The Design of a Multi-Axis Rotational Amusement Park Ride Coupled with Architectural and Thematic Elements

by

Joseph A. Brown

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ABSTRACT

The art of creating a successful theme park ride involves seamlessly fusing complex mechanical systems with elegant architecture. More importantly, it is the job of telling a story that serves as a foundation for designing effective themed rides. This project involves the conceptual design of a ride system versatile enough to accommodate for numerous themed scenarios. Although the scope of this project is conceptual, we cannot ignore the constraints that may inhibit the design's feasibility; hence, calculations are made based on standards and guidelines for amusement park rides. Furthermore, a combination of sketches and diagrams are provided to assist in the visualization of the proposed design.

Thesis Supervisor: John J. Leonard
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1. Introduction

Over the years, theme parks have become top destinations in the entertainment and leisure realm. Part of the mystique of theme parks is that they remove their attendees from the real world, allowing them to experience situations outside of their normal daily routines. From traversing the world in a day to traveling back in time, the possibilities of what one may experience at a theme park extend as far as the designer's imagination.

Creating these experiences though involves a very intensive design process that sometimes takes several years to develop. We may only see the construction of an attraction, but this phase is relatively short as compared to the conceptual and technical design. In addition, there are several other factors that affect ride development; client demand and target audience tend to be key components of this foundation.

2. Background

Several ride manufacturers exist that industry powerhouses like Disney and Universal often outsource from when considering a new attraction. International companies like Chance Morgan, Zamperla, and HUSS, are consulted by theme parks for their ingenious ride systems, especially those with versatile movements with sequence programming capabilities. This freedom enables the company to match the specific experience a client is working to accomplish for their attraction.

For example, in 2002, Paramount's Kings Island consulted HUSS Rides, a German-based amusement park ride manufacturing company, for one of their latest inventions, the Giant Top Spin as seen in Figure 1.

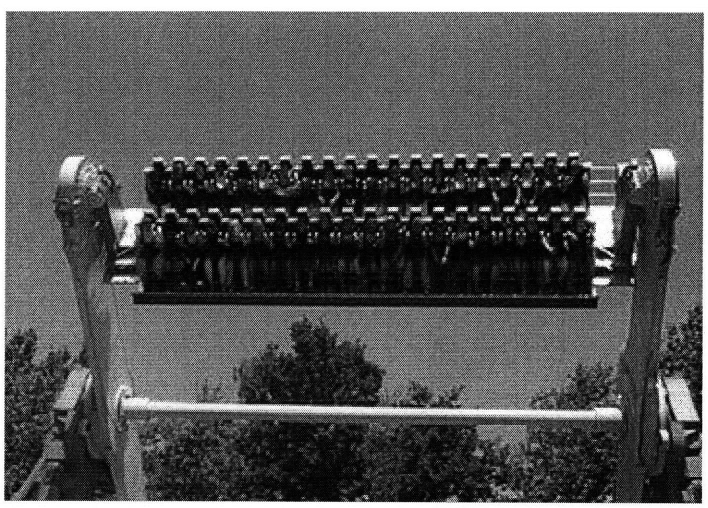


Figure 1: Giant Top Spin *(courtesy: Huss Rides)*

Known for themed rides related to recent Paramount movies, Kings Island chose to recreate scenes from Tomb Raider as seen in the concept art in Figure 2. In hopes to match the intense action and airborne stunts of the movie the thrilling Giant Top Spin model was an appropriate match. Once the system was chosen, a design team had to configure architectural housing that could accommodate for the ride dimensions as well as fit the profile of the chosen theme. It is a crucial task in delivering this combination seamlessly such that passengers have no visual sense of the outside world.

Figure 2: Tomb Raider *(courtesy: Paramount's Kings Island)*

Prior to actual theme production, though, there was considerable amount of technical design work done to create the actual ride system. There are a series of guidelines to be followed as stated in the American Society for Testing and Materials (ASTM) guidebook on *Standard Practice for Design of Amusement Rides and Devices*. The entire ride system must meet these extensive regulations to be placed on the market for potential buyers.

3. Purpose

Inspiration for the following projection stems from personally experiencing a variety of stationary (trackless) motion simulator rides and yet being unsatisfied with the thrill level. The basic idea here is to couple the grand scale and imagery of IMAX theatres with an exciting ride system, without being too extreme or intense for even the most daring thrill seeker. The target audience is the "teenager to adult" category who would appreciate more "bang" in this specific ride category.

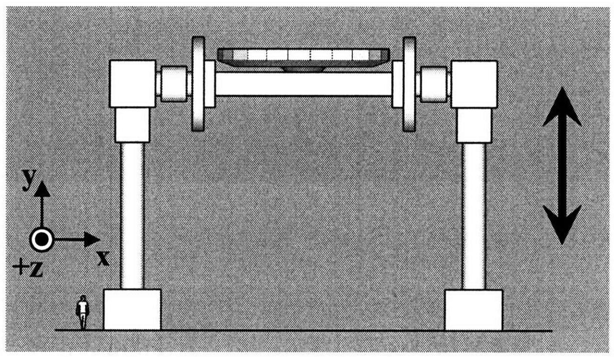
Within this project, we will design a new ride system accompanied by an architectural housing. The scope of this project is conceptual, but it is understood that further technical analysis is required in subsequent phases of this project. However, we will offer some approximations in our analysis for the sake of feasibility.

The appropriate mechanisms for operating the ride will be chosen as well as thorough background information for each component. We will then model how these mechanisms will be applied or fitted to the ride system. Three-dimensional visualizations will also be provided to help further your understanding of the mechanical system, architectural housing, and how each is fused with one another. In the future, following this initial phase's completion, we hope to continue work on this prototype with hopes of patenting the design for potential clients.

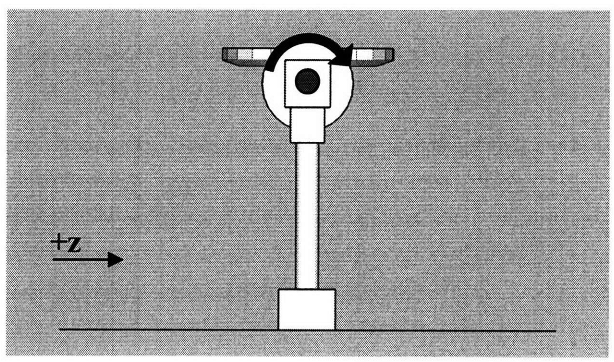
4. System Design

4.1 Mechanics

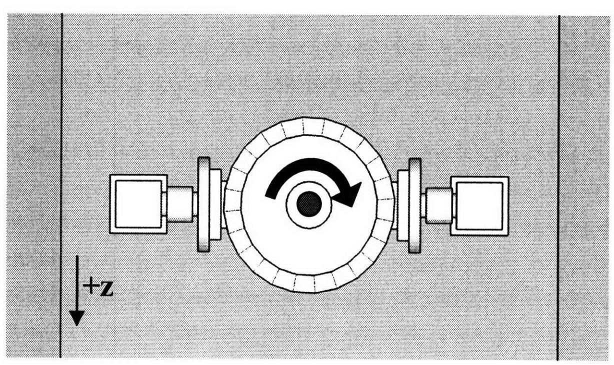
The overall mechanical system consists of two pneumatically controlled pistons (air cylinders) that support and control the vertical positioning of a multi-axis rotational platform whose motion is operated by a series of motors. As seen in Figure 1, three degrees of freedom exist: (1) vertical (2) tilt /rotation and (4) spin, allowing for a very unique, versatile ride system.



(1) Vertical limits based on height of stroke length; controlled by piston extension



(2) Tilt/Rotation (platform) free to rotate 360° in each direction; controlled by motor



(3) Spin (platform) free to rotate 360° in each direction; controlled by motor

Figure 3: Overall Ride System

For a clear understanding of the ride system, the mechanical components were categorized based on their relevance in achieving the three degrees of freedom.

Vertical Lift

The ability for passengers to experience a number of live action scenes during the ride sequence (to be discussed in the next section) without actually traversing across a large blueprint was very important to the system's versatility and marketability. Instead of spreading the scenes throughout a sprawling building, they will be "stacked" vertically on separate levels.

For passengers to experience these action sequences subdivided in vertical levels, a safe and robust lifting mechanism will be included. Initially, we considered a cable lift system similar to an elevator; however, accomplishing faster and smoother transitions would call for more reinforcement. Cable lifts have the tendency to snap after much wear, especially with quick up and down motion, which could potentially be a safety hazard.

After reviewing a number of similar thrill rides, we discovered the majority use some system of pneumatics or hydraulics to accomplish fast movements. The Fabbri Smashing Jump pictured below in Figure 4 uses a jointed piston that when actuated, quickly rotates an attached arm up and down about a pivot. These fast transitions are accomplished via the sudden yet controlled release of pressurized air. Essentially, upward movement occurs due to air entering the piston chamber; whereas descending requires air expulsion.

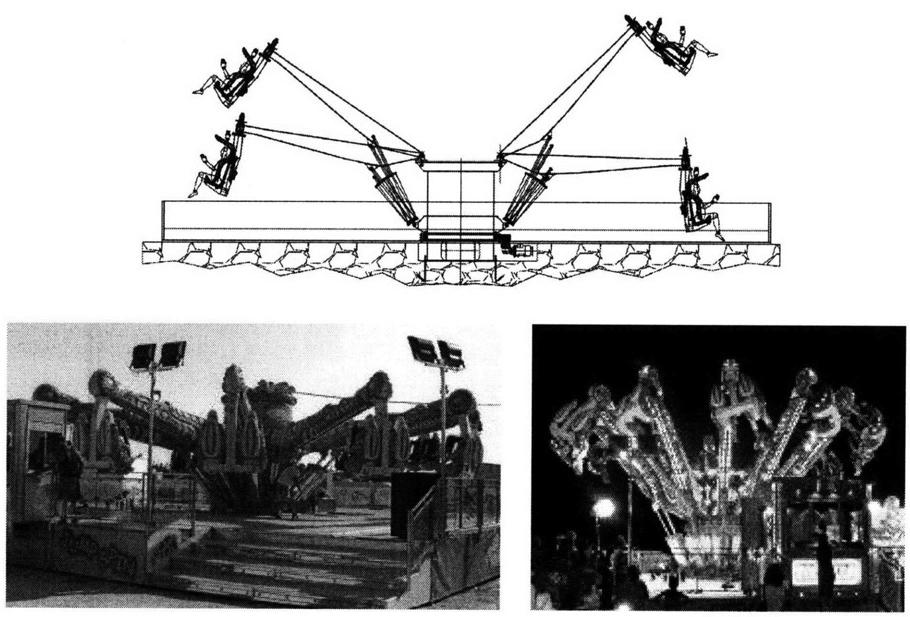


Figure 4: Fabbri Smashing Jump *[Fabbri Group]*

The Fabbri Smashing Jump ride system was of particular interest, as "blasting off" or "shooting down" can create quite an exciting ride sequence; a sequence that complements the vertical motion sought for this project. Figure 5 displays how two large stationary pneumatic pistons will be employed to accomplish such movement.

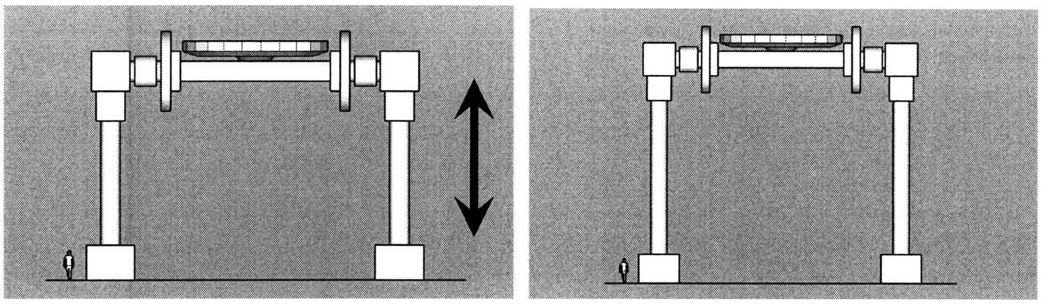


Figure 5: System vertical motion via pneumatics

Pneumatic Pistons (Air Cylinders)

The rapid vertical transitions accomplished in the Fabbri Smashing Jump are attained via a pressure force (pneumatics). Air cylinders are commonly used to produce this needed force. Air is pumped into these cylinders to either push or pull an inner piston/rod component. The amount and speed at which the air enters the cylinder is controlled by an electro-pneumatic transducer that converts voltage or current into a powerful pressure output. This type of system can be seen in everyday applications including modern transport vehicles, such as buses. Buses equipped with remote-controlled doors can be opened or shut by an operating switch which signals an air cylinder/transducer system as seen below in Figure 6.

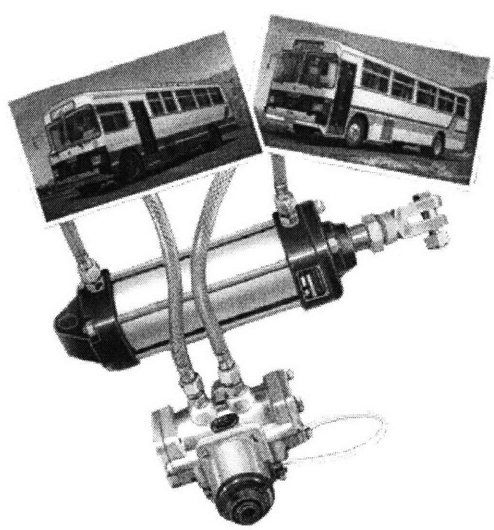


Figure 6: JENCO air cylinder used to operate remote-controlled bus doors *(courtesy: JENCO)*

Operating an Air Cylinder

To understand how an air cylinder works, further analysis of its internal structure must be taken. First, there are two main types of air cylinders that exist: single and double acting. The former requires the piston/rod only be controlled to move in one direction via air pressure with an internal spring returning it to its original position; whereas, the latter is controlled in both directions via air. Figure 7 shows the basic layout of a double acting air cylinder.

As seen in Figure 7a, piston/rod retraction involves air flow, denoted by the blue color, entering valve 2 which enters the inner cylinder (bore) pushing the component to the left. The initial contained air is expelled through a separate smaller exhaust valve located at the rear of the cylinder.

Figure 7b shows piston/rod extension is just the opposite of the above process. Air is pumped into valve 1 which displaces the piston to the right.

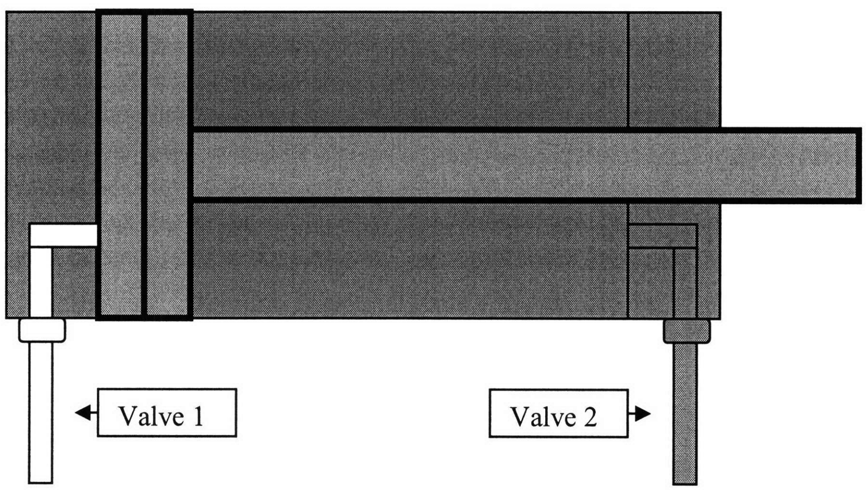


Figure 7a: Air cylinder retraction

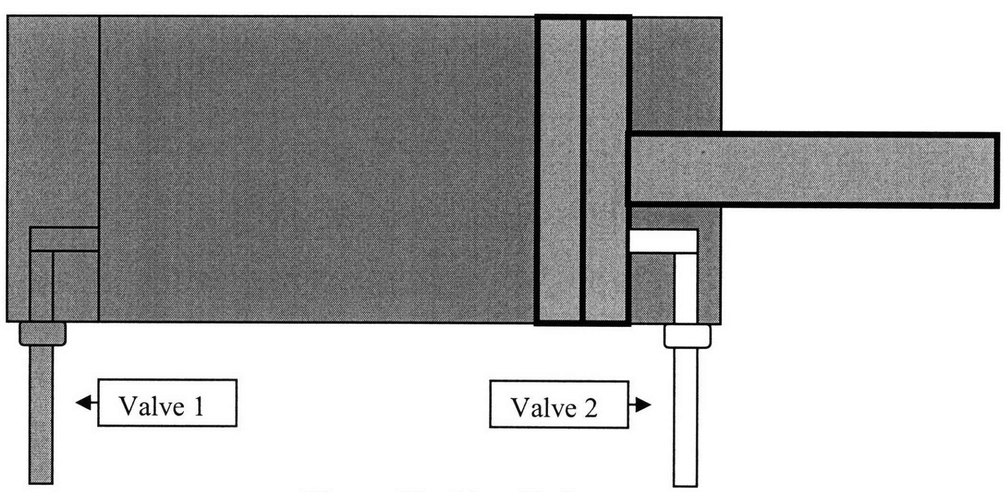


Figure 7b: Air cylinder extension

Electro-pneumatic Transducer

As seen above, operating a double acting cylinder requires air flow through two valves. For this ride system, the ability to control the piston's stroke length and speed is quite important to achieving its goal of versatile height transitions. Achieving accurate and reliable pressure outputs to the cylinders requires an electro-pneumatic transducer, a component commonly used in the industry to convert voltage or current to a high pressure output.

To help further our understanding of a transducer, Figure 8 displays a schematic of a ControlAir Inc. Type 500X transducer.

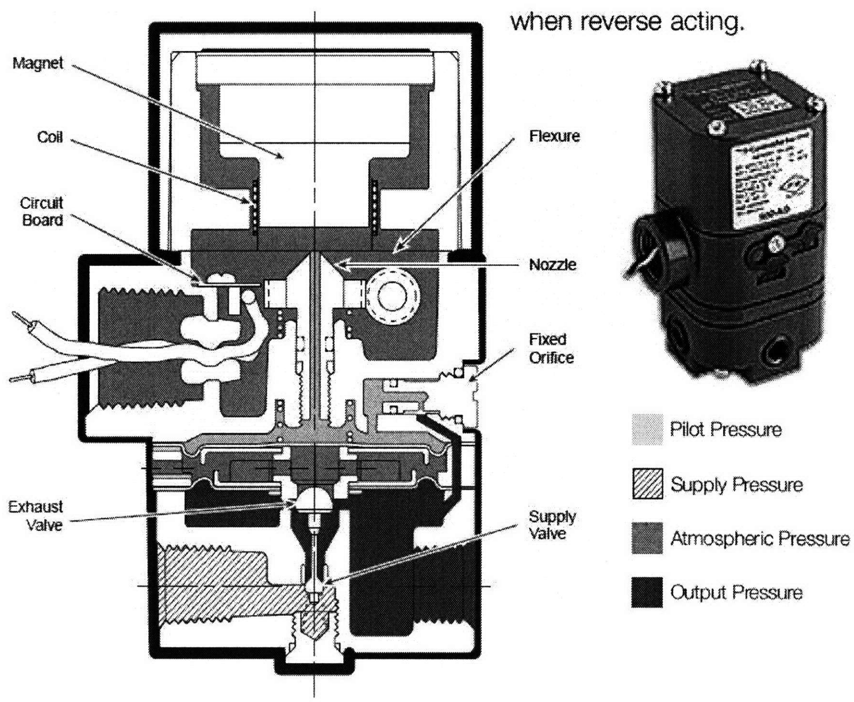
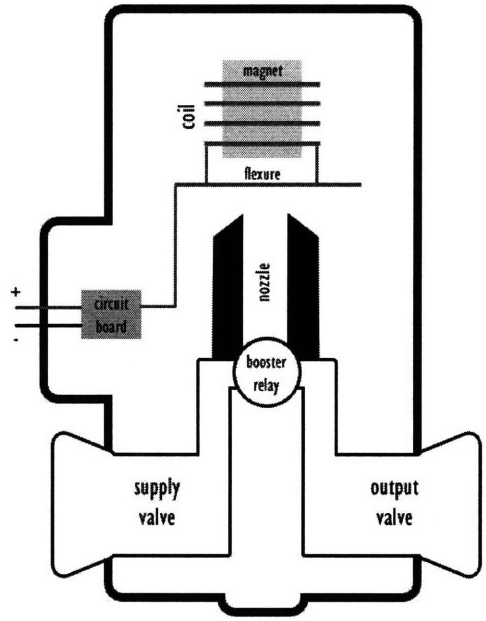


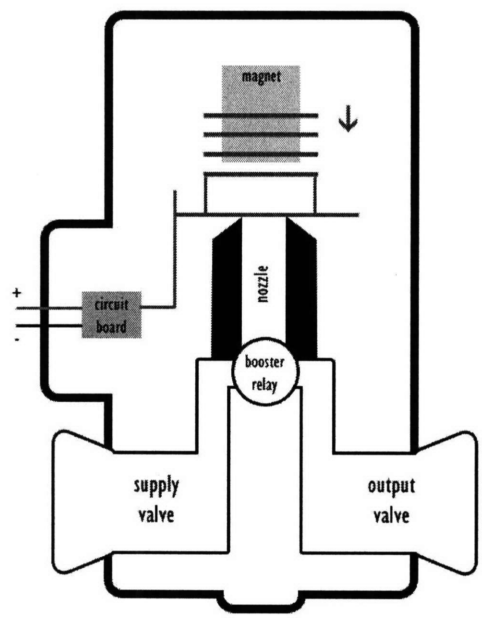
Figure 8: Electro-pneumatic Transducer *(photo courtesy of: ControlAir Inc.)*

Operating an Electro-pneumatic Transducer

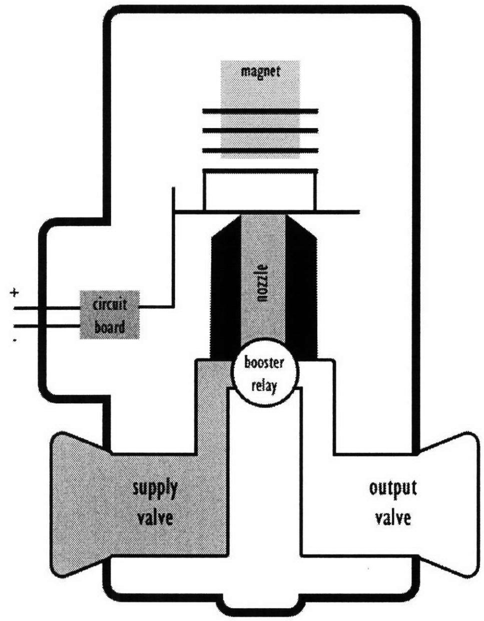
A simplified diagram of transducer operation is provided below in Figure 9. Operation of the transducer is as follows:



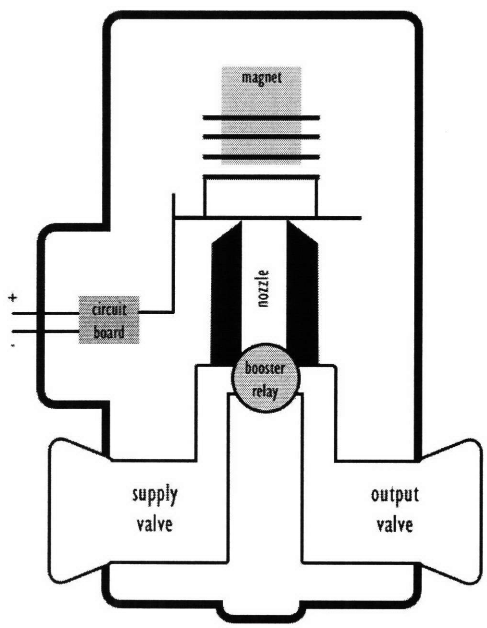
(1) The transducer converts current or a voltage input signal to a linearly proportional pneumatic output pressure. Within the transducer, supply voltage produces a current through a coil



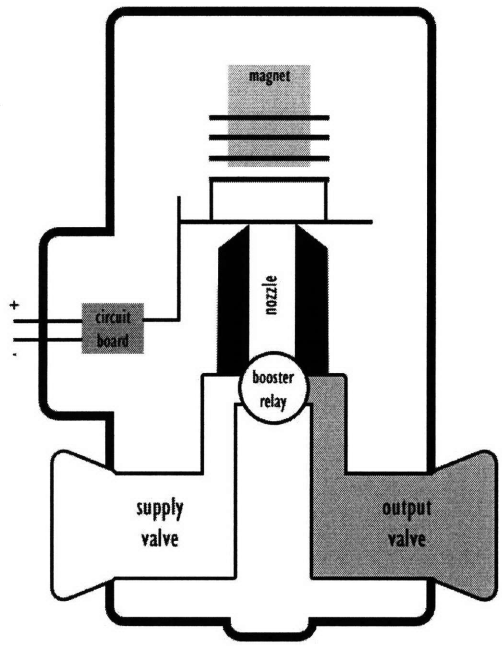
(2) This current forces the coil and an attached flexure to move down around a magnet.



(3) When forced down it closes the nozzle entrance causing back pressure.



(4) Back pressure acts as a pilot pressure to an integral boost relay.



(5) The increase (or decrease for reverse-acting) in the input signal causes a proportional output pressure increase. This pressure increase, in addition to the input pressure provided, is both transferred to the air cylinders. Again, the direction of the piston's movement is determined by which valve pressure is sent to.

Figure 9: Electro-Pneumatic Transducer Processes 1-5

Note: The type of transducer to be used for our ride system requires further investigation based on how many outputs, how much pressure is required for ride operation, etc.

Application of Air Cylinder-Transducer System

In Figure 10, the pneumatic system discussed previously is incorporated into the ride system. Each support piston will be driven separately, each with its own transducer, but will share one main controller to synchronize their movements. Both cylinders will be supplied with air taken from the environment, which will then undergo high pressurization via the electro-pneumatic transducers. Again, both transducers will be programmed and controlled by one source that determines the quantity of air sent and the appropriate valve to send to.

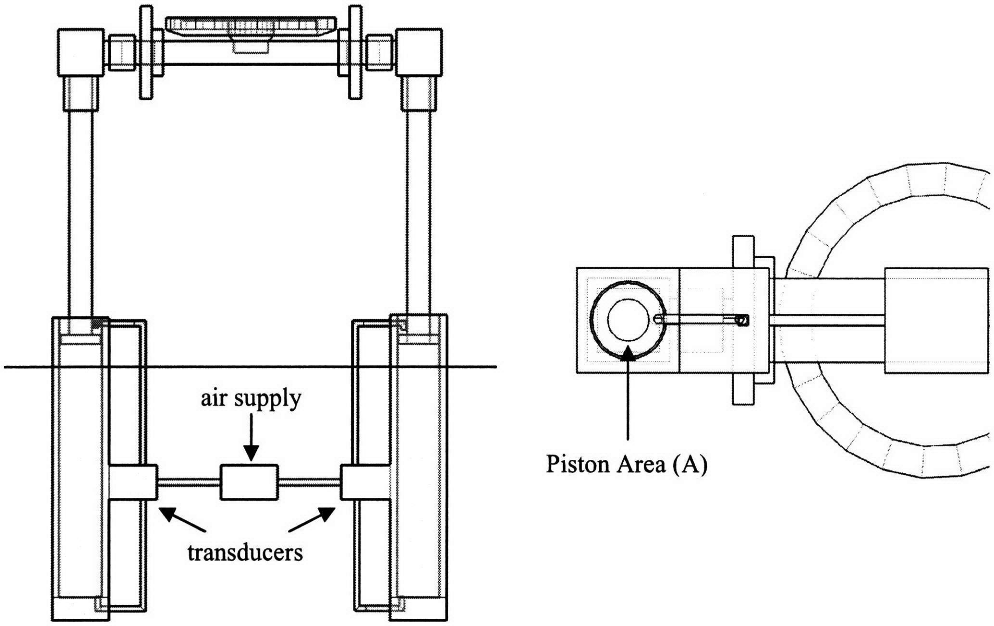


Figure 10: Pneumatic/air cylinder applied to ride system

Although the focus of this thesis is conceptual design, we must consider the feasibility of using a pneumatic vertical lift system. The following are approximations for operation referencing the ASTM guidebook (to be discussed further in Section 4.3.1):

- Mass of mechanism: $m_1 = 2000$ kg
- Mass of total passengers: $m_2 = 77\text{kg} \times 30$ passengers = 2310 kg
- Acceleration of gravity: $g = 9.801\ m/s^2$
- Force required to lift mechanism: $F = (m_1 + m_2) \cdot g = 4.22 \times 10^4$ N
- Surface area of each piston: $A = 2\pi r^2 = 9m^2$
- Pressure required to lift mechanism (per piston): $p = F/2A = 2344\ N/m^2$
- Velocity of vertical lift (max.): $v_{max} = 40$ mph = 17.9 m/s
- Power to lift mechanism: $P = F \cdot v = 7.55 \times 10^5$ W

Tilt/Rotation

The passenger vehicle/disk will rotate as depicted below in Figure 11. This motion will be driven by a programmable stepper motor. During a ride sequence, the disk has the capability of rotating 360° in either direction completely inverting passengers.

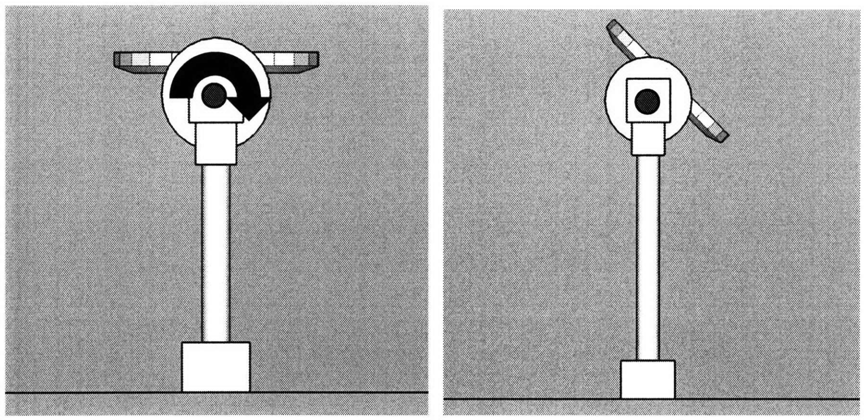


Figure 11: Tilt/Rotation

Stepper Motor

A stepper motor is a brushless, synchronous electric motor that can divide a full rotation into a large number of steps. The motor's position can be controlled precisely, without any feedback mechanism. This type of motor is ideal considering one goal of the system is to tilt and invert riders at varying degrees to match the on-screen and live action thematic elements.

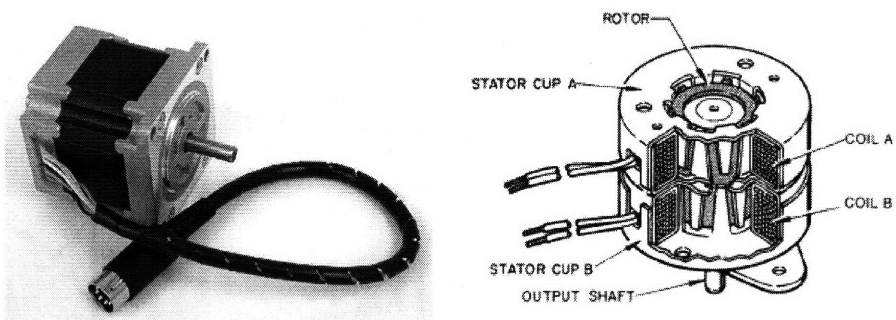
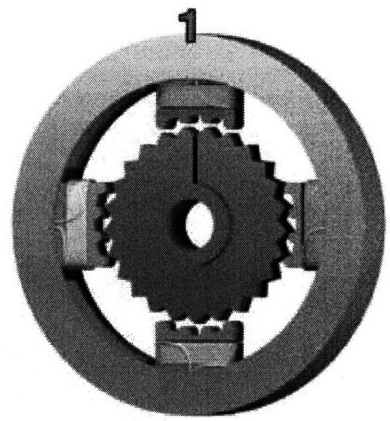


Figure 12: (l-r) typical stepper motor *[Sherline];* internal setup *[engineersedge.com]*

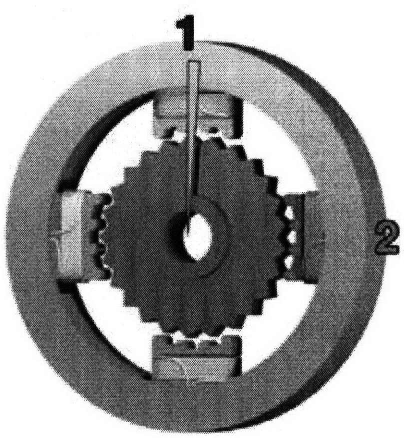
Operating a Stepper Motor

Stepper motors operate very differently from normal DC motors, which rotate when voltage is applied to their terminals. Stepper motors, on the other hand, effectively have multiple "toothed" electromagnets arranged around a central gear-shaped piece of iron. The electromagnets are energized by an external control circuit, such as a microcontroller.

To make the motor shaft turn, first one electromagnet is given power, which makes the gear's teeth magnetically attracted to the electromagnet's teeth. When the gear's teeth are thus aligned to the first electromagnet, they are slightly offset from the next electromagnet. When the next electromagnet is turned on and the first is turned off, the gear rotates slightly to align with the next one, and from there the process is repeated. Each of those slight rotations is called a "step." In that way, the motor can be turned a precise angle. The following example illustrates this step process[1]:

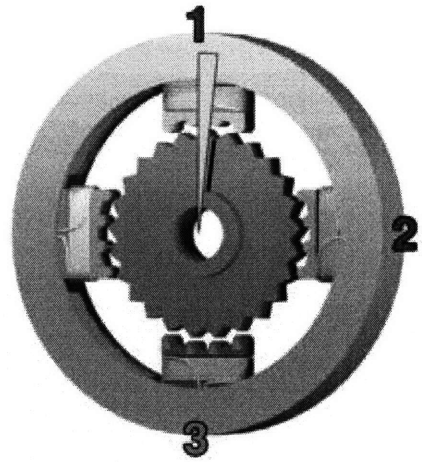


The top electromagnet (1) is turned on, attracting the nearest teeth of a gear-shaped iron rotor. With the teeth aligned to electromagnet 1, they will be slightly offset from electromagnet 2.

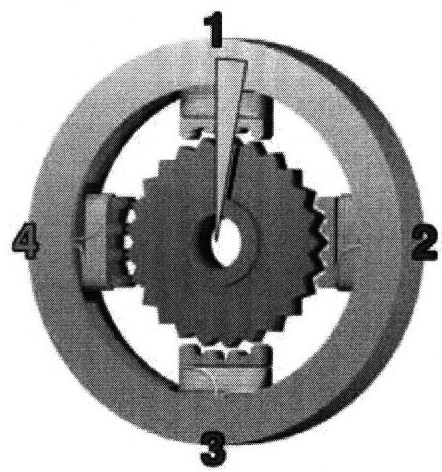


The top electromagnet (1) is turned off, and the right electromagnet (2) is energized, pulling the nearest teeth slightly to the right. This results in a rotation of 3.6° in this example.

[1] Wikipedia. http://en.wikipedia.org/wiki/Stepper_motor.



The bottom electromagnet (3) is energized; another 3.6° rotation occurs.



The left electromagnet (4) is enabled, rotating again by 3.6°. When the top electromagnet (1) is again enabled, the teeth in the sprocket will have rotated by one tooth position; since there are 25 teeth, it will take 100 steps to make a full rotation in this example.

Characteristics of a Stepper Motor

Stepper motors are constant-power devices ($P = \omega \cdot \tau$). As motor speed ω increases, torque τ decreases. The torque curve may be extended by using current limiting drivers and increasing the driving voltage.

Steppers exhibit more vibration than other motor types, as the discrete step tends to snap the rotor from one position to another. This vibration can become very bad at some speeds and can cause the motor to lose torque. The effect can be mitigated by accelerating quickly through the problem speed range, physically dampening the system, or using a micro-stepping driver. Motors with greater number of phases also exhibit smoother operation than those with fewer phases. In the case of this ride system, tilt/rotation speed will be relatively slow, reducing problems with vibration and losing torque.

Application of Stepper Motors

Figure 13 below illustrates the stepper motor application to the ride system. Each of the motors will be housed in a cube-like structure attached to the top of each piston. The motor's shaft of radius **R** will extend out of the housing, where it will be conjoined to the passenger vehicle shaft via a coupling; this coupling is necessary such that the shaft and vehicle rotate at the same rate **ω**.

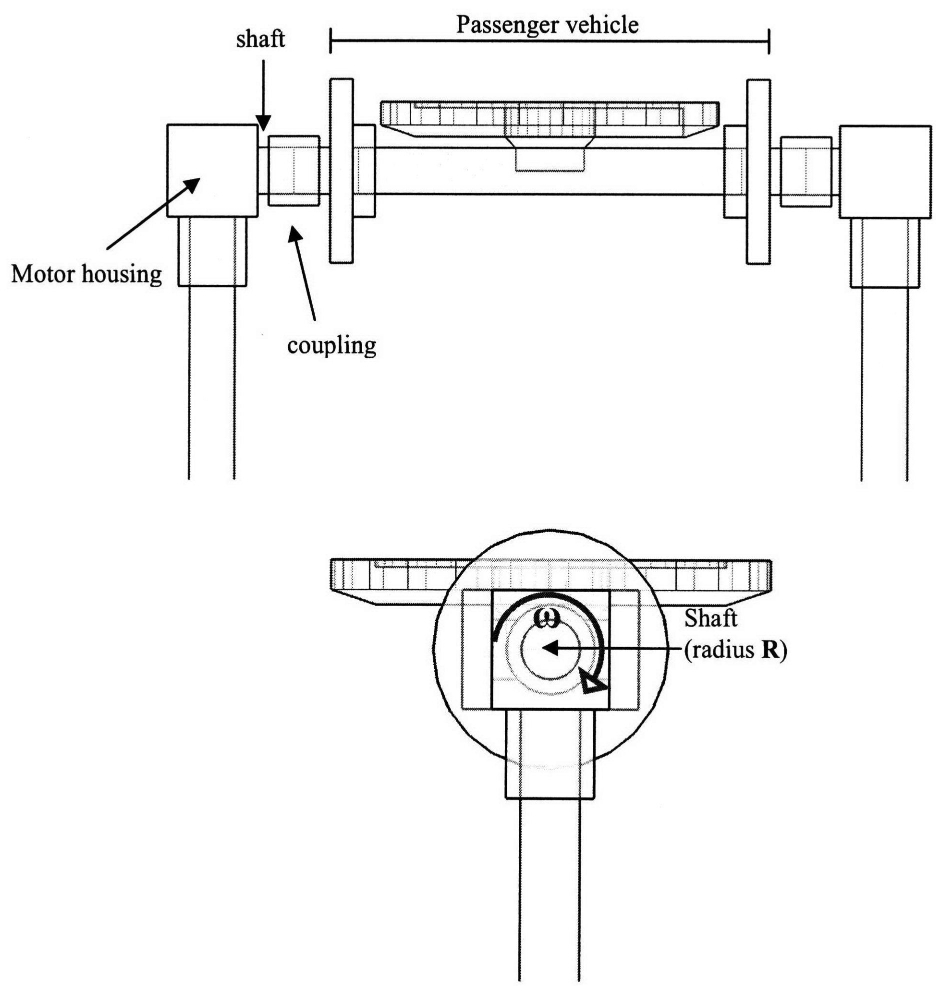


Figure 13: Stepper motor mechanism applied to ride system

Once again, we must consider the feasibility of this ride system which requires further analysis. The following are approximations for tilt/rotation operation (refer to Section 4.3.1 for more detail):

- Mass of total passengers: m_2 = 77kg x 30 passengers = 2310 kg
- Mass of disc plus support arm: m_3 = 700 kg
- Acceleration of gravity: g = 9.801 m/s^2
- Radius of rod: R = 2 ft. = .6096 m
- Radius of disk: R_d = 15 ft. = 4.5720 m
- Angular velocity of disk edge = 1.5 rad/s

- Force required to spin vehicle: $F = (m_2 + m_3) \cdot g = 29501$ N
- Torque: $\tau = R \times F = 17984$ N · m
- Power to drive motor: $\mathbf{P} = \omega \cdot \tau = 2696$ W

Spin

To offer unique ride experiences each cycle, passengers will sit atop a rotating disc/turntable facing radially outward. Similar to how the tilt/rotation mechanism operates, stepper motors will drive the movement. The system will be programmed to rotate +360° in both clockwise and counterclockwise directions as seen in the following diagram.

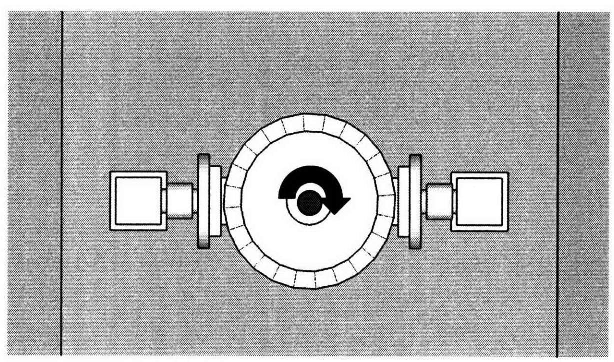


Figure 14: Spin Operation

The following are approximations of values required for spin operation:

- Mass of total passengers: m_2 = 77kg x 30 passengers = 2310 kg
- Mass of disc: m_4 = 500 kg
- Acceleration of gravity: g = 9.801 m/s^2
- Radius of disc: r = 15 ft. = 4.572 m
- Angular velocity of disk: ω = 2 rad/s (max. value)
- Weight of disc and passengers: $F = (m_2 + m_4) \cdot g = 27541$ N
- Torque: $\tau = r \times F = 2.70 \times 10^5$ N · m
- Power to drive motor: $\mathbf{P} = \tau \cdot \omega = 5.4 \times 10^5$ W (max.)

Seating Configuration

As mentioned before, passengers will be seated on individually mounted chairs facing radially outward atop the vehicle disk of radius $r = 4.572$ m. A width of approximately 3 feet will be allocated per passenger allowing for a wide range of body types. Inspiration for this arrangement stems from two current ride systems: (1) Zamperla's Disk-O and (2) HUSS Rides' Giant Frisbee as seen in Figure 15.

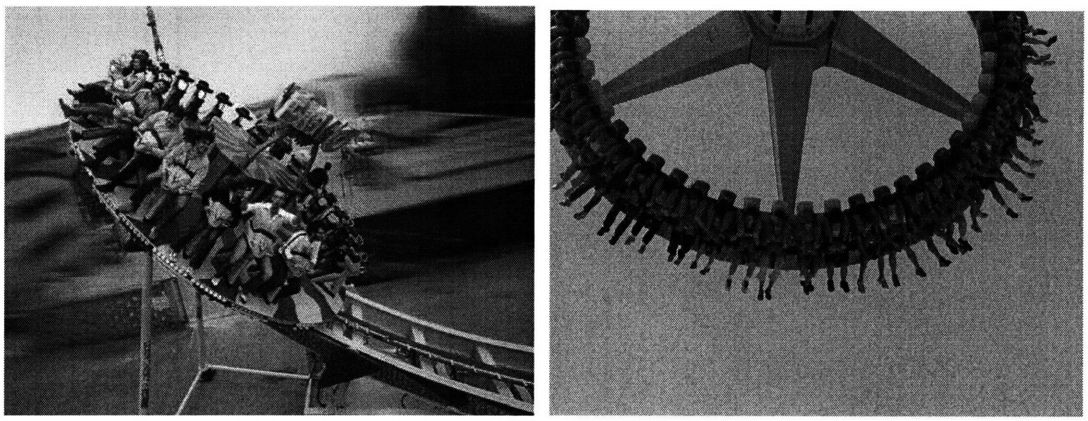


Figure 15: (l-r) Zamperla's Disk'O *[Zamperla]* and HUSS Rides Giant Frisbee *[HUSS]*

The ride will marry the two ideas of passengers sitting atop a platform but also requiring over-the-shoulder restraints or harnesses due to its inverting capabilities. The combined ideas are as represented below in Figure 16.

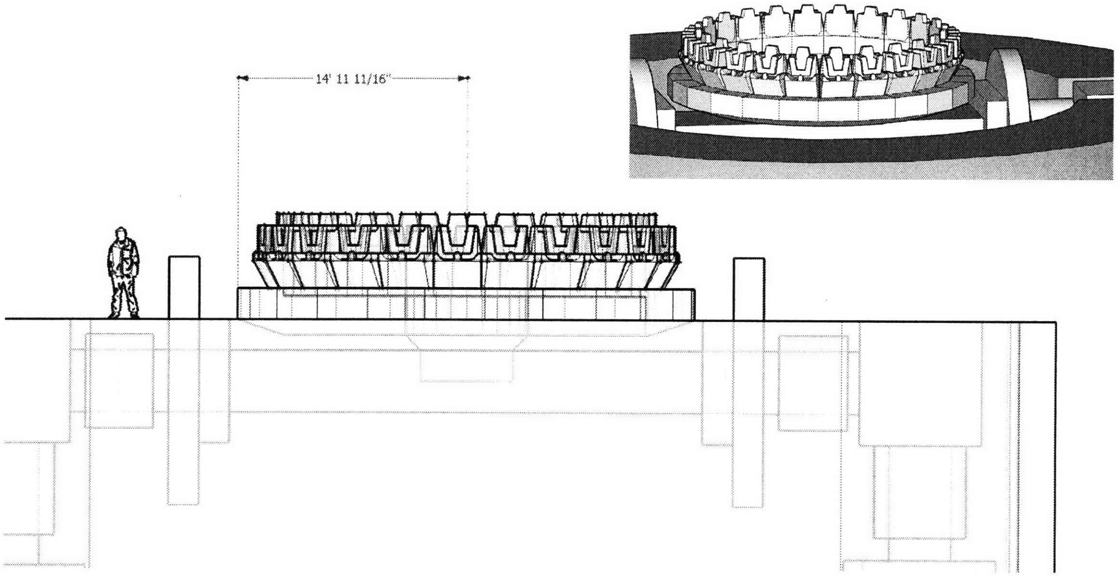


Figure 16: Passenger vehicle disk

Situating riders as seen above allows riders to experience the surrounding screen projections and live action effects without the obstruction of a person's head (something that happens too often in movie theatres and other attractions with rows). In addition, the circular configuration fits the cylindrical housing shape to be discussed in the next section.

4.2 Architecture

The overall architectural housing will consist of a closed cylindrical shell capped with a retractable dome. The shell's length will be subdivided into "levels" that will consist of 360° screen projections and physical set props with live action capabilities including animatronics and programmed elements of a fire, wind, and water. The retractable dome will have two main functions: (1) displaying projections on the interior surface similar to a planetarium and (2) a means of connecting passengers and potential riders/guests curious about the ride. Figure 16 below provides a basic diagram of the housing.

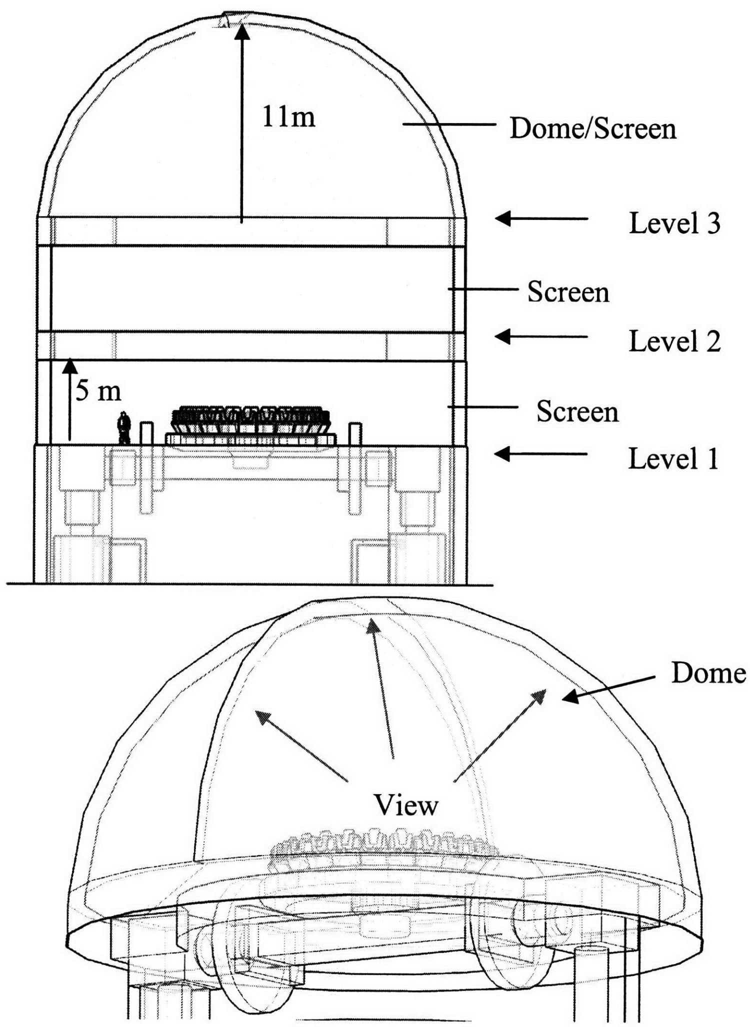


Figure 16: Housing diagram

Shell Design

One of the major draws of this attraction is the interaction between passengers and their virtual and physical surroundings. It is important that they feel encapsulated in this partially fictitious environment, with no sense of the outside world. In order to accomplish such a feat, we must first understand the constraints of human optical performance to determine appropriate dimensioning for the cylindrical shell and its subdivisions.

Inition, a global production and consulting firm highly specialized in 3D technology, provides useful information on a human's *field of view*, or the angular extent of the observable world seen at a given moment.

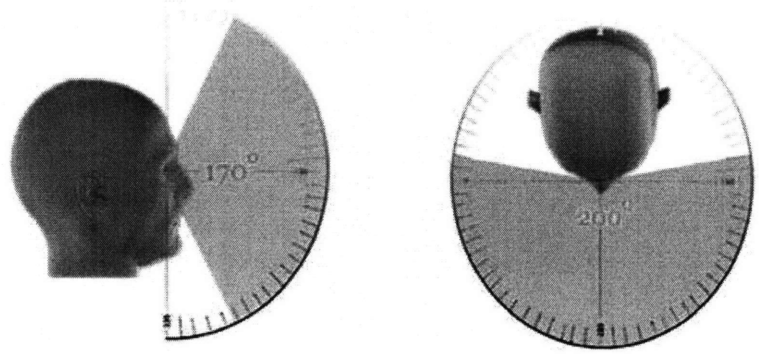


Figure 17: Human field of view *[courtesy: Inition]*

As seen in figure 17, we note that together, both eyes provide a vertical field of view of up to 170° and a horizontal field of view of up to 200°. Keep in mind this span includes both central (sharp macular) and peripheral (blurry) vision. Central vision usually ranges between 75 and 95 degrees, leaving the remaining degrees of view to peripheral.[2] This range is depicted in figure 18 below.

[2] www.abledata.com. This information references ABLEDATA which provides objective information about assistive technology products.

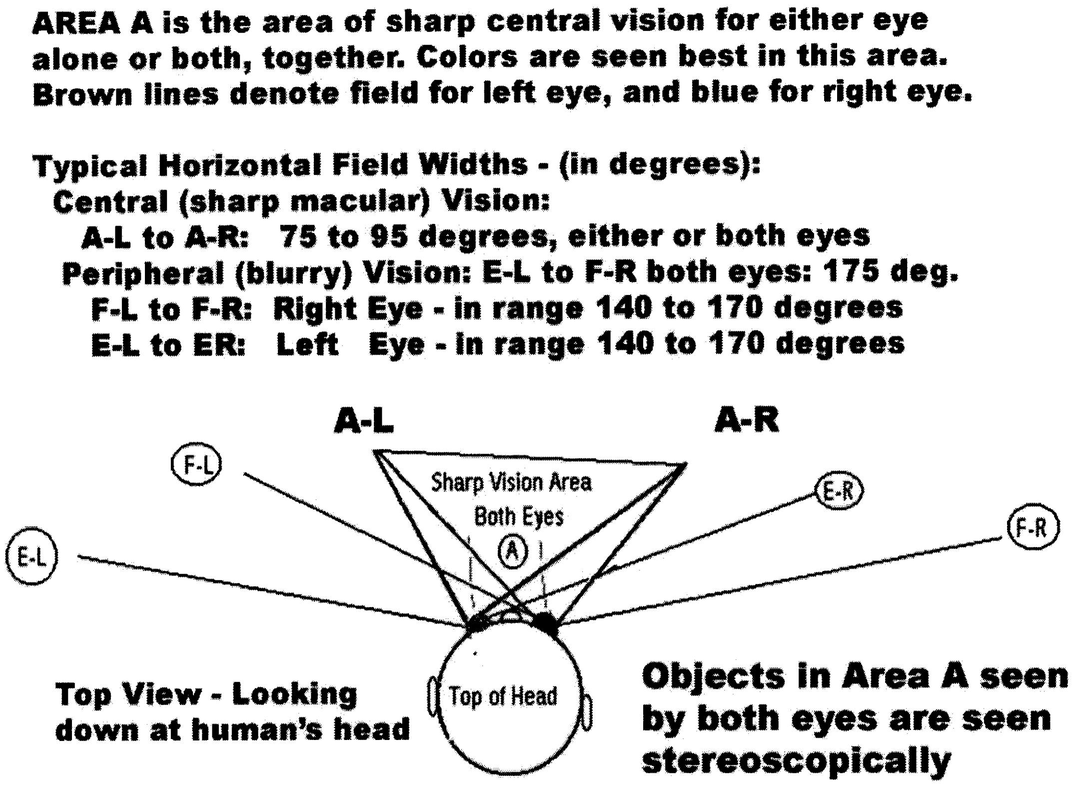


Figure 18: Central vision diagram *[courtesy: ABLEDATA 2006]*

Now let us apply this range to both horizontal and vertical fields of vision. With this in mind, we can determine the appropriate height of the projection screens and their distance away from passengers. To attain these values we will assume this central vision range applies both to vertical and horizontal fields of view.

In order for passengers to feel engulfed in the "scene," the projection screen must be close enough to diminish any void of space but also be far enough for the horizontal field of view to capture a good portion of the screen. Using dimensions of the mechanical system as a guide, we know that the distance from the edge of the disc, where passengers are positioned, to the edge of the piston "cap" is approximately 22 feet. If a passenger has central vision range of 90° for their vertical field of view, this will yield a projection of about 43 feet high at the edge of the piston cap as seen in figure 19.

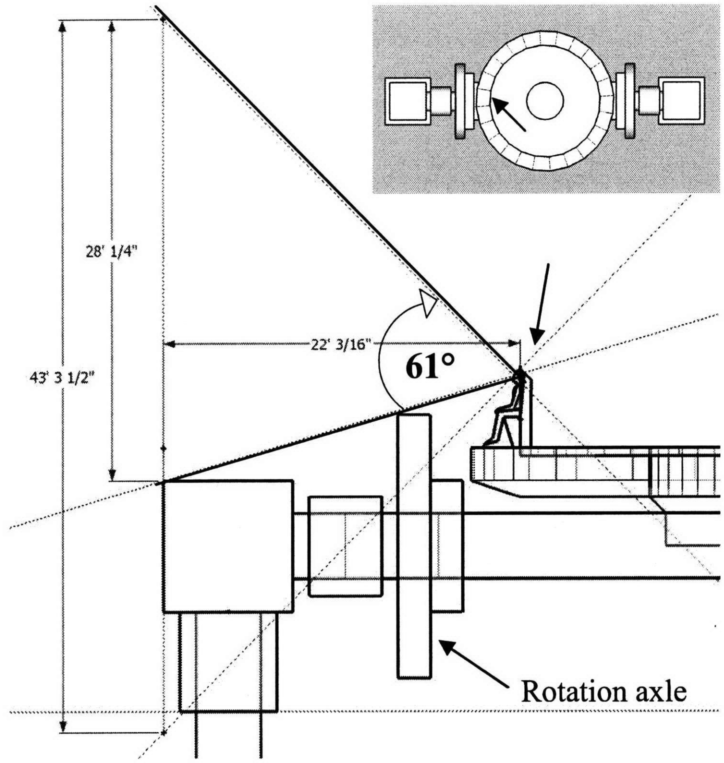


Figure 19: Field of view applied to ride system

Using geometry, the passenger's total vertical field of view is cut to 61° when facing the rotation axle. At this stage, this obstruction enables the height of the screen to reduce to approximately 28 feet high, yielding the lower half of the shell (excluding the retractable dome) to reach about 60 feet for a two-level projection system. Although the vertical field of view is the full 90° when not positioned in front of the axle, the screen will reach up to 28 feet high for the entire circumference, for the sake of keeping the projection screen at a uniform level. The remaining 29° span will be lined with physical props and live action effects to fulfill this idea of immersion.

Projector

Now that we have the approximate height for the screen, we must consider what type and how many projectors will be suitable for this height and for a curved surface spanning 360°; not to mention, we must determine their positioning to avoid collision with the ride vehicle, axle, and piston cap.

To accomplish projecting a full 360 panoramic projection, we will refer to iCinema's AVIE (Advanced Visualisation and Interaction Environment) system – the world's first 360-degree stereoscopic[3] panoramic projection environment, launched in 2004.

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[3] *Wikipedia 2006.* Stereoscopic imaging or 3-D (three dimensional) imaging is any technique capable of recording three-dimensional visual information or creating the illusion of depth in an image. The illusion

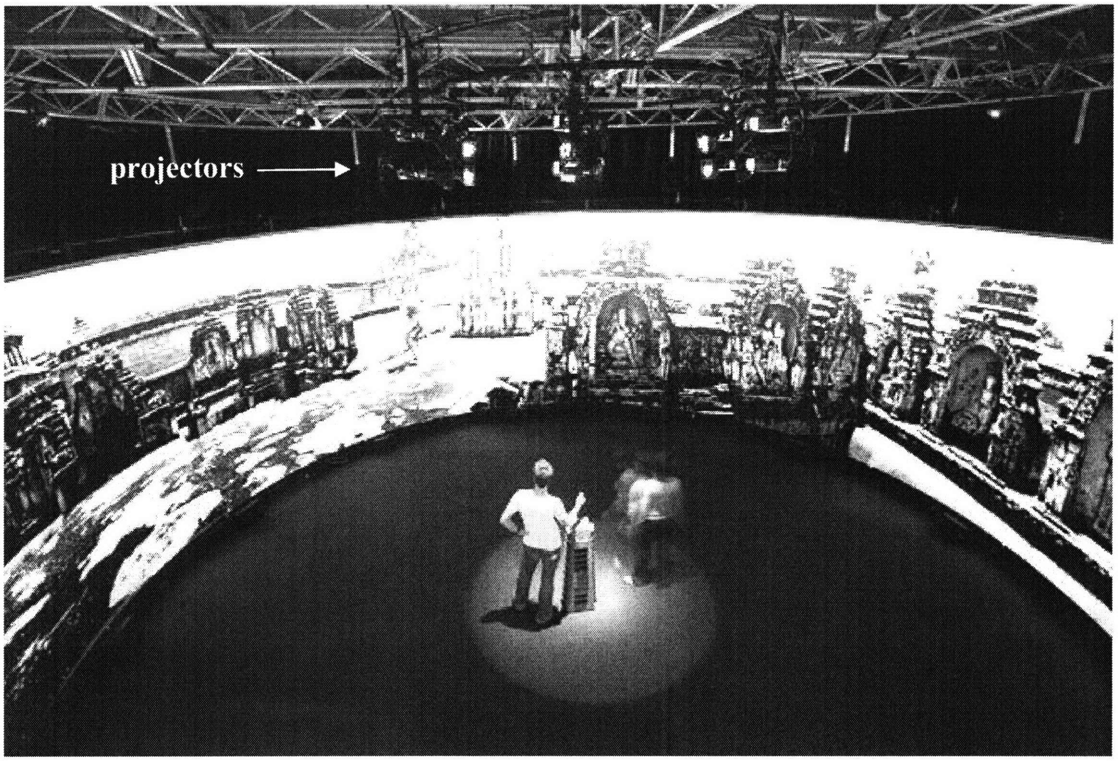

Figure 20: iCinema, AVIE *(courtesy: Projectiondesign)*

The usual setup uses a cluster of 7 PC's and 12 F1+ projectors, arranged in stereoscopic pairs fitted with polarization filters as noted above in figure 20. The total resolution is approximately 8,000 x 1,000 pixels, and the iCinema team has also developed custom warping and edge-blending software for a seamless fully immersive experience. AVIE consists of a cylindrical, silvered screen measuring 4 meters high by 10 meters in diameter, on the internal surface of which 360-degree 3D panoramic multimedia content can be projected.[4]

Due to lack of the exact means of calculating how this particular setup translates to a larger scale we will have to make a few assumptions considering the given dimensions.

If 12 projectors, in 6 groups of 2, can cover a cylindrical screen 4 meters high by 10 meters in diameter d; with this ratio in mind our system who's screen is approximately 28', will require more groups of projectors. We can determine this by dividing the circumference of the screen by the number of groups of projectors, n_{group}, to determine the arc length s that each group projects. Once s is determined we can find how many of these lengths fit within the confines of our projection screen circumference and thereby

of depth in a photograph, movie, or other two-dimensional image is created by presenting a slightly different image to each eye.

[4] *iCinema*

find the number of projectors needed. This method is represented in the following equations:

$$s = \frac{\pi \cdot d}{n_{group}}$$

$$N_{projector} = \frac{2\pi \cdot D}{s}$$

Using $d = 10$m and $n_{group} = 6$, we get an arc length s of 5.24 meters. Now using this s and D = 68 feet = 20.7 meters, we get the number of projectors $N_{projector}$ = 24.8 ≈ 24 projectors. We rounded down due to stereographic projections requiring 2 projectors each.

Now that we know the number of projectors needed, we must determine their positioning. We know that the F1+ projector produces an image 4 meters high from a distance of about 5 meters (radius of cylinder r). As seen in figure 21, we can use geometry to determine the angle θ of the projection's vertical span.

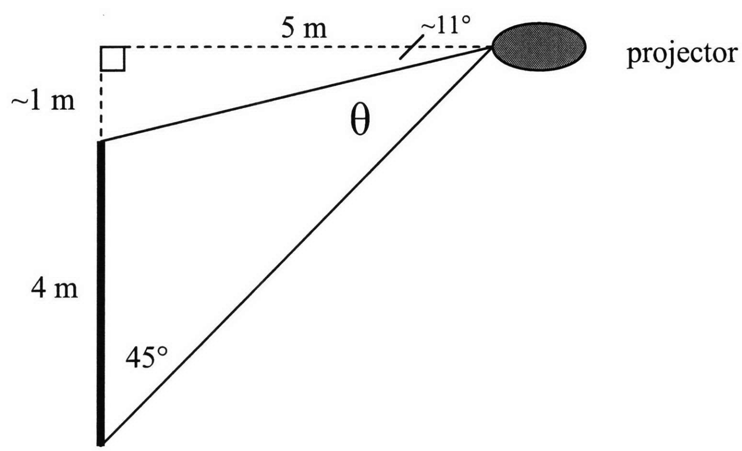

Figure 21: Angle of projection

Assuming the projector hangs about 1 meter above the screen, we get a projection angle of 34°. We must now consider that the projectors in the example were located at the center of the cylinder. We cannot exactly provide the same setup as our vertically mobile ride will collide with the projectors. We must position each of the 24 projectors such that they will not interfere with the ride vehicle. Also, the physical and live action effects will be partitioned into two identical components with space in between each for the piston cap to travel through. A possible configuration is represented in figure 22 below.

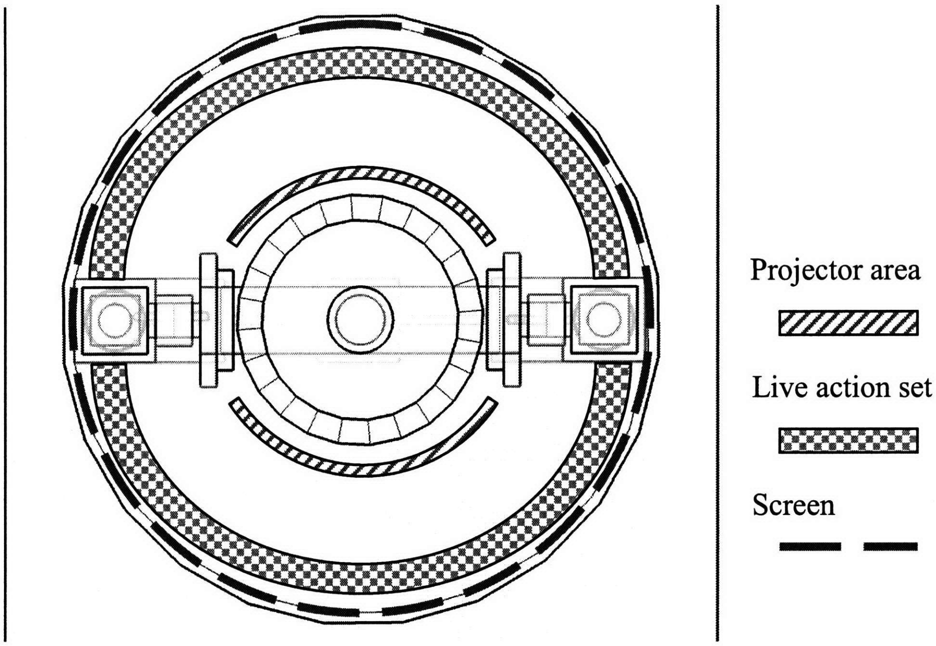

Figure 22: Projector placement

As positioned in the above configuration, the projectors will hang in a concentric lattice work about 1 m from the edge of the disc. Due to spatial constraints, the projectors will continue to project a 4-5 meter image on the surrounding screens.

Retractable Dome

As an added feature a retractable dome (hemisphere) will sit atop the cylindrical shell. This component will allow interaction between passengers and off-ride guests to increase attraction to the ride. The retraction will occur via moving panels that will unveil the vehicle when it reaches its highest point as a means of giving guests a "sneak-peak" of what the ride entails. It also provides temporary relief for those on-board who may feel a bit claustrophobic in an enclosed arena. The retraction system for the dome will be further investigated in subsequent reports as more background is needed.

4.3 Safety Requirements

When designing any amusement park ride, there are guidelines that we must abide by in order to meet safety approval. No ride may be sold or operated without being approved first. For the purposes of this project, we followed the 2006 ASTM guidebook on *Standard Practice for Design of Amusement Rides and Devices*.

Under General Design Criteria (section 5), 5.3.2 provides us with a coordinate system for passengers that helps us understand what forces they will be objected to during a ride sequence. The guide also provides us with a standard weight range of an adult at 170 lb or 0.75 kN (300 lb. max) whom our ride is geared towards.

4.3.1 Vertical and Lateral G's

Due to the rapid vertical movement of our ride we must be sure our ride is safe enough. Section 7 states and diagrams the acceleration limits or allowable G-forces for our system and will determine how fast these vertical and lateral transitions can be.

4.3.2 Seat Design

Section 7.1.4.7 provides information for what basic restraint type is needed for certain ride systems. Due to the nature of our ride inverting and possible producing relatively high vertical, lateral (and centripetal) forces we must use an Over-the-Shoulder (Class-5 Restraint) system as noted in the seating configuration section.

5. Continuing Work

With the hopes of attaining a patent for this particular ride design, further analysis will be conducted on the mechanical structure as far as materiality and those laws that are applicable to the construction of a ride (i.e. stress-strain relationships). Also, reevaluation of the architectural housing will be conducted as far as important relationships such as space, lighting, heating/cooling systems, ventilation, and aesthetical value. Design analysis of the retractable dome will also be a part of the next phase. Furthermore, conceptual art of the two systems being married seamlessly via theme possibilities will provide great visuals for potential clients.

Sources Cited

ABLEDATA. Central Vision Diagram. http://www.abledata.com/abledata_docs/Distance-Fig-1.jpg. April 2008.

ASTM International. Standard Practice for Design of Amusement Rides and Devices. PA, USA. 2006.

Control Air Inc. Air Regulators – Including Air Pressure Regulator and Compressed Air Regulator.Electro-pneumatic Transducer. http://www.controlair.com/transducers.html. January 2008.

Engineersedge. Stepper motor. http://Engineersedge.com/. April 2008

Fabbri Group. Fabbri smashing jump. http://fabbrigroup.com/. April 2008.

HUSS Rides. http://www.hussrides.com/. April 2008

INITION. Guides, HMDs, Head-up displays. http://www.inition.co.uk/inition/guide_hmds_headup.htm. April 2008.

JENCO VALVES MANUFACTURING CO. http://www.jencovalves.com/automatic.htm. April 2008.

Paramount's Kings Island. Tomb Raider. http://www.pki.com/. April 2008

Projectiondesign: high performance projectors. Evolving the art of panoramic projection. http://www.projectiondesign.com/?ItemID=3777. May 2008

Sherline. Typical stepper motor. http://sherline.com/. May 2008

Wikipedia, the free encyclopedia. Stepper Motor. http://en.wikipedia.org/wiki/Stepper_motor. May 2008.

Zamperla Rides. http://www.zamperla.it/. May 2008

Appendix

ASTM International: Standard Practice for Design of Amusement Park Rides and Devices

5. General Design Criteria
   5.3.2

6. Restraint Configuration
   6.4.3 Restraints Required Due to Acceleration and Seat Inclination
   6.6.4.2

7. Acceleration Limits
   7.1.4.1
   7.1.4.3
   7.1.4.4
   7.1.4.7
   7.1.7