IN-002-DOC-000101

TruFlight Theater®

Theory of Operations

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Revision History

Rev	Date	Description	By
0	06/15/2022	Initial Content	AY
1	07/06/2022	Revised and Added Content	AY
2	10/06/2022	Edited Content Based on Design Changes	AY

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1 Introduction

There's a dramatic difference between flying a hang glider and flying an F-18 fighter jet. One gives you the gentle sensation of flight while the other can throw you through the seat at takeoff and take your breath away with twists and turns. The same holds true for current flying theaters when compared to Medici XD's revolutionary new patent pending TruFlight Theater®.

The Medici XD TruFlight Theater improves upon decades of flying theater technology to deliver an incredibly versatile new tool into the hands of passionate story tellers. With the widest range of controlled movement of any theater in its class, TruFlight Theater boasts unparalleled flexibility and a seamless transition between exhilarating to family-friendly fun in a truly customizable flying experience.

In the primary "bottom-up" configuration, guests are whisked away as they're pulled up into a one-of-a-kind flying experience travelling along rails that can be uniquely reshaped based on a customer's specified ride path. In the alternative "top-down" configuration, guests are dropped into the action from above, experiencing a falling sensation unlike any other flying theatre on the market.

TruFlight Theater includes a generous one meter of precisely controlled rising and falling "heave" motion combined with a revolutionary dual-actuator driven "secondary heave" motion. Combining these two motions creates "flutter" and "turbulence" effects as well as graceful left to right tilting and banking for the ultimate free flying experience.

TruFlight Theater also features a unique and generous "pitch" motion providing the added sensation of swinging from above. Featuring a longer range of travel than any other flying theater, guests can now experience the diving and swooping sensations of real flight. The theatre package includes a full complement of onboard special effects, fog, mist, smells, seat vibration, and optional onboard audio to enhance the experience.

Flying theaters have provided memorable experiences to many guests all over the world. Now, with the state-of-the-art Medici XD TruFlight Theater, the next generation of guests will experience a heightened level of unforgettable excitement and wonder.

The TruFlight Theater is available from Medici Machines as a standalone ride system or may be packaged as a perfectly integrated solution with Medici Media for ride film design & production.

2 Terminology and Acronyms

Term	Meaning
VCS	Vehicle Control System
RCS	Ride Control System
OCC	Operator Control Console
RV	Ride Vehicle
THRC	Theoretical Hourly Rider Capacity
G	Acceleration Experienced as Gravity, Earth Gravity Listed as 1 G
HMI	Human Machine Interface
PLC	Programmable Logic Controller
I/O	Input/Output
CIP	Common Industrial Protocol
N.C.	Normally Closed
N.O.	Normally Open
PPR	Pulses Per Revolution
UPS	Uninterrupted Power Supply

3 Performance Description and Parameters

The following section serves to outline the performance, motion, and values of the TruFlight® Theater.

3.1 Guest Motion

The motion of the guests is intended to replicate a non-specific flying machine, having the ability for some more aggressive motions beyond a floating or gliding experience.

The motion can be broken down into 5 motions, the takeoff and media reveal, primary heave, secondary heave, roll, and finally pitch.

3.1.1 Takeoff and Media Reveal

The first direct motion the guests experience is a forward surge at a shallow upwards angle into a composite curve having a tighter radius followed by a larger radius for the main travel during a show. The tighter radius provides additional G forces into the seat pan such that when the guest is in the show section of the track they have a weightless sensation.

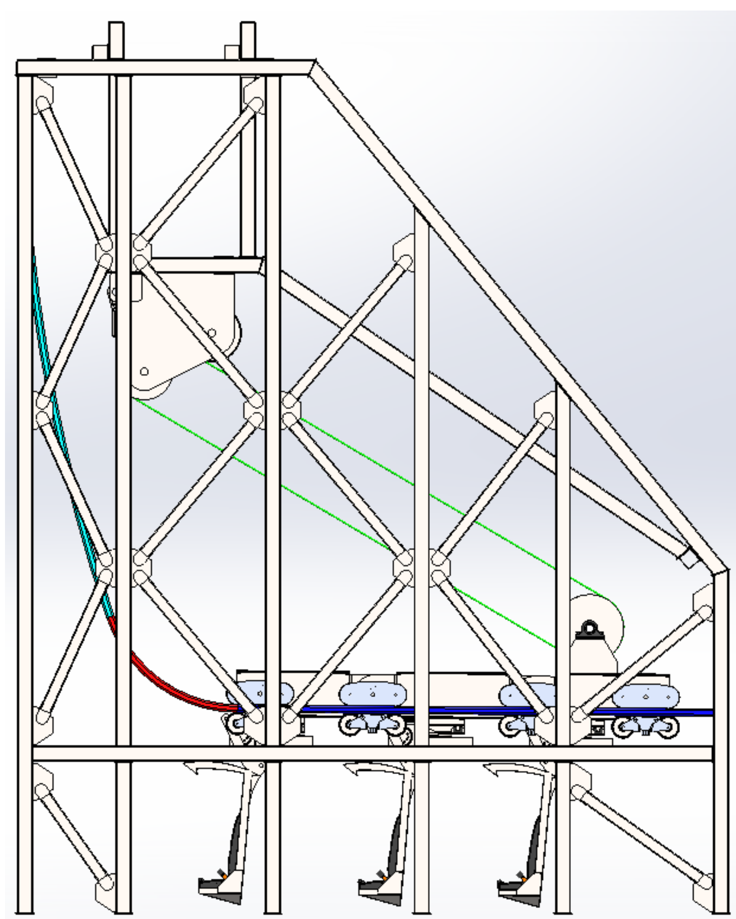

Figure 1: Load and Takeoff Position – Structure Visible

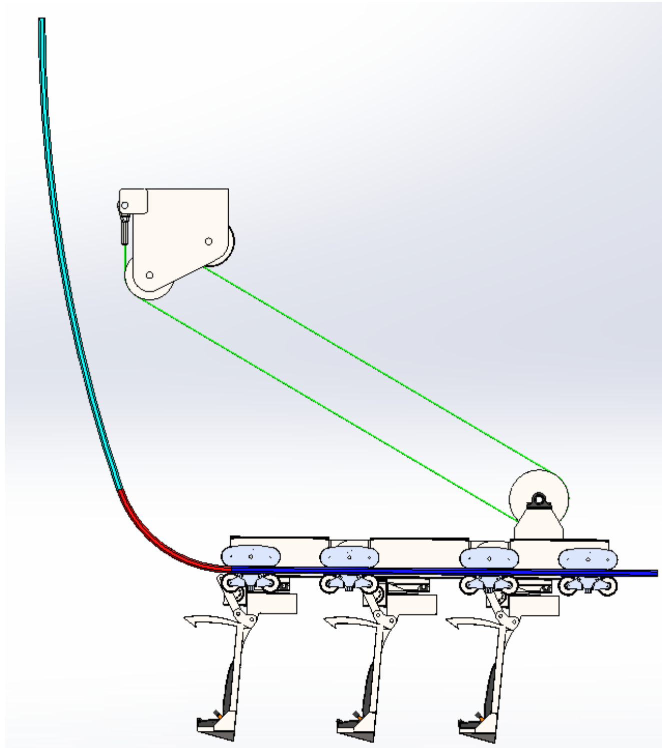

Figure 2: Load and Takeoff Position - Structure Hidden

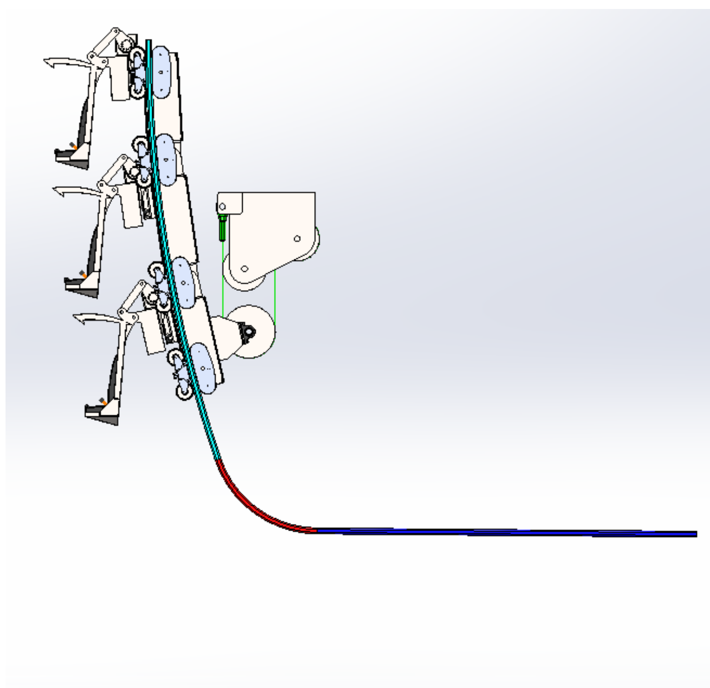

Figure 3: Show Position - Structure Hidden

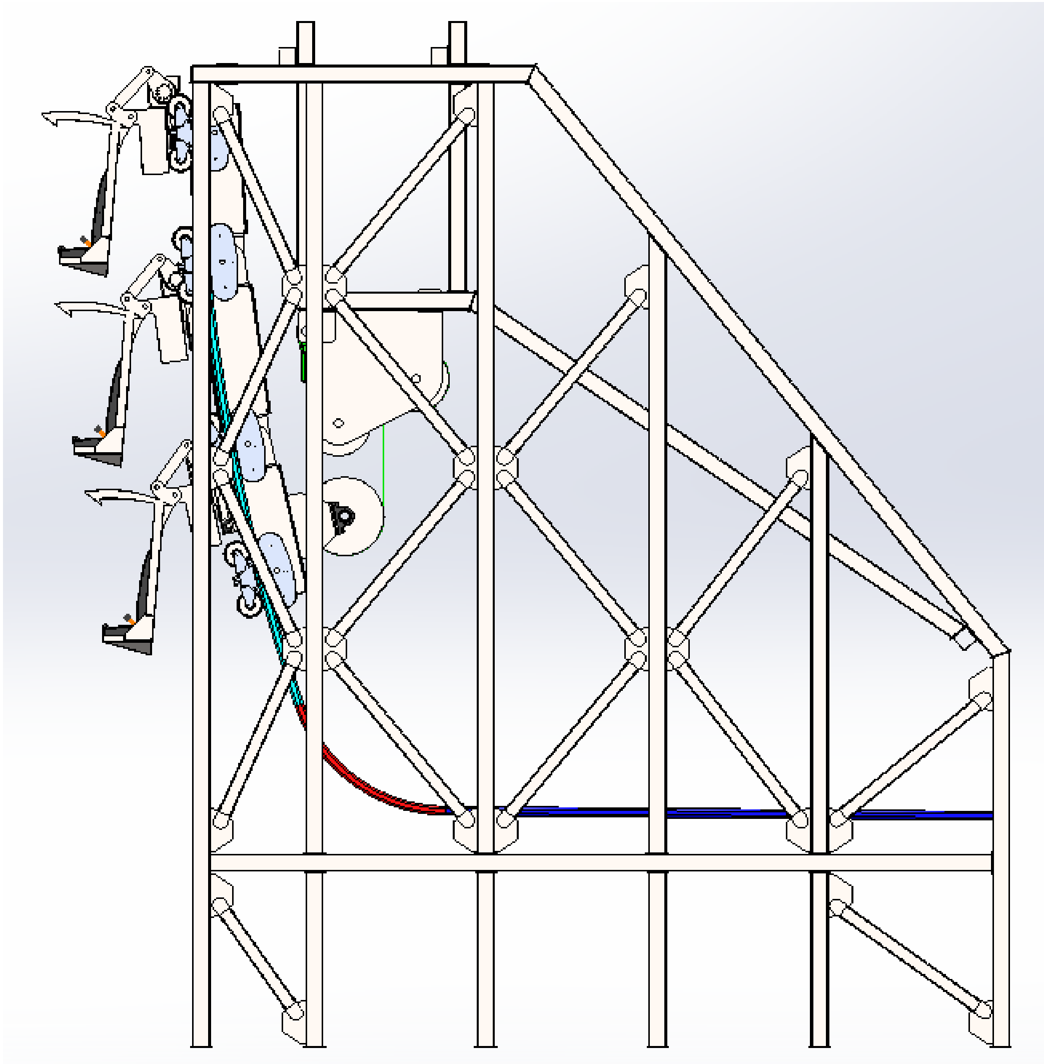

Figure 4: Show Position – Structure Visible

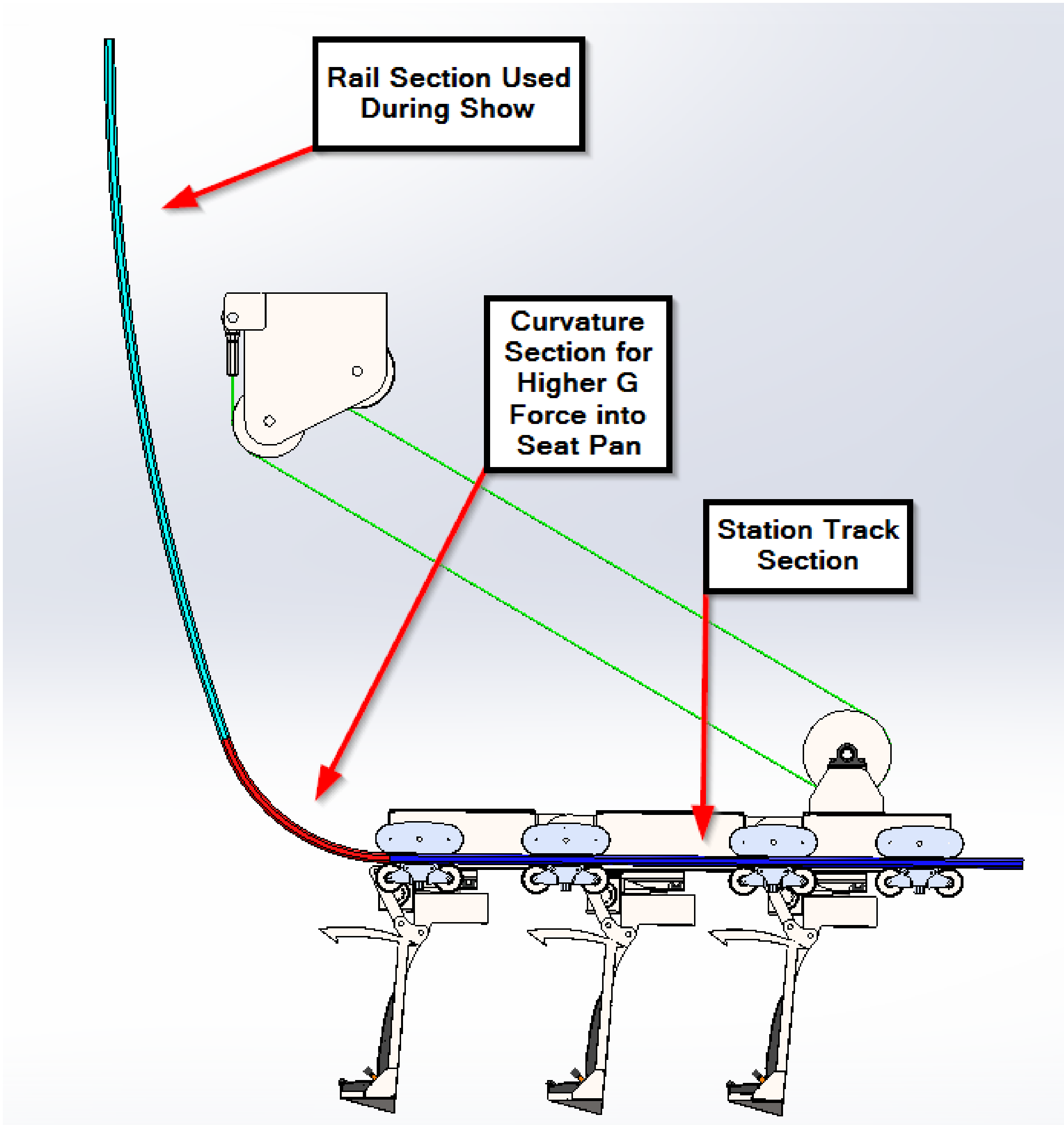

Figure 5: Highlighted Track Sections

Below the major assemblies of one of the ride vehicles are labeled.

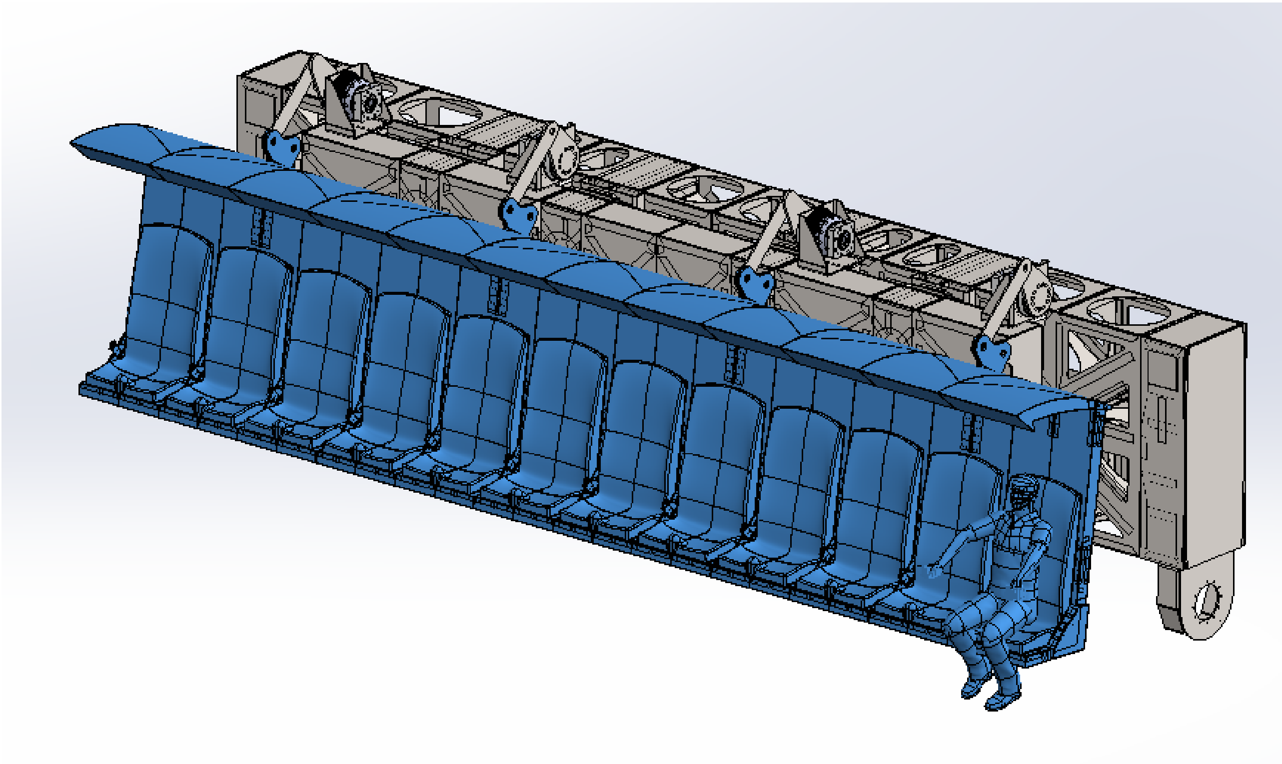

Figure 6: RV Cabin

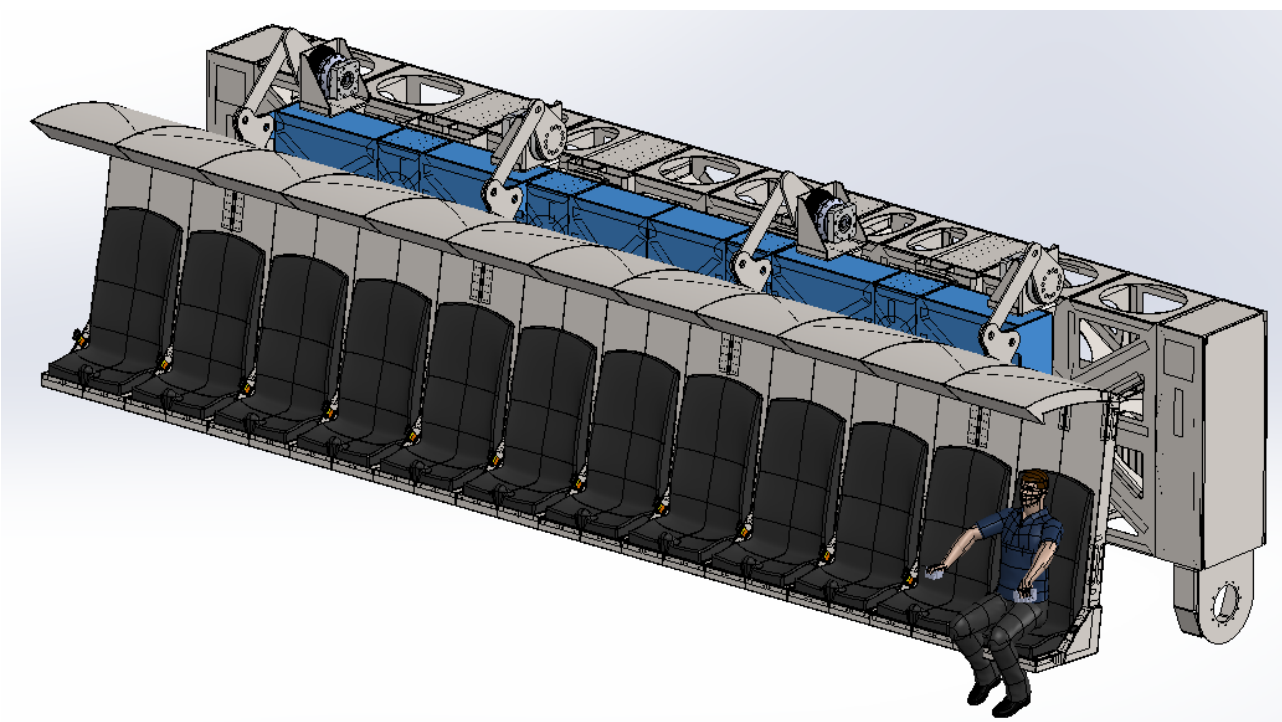

Figure 7: Carriage

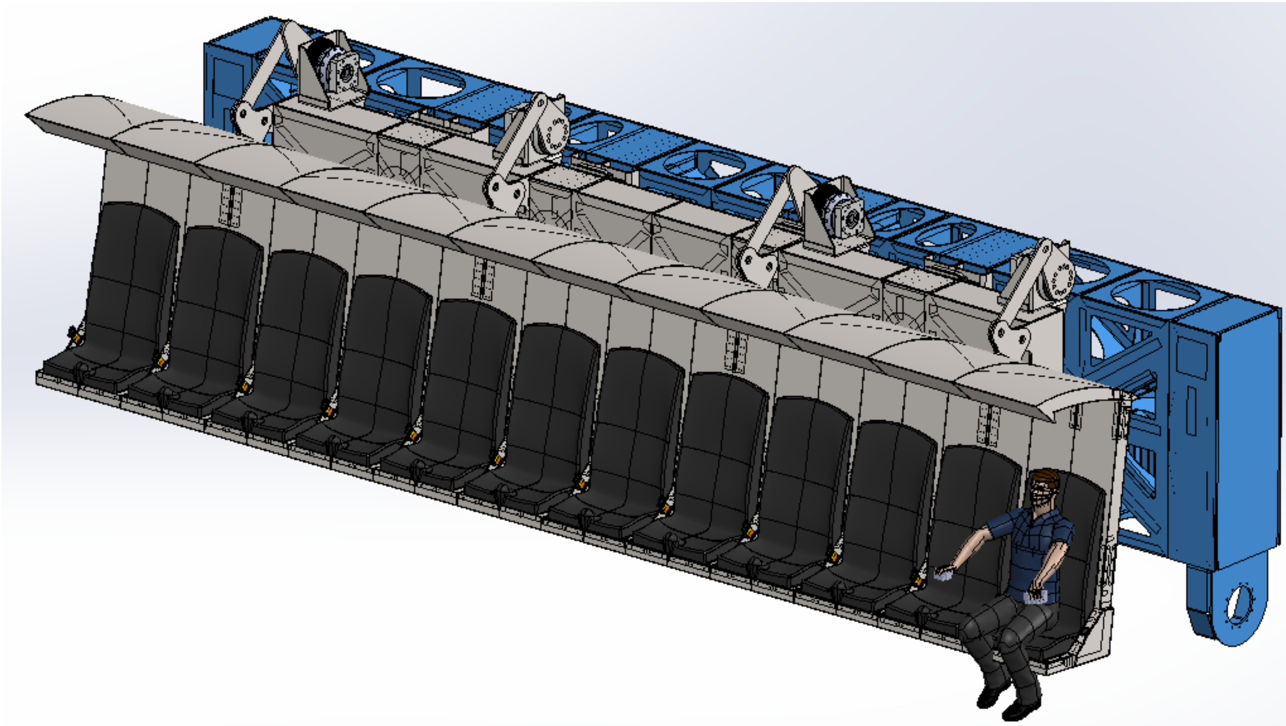

Figure 8: Transport

3.1.2 Primary Heave

The primary heave will be accomplished through a series of cables for redundancy as well as load sharing that ensure repeatability. The cable ends will be fixed to the ride super structure, where one end is wrapped around a drum that is rotated by a gearbox, brake, and motor combination, and the other is attached to the superstructure.

The cable is attached to the ride vehicles through a pulley that doubles over such that the entire weight of the RVs is divided by both sides of the cable. The advantage of this is that the torque required is reduced by half, and the speed required is doubled. While a doubling of the required input speed may not seem like and advantage, the motors in this case operate at a lower speed such that there is no negative performance impact.

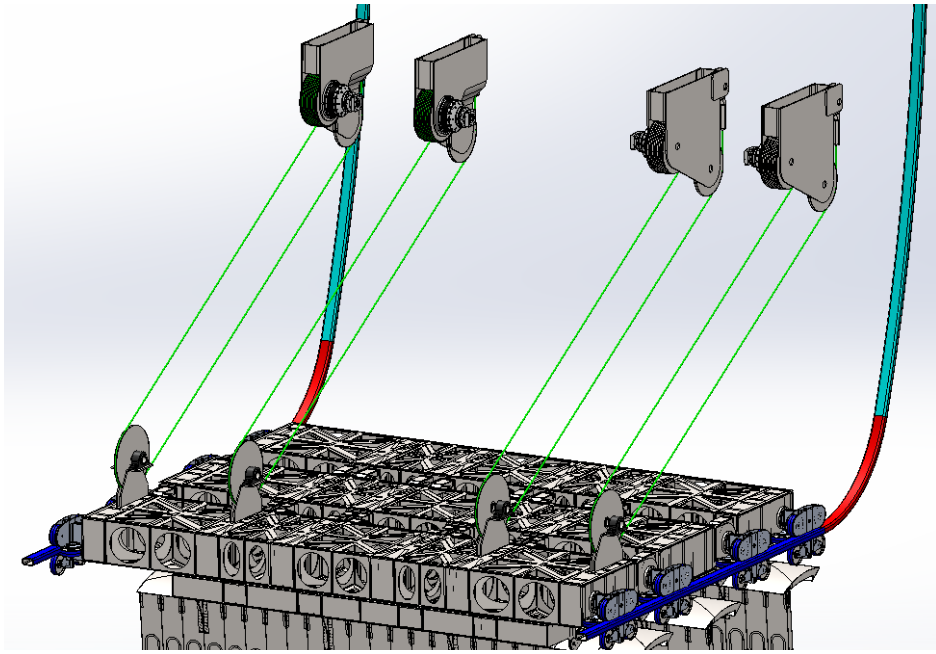

Figure 9: Primary Heave Cable Set

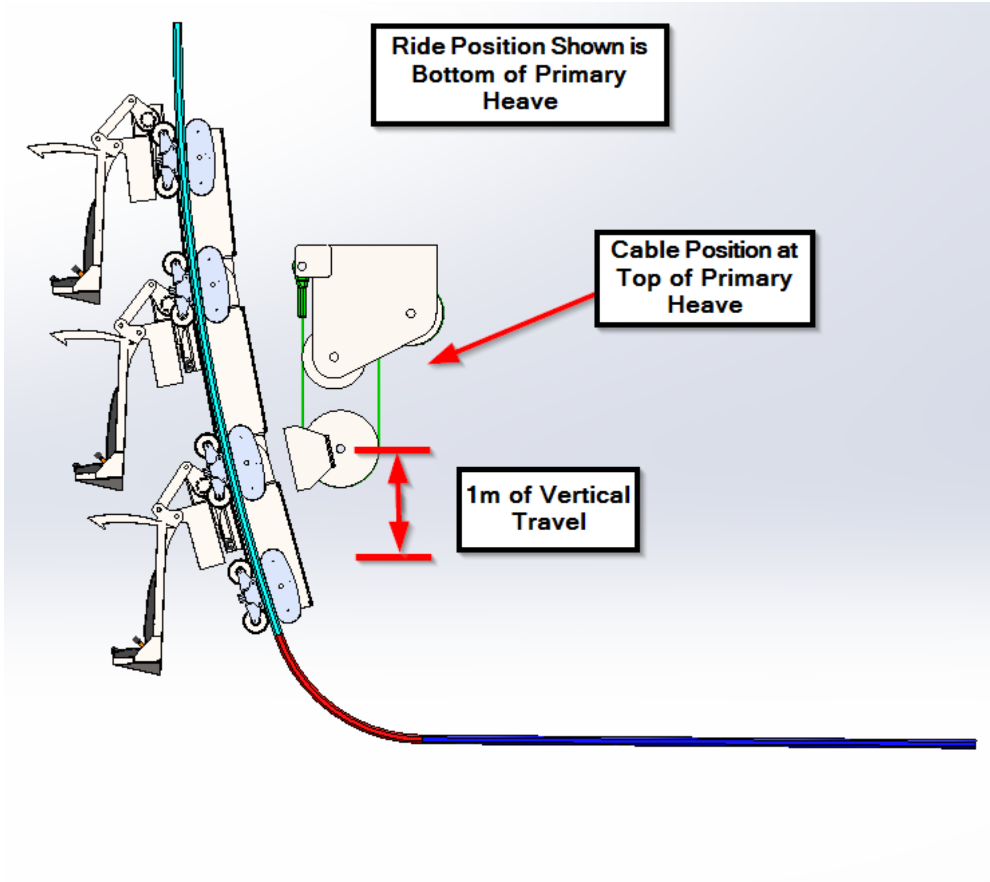

Figure 10: Vertical Travel for Primary Heave

Each cable passes through a magnetic field sensor that is able to measure the internal wire structure for any damage or wear that maintenance personnel wouldn't be able to detect.

The heave performance values can be found in Table 1: Ride Performance Specifications.

These values correspond with the industry leaders in flying theaters, these values allow for some aggressive maneuvers without having to utilize over the shoulder restraints.
The three ride vehicles travel along the two guide rails on a bogie system similar to a roller coaster.

3.1.3 Secondary Heave

The secondary heave utilizes several actuators to support the guest compartment as well as provide additional heave with a travel of around 10.13 inches. The maximum speed would not to exceed 1 ft/s with a maximum acceleration of 0.1 G. The reasoning for the lower number is that this secondary heave is intended to act as a support for providing the sensation of additional range of motion, or smaller bumps for turbulence or similar types of motion encountered.

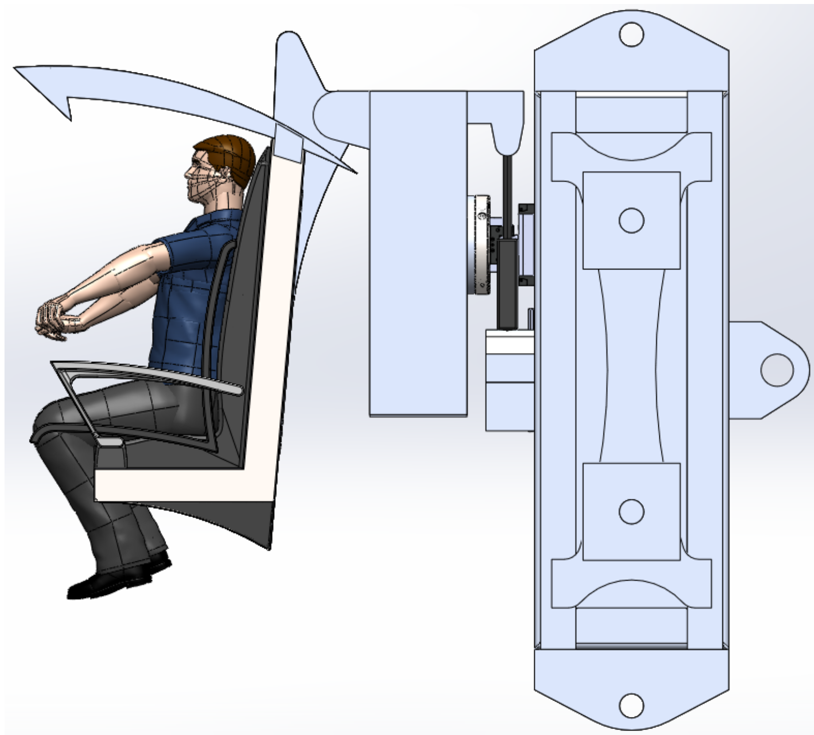

Figure 11: Ride Vehicle Side View

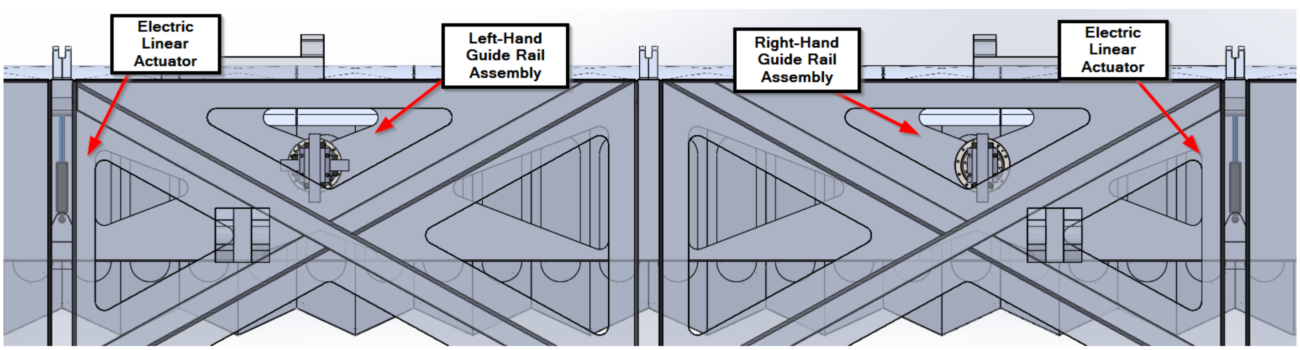

Figure 12: Secondary Heave Components

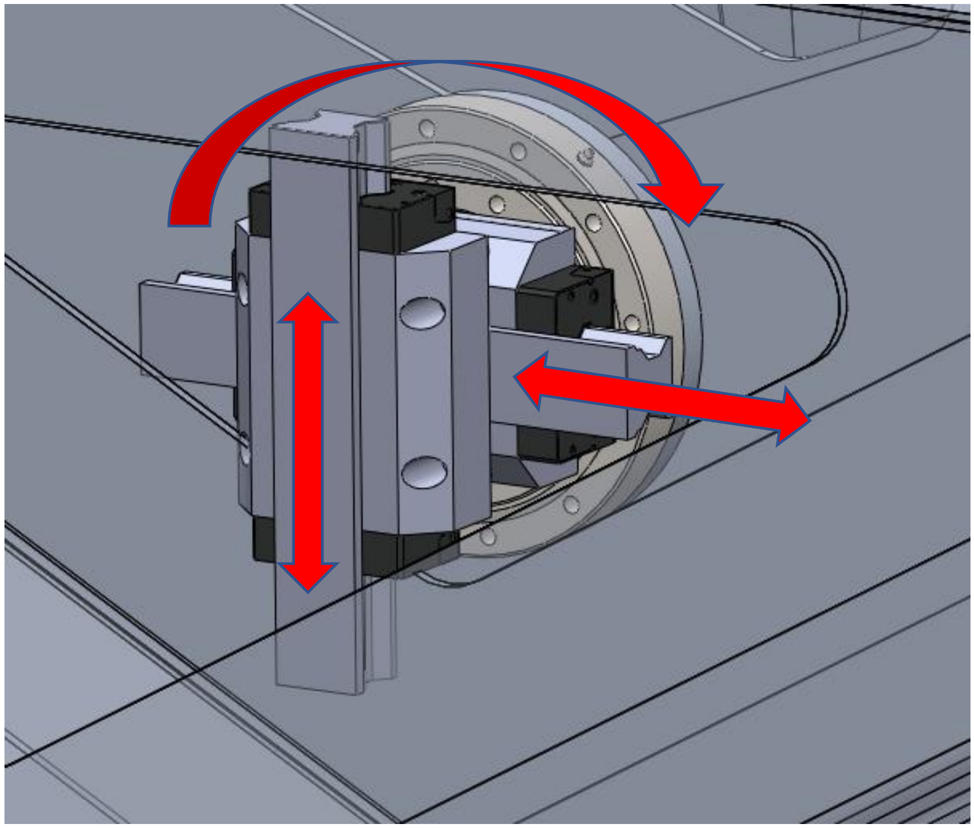

Figure 13: Guide Rails and Slewing Ring Assembly

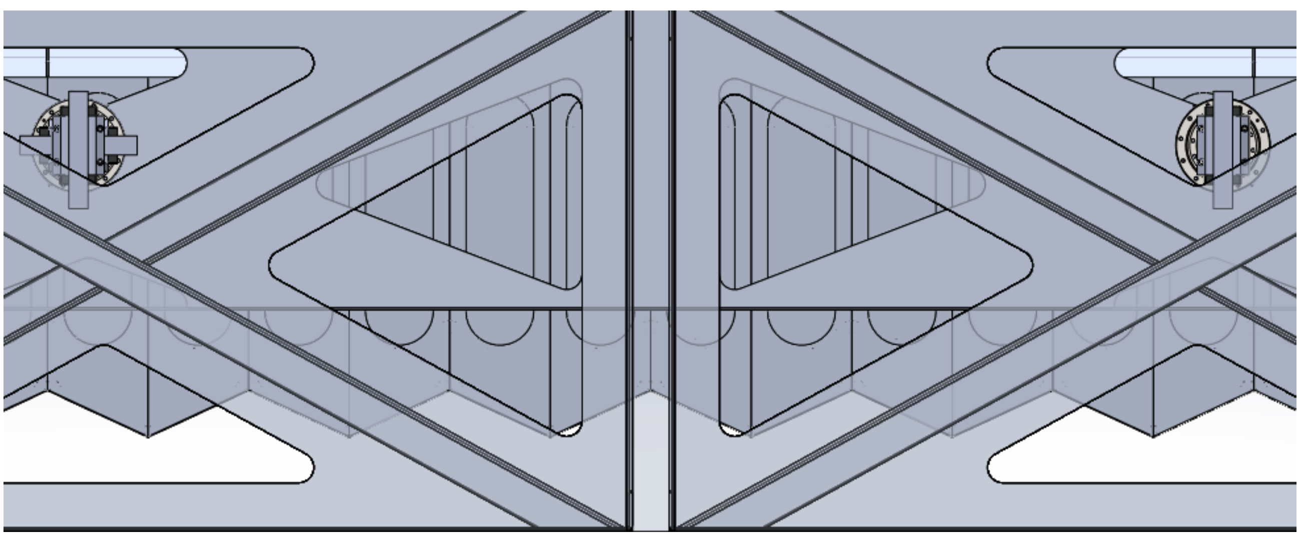

Figure 14: Left- and Right-Hand Guide Rail Assemblies

The left- and right-hand configurations of the guide assemblies are different as when the roll motion is accomplished the carriage with the guest cabin move in an arc requiring some lateral motion to prevent structural strain and stress.

3.1.4 Roll

The secondary heave also allows for rolling of the carriage and guest cabin through the linear rails and slewing rings allows for the proper motion freedom.
The range of motion is slight as the roll is meant to accentuate any rolling camera work in the media being presented to the guests. The carriage can roll a maximum of +/- 2 degrees (roll left and roll right) for a full range of 4 degrees, at a maximum speed of 2 deg/s and a maximum acceleration of 6 deg/s^2.

Having the two free pivot points allows the center of rotation to be moved such that the cabin bench can rotate about a variable location rather than a fixed central pivot point.

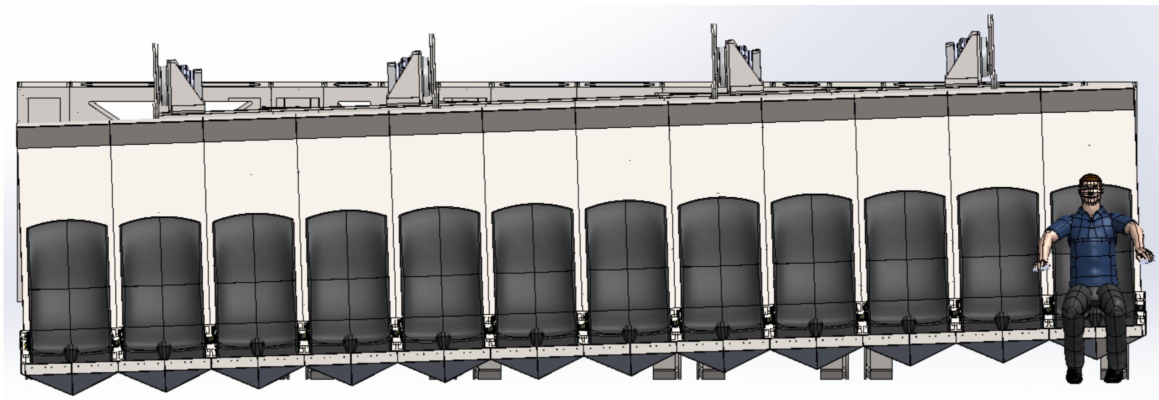

Figure 15: Roll Center of Rotation About Edge Seat

3.1.5 Pitch

The cabin has a large range of motion, such that the seat pan is level to the floor plane during loading, as well as having a 10 deg additional range at the upper end of the heave guide rails. This results in approximately a 100 deg range of motion for the leading ride vehicle.

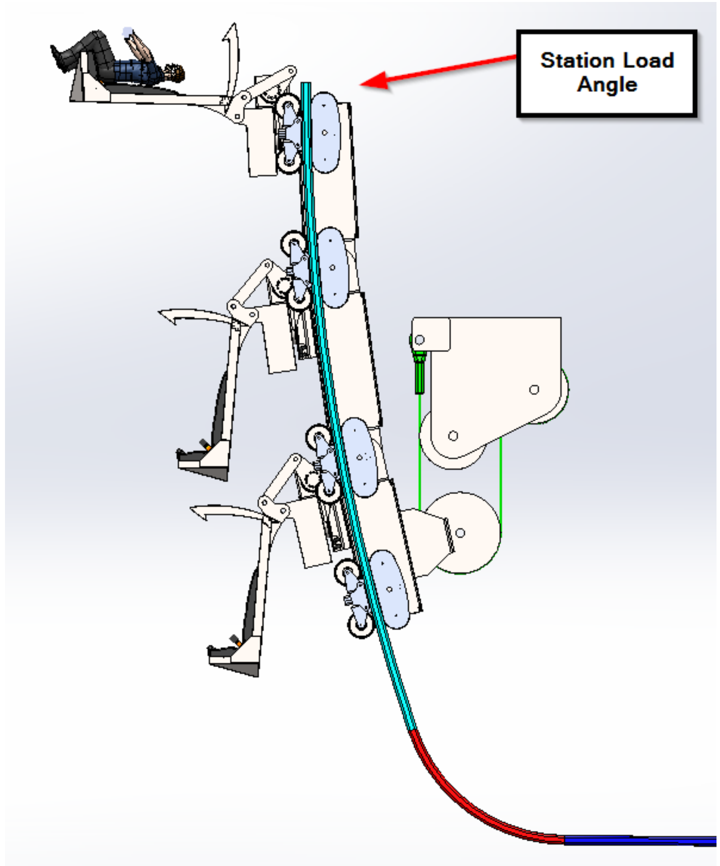

Figure 16: Side View with RV 1 at Station Angle

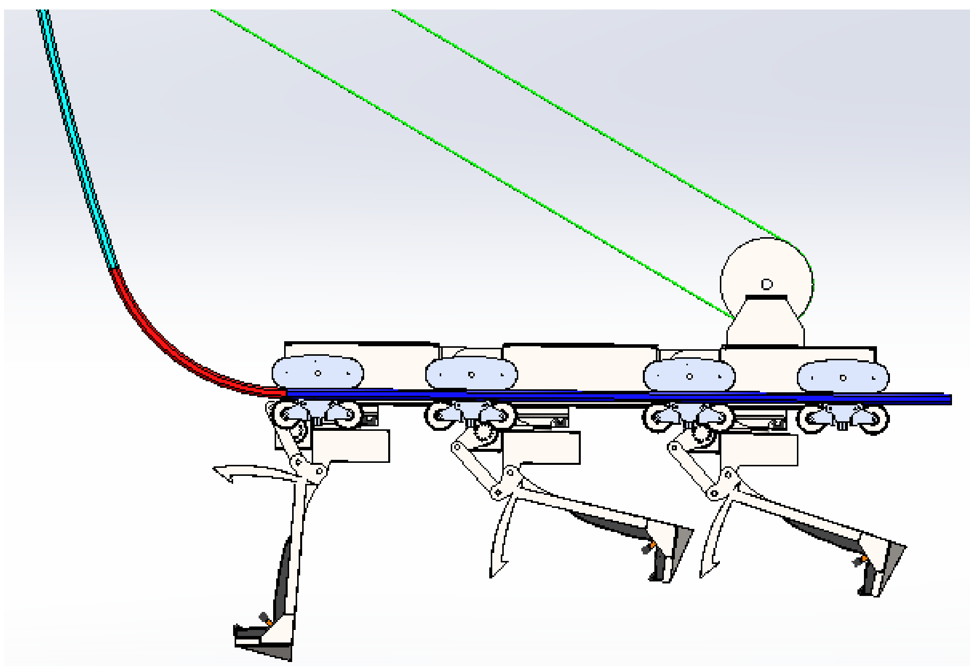

Figure 17: Side View with RV 2 and RV 3 at Show Angle

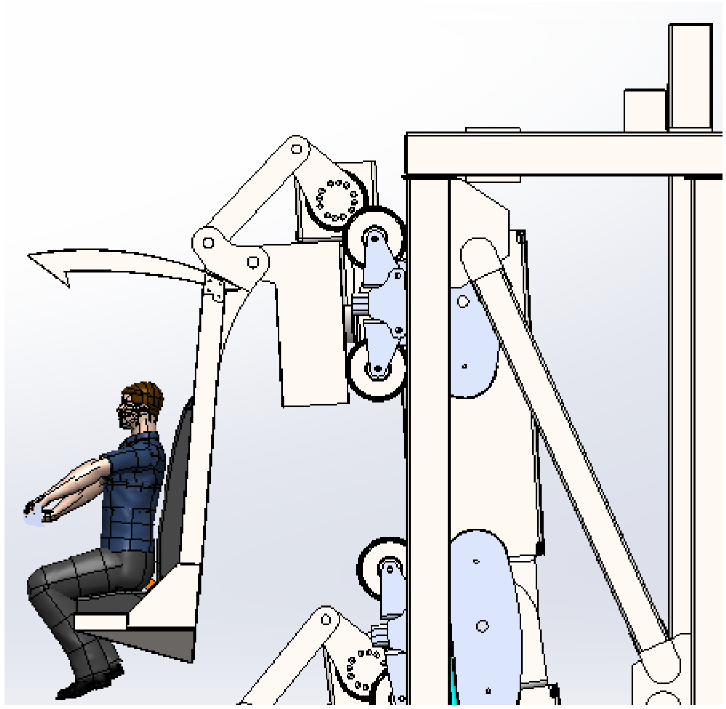

Figure 18: Guest Cabin at Neutral Pitch

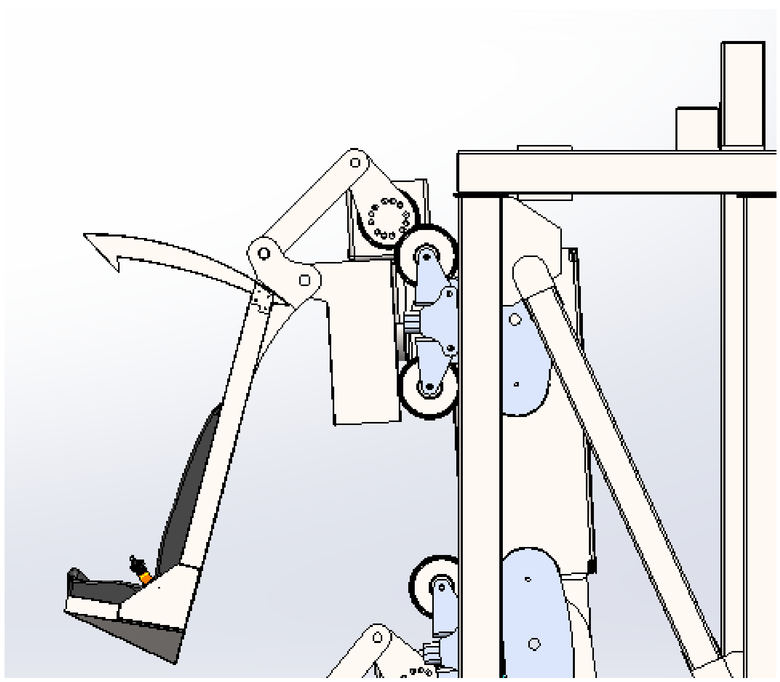

Figure 19: Guest Cabin at +10 Deg Pitch

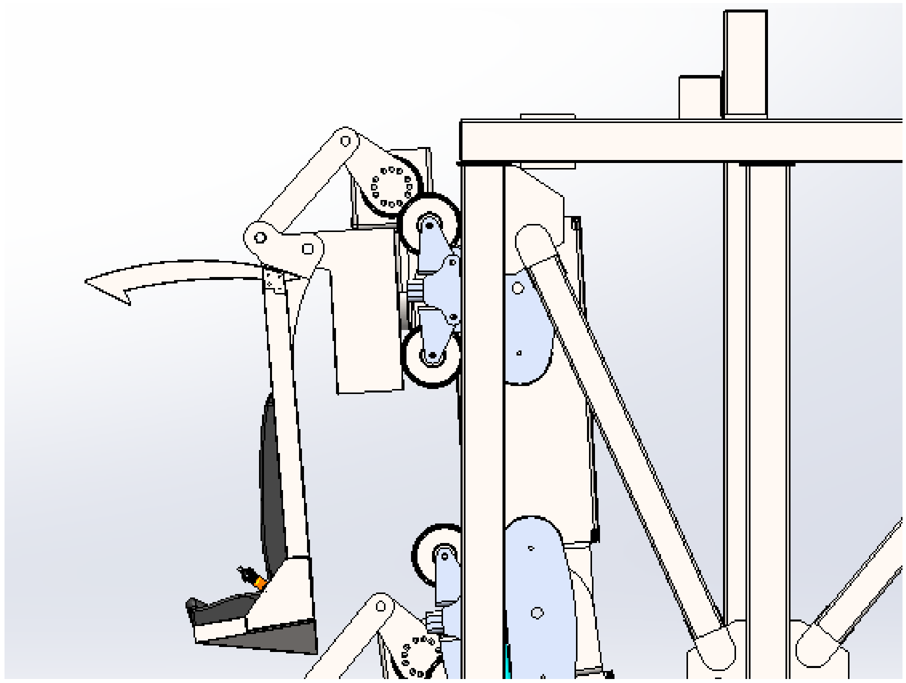

Figure 20: Guest Cabin at -10 Deg Pitch

3.2 Performance Values

This section summarizes the performance values for the TruFlight Theater, these values may vary slightly between document releases depending on information discovered during the design process.

Axis of Motion	Range of Motion	Speed	Acceleration
Primary Heave	3.406 ft (1.038 m)	2.624 ft/s (0.8 m/s)	0.18 G
Secondary Heave	10.50 in	10.13 in/s	0.10 G
Roll	+/- 2.00 Deg	2.00 deg/s	6.00 deg/s^2
Pitch	+/- 10.00 Deg	20.00 deg/s	50.00 deg/s^2

Table 1: Ride Performance Specifications

A key aspect is the Theoretical Hourly Rider Capacity (THRC), for this configuration of 3 rows of 12 riders would result in a THRC of 540 people for a 4-minute cycle beginning at load and ending at unload.
It is assumed that 30s would be for loading and unloading each including verification steps and other actions up to the RCS beginning the motion program that is preloaded.

$$THRC = \frac{(Guest\ QTY) * 3600s}{Ride\ Cycle\ Time\ Incl. Load/Unload}$$

	Single Tower – 36 Guests	Double Tower – 72 Guests
3 Minute Show + 30s L/UL	540	1080
3 Minute Show + 45s L/UL	480	960
4 Minute Show + 30s L/UL	432	864
4 Minute Show + 45s L/UL	392	784

Table 2: THRC Values for Guest Capacity and Show Time

The above table illustrates the THRC for various configurations in guests per hour.

4 Operation of Attraction and Functional Elements

The following section serves to outline the intended operation of a normal ride cycle, including descriptions of some of the safety elements and actions that are not directly engaged by the operator.

4.1 Ride Cycle Operation

The ride cycle begins with the opening of safety doors, with the guests entering from a specified side and exiting from the opposite side. These doors are also installed such that impact points are minimized if a guest were to stick out their arm during the takeoff motion.

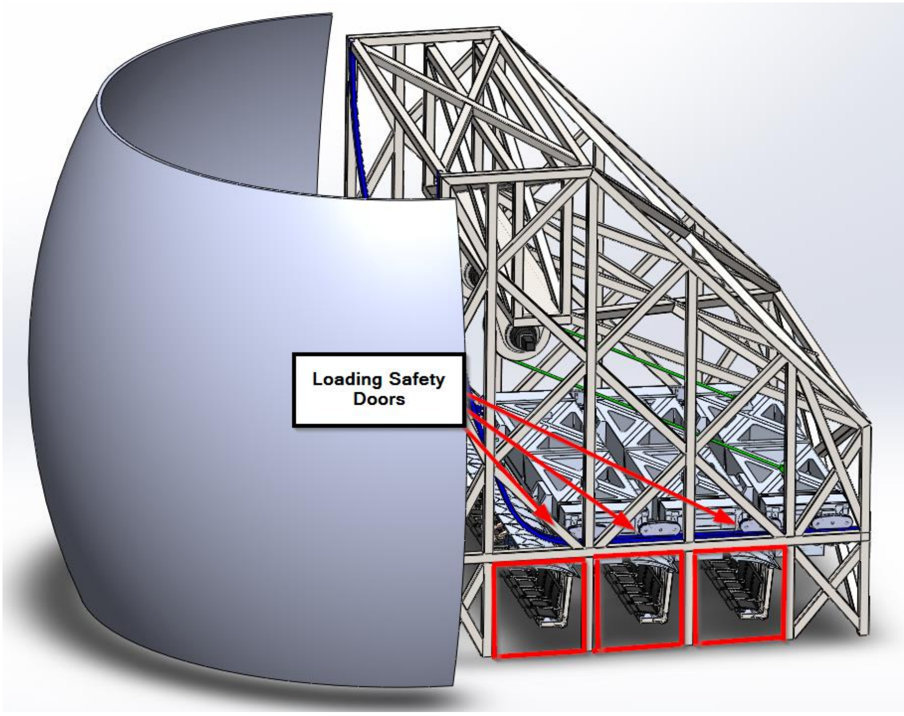

Figure 21: Guest Door Locations

Guests seat themselves and secure themselves using a locking seatbelt that features a release button (in red) that is able to be illuminated when desired in order to aid guests in locking and unlocking their restraints during load and unload.

The seatbelts feature an extended loop such that in addition to the built-in sensors to verify proper engagement, the guests will tug on the loop to show the operator that the seatbelt is fully engaged.

A light will be placed either above the guest or near the seatbelt receiver such that an operator can visually verify full engagement.

Figure 22: Locking Seat Belt Assembly

When all guests are seated and restraints verified the operator will activate a switch out of guest reach to confirm they have verified all restraints. This places a fair amount of responsibility of ensuring guests are properly safe on the operator, there may be other methods to remove some of this responsibility that will be investigated.

Once all restraints are verified the operator(s) they engage a switch at a location deemed to be out of any line of moving machinery, such that the safety door close and then the ride can dispatch.

The ride goes through the pre-determined show profile and back to the station to unload. At this point the safety doors open and the red release button illuminates on each guest's restraint so they know it is possible to release.

The guests exit and the cycle repeats.

4.2 System Description

The following section overviews the function of various aspect of the ride from a system perspective of the control system executing its base required functions.

The ride is comprised of several control systems, each moving segment is defined as a Ride Vehicle (RV), each having a safety rated Programmable Logic Controller (PLC) that supervises all local functions and relays safety critical information to the Ride Control System (RCS).
The RCS verifies all safety critical data such as RV positioning along the ride path as well as accuracy of the pitch, roll, and secondary have compared to the intended vehicle path within a specified tolerance.

The overall methodology behind the motion control can be reduced to a lookup table with a location value corresponding to a time value, effectively giving a time window for the ride to get to that listed point with a specified interpolation method. The interpolation method generally falls to a linear point to point or a 3rd order smoothness that results in much smoother motion with a natural flow.
The linear method is used for certain now show motive functions where a brief pause is acceptable or where a vehicle needs to engage in a parking function and a linear method ensure the desired point is fully achieved.

Once the guests are seated and their belt tab is properly inserted into the receiver, a built-in sensor is activated registering a corresponding signal that is read by the VCS. The Operator Control Consoles (OCCs) will display either through a series of LEDs or on the OCC screen the status of each restraint belt assembly as well as if the relevant operator has confirmed all restraints have been verified.

The safety doors then close and any lighting used to help guests load will shut off, any homing or motion that the RVs need to aid in going from station to show will happen at this point.

The heave system will then pull the RVs forward along the guide rails into the show position through the heave cables and motive assemblies.

The primary heave is used for major flight motion ranges while the secondary have can be used in combination for additional motion at the ends of the primary heave range or to add smoothness and/or additional accelerations in directional changes for the primary heave.

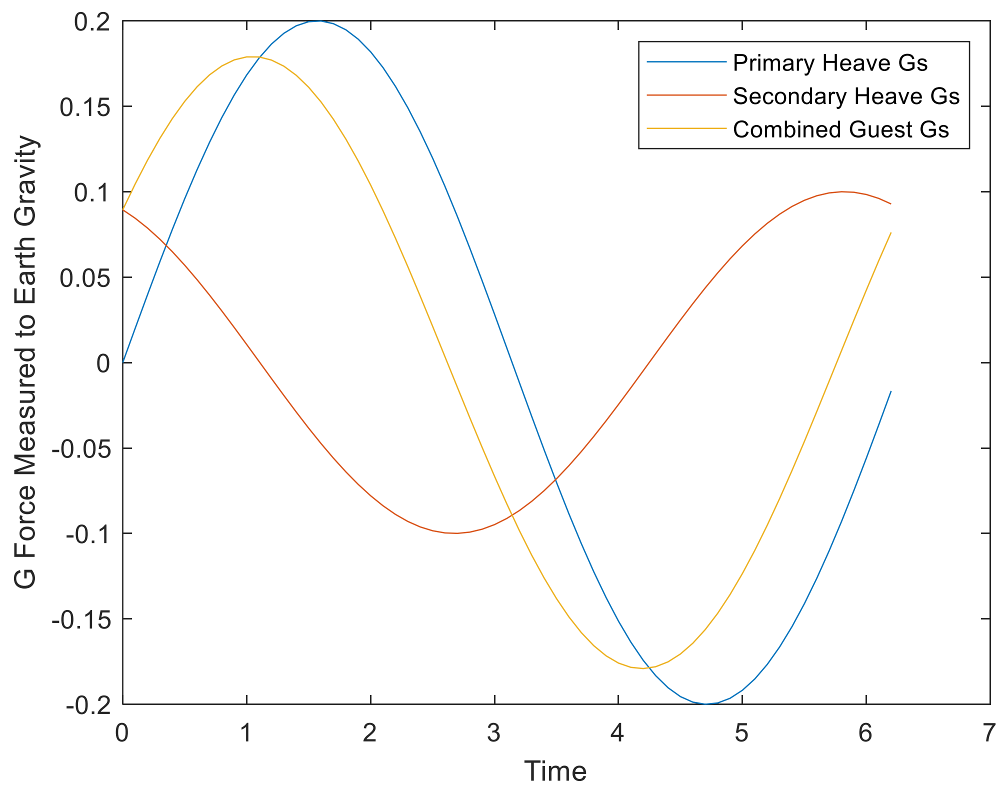

Figure 23: Primary and Secondary Heave Combination

The secondary heave doubles as providing roll to the guests where it can be varied along the bench such that a central point of rotation does not result in one seat having less of an experience than another.

Figure 24: Full Roll About Edge Seat

The reason for the important of this motion specifically relates to the majority of flying experience that turn left or right engage in a motion known as banking.
Banking is how the majority of flying devices and animal operate involving roll and yaw (rotation about the vertical axis) to accomplish a turn.

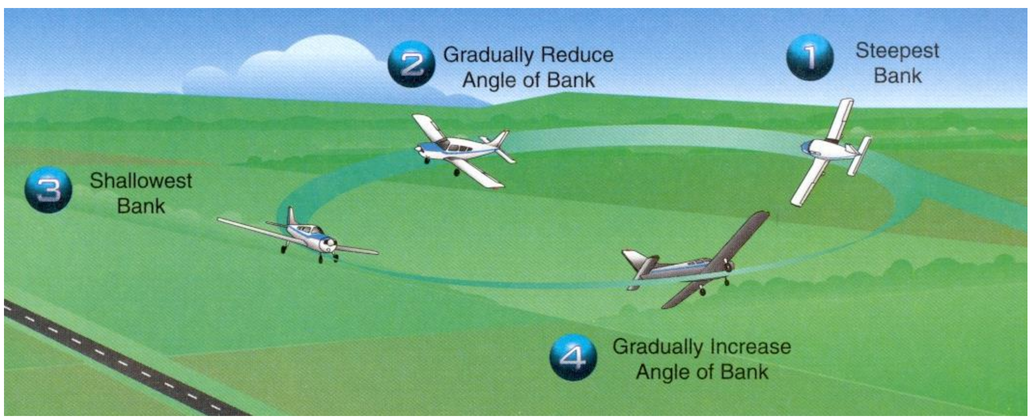

Figure 25: Banking Example

Due to the nature of the theater yaw is not as effective of a motion and the costs associated with it do not add significant experience when compared to yaw and roll being used to trick the guest into thinking more motion is occurring than actually is.
This is accomplished by two linear actuators that support the load and provide the accelerations and motion commanded.
The overhung load is taken up by a combination of linear rails and slewing rings such that the actuators are only subject the loads they are suited to support.

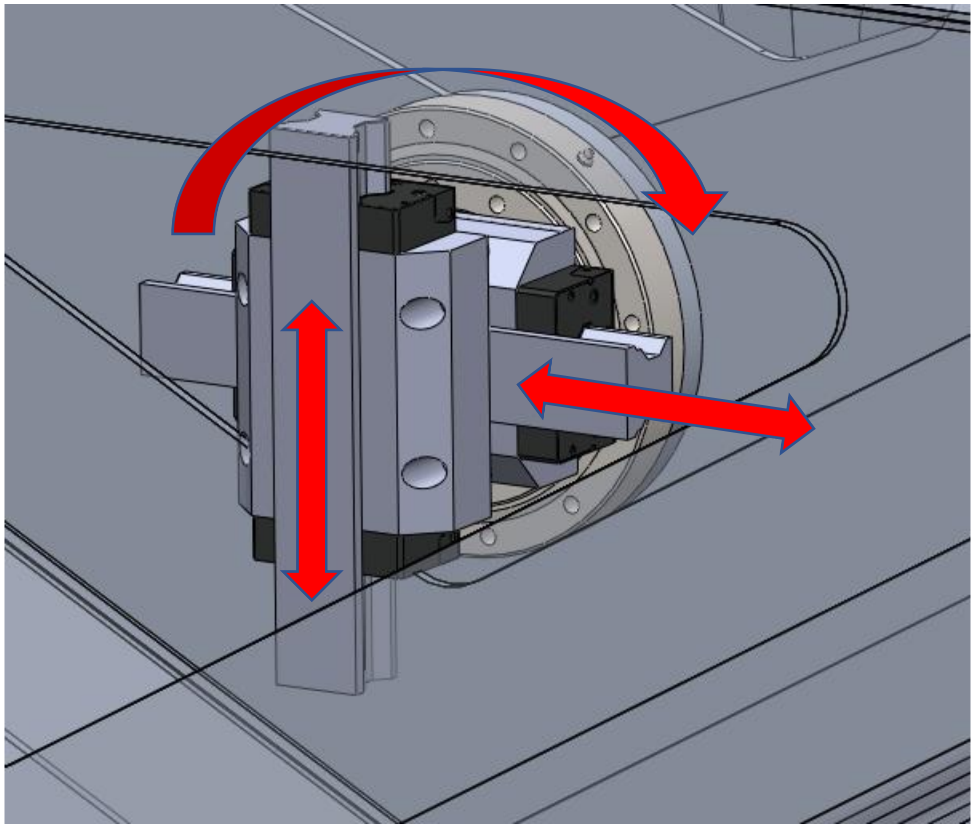

Figure 26: Roll Support Items

Pitch is a key motion as when combined with heave it allows for diving swooping motions that are commonly thought of when flying.

As the ride comes to an end it is lowered along the guide rails into a series of permanent magnetic brakes such that in the event of a fully catastrophic failure, the ride would come to a safe stop.

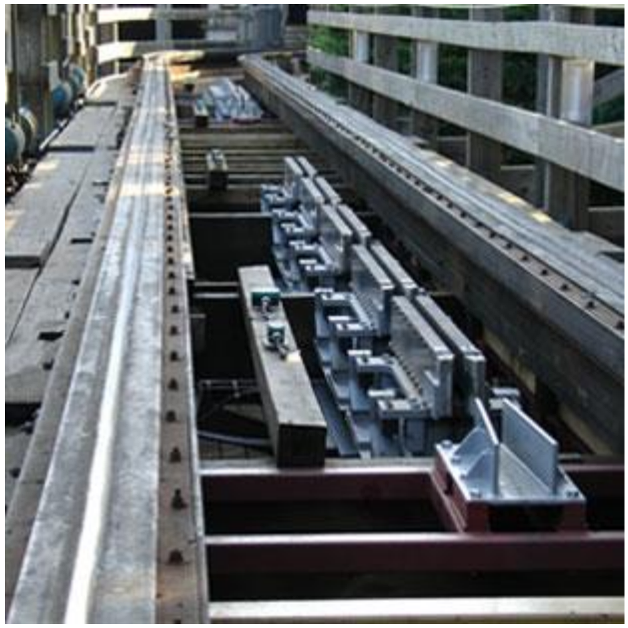

Figure 27: Permanent Magnetic Brake

The ride receives power through bus rail located outside of guest view with the slot facing downwards to prevent dirt and debris from getting in the rail.

Figure 28: Bus Bar with Cross Section

Figure 29: Bus Bar Shoe Assembly

Communication is handled through a wireless mesh network where each of the RVs has its own transceiver to communicate with the RCS.

Figure 30: Fluidmesh Transceiver

This saves on wear and tear that would happen to flexing cables and the support items needed to ensure proper motion.

The positioning of each RV is handled through a safety rated QR code tape.

Figure 31: Safety Rated Linear QR Reader

This allows for easy replacement of broken or damaged tape, as well as the sensor can report data with some dirt or dust obstructing a portion of the tape.
Other linear positioning system require a larger emphasis on alignment and tolerance whereas the above system is fairly low impact in term of setup and maintenance.

The superstructure will also feature a series of catwalks and strategic lifting points to help maintenance personnel complete maintenance tasks such as lifting or moving key components. This structure is built with a focus on assembly and self-centering such that a typical installation crew has the ability to assemble the structure with smaller equipment with less intrusion to the facility it is being built in.

4.3 Fabrication and Assembly Strategy

The following section details the strategies to be used for optimizing the design of the ride to reduce costs for fabrication, shipping, and assembly.

4.3.1 Fabrication Strategy

The majority of ride systems utilize a combination of fabrication strategies but typically rely on welding of primary assemblies and fasteners to bolt those assemblies together.

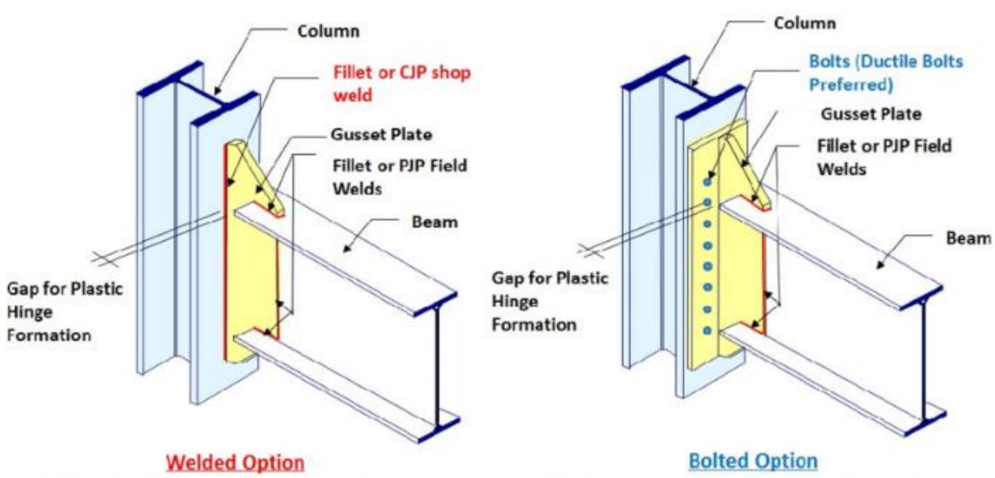

Figure 32: Fully Welded Connection and Bolted Connection

This method of bolted weldments is well known but faces several disadvantages.

Welded assemblies must employ jigs to ensure alignment and length relations which introduces variances between repeated assemblies. Variability in dimensions can be absorbed with design but also leads to additional documentation to cover tolerance stack ups and variability. This may be required to calibrate control system monitoring to avoid repeated faults.

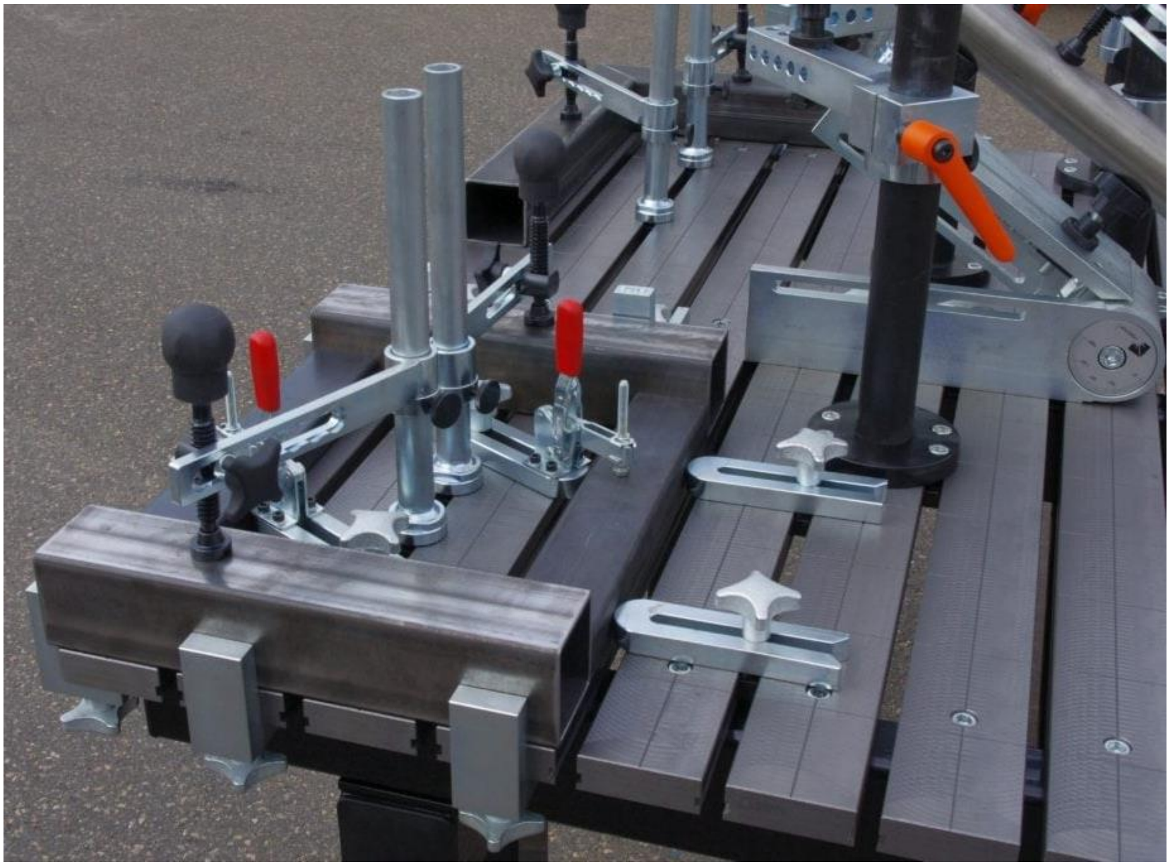

Figure 33: Weldment Jig Set-Up Example

Welded assemblies also require additional time and labor devoted to quality control, with the inspection from a properly qualified person of the fabrication drawings and the welded assemblies themselves. In addition, all welders must have qualified work samples available for 3rd party inspection as required.
With all that welds are still vulnerable to material and work defects resulting in cracks from stress concentrations that cannot be detected due to work variance, or from repeated fatigue stress.

On the maintenance side of this method of joining regular inspection intervals are needed to ensure any cracking is identified as soon as possible. This can be incredibly time consuming and difficult depending on location of access panels and number of welds needing inspection.

Bolted connections can improve upon those shortcomings. Dimensions and tolerances can be more accurately estimated and determined depending on the methos used to locate and create holes for the hardware. With laser cutting or water jet not only can an accurate perimeter be profiled but the hole locations benefit from this in their location and size.

Bolted connections have their own set of shortcomings that depend on the type of fasteners used. All bolted connections require the fastener stack-up to be torqued to a pre-determined amount in order to provide a clamping load to create friction between the two surfaces. As such the clamping force provided by the bolted connection must not diminish otherwise failures can occur.
To monitor these connections after proper torque is applied and the appropriate assembly documentation is signed off, a compound known as torque seal is applied. This is more commonly referred to as torque stripe.

Torque seal can be best described as a paint style compound coming in various colors, the applied paint is what is technically a torque stripe. The various colors allow different department personnel to individually mark a connection which can be useful for QC inspections.

Figure 34: Bolt with 5 Different Torque Stripes

This helps with inspection as a broken line can easily be seen and verified. The drawback of a typical connection is that the nut can always become loose over time with an additional element to provide true locking making it a semi-permanent connection.
A solution to this is a locking washer which through the illustrated geometry relation will prevent any possible catastrophic loosening of the connection.

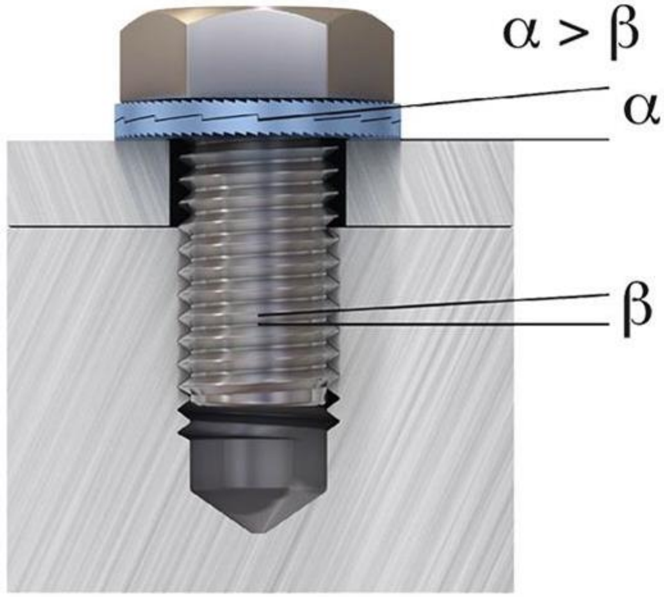

Figure 35: Locking Washer Geometry Relation

The downside of all of this is the number of components involved in the hardware stack-up to provide a semi-permanent connection.

To remedy this a permanent bolted connection can be used with two preferred types, rivets and Huck bolts.
Rivets are often pictured as blind rivets, shown below is an illustration of a typical installation.

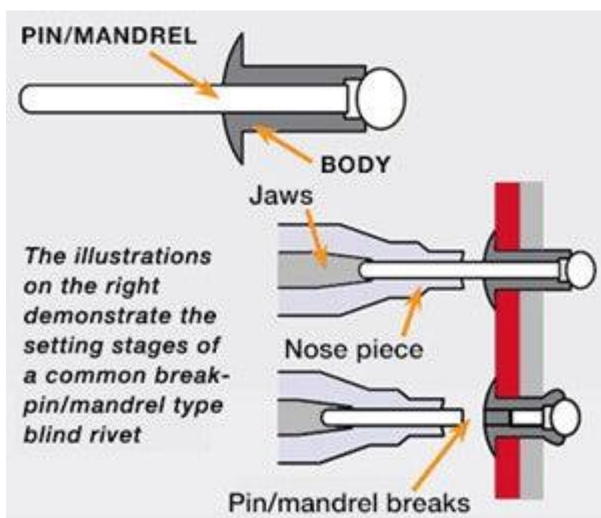

Figure 36: Blind Rivet Installation

This type is fairly straightforward with the mandrel breaking off then the proper level of clamping force is attained. As the rivets are smaller more are needed to provide clamping force however this allows for strategic reinforcement of different elements as needed allowing for reduction in weight and creating much more rigid shapes.

A similar fastener to a rivet is a Huck bolt, where a collar is clamped and deformed to permanently fix the fastener into place.

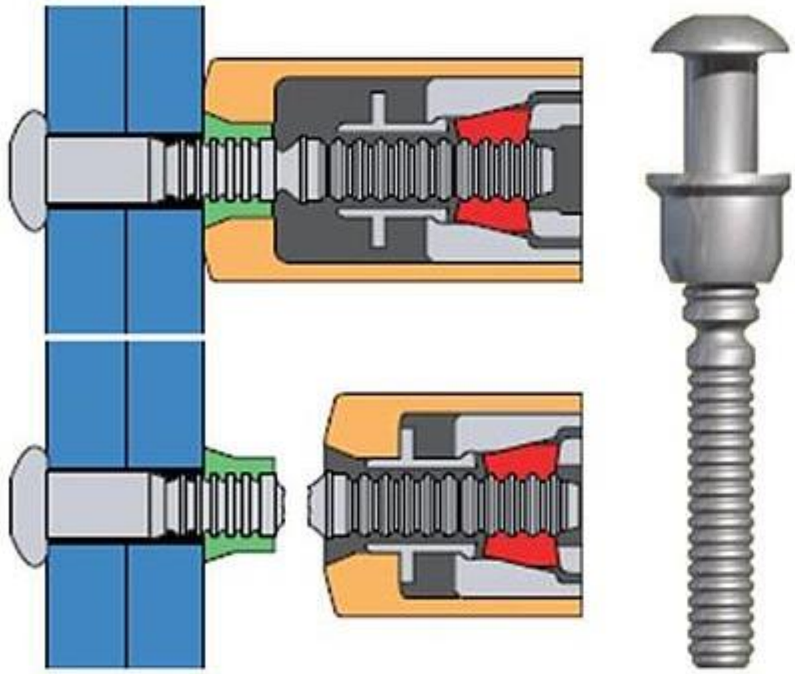

Figure 37: Huck Bolt Installation

The advantage of these over rivets is that they provide the same clamping force as a fastener that would have been otherwise used. The downside being that the installation tool takes up a fair amount of space and may not be suitable for locations where tool space may not be available.

To remove a Huck bolt the collar is broken by a special tool and the fastener can be removed.

These methods are intended to be employed for the fabrication of the cabin as well as other major items. This is intended to be weight saving as well as provide reduced inspection time for maintenance personnel.

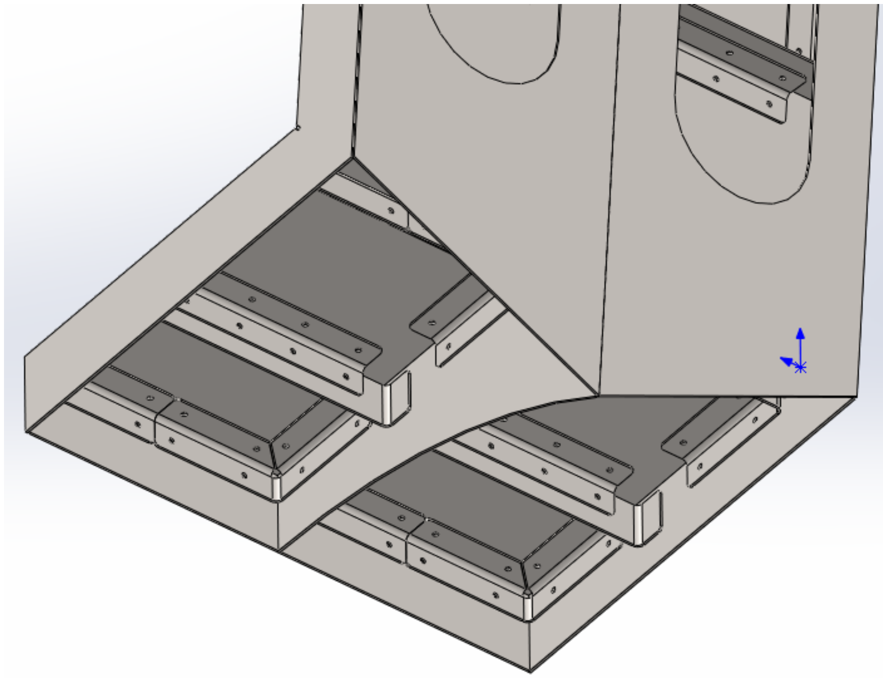

Figure 38: Guest Cabin Seat Design

The above image showcases a fabrication example where sheet metal would be cut to shape and riveted together at the dotted locations that can be seen.

Most importantly is how this method would apply to the guide rails.
Riveted roller coaster track has been used in several instances boasting faster assembly time as well as lower cost due to minimizing of welds.

Figure 39: Rivet Coaster Track Example

As can be seen the curvature of the track is accomplished by cutting the sheet metal to a predetermined profile and having the desired profile and twist naturally be accomplished through this assembly process.
This has the added benefit of locating support points on the track as the most convenient locations for a lower cost than having to weld support plates.

4.3.2 Assembly Strategy

The assembly strategy for this ride looks to break down the major assemblies into smaller subsections in order to take advantage of shipping price breaks available when using standard shipping containers.
This also aims to allow workers to move components without needing large heavy machinery such as cranes or other machinery that would normally require a portion of the facility roof to be cut out and replaced or major walls being modified in order to fit the components.

This also extended to the assembly and maintenance of key items by providing lifting points and other key elements that would be beneficial for maintenance personnel to replace large and heavy items. Catwalks, hoisting points, and other such items will be designed and located with the understanding that ease of ownership relates to direct savings to the customer as well as increased fidelity during the lifecycle of the attraction.

In addition, this design looks to be suitable for retrofitting of any spaces that look to upgrade their flying theaters to the Medici XD TruFlight Theater.

5 Control System and Methodology

The following section outlines the components, and the logic of the RCS and how different subsystems communicated with each other.

This section is no meant to be exhaustive but rather a general introduction that will be expanded upon as the design matures.

5.1 Component Overview

The control system components are housed within various enclosures with size depending on the components being housed within the enclosure and on the surface of the enclosure.

The internal components serve various purposes that will be discussed further in this section, however as an overview they fall into several categories, power distribution, input and output, communication, and logic.

Figure 40: Sample Enclosure Internal Layout

Cabinets can also have Human Machine Interfaces (HMI) attaches generally to the front hinged enclosure door. These HMIs could take the form of push buttons, switches, or a touch screen as can be seen below.

Figure 41: Enclosure Example with Pushbutton HMI

Figure 42: Enclosure Example with Touchscreen HMI

Within an enclosure a variety of components may be found but for the purpose of this introduction the components listed will be those found in a primary enclosure that includes logic related items as well as power distribution.

The intended breakdown of the control system configuration involves treating each ride vehicle assembly as an individual subsystem

5.1.1 Ride Control System Logic Components

The logic related components of a ride control system allow for robust function with high fidelity and reliability.
Components receive and send signal through input/output modules as well as communication modules that generally communicate over a standard communication protocol for the entire control system for ease of programming.
Input/Output modules, known as I/O, are either digital or analog, where digital refers to on or off signals (high/low, 1/0), where analog refers to a variable signal that is between 0 and 1023.

Digital components can be a physical switch or a contactless component such as a magnetic tag and reader.
All digital methods can be either Normally Closed, N.C., or Normally Open, N.O., where the default signal is High, 1, or Low, 0, respectively. Where below it can be seen that a N.O. input connection requires the switch or signal device to be activated for a High signal and the N.C. input connection does not.

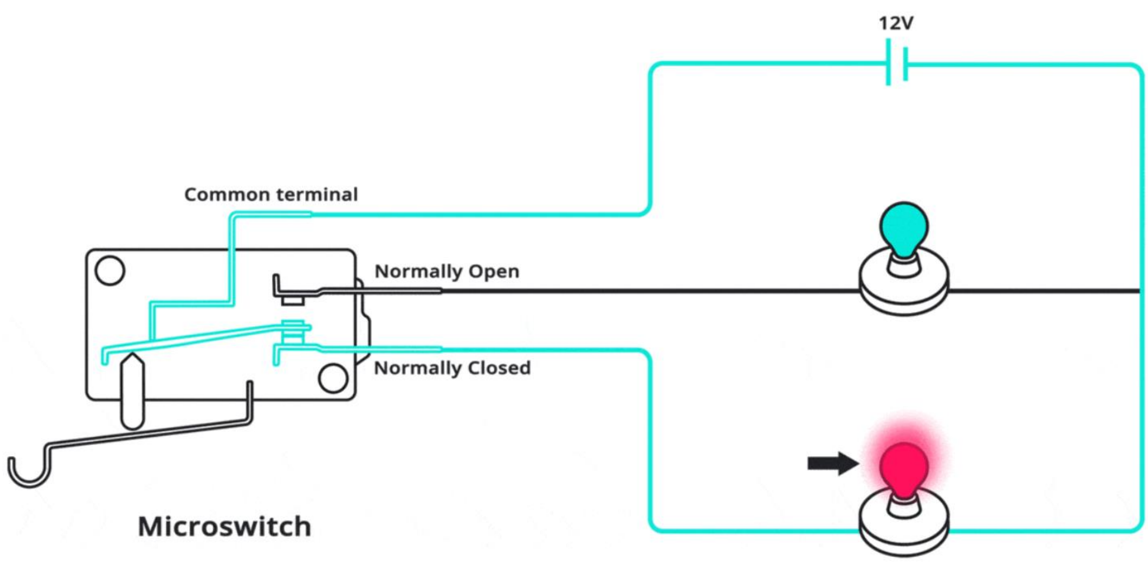

Figure 43: Normally Closed Digital Switch

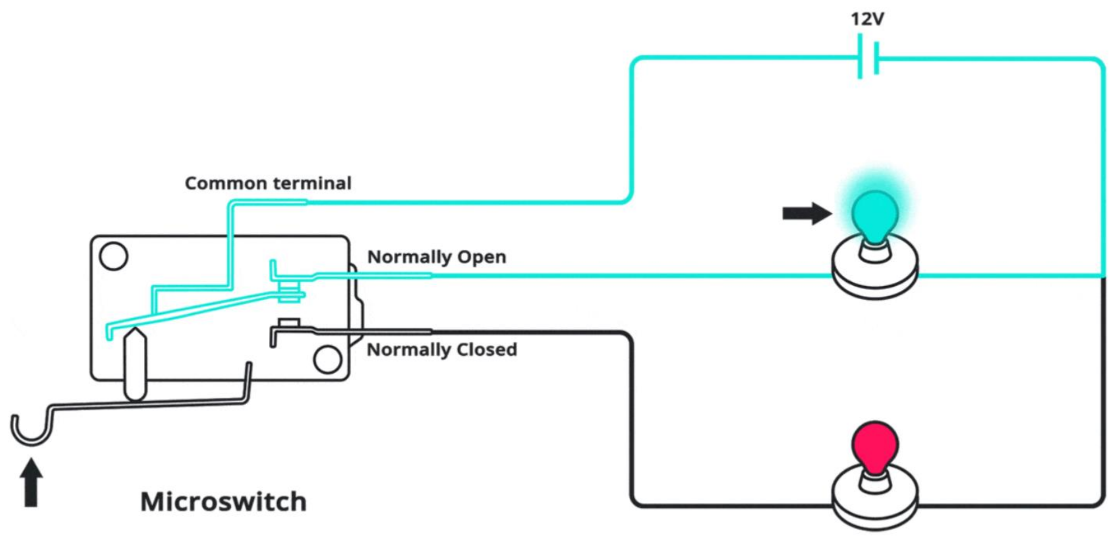

Figure 44: Normally Open Digital Switch

An output digital signal serves a similar purpose, providing a high or low to indicate component status. As an example this could serve to turn on a light to let an operator know a status, or to change the engagement status of a lock.

An analog switch is typically a potentiometer-based sensor where rotational limits exist to keep the signal between 0 and 1023.

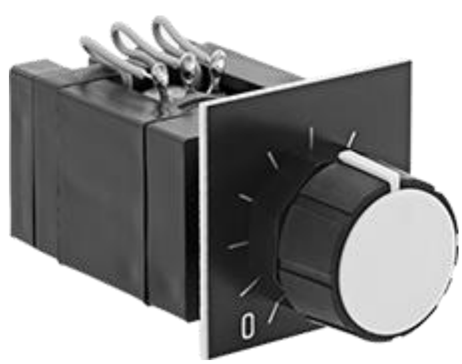

Figure 45: Potentiometer Dial

These switches are more often used with HMI consoles with non-safety related tasks such as lighting.

Any I/O signal must be received or sent through a corresponding module, either digital or analog. These modules can support multiple devices, referred to as channels, that are individually addressed when setting up the control system communication between components.

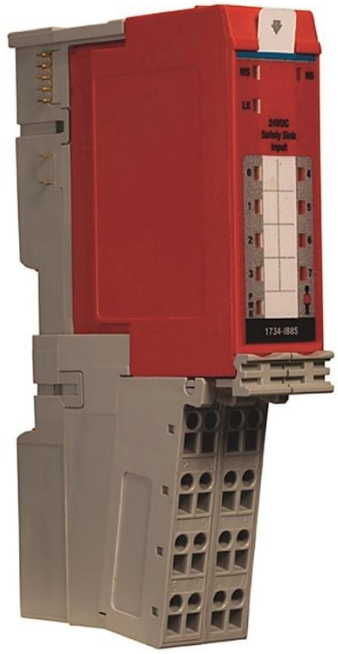

Figure 46: Safety Rated 8 Channel Digital Point I/O

Communication between modules and components can be done with different communication protocols depending on component brand and design. For the purposes of this document and simplicity EtherNet/IP will be the primary focus.

EtherNet/IP is a communication protocol that's part of the Common Industrial Protocol (CIP), which defines the object structure and specifies the message transfer. Effectively EtherNet/IP allows for a message of a predetermined length to be sent and received from other logic controllers or motor drives.

An example of an Ethernet management switch can be seen below.

Figure 47: Stratix EtherNet Switch

This switch supports a predetermined number of devices and allows for easy of communication and thereby programming and troubleshooting throughout the design lifecycle.

All signals are processed and commands issues by a Programmable Logic Controller (PLC) which utilizes ladder logic to safely process and issue commands based on safety related checks and the current machine state.

Ladder logic is a language style that allows for a more visual based programming based on the circuit diagrams of traditional relay logic. The overall shape of the program is evaluated sequentially as “rungs” where the line drawn paths indicate the conditions to satisfy inputs and control any outputs that may be listed.

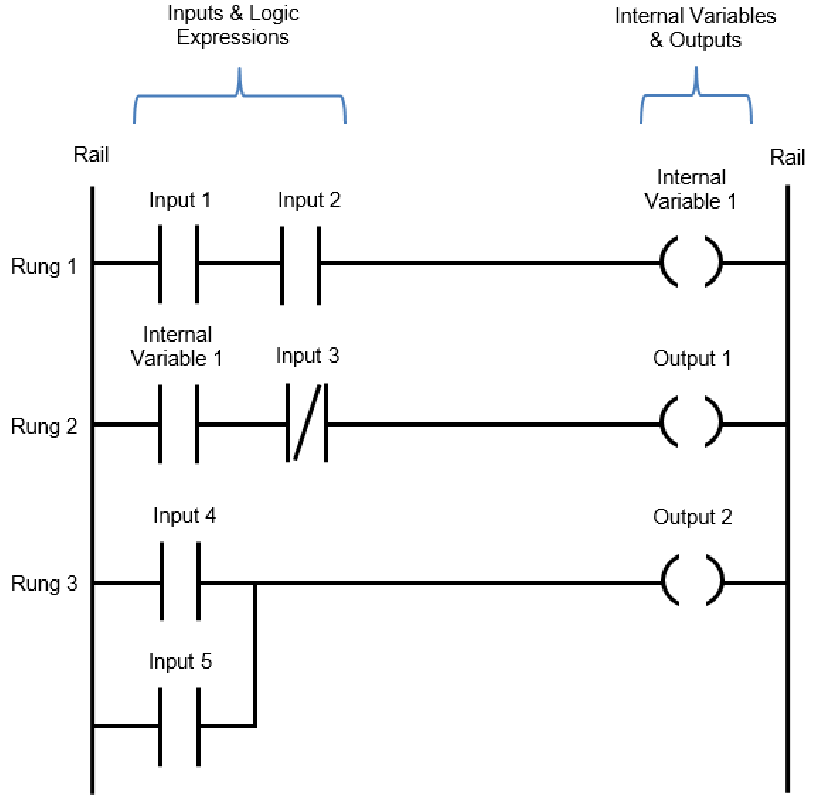

Figure 48: Ladder Logic Diagram

Figure 49: Allen-Bradley Compact GuardLogix PLC

PLCs, like many control system components, can be safety rated or non-safety rated, where safety ratings correspond to probability of dangerous failure per hour, and a component being safety rated refers to a certain level of the safety rating.

PL (Performance Level)	PFH_D (Probability of Dangerous Failure per Hour)	SIL
a	$\geq 10^{-5}$ to $<10^{-4}$	None
b	$\geq 3 \times 10^{-6}$ to $<10^{-5}$	1
c	$\geq 10^{-6}$ to $<3 \times 10^{-6}$	1
d	$\geq 10^{-7}$ to $<10^{-6}$	2
e	$\geq 10^{-8}$ to $<10^{-7}$	3

Figure 50: Performance Level Chart and Safety Integrity Level (SIL)

The above image shows the relation between the Performance Levels, PL, and Safety Integrity Levels (SIL), to the Probability of Dangerous Failure per Hour.

The PL and Sil requirements are determined through safety related documentation during ride system design where a Hazard Analysis (HA), and a Failure Modes and Effects Analysis (FMEA) are carried out to identify risks and document their mitigation strategies. The goal is to mitigate hazards through design means such that the design itself is intrinsically safe, however in the event where that cannot be done safety functions are developed within the control system and components are selected to meet the determined safety requirement.
An example of this would be that a machine can be commanded to make an unsafe motion either to itself or guests despite having a technically high safety rating overall. As such a safety function can be configured to enforce relations or other aspects.

5.1.2 Ride Control System Power Distribution Components

The power distribution system involves fewer components than the logic related items.

Beginning with the input voltage it must go through some form of quick disconnect that can be locked out during maintenance or other applications. This is then fed directly into motor drives that will be covered in the next section.

Figure 51: Example of External Power Disconnect Switch

This feed also goes into a power supply device that rectifies the voltage to be suitable for the control system components which typically operate at a lower voltage than the motive components. The exact amount of power supplies needed is determined during the design off the ride system.

Figure 52: Example Voltage Rectifying Power Supply

Lastly a key item to the electrical system is the Uninterrupted Power Supply (UPS), which is effectively a backup battery such that key safety critical functions can remain operational during a larger facility power failure.
The exact sizing of the UPS is done based on which key systems need to be operational and the time required to perform an evacuation on the ride.

5.1.3 Ride Control System Motion Components

The motive components of the ride system fall into linear actuation and rotary actuation, where the secondary heave system uses linear actuators, and the primary heave and pitch systems each use rotary motion. The components are listed in a general order and not necessarily in the exact configuration.

Beginning with the pitch system the first component after the linkage system is the gearbox. The gearbox has no electrical related components and is listed simply for informative purposes.
Next is the brake, this item is a N.C. component such that applying power releases the brake, N.O. options also exist but typically for guest safety applications all motive components must be fail safety and come to a full stop during removal of power.

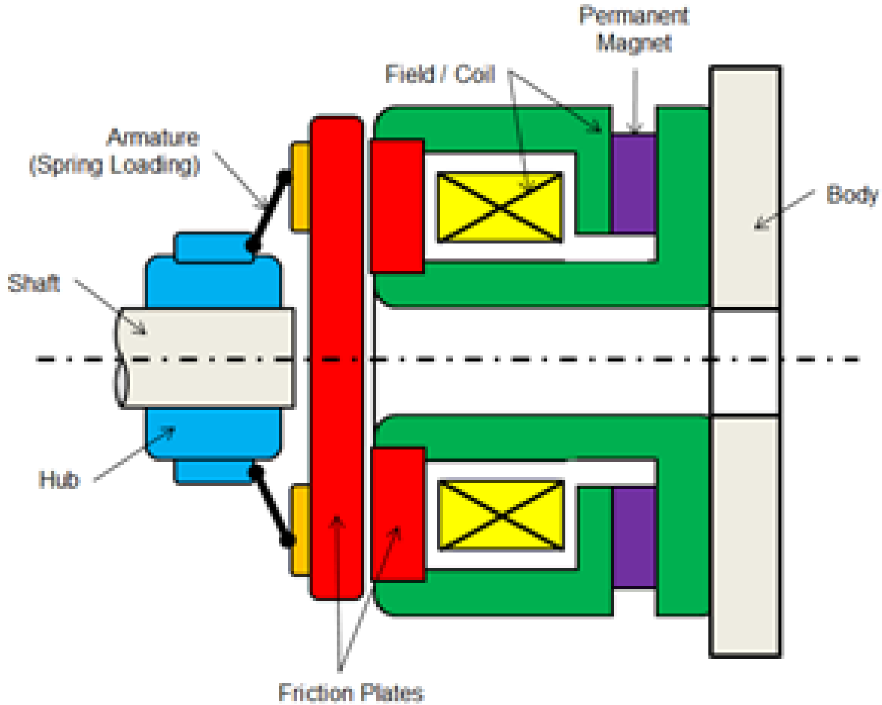

Figure 53: Electromechanical Brake Where Power is Applied to Disengage

Next is the motor itself, in this ride system all motors are electric. Electrical motors fall in multiple categories but for the sake of this application they will be summarized into two categories with a focus on the style and configuration being used in this application.

The first category is known as squirrel cage motors or induction AC motors. These motors are generally intended for constant torque applied is a steady state application. One of the major drawbacks of this type of motor is that it isn't very torque dense, meaning that for smaller motor applications these motors will require a larger volume and thereby weigh more than the other main category of motor. These motors are well suited for large power requirements such as elevators or large mechanical equipment where the weight of the motor isn't a major concern.

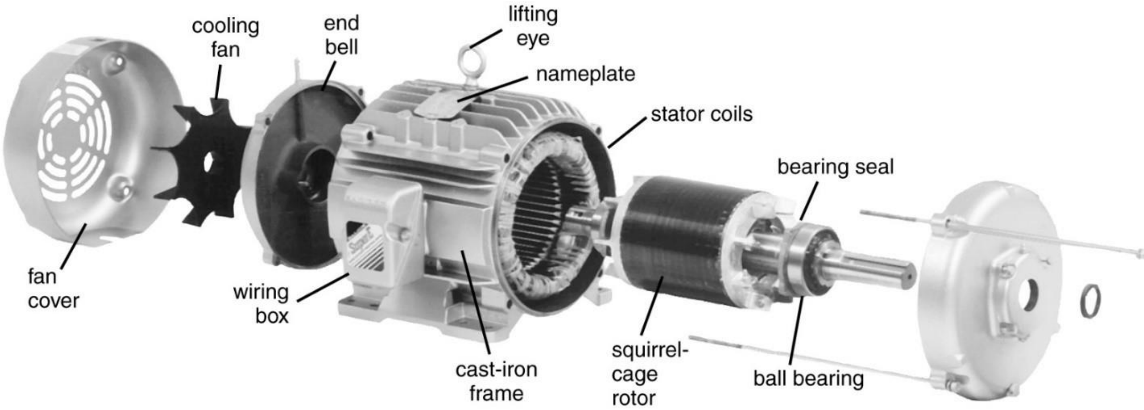

Figure 54: AC Induction Motor Diagram

The other category is known as a servo motor, they are used for high precision applications with a much more compact form. Servo motors are much more torque dense than AC induction motors, this combined with higher precision leads themselves well to ride vehicle applications, the weight reduction in some cases for the same torque can be as high as 3 times less to even 5 times less depending on the specific configuration.

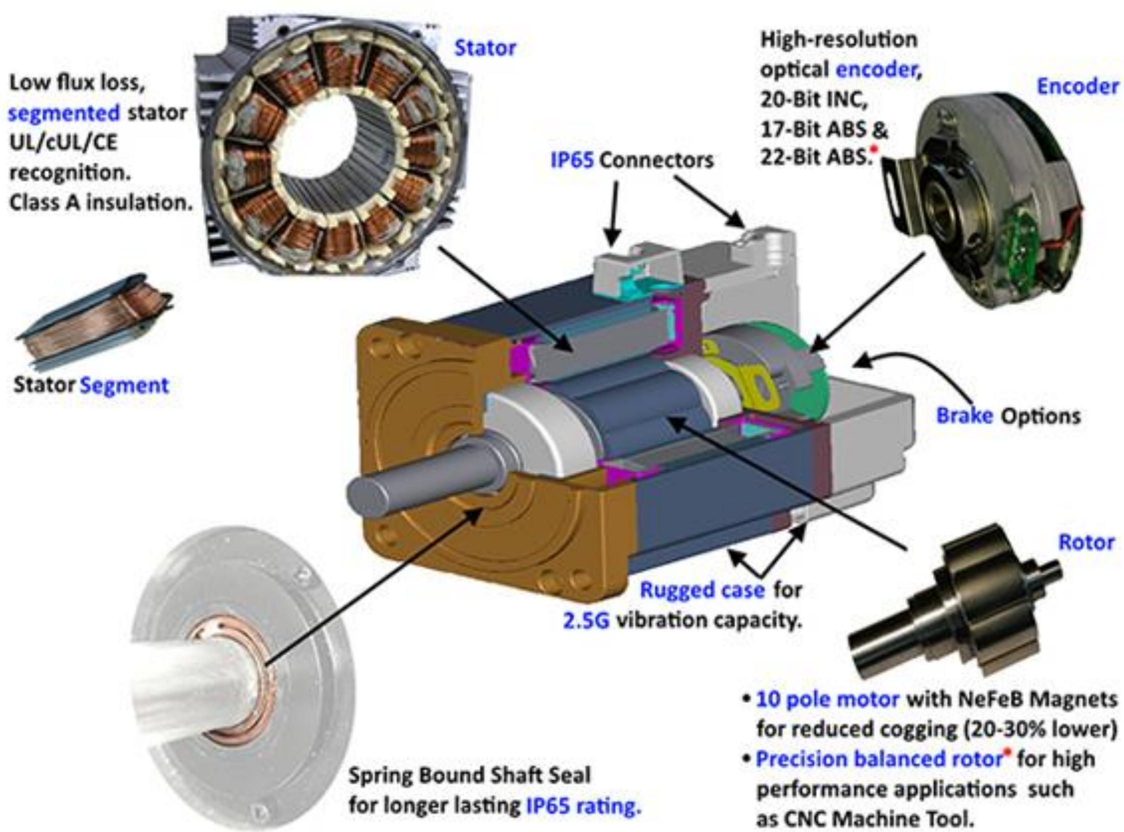

Figure 55: Servo Motor Configuration Example

Each type of motor can have additional components such as holding brakes and encoders for feedback.
A holding brake is used for temporary holding of a load or location versus the stopping brake which is for stopping the motion and bringing the device to a safe stop.

Encoders are devices used for position feedback, they can have either an incremental increase in position where only the step is relayed or an absolute positioning method that provides the precise location of the signal within the scale. These can also be multi turn, such that in the case of a rotary encoder the encoder will also keep track of the number of full rotations of the shaft in addition to the specific position of the encoder as well. As they are feedback devices they have varied safety ratings.

Figure 56: Rotary Encoder Example

Figure 57: Difference Between Absolute and Incremental Rotary Encoders

There are also sizing concerns with rotary encoders where the data sheet values for encoder resolution and frequency response are used as shown below.
The tow values are known as Pulses Per Revolution, PPR, and Frequency response given in Hertz, Hz.

$$Frequency\ Response\ (Hz) = \frac{PPR * rpm}{60\ s}$$

The above equation shows the relation with maximum rotational speed to the encoder design values, this has a governing relationship to any gearing or other connection methods for the encoder to track values.

Lastly linear actuators will be covered, these are very similar to rotary such that the commonalities will not be covered simply the differences.

Actuators can be configured with the previously mentioned motors; these motors can be configured to attach through multiple means at can be seen below.

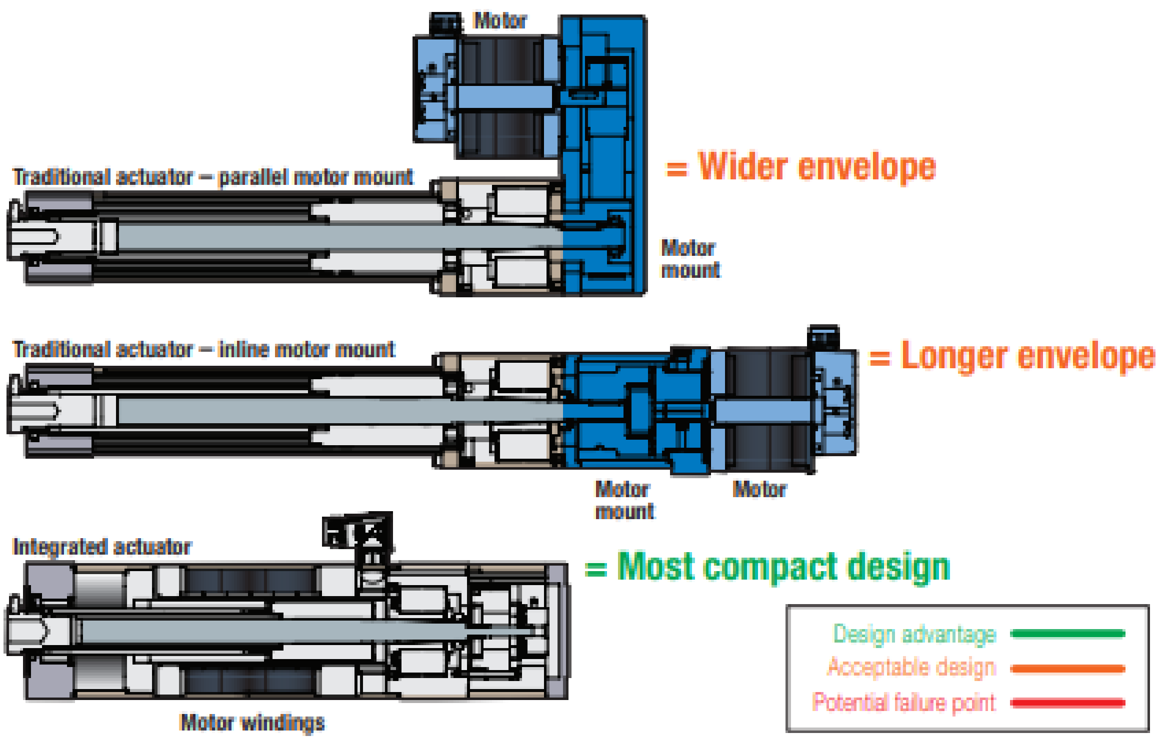

Figure 58: Linear Actuator Configurations

From here the rod and screw system falls into three methods, lead screw, ball screw, and planetary roller. Lead screw effectively works as a nut on a screw where the base of the actuator rod is attached to the lead nut.

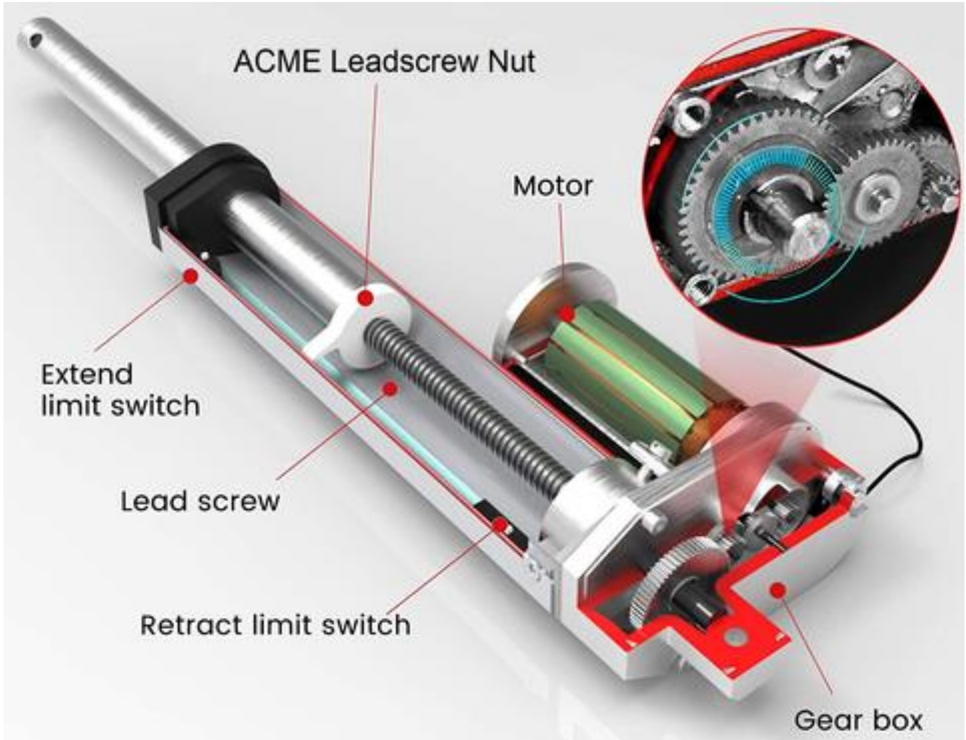

Figure 59: Lead Screw Actuator Component View

The above image shows similar components across all actuator styles.
A ball screw is similar in all components apart from the leadscrew nut is replaced with a ball bearing system where the bearings travel along a path such that the load is distributed between the spheres and the channel.

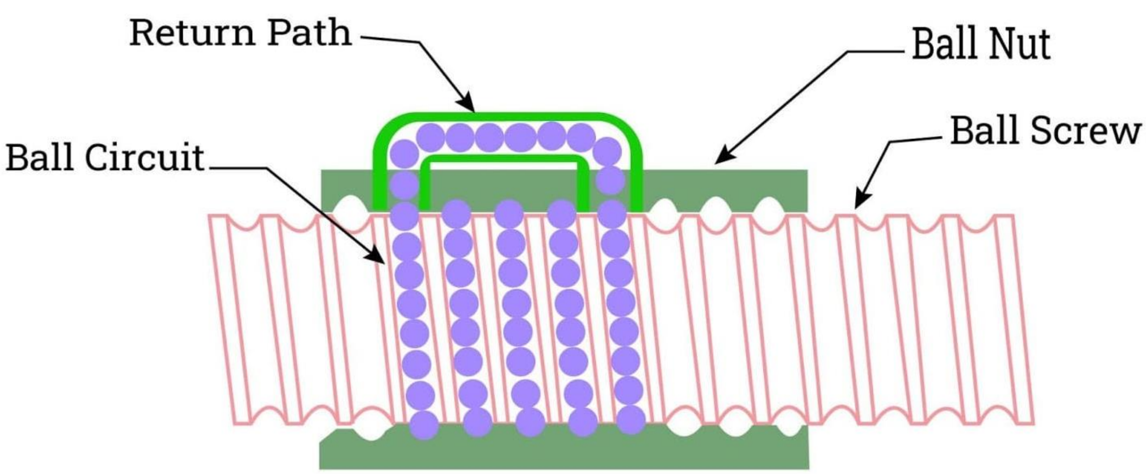

Figure 60: Ball Screw Component View

Lastly the planetary roller screw uses a series of screws that fit in with the internal actuator screw for a greater capability.

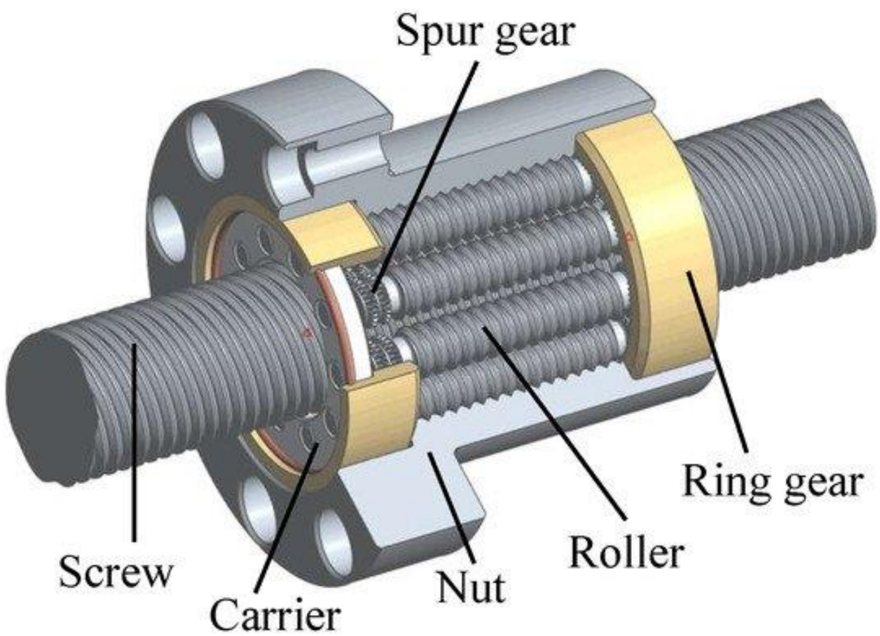

Figure 61: Planetary Roller Screw Component View

This configuration is higher in cost but as there is more contact area between the rollers than with ball bearings.

As a last note it is important to know that it is preferred to have the actuators installed suspended such that they are pulling the load versus pushing. This has to do with the potential for buckling in the long-term usage, while a small concern when the actuator is properly sized it is still preferrable to avoid problems altogether.