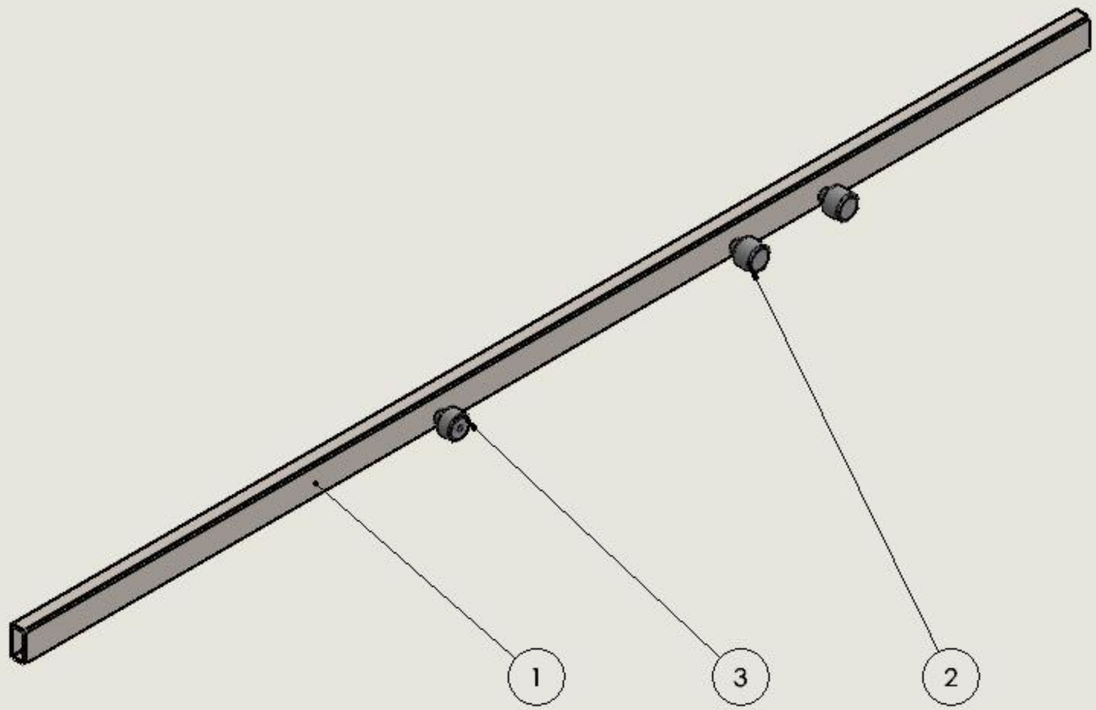
ANGULAR: MACH ±0° 30
TWO PLACE DECIMAL ±.01
THREE PLACE DECIMAL ±.002
Vehicle Lift Design
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14. 5M-1994
NAME
DATE
DO NOT SCALE DRAWING
DRAWN DG 11/20/2020
MATERIAL BUTYL
CHECKED DG 11/29/2020
FINISH Standard
NUMBER 7786398
TITLE:
1025
SIZE
A
DISCRIPTION:
Inner Belting
REV
0
SCALE: 1:10
WEIGHT: 3069.77 lb
SHEET 1 OF 1
5
4
3
2
1

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	1026_Platform Rails	Platform Rails	1
2	4725K33	Rollers	2
3	6721K9	Rollers	1



ORV SOLUTIONS

ORV Solutions

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: MACH±0° 30'
TWO PLACE DECIMAL ±.01
THREE PLACE DECIMAL ±.002

Vehicle Lift Design

INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14. 5M-1994	NAME	DATE
DO NOT SCALE DRAWING DRAWN	DG	11/22/2020
MATERIAL CHECKED	DG	11/29/2020
FINISH NUMBER	7786398	

TITLE: **1027**

SIZE	DESCRIPTION:	REV
A	Platform Rail-Rollers L	1

SCALE: 1:7 WEIGHT: 6031.30 lb SHEET 1 OF 1

5 4 3 2 1

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
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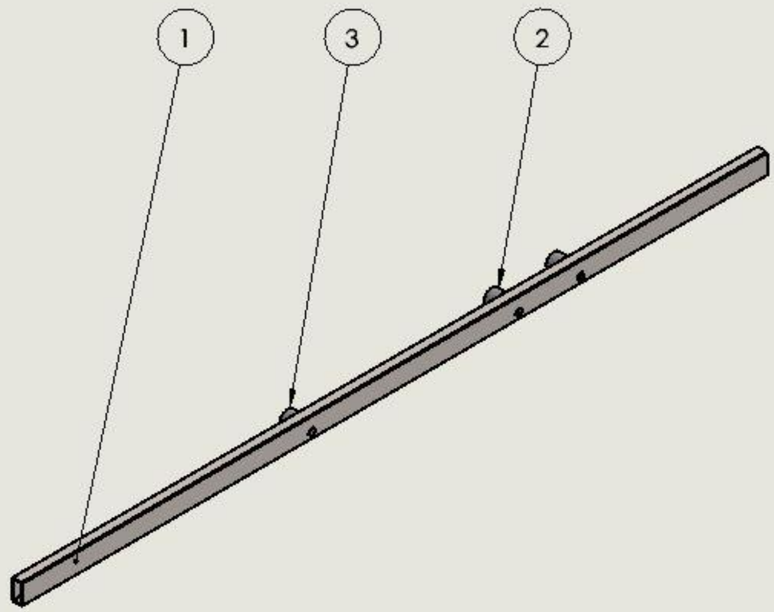
2	6318K69	Rollers	2
3	6721K9	Rollers	1



ORV SOLUTIONS

ORV Solutions

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: MACH ±0° 30'
TWO PLACE DECIMAL ±.01
THREE PLACE DECIMAL ±.002

Vehicle Lift Design

INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14. 5M-1994

DO NOT SCALE DRAWING

MATERIAL

FINISH

	NAME	DATE
DRAWN	DG	11/22/2020
CHECKED	DG	11/29/2020
NUMBER	7786398	

TITLE: **1028**

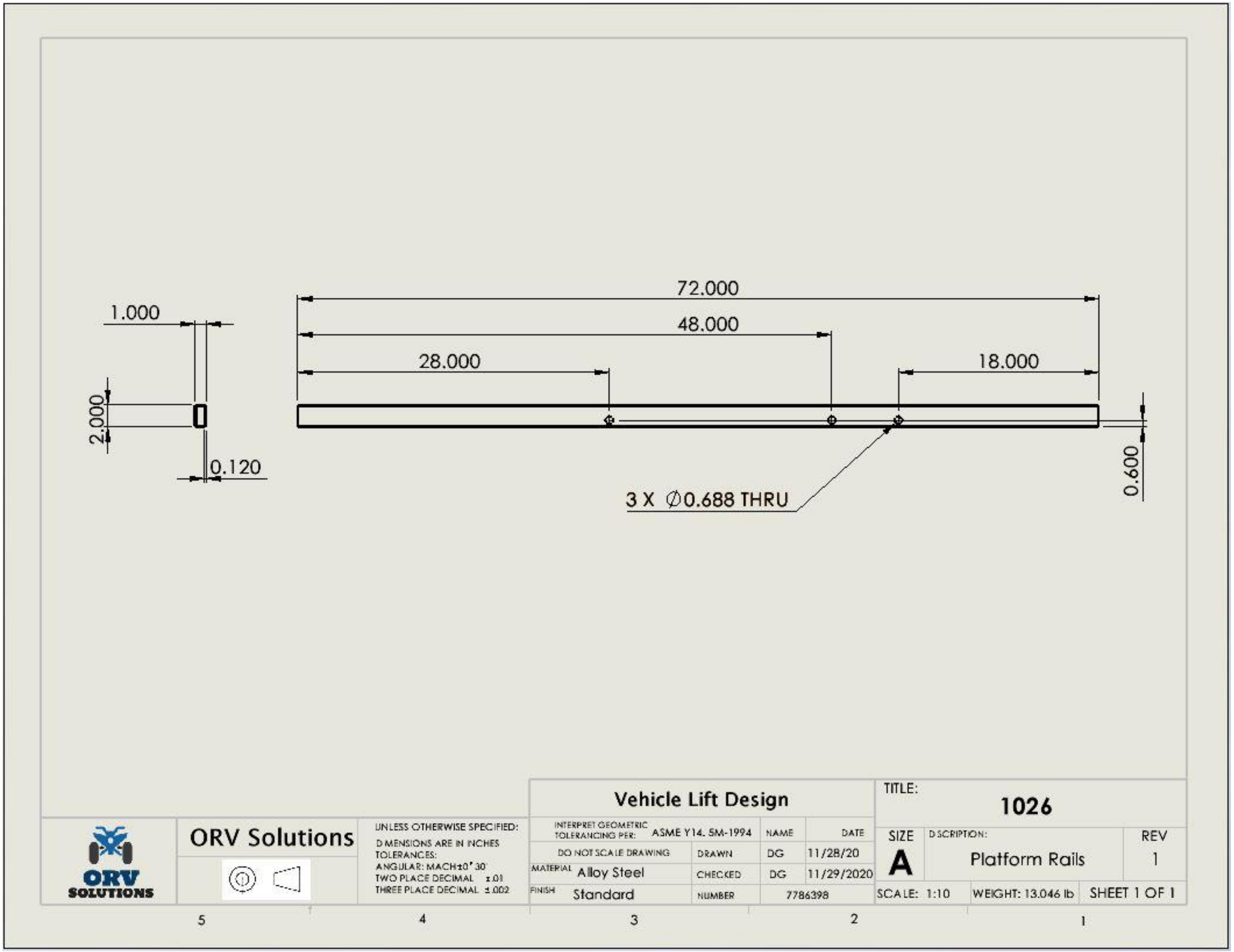
SIZE: A

DESCRIPTION: Platform Rail-Rollers R

REV: 1

SCALE: 1:10 WEIGHT: 6029.58 lb SHEET 1 OF 1

5 4 3 2 1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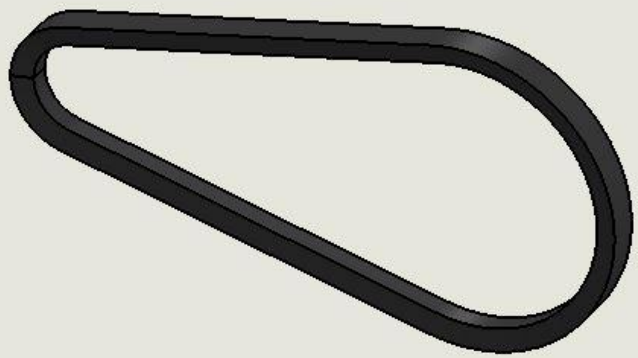
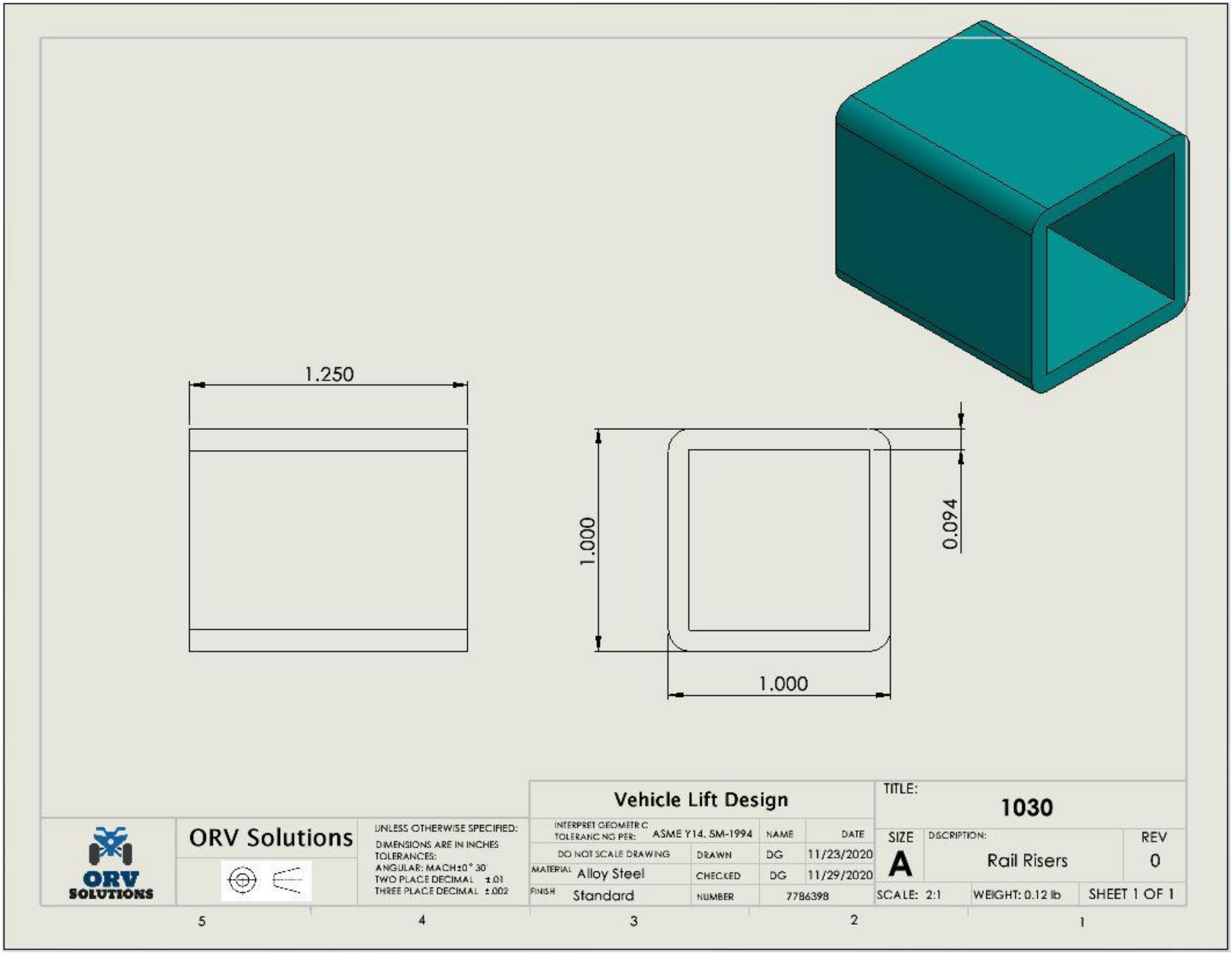
Vehicle Lift Design
TITLE:
1026
ORV SOLUTIONS
ORV Solutions
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: MACH±0° 30'
TWO PLACE DECIMAL ±.01
THREE PLACE DECIMAL ±.002
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14. 5M-1994
DO NOT SCALE DRAWING
MATERIAL Alloy Steel
FINISH Standard
NAME
DATE
DRAWN DG 11/28/20
CHECKED DG 11/29/2020
NUMBER 7786398
SIZE
A
DESCRIPTION:
Platform Rails
REV
1
SCALE: 1:10
WEIGHT: 13.046 lb
SHEET 1 OF 1
5
4
3
2
1



ORV SOLUTIONS	ORV Solutions	UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES TOLERANCES: ANGULAR: MACH±0° 30' TWO PLACE DECIMAL ±.01 THREE PLACE DECIMAL ±.002	Vehicle Lift Design			TITLE: 1029
			INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5M-1994	NAME	DATE	SIZE A
			DO NOT SCALE DRAWING	DRAWN DG	11/25/2020	DESCRIPTION: A19 V-Belt
			MATERIAL EPDM 60 Durometer	CHECKED DG	11/30/2020	REV 0
			FINISH Standard	NUMBER	7786398	SCALE: 1:2 WEIGHT: 55.32 lb SHEET 1 OF 1

5 4 3 2 1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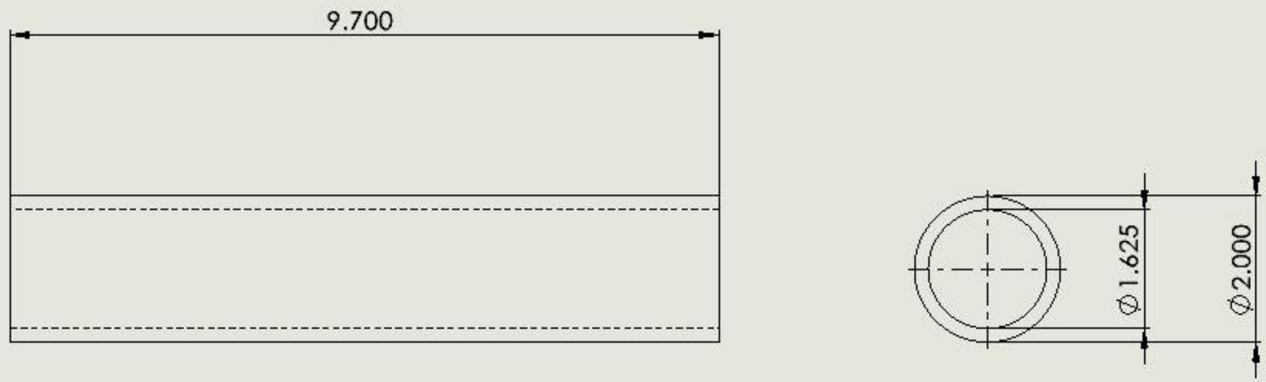
TWO PLACE DECIMAL ±.01
THREE PLACE DECIMAL ±.002
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14. 5M-1994
DO NOT SCALE DRAWING
MATERIAL Alloy Steel
FINISH Standard
NAME
DATE
DRAWN DG 11/23/2020
CHECKED DG 11/29/2020
NUMBER 7786398
SIZE A
DESCRIPTION: Rail Risers
REV 0
SCALE: 2:1
WEIGHT: 0.12 lb
SHEET 1 OF 1
5
4
3
2
1



Vehicle Lift Design

ORV SOLUTIONS

ORV Solutions

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: MACH±0° 30'
TWO PLACE DECIMAL ±.01
THREE PLACE DECIMAL ±.002

INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5M-1994

	NAME	DATE
DRAWN	DG	11/25/2020
CHECKED	DG	11/29/2020

DO NOT SCALE DRAWING

MATERIAL Alloy Steel

FINISH Standard

NUMBER 7786398

TITLE: 1031

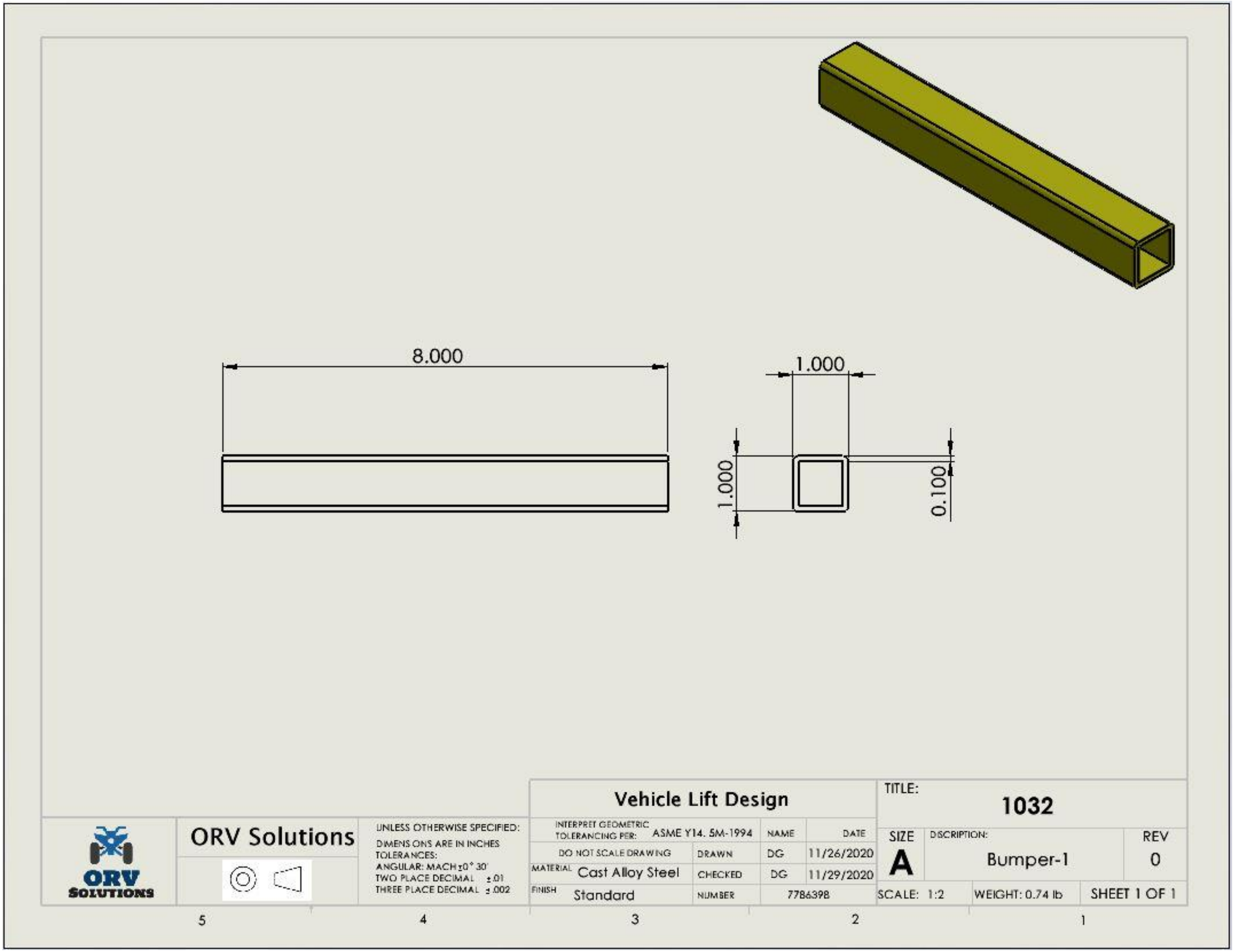
SIZE A

DISCRIPTION: Belt Powered Roller

REV 0

SCALE: 1:2 WEIGHT: 2.88 lb SHEET 1 OF 1

5 4 3 2 1



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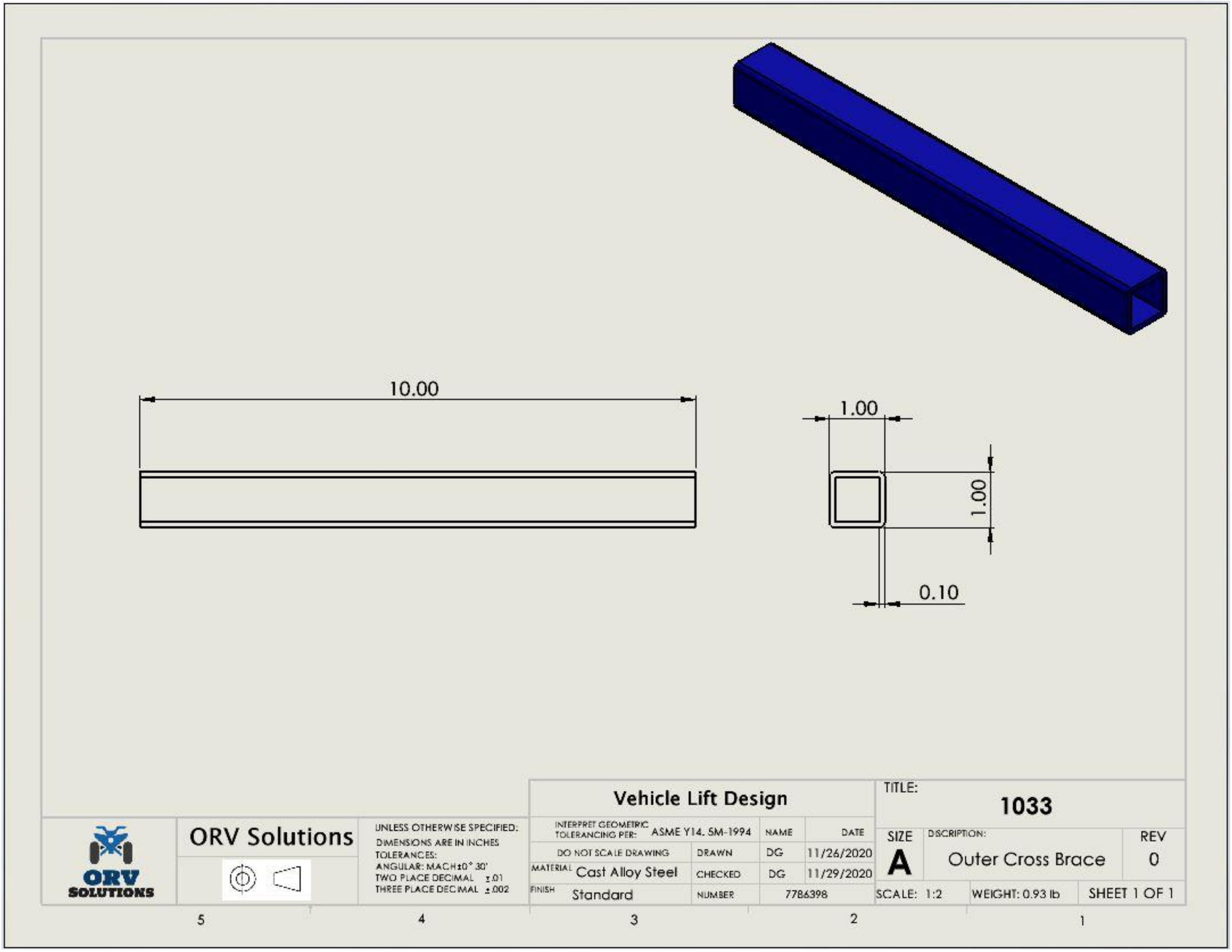
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: MACH ±0° 30'
TWO PLACE DECIMAL ±.01
THREE PLACE DECIMAL ±.002
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14. 5M-1994
NAME
DATE
DO NOT SCALE DRAWING
DRAWN DG 11/26/2020
MATERIAL Cast Alloy Steel
CHECKED DG 11/29/2020
FINISH Standard
NUMBER 7786398
SIZE A
DESCRIPTION: Bumper-1
REV 0
SCALE: 1:2
WEIGHT: 0.74 lb
SHEET 1 OF 1
5
4
3
2
1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ORV Solutions
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TOLERANCES:
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TWO PLACE DECIMAL ±.01
THREE PLACE DECIMAL ±.002
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14. 5M-1994
NAME
DATE
DO NOT SCALE DRAWING
DRAWN DG 11/26/2020
CHECKED DG 11/29/2020
MATERIAL Cast Alloy Steel
FINISH Standard
NUMBER 7786398
SIZE
A
DISCRIPTION:
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0
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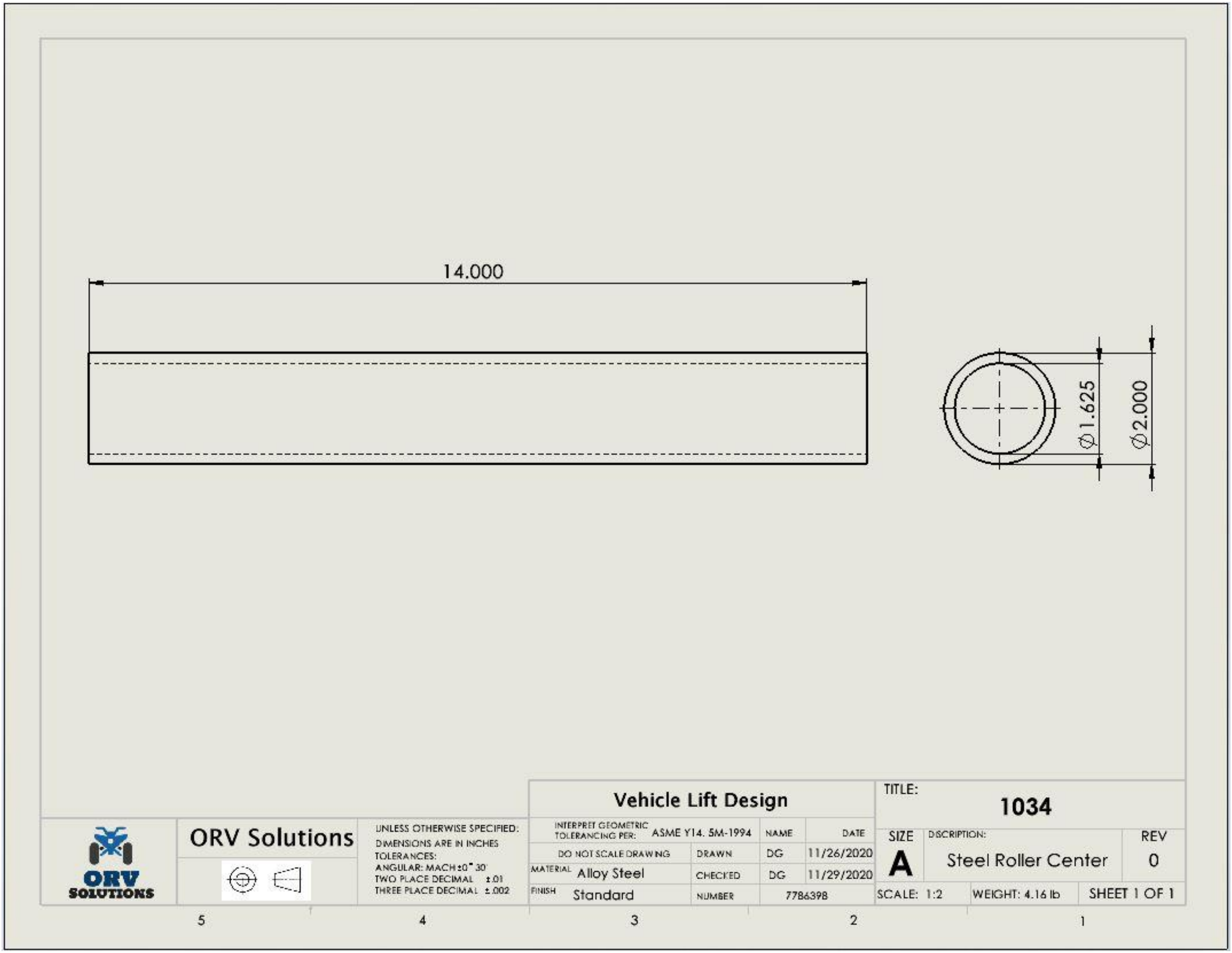
WEIGHT: 0.93 lb
SHEET 1 OF 1
5
4
3
2
1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ORV SOLUTIONS
ORV Solutions
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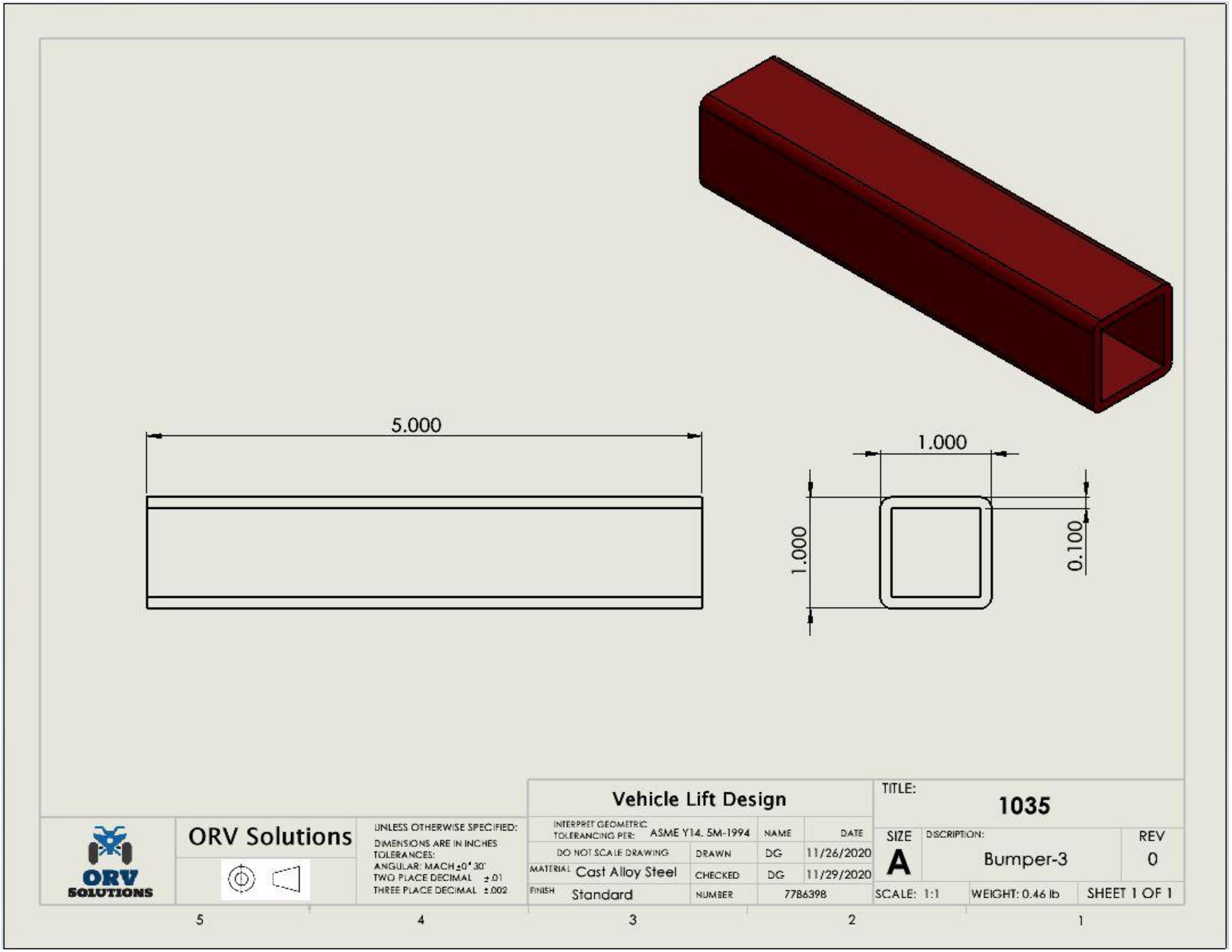
TWO PLACE DECIMAL ±.01
THREE PLACE DECIMAL ±.002
Vehicle Lift Design
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14. 5M-1994
NAME
DATE
DO NOT SCALE DRAWING
DRAWN DG 11/26/2020
MATERIAL Alloy Steel
CHECKED DG 11/29/2020
FINISH Standard
NUMBER 7786398
TITLE:
1034
SIZE
A
DESCRIPTION:
Steel Roller Center
REV
0
SCALE: 1:2
WEIGHT: 4.16 lb
SHEET 1 OF 1
5
4
3
2
1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ORV Solutions
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TOLERANCES:
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THREE PLACE DECIMAL ±.002
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14. 5M-1994
NAME
DATE
DO NOT SCALE DRAWING
DRAWN DG 11/26/2020
MATERIAL Cast Alloy Steel
CHECKED DG 11/29/2020
FINISH Standard
NUMBER 7786398
SIZE
A
DESCRIPTION:
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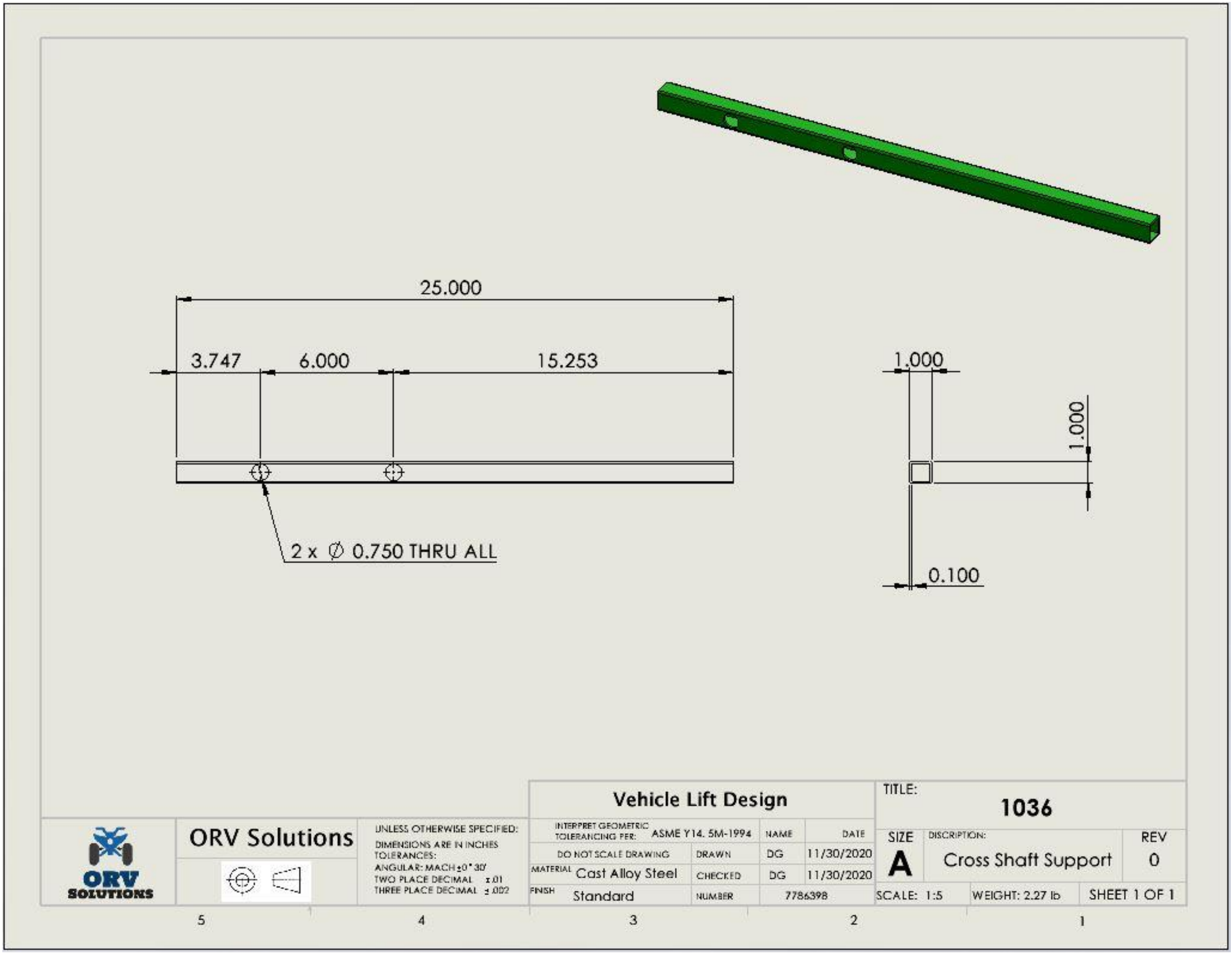
REV
0
SCALE: 1:1
WEIGHT: 0.46 lb
SHEET 1 OF 1
5
4
3
2
1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1.000
0.100
Vehicle Lift Design
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ORV Solutions
UNLESS OTHERWISE SPECIFIED:
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TOLERANCES:
ANGULAR: MACH ±0 ° 30'
TWO PLACE DECIMAL ±.01
THREE PLACE DECIMAL ±.002
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14. 5M-1994
DO NOT SCALE DRAWING
MATERIAL Cast Alloy Steel
FINISH Standard
NAME
DATE
DRAWN DG 11/30/2020
CHECKED DG 11/30/2020
NUMBER 7786398
SIZE
A
DISCRIPTION:
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REV
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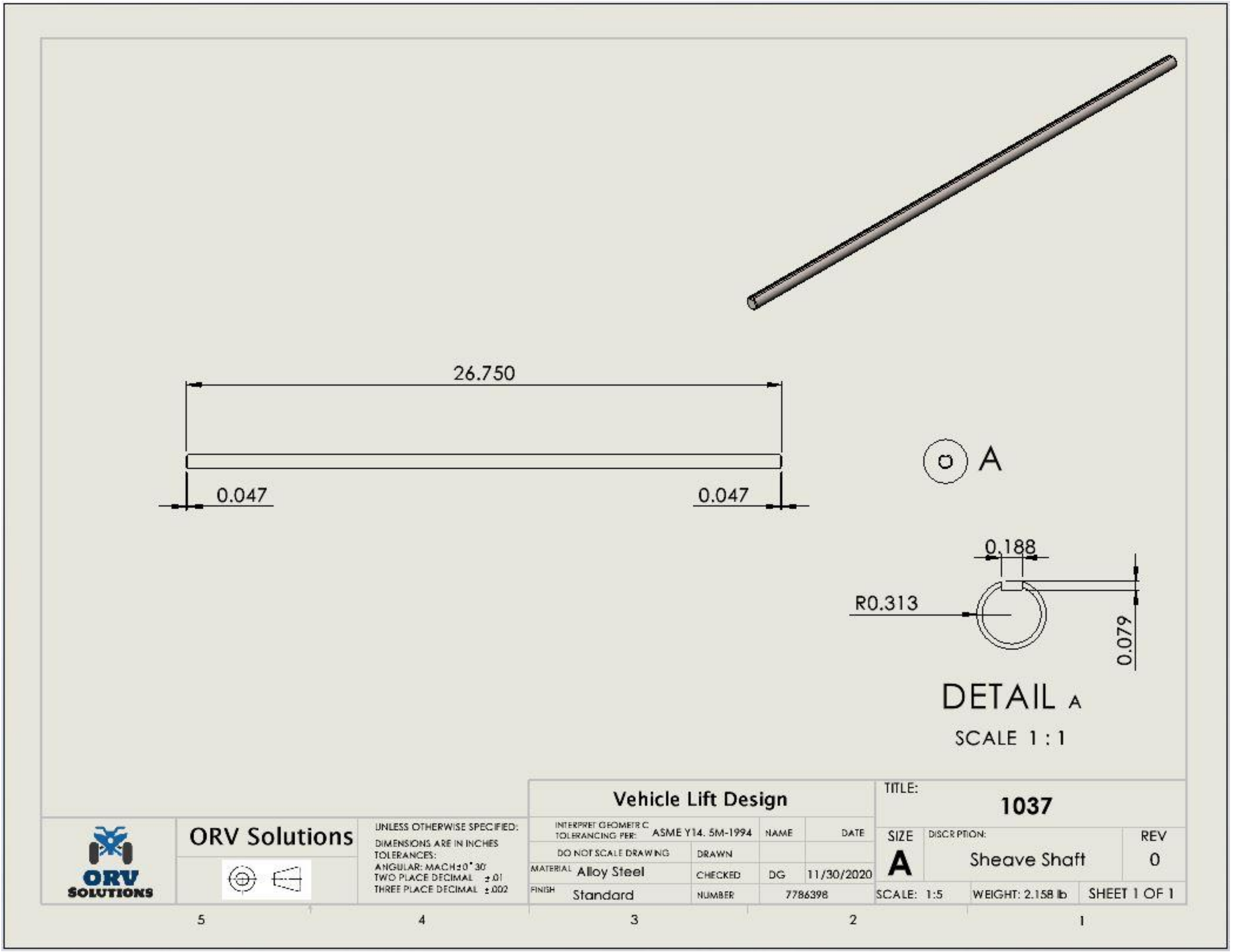
SCALE: 1:5
WEIGHT: 2.27 lb
SHEET 1 OF 1
5
4
3
2
1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SCALE 1 : 1
ORV SOLUTIONS
ORV Solutions
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: MACH±0° 30'
TWO PLACE DECIMAL ±.01
THREE PLACE DECIMAL ±.002
Vehicle Lift Design
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14. 5M-1994
NAME
DATE
DO NOT SCALE DRAWING
DRAWN
MATERIAL Alloy Steel
CHECKED
DG
11/30/2020
FINISH Standard
NUMBER
7786398
TITLE:
1037
SIZE
A
DISCRIPTION:
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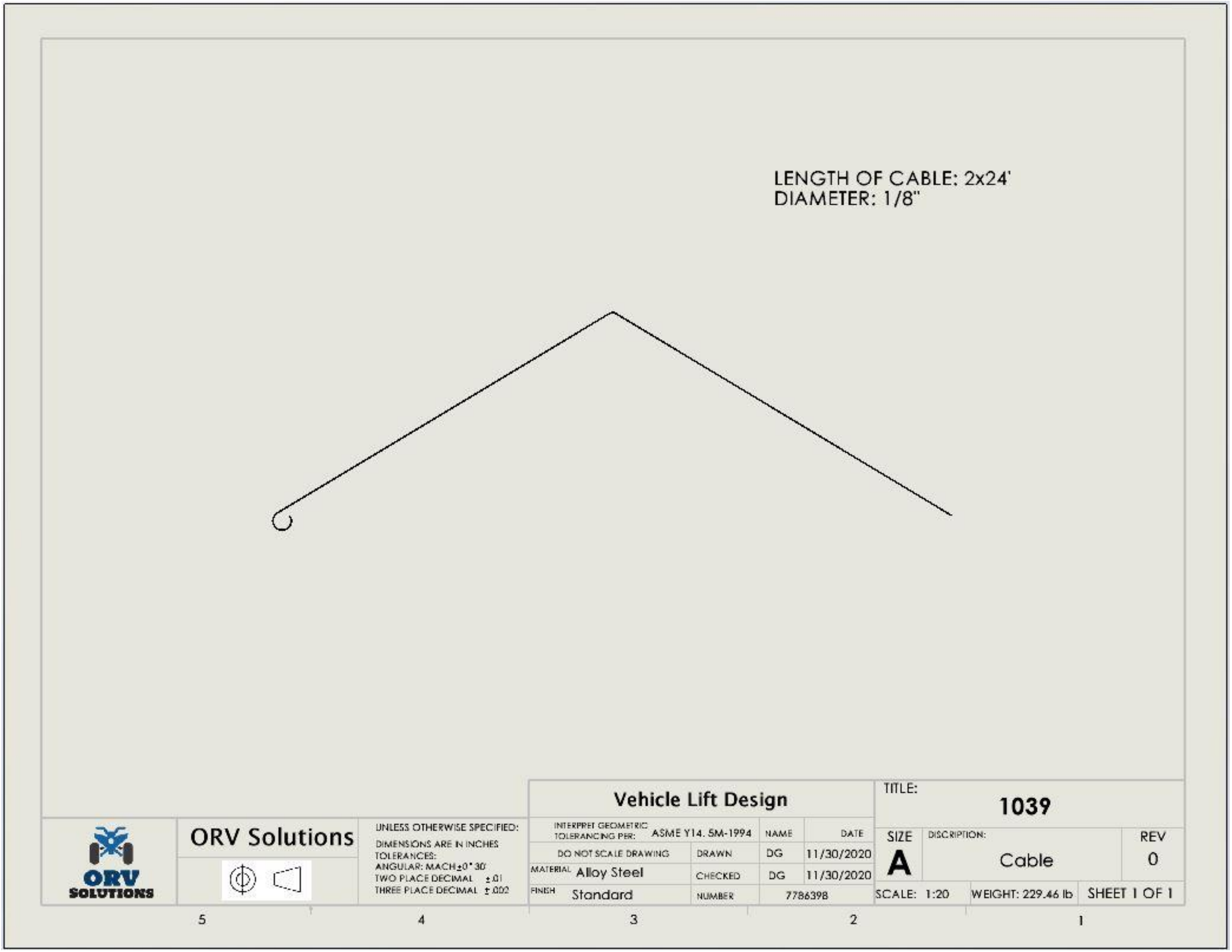
REV
0
SCALE: 1:5
WEIGHT: 2.158 lb
SHEET 1 OF 1
5
4
3
2
1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DIAMETER: 1/8"
Vehicle Lift Design
TITLE:
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ORV Solutions
UNLESS OTHERWISE SPECIFIED:
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TOLERANCES:
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TWO PLACE DECIMAL ±.01
THREE PLACE DECIMAL ±.002
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14. 5M-1994
NAME
DATE
DO NOT SCALE DRAWING
DRAWN DG 11/30/2020
CHECKED DG 11/30/2020
MATERIAL Alloy Steel
FINISH Standard
NUMBER 7786398
SIZE A
DISCRIPTION: Cable
REV 0
SCALE: 1:20
WEIGHT: 229.46 lb
SHEET 1 OF 1
5
4
3
2
1

Appendix B: Compatibility Research

B.1 All-Terrain Vehicle Measurement

Terminology can vary for various off-road vehicles, even so far as using the same word to describe different measurements. Figure 1 presents the measurement system for all-terrain vehicles as well as side-by-sides.

[redacted]

Figure 1: ATV/SxS wheel dimensions [16]

Each of the below ATV types have their own wheelbase and track dimensions. All measurements vary to a degree based on ATV brand. Furthermore, wheelbase can vary based on engine size, or can be modified post-manufacturing assembly. Most ATV's are measured in width based on their track, which excludes any additional body or frame width. This is to be accounted for in the design ensuring that the entire vehicle fits within the truck bed. Table I presents pertinent information for popular ATVs currently on the market, including its wheelbase, track, and weight.

TABLE I: ATV SPECIFICATIONS [17]

Make And Model	Wheelbase (Inch)	Track (Inch)	Weight (lbs)
Polaris Sportsman 450/850/1000	83	48	696/839/927
Can-Am Outlander 450/570	83	46	678/704
Can-Am Renegade 570	86	48	628
Honda FourTrax	84	48	573
Yamaha Grizzly 700	82	48	701

Yamaha Raptor 700	72	46	396
Yamaha YFZ450	70	48	405
Suzuki King Quad 500/700	85	48	665
Arctic Cat Alterra 570/700	84	48	700/809

For most ATVs, the tracks are between 46 and 48 inches. The wheelbase however can vary on utility or passenger limits, in the case of the above ATVs between 70 and 86 inches. Ensuring the track of the ATVs conform to the design product will be key during the concept generation phase since truck bed space is more limited by width than by length.

B.2 Pickup Truck Measurements

Generally, pickup trucks have one of three bed sizes: short, standard, or long. Based on manufacturer and model, these terms can have different meanings. A standard bed length for one model is not necessarily the same length for another manufacturer or even for a different model from the same manufacturer.

The wheel wells protrude into the bed space since pickup truck beds are located squarely over the rear axle. This is to maximize the overall width of the bed, while at the same time keeping the floor as low as possible. Figure 2 displays the various measurements for the truck bed, with a significant reduction in the bed center.

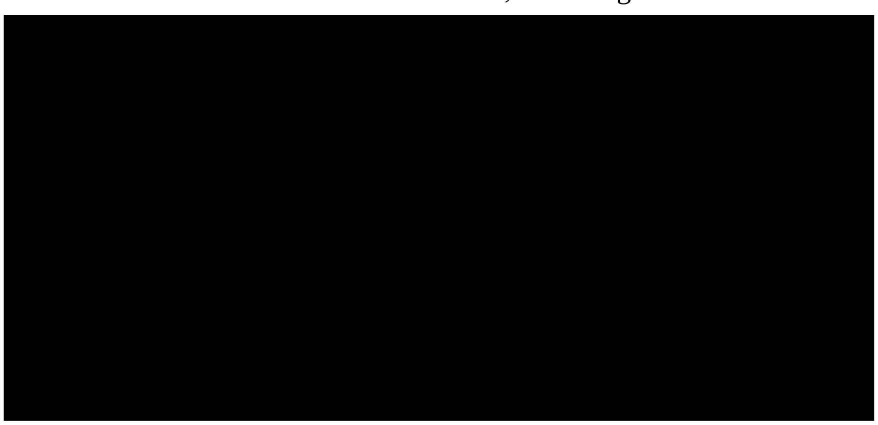

Figure 2: Pickup Truck Dimensions [18]

Table I tabulates truck bed measurements for the best-selling Half-Ton trucks in North America in 2019 [19]. The scope of applicable trucks is limited to half-ton trucks only, considering the payload would include both the design and the weight of the off-road vehicle.

TABLE II: PICKUP TRUCK BED SPECIFICATIONS [20] [21]

Truck	Bed Type	Advertised Length (in)	Actual Length (in)	Width (in)	Wheel Well Width (in)	Base Payload (lbs)
Chevy Silverado*	Short	69	69.3	63.6	51	2,285
	Standard	79	78.8	63.6	51	2,202
	Long	98	97.8	63.6	51	2,318
Dodge Ram*	Short	67	67.4	65.5	51	1,830
	Standard	76	74.5	65.5	51	1,880
	Long	96	96.3	65.5	51	1,900
Ford F-150*	Short	67	67.1	65	50	3,230
	Standard	79	78.9	65	50	3,230
	Long	98	97.6	65	50	3,230
GMC Sierra	Short	69	69.3	63.6	51	1,730
	Standard	79	78.8	63.6	51	2,200
	Long	98	97.8	63.6	51	2,280
Chevrolet Colorado	Short	63	62.7	57	44.4	1,561
	Long	74	74	57	44.4	1,551
GMC Canyon	Short	63	62.7	57.8	44.4	1,426
	Long	98	97.8	57.8	44.4	1,602

*Top 3 Selling Trucks in North America

Manufacturers advertise the approximate length of their pickup truck beds, however there is normally some variation to the true length. The width dimensions for pickup trucks are not as explicit in manufacturer marketing as bed length, hence values are determined by third parties measuring the width themselves, leading to variation based on measurement.

Although truck bed space is more limited by width than by length, it is imperative that that the width of the product design conforms to the common pickup truck bed widths. Furthermore, the wheel well (wheel housing) width must be considered, as the space is drastically reduced (See: Table II, columns 5 and 6).

Appendix C: Patent Search

While the design of the lifting mechanism developed might be new to Atom-Jet, it might be unintentionally similar to a device already designed. In order to determine if such a design may already exist, a patent search was performed on patents filed in the United States and Canada. The reason which a patent search was restricted to just the U.S. and Canada is because that is where it is expected for the product to be sold primarily.

Performing a patent search in the United States did not find any patents covering the loading of an ATV (ORV) using any sort of lifting method. Patents which were found were all relating to the loading of the ATVs using a variation of a ramp or being lifted onto a rack on the back. Figure 3 shows one of the patent images that which were found during the U.S. patent search.

Figure 3: Patented Ramp Design [22]

While performing a patent search for patents filed in Canada, a patent was discovered which had concepts that were researched by ORV Solutions. Patent 2807757, “Methods and Apparatus for Loading and Unloading an ATV”, is a design which uses a combination of a winch and a ramp system in order to pull an ATV up on to a truck bed [23].

Figure 4: Patent 2807757 Drawing [23]

The winch was researched for potential use in a concept. While this patent does use a winch, the patent itself was not determined to be a concern due to the platform remaining stationary against the truck, while the design ORV Solutions developed pivots into the truck.

Appendix D: Part Register

The following excel spreadsheet was used to keep track of all the components in the design, while providing information concerning the designer, date designed, as well as sourcing information for purchased components. The spreadsheet was aptly named the Part Register.

TABLE III: PART REGISTER

PART #	REV	NAME	MASTER ASM QTY	CHECKED IN?	DESIGNER	DATE DESIGNED	CHECKED BY	DATE CHECKED	REV REQ?	MATERIAL
1001	0	Truck Model	1	Yes	DG	9/30/2020	DG	11/29/2020	No	-
1002	0	ATV Model	1	Yes	DG	11/16/2020	DG	11/29/2020	No	-
1003	0	Snomobile Model	1	Yes	DG	11/16/2020	DG	11/29/2020	No	-
1004	0	Long Beam	6	Yes	RD	11/16/2020	DG	11/29/2020	No	Steel
1005	1	Angled Truss Member	2	Yes	RD	11/30/2020	DG	11/30/2020	No	Steel
1006	0	Side Brace	6	Yes	RD	11/30/2020	DG	11/30/2020	No	Steel
1007	2	**Weldment Bed Frame ASM**	**1**	Yes	RD	11/16/2020	DG	11/29/2020	No	**(ASM)**
1008	3	Angle Iron Rails	2	Yes	RD	11/21/2020	DG	11/29/2020	No	Steel
1009	1	Bearing Housing	6	Yes	DG	11/17/2020	DG	11/29/2020	No	Steel
1010	2	Drive Shaft	2	Yes	DG	11/17/2020	DG	11/29/2020	No	Steel
1011	3	**Platform ASM**	**1**	Yes	DG	11/19/2020	DG	11/29/2020	No	**(ASM)**
1012	0	**Rollers ASM**	**1**	Yes	DG	11/17/2020	DG	11/29/2020	No	**(ASM)**
1013	0	Left Grating	1	Yes	DG	11/19/2020	DG	11/29/2020	No	G. Steel
1014	0	Right Grating	1	Yes	DG	11/19/2020	DG	11/29/2020	No	G. Steel
1015	1	Center Left Grating	1	Yes	DG	11/19/2020	DG	11/29/2020	No	Steel
1016	1	Center Right Grating	1	Yes	DG	11/19/2020	DG	11/29/2020	No	Steel
1017	3	Spool-1	2	Yes	DG	11/19/2020	DG	11/29/2020	No	Steel
1018	0	Spool-2	4	Yes	DG	11/19/2020	DG	11/29/2020	No	Steel
1019	0	**Spool ASM**	**2**	Yes	DG	11/19/2020	DG	11/29/2020	No	**(ASM)**
1020	2	Drive Shaft-2	2	Yes	DG	11/26/2020	DG	11/29/2020	No	Steel
1021	1	Roller Frame-ND	6	Yes	RD	11/28/2020	DG	11/30/2020	No	Steel
1022	0	Outer Cross Brace	17	Yes	DG	11/20/2020	DG	11/29/2020	No	Steel
1023	0	Inner Cross Brace	8	Yes	DG	11/20/2020	DG	11/29/2020	No	Steel
1024	0	Outer Belting	2	Yes	DG	11/20/2020	DG	11/29/2020	No	Belting
1025	0	Inner Belting	1	Yes	DG	11/20/2020	DG	11/29/2020	No	Belting
1026	0	Platform Rails	2	Yes	RD	11/21/2020	DG	11/29/2020	No	Steel
1027	0	**Platform Rail-Rollers L**	1	Yes	DG	11/22/2020	DG	11/29/2020	No	**(ASM)**
1028	0	**Platform Rail-Rollers R**	1	Yes	DG	11/22/2020	DG	11/29/2020	No	**(ASM)**
1029	0	V-Belt	4	Yes	DG	11/23/2020	DG	11/29/2020	No	V-Belt
1030	0	Rail Risers	8	Yes	DG	11/23/2020	DG	11/29/2020	No	Steel
1031	0	Steel Roller	2	Yes	DG	11/26/2020	DG	11/29/2020	No	Steel
1032	0	Bumper-1	4	Yes	DG	11/26/2020	DG	11/29/2020	No	Steel
1033	0	Bumper-2	2	Yes	DG	11/26/2020	DG	11/29/2020	No	Steel
1034	0	Steel Roller Center	1	Yes	DG	11/26/2020	DG	11/29/2020	No	Steel
1035	0	Bumper-3	6	Yes	DG	11/26/2020	DG	11/29/2020	No	Steel
1036	0	Cross Shaft Support	1	Yes	DG	11/30/2020	DG	11/30/2020	No	Steel
1037	0	Sheave Shaft	2	Yes	DG	11/30/2020	DG	11/30/2020	No	Steel
1038	1	Small Bottom Brace	4	Yes	RD	11/28/2020	DG	11/30/2020	No	Steel
1039	0	Cable	2	Yes	DG	11/30/2020	DG	11/30/2020	No	Aero Steel
1040	2	Roller Angle	2	Yes	DG	12/1/2020	DG	12/1/2020	No	Steel
	6	**FINAL ASM**	1	YES	DG	12/1/2020	DG	12/1/2020	NO	**(ASM)**
		TOTAL MANUF. PARTS	**104**							

TABLE IV: LIST OF PURCHASED COMPONENTS

PURCHASED COMPONENTS								
	Supplier/Part No.	DESC.	ASM Ref	QTY	COST	TOT	NOTES	LINK
1	2276T130	12"x2" Roller		4	$12.47	$49.88		
2	2276T630	16"x2" Roller		2	$14.61	$29.22		
3	UBS-Unistrut	18.75" wide Grating	1013/14	2	$115.58	$231.16	6246T38	https://unistrutstore.com/safety-grating/grip-strut/grating-plank-81512-12.html
4	6384K650	Drive Shaft Bearing		6	$12.14	$72.84		
5	5907K11	Hex Bearing		6	$3.36	$20.16		
6	6527K99	0.12", 1x2in Tube	1026	2	$40.19	$80.38		
7	9017K17	Angle Iron	1008	2	$22.47	$44.94		
8	6318K69	Threaded Track Roller		4	$59.62	$238.48		
9	MetalDepot	2"x1" Rect Steel Tubing	1004/05/06/38	1	$163.38	$163.38		https://www.metalsdepot.com/catalog/cart
10	Russell Metals	0.25x4'x8' Steel price per ft	1015/16	6	$4.99	$29.94	Ref: 8975K142	
11	Russell Metals	1"x1" 1/8" sq. tubing per ft	1011/23/30/32/33/35	53	$1.28	$67.84		
12	Russell Metals	2" x3/16" Rnd Tube	1031/34	3	$3.28	$9.84		
13	5994K7	18" Rough Surface Belt	1025	9	$11.11	$99.99	Black SBR Rubber	
14	5994K7	12" Rough Surface Belt	1024	10	$7.42	$74.20	Black SBR Rubber	
15	9017K91	2.5x2.5x0.5 Angle Iron	1009	1	$18.89	$18.89		
16	9017K77	2x1.5x0.25 Angle Iron	1021	1	$7.64	$7.64		
17	9056K33	0.75OD 0.5ID 0.5' Rnd Tube	1017	1	$4.15	$4.15		
18	8910K591	0.25x6x24 Steel Bar	1018	1	$43.34	$43.34		
19	Ben-Mor	1/8 S. Steel 304 cable 7x19		48	$0.22	$10.56	AGRAGDBC381200	
20	3099T34	Cable Pulley		2	$7.38	$14.76		
21	Princess Auto	Weld On Hub		6	$6.99	$41.94	3845104	https://www.princessauto.com/en/detail/5-8-in-bore-v-series-weld-on-hub/A-p3845104e
22	14895A41	Handles		2	$2.15	$4.30		
23	98491A100	Machine Key		1	$3.04	$3.04		
24	6338K575	5/8"s, 3/4" S OliteBushings		4	$1.49	$5.96		
25	Princess Auto	5/8" x 3ft Keyed Shaft		3	$29.99	$89.97		https://www.princessauto.com/en/detail/5-8-in-x-3-ft-keyed-shaft/A-p8079725e
26	PrincessAuto	5/8" Mounted Bearing		4	$11.99	$47.96		https://www.princessauto.com/en/detail/5-8-in-2-bolt-standard-duty-flange-mount-bearing-assembly/A-p3870177e
27	Princess Auto	2.5" x 5/8" V-Belt Pulley		4	$11.99	$47.96		https://www.princessauto.com/en/product/PA1000001339#8178758
28	PrincessAuto	5" x 5/8" V-Belt Pulley		4	$21.99	$87.96		https://www.princessauto.com/en/product/PA1000001339#8178758
29	V-Belt Supply	V-belt (A19)		4	$1.06	$4.24		https://www.vbeltsupply.com/conventional-wrapped-belts/a-section-conventional-wrapped-belts
30	6721K9	Threaded Track Roller-2		2	$36.54	$73.08		
					TOTAL:	$1,718.00		
				Remaining Budget		-$218.00		
			TOTAL PURCH. PARTS:	59				
			TOTAL STOCK UNITS:	134				