2/2/2018

EML4551-2

Team 10: Flight Simulator Cockpit

Egress System

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1.1 Project Scope

The project description asks the team to create a modular system for ingress and egress for the Lockheed Martin F-16 cockpit simulator. The objectives of this project are to make the cockpit simulator easier to enter and exit, and to mitigate damage to components in the flight simulator due to pilot entrance and exit. The customer of this project is the aerospace and defense company, Lockheed Martin, who requested this system to be used for their F-16 cockpit simulator.

1.2 Customer Needs

Lockheed Martin tasked the team with designing and prototyping a track system on which the cockpit seat will mount. Lockheed Martin outlined the following requirements: the system must be mobile and attach with the current base of the cockpit, the seat must move fully into and out of the cockpit dome to allow the ingress and egress of a 95th percentile male occupant per MIL Standard 1472, guide bundled wires from the base of the cockpit, the system must allow for a quick egress in the event of an emergency, and the ingress/egress system must mount flush with the existing cockpit base.

1.3 Functional Decomposition

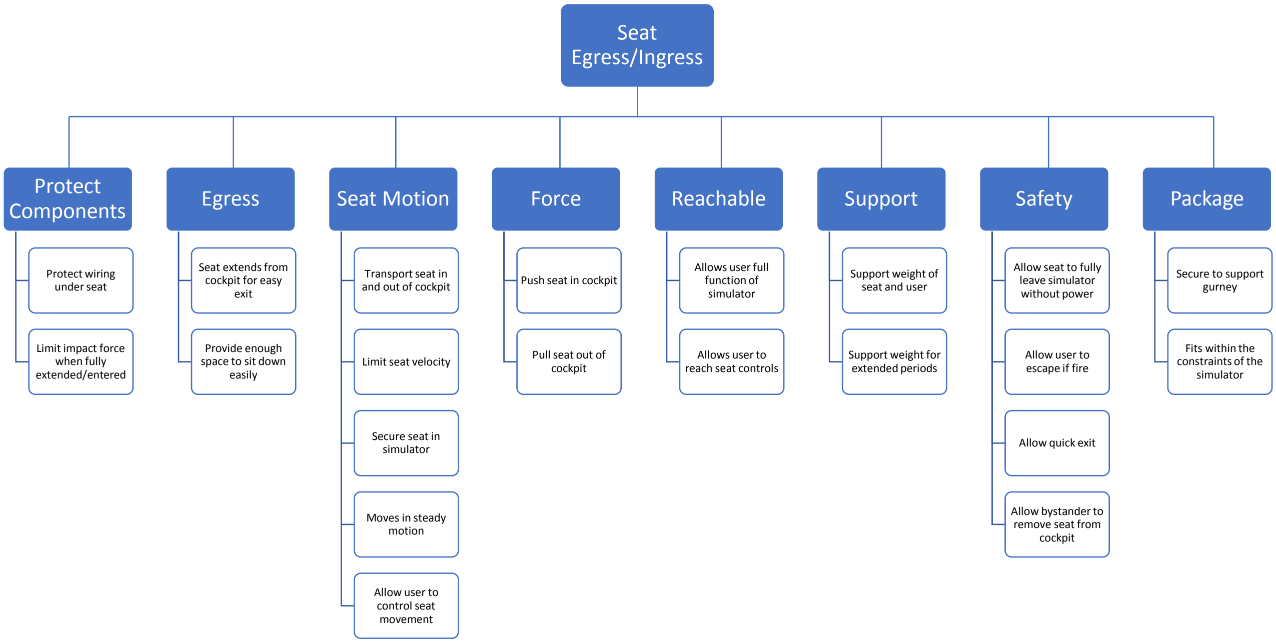


Figure 1: Functional Decompositon

1.4 Target Summary

Table 1: Critical targets for completion of the project

Metric	Measure	Target
Width clearance under seat	Length	16.1 in.
Clearance to sit in seat (buttock-knee length)	Length	26 in.
Maximum axial force	Force	338 lbf
Force required for seat movement	Force	TBD
Seat controls within user's reach	Length	28.2 in.
Material deflection under passenger load	Length	TBD

Force to manually move seat (feet on ground)	Force	23 lbf
Width clearance to fit inside cockpit dome	Length	20.3 in.

1.5 Concept Generation

In concept generation the team brainstormed individually at first then came together to communicate ideas and develop more ideas. Each concept has two systems, a way to produce motion and guiding system for the seat as it moves. In total we produced 12 concepts some concepts overlap on others but differ slightly. When coming up with concepts it was key to keep the customer requirements in mind such as the 2 inch constraint that our design must be contained in.

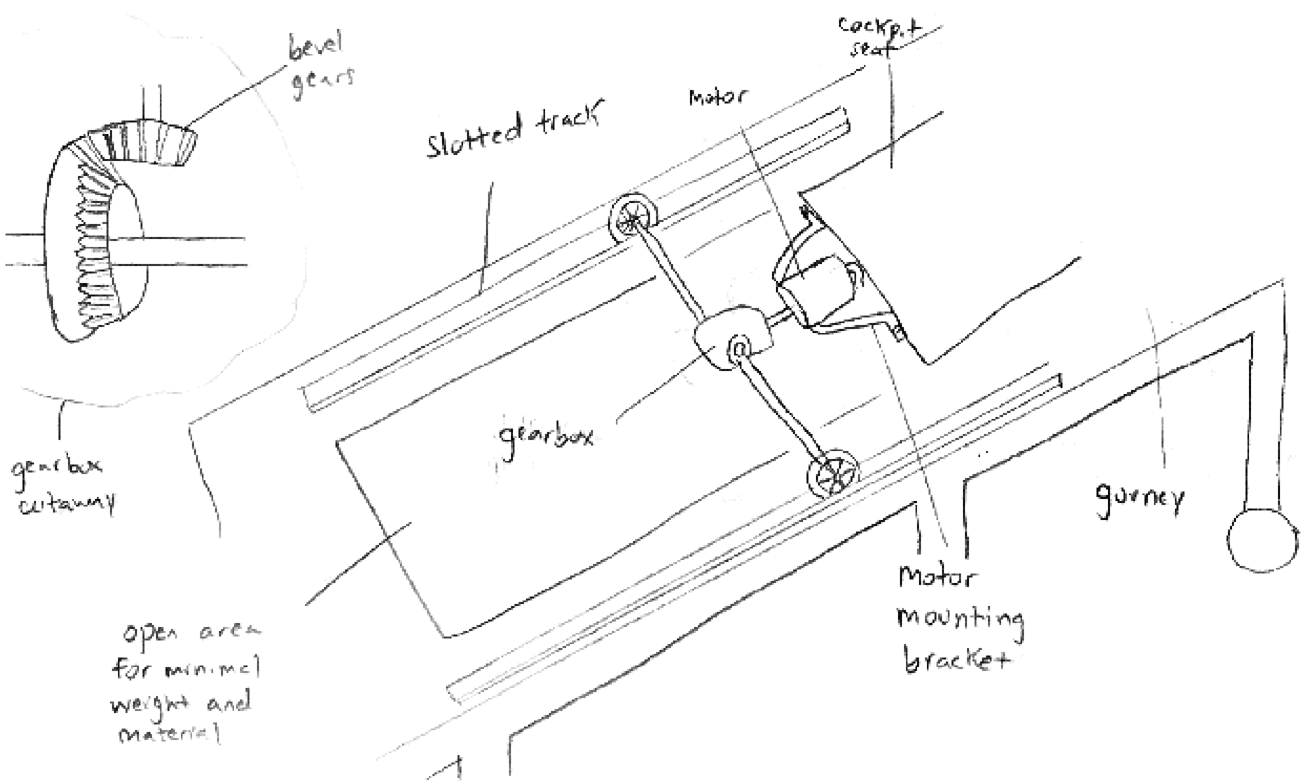
Table 2: Contents of concept generation

Concept	Motion	Guide	Designer
Concept 1	Motor with bevel gears	Wheels with slotted track	Andrew Porter
Concept 2	Motor with chain and gears	Cylindrical rails	Andrew Porter
Concept 3	Human	Wheels with slotted track	Andrew Porter
Concept 4	Motor with rack and pinion	Slotted track	Daniel Swope
Concept 5		Cylindrical rails	Daniel Swope
Concept 6	Human	Rectangular rails	Daniel Swope
Concept 7	Motor with belt	Cylindrical rails	Frank Cullen
Concept 8	Air compressor	Cylindrical rails	Frank Cullen
Concept 9	Motor with rack and pinion	Cylindrical rails	Frank Cullen

Concept 10	Motor with worm gear	Cylindrical rails	Andrew Filiault
Concept 11	Motor with pulley system	Cylindrical rails	Andrew Filiault
Concept 12	Motor with rack and pinion	Raised track with rollers	Andrew Filiault
Concept 13	Motor with rack and pinion	C-beam rails with rollers	Andrew Filiault
Concept 14	Motor with belt	I-beam rails with rollers	Andrew Filiault
Concept 15	Telescoping linear actuator	I-beam rails with rollers	Andrew Filiault

Concept 1:

This concept revolves around the use of a motor attached behind the cockpit seat. Power is transmitted to the wheels in a slotted track via bevel gears.



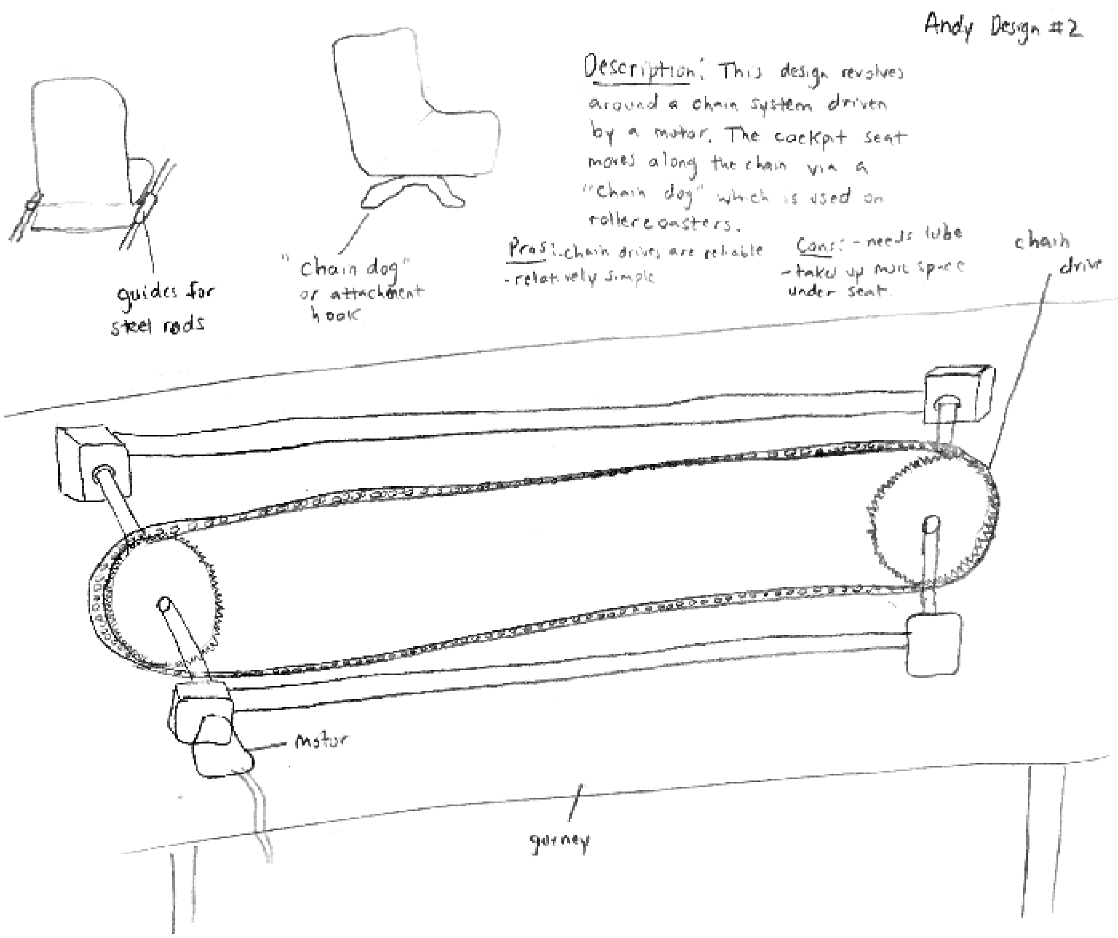
Concept 1.

Concept Pros: Direct power transfer from motor, minimal moving parts, motor in same moving plane as cockpit seat.

Concept Cons: Motor mounted behind seat, bevel gear design, wheel axle further away from center of mass.

Concept 2:

This concept revolves around a chain system driven by a motor. The cockpit seat moves along the chain via a “chain dog” which is used on rollercoasters.



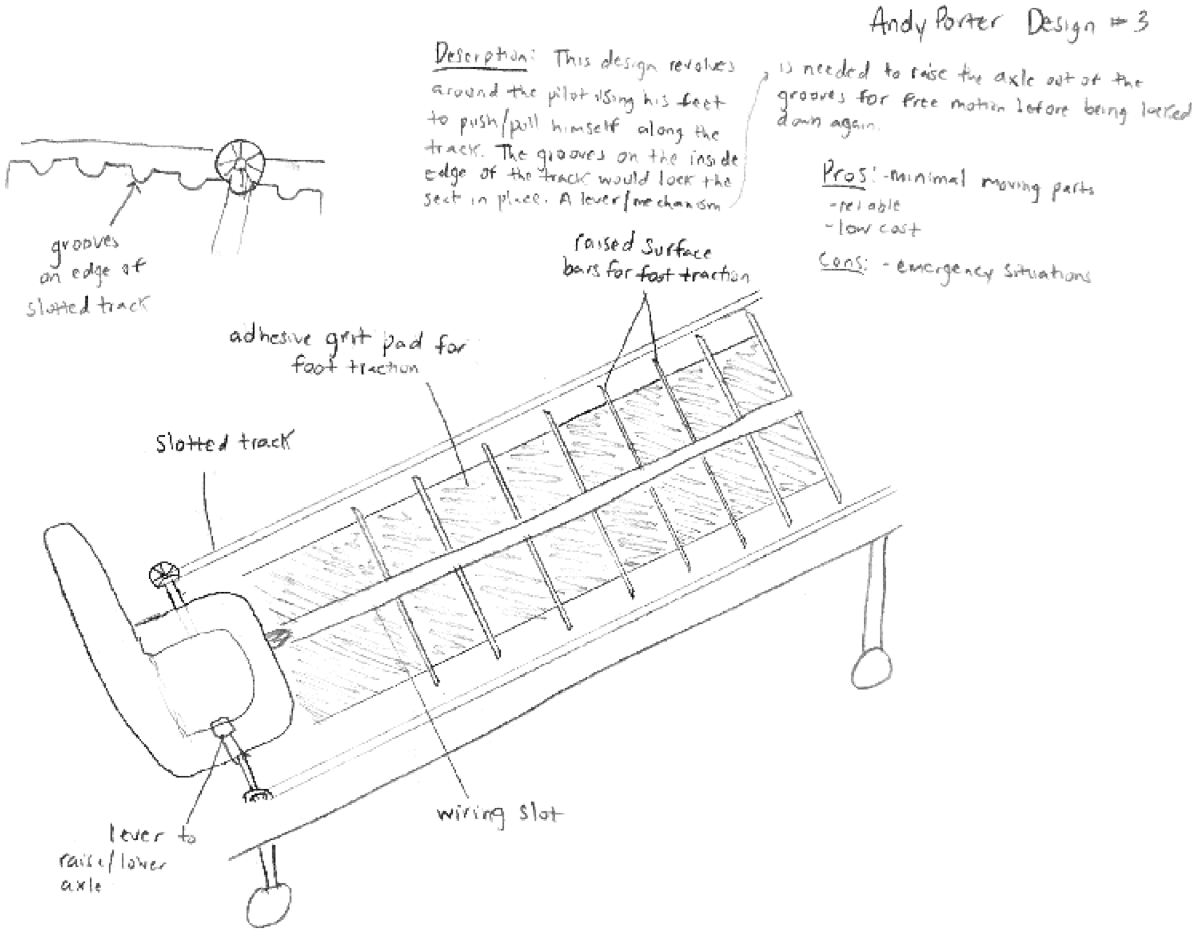
Concept 2.

Concept Pros: Chain drives are reliable, simple design.

Concept Cons: Chain needs to be lubricated, must be mounted under the seat area.

Concept 3:

This concept revolves around the pilot using his feet to push/pull himself along the track. The groves on the inside edge of the track would lock the seat in place. A lever is needed to raise the axle out of the grooves for free motion before being lowered down again.



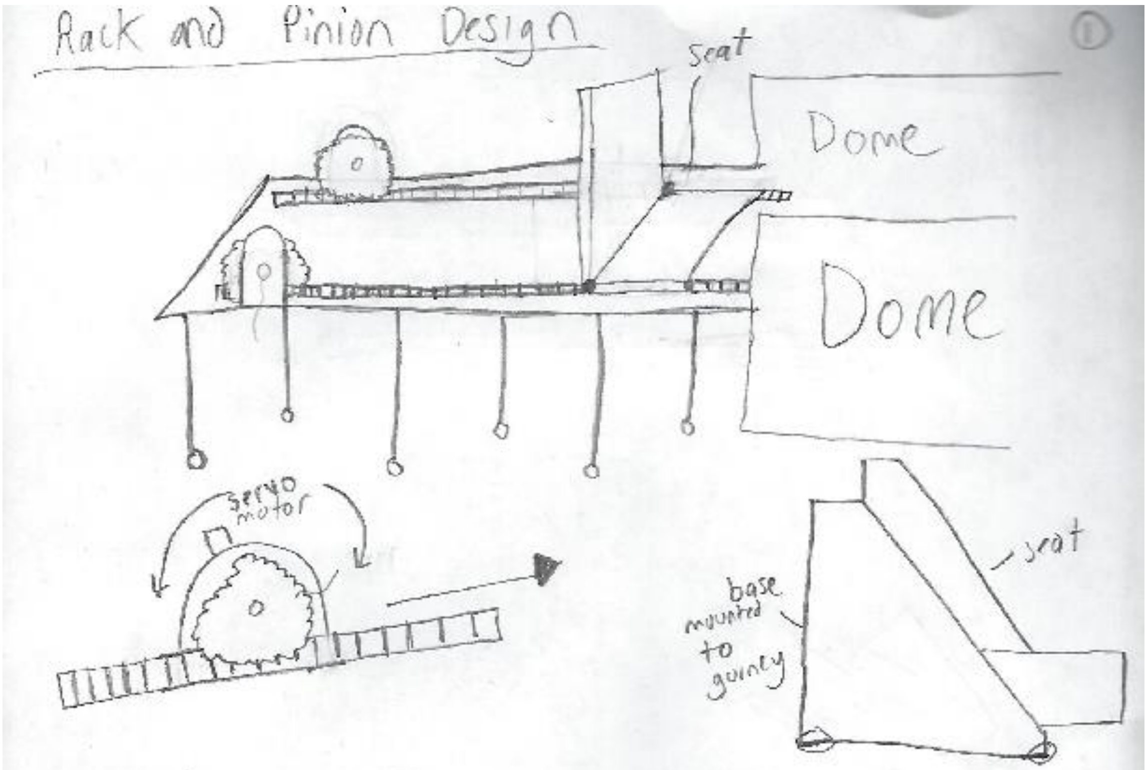
Concept 3.

Concept Pros: Minimal moving parts, reliable, low cost.

Concept Cons: Will not perform well in emergency situations.

Concept 4:

By using aa rack and pinion this design will move the seat in a linear motion inside and out of the cockpit simulator.



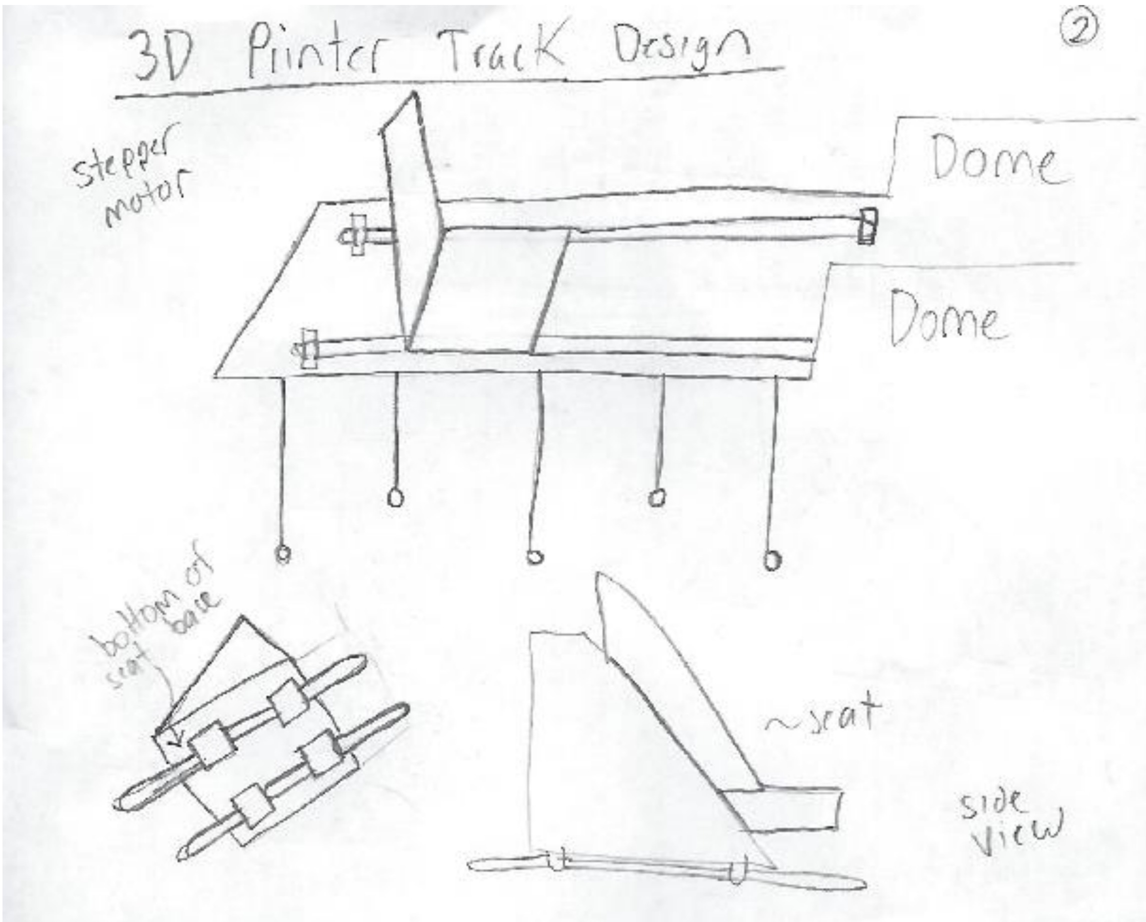
Concept 4.

Concept Pros: Constant stiffness, start and stop on gradients.

Concept Cons: Backlash potential, long moving rack gear.

Concept 5:

This system allows for cylinder rods be attached to base pf the seat allowing seat to slide into and out of the cockpit dome powered by a stepper motor.



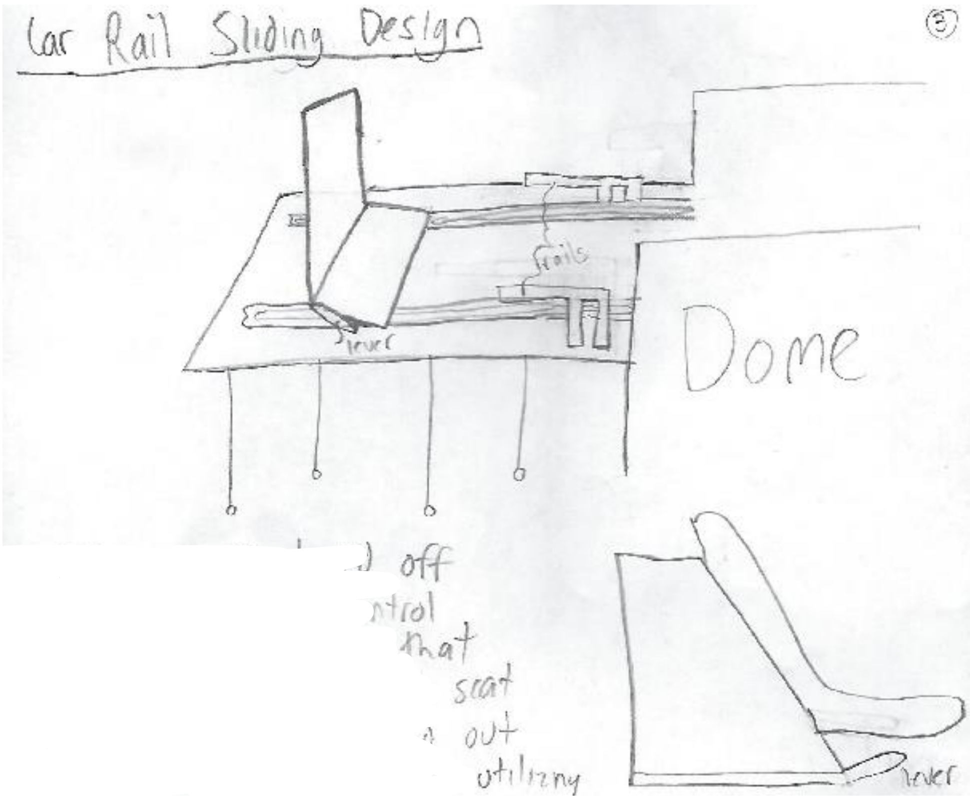
Concept 5.

Concept Pros: Linear motion, smooth guidance, time efficient.

Concept Cons: Stability, problem supporting weight.

Concept 6:

Design based off a manual control car seat system. This allows the seat to slide into and out of the dome by utilizing a lever and rails on the gurney to allow the user to push themselves into the cockpit dome. The lever acts as a locking mechanism for motion in a linear pathway.



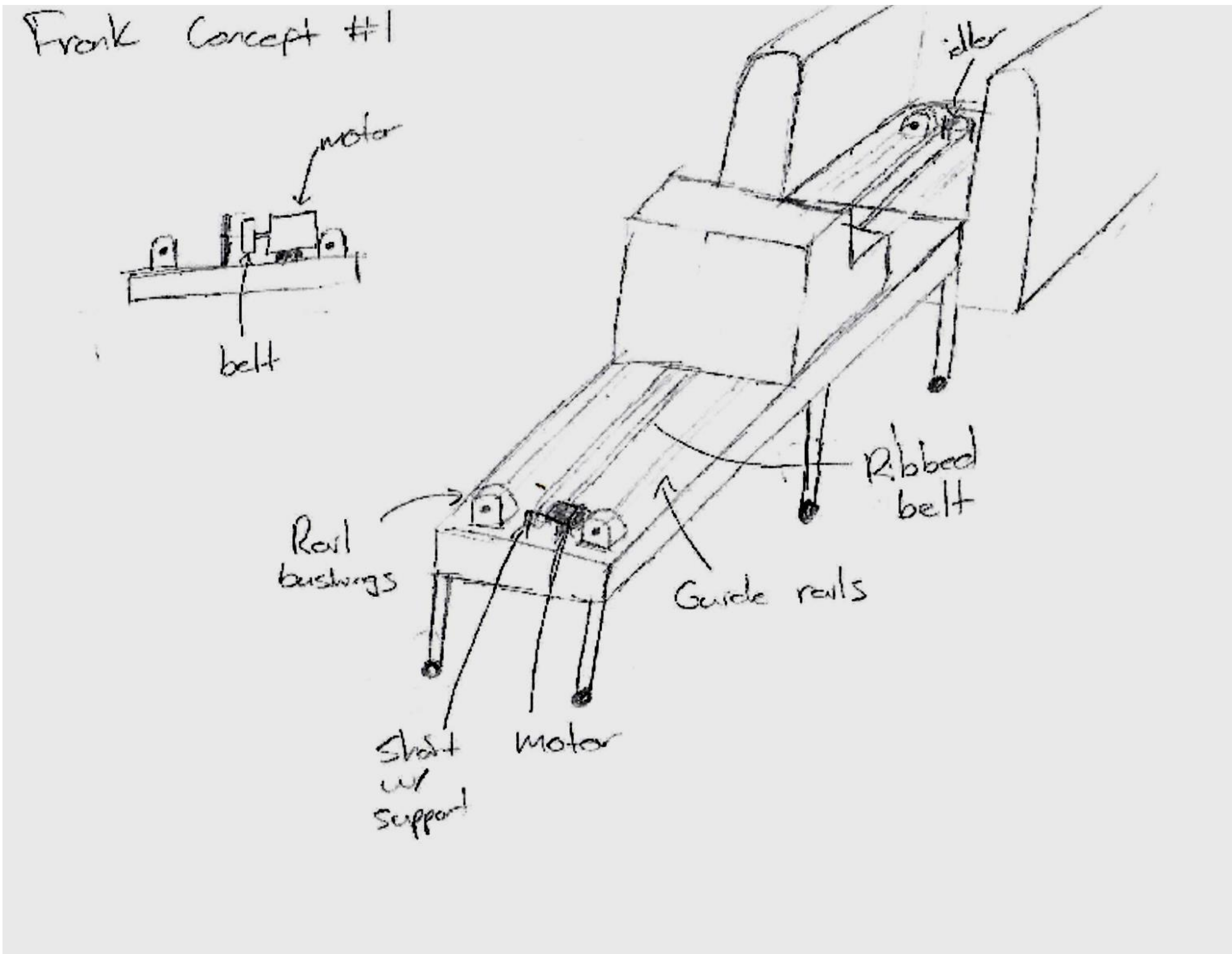
Concept 6.

Concept Pros: Linear motion, locking and unlocking, rail for supporting users movement.

Concept Cons: Large design, will not perform well in emergency situations.

Concept 7:

This concept uses a motor gearbox pair to drive a belt. The belt will be attached to the seat base, moving it forward/back depending on the direction of rotation of the motor.



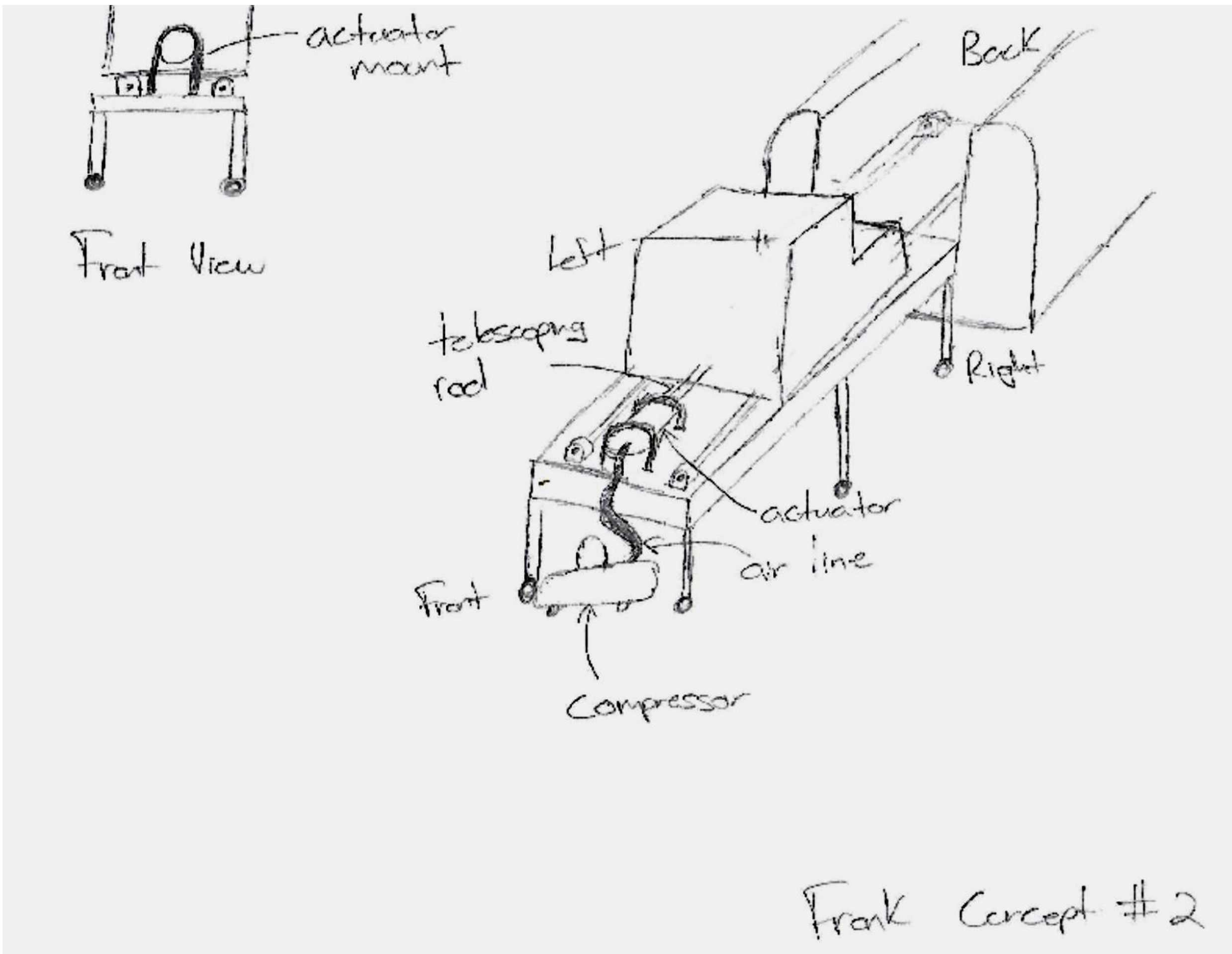
Concept 7.

Concept Pros: Few components, system has been used in other industries.

Concept Cons: Belt will need to be replaced over time.

Concept 8:

This concept uses an air compressor and actuator to drive the seat. The actuator will be connected to the seat by a telescoping shaft.



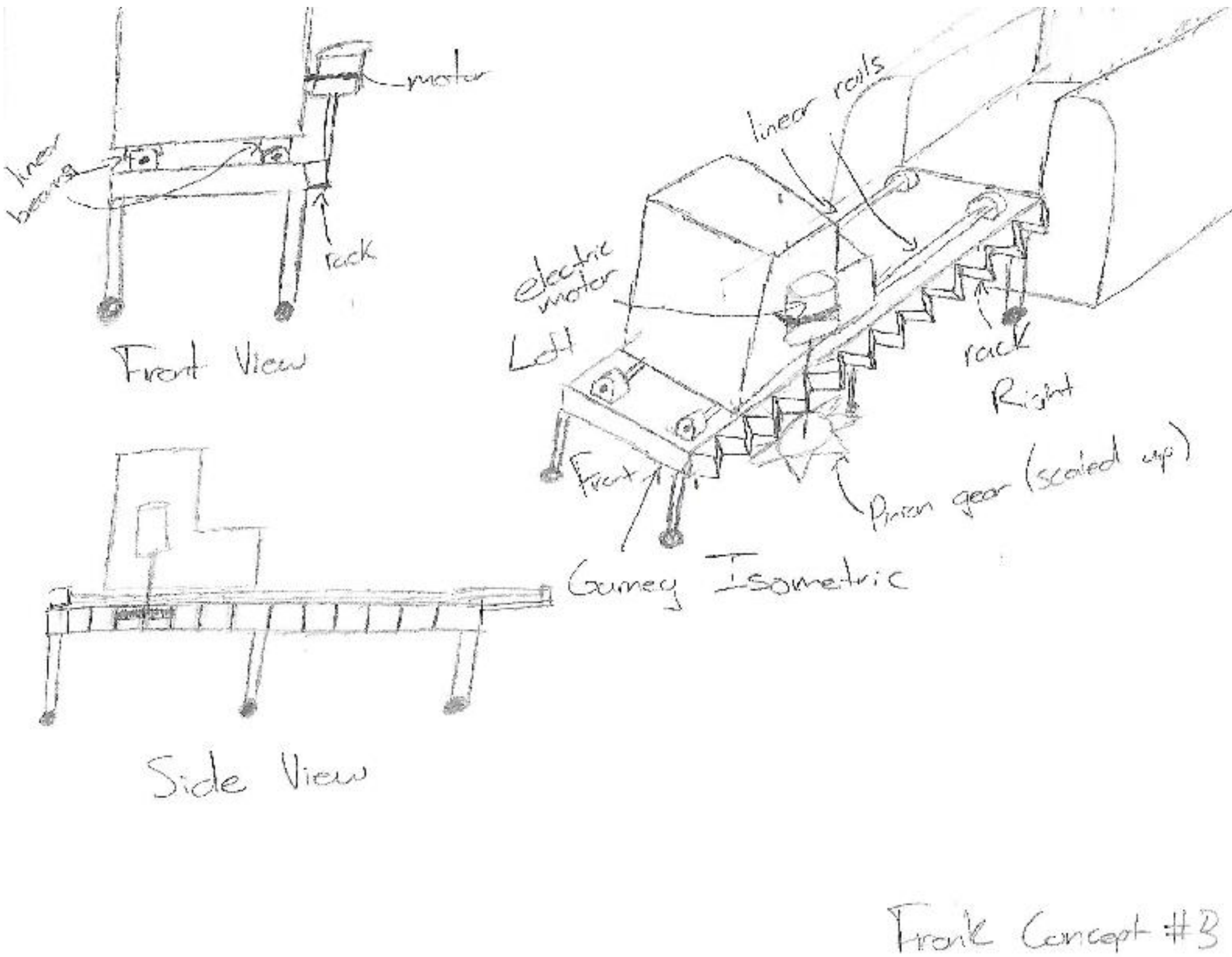
Concept 8.

Concept Pros: Actuator can provide large force, system can be mounted behind seat.

Concept Cons: Complex design, telescoping shaft will be difficult to implement.

Concept 9:

This concept utilizes a rack and pinion to provide the linear motion. The rack can be mounted in several places such as the side of the gurney(pictured).



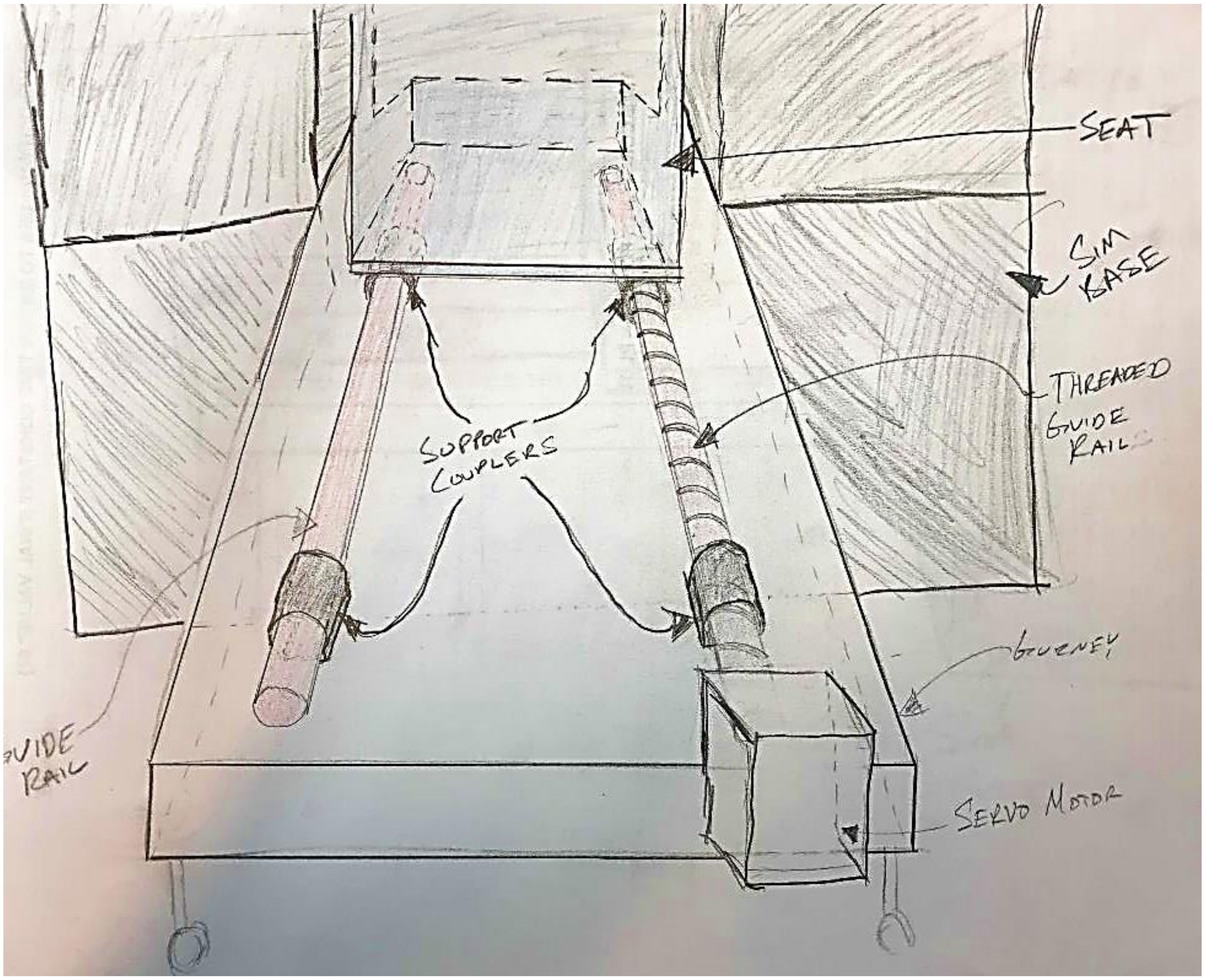
Concept 9.

Concept Pros: Large mechanical advantage, robust design, can handle large forces.

Concept Cons: Needs lubrication to extend life, operation will be slow.

Concept 10:

The motion of this design is from a servo motor that turns a worm gear. The worm gear is connected to the seat by a threaded coupler that will move the seat as the motor turns. The seat is guided by the guide rail and the worm gear.



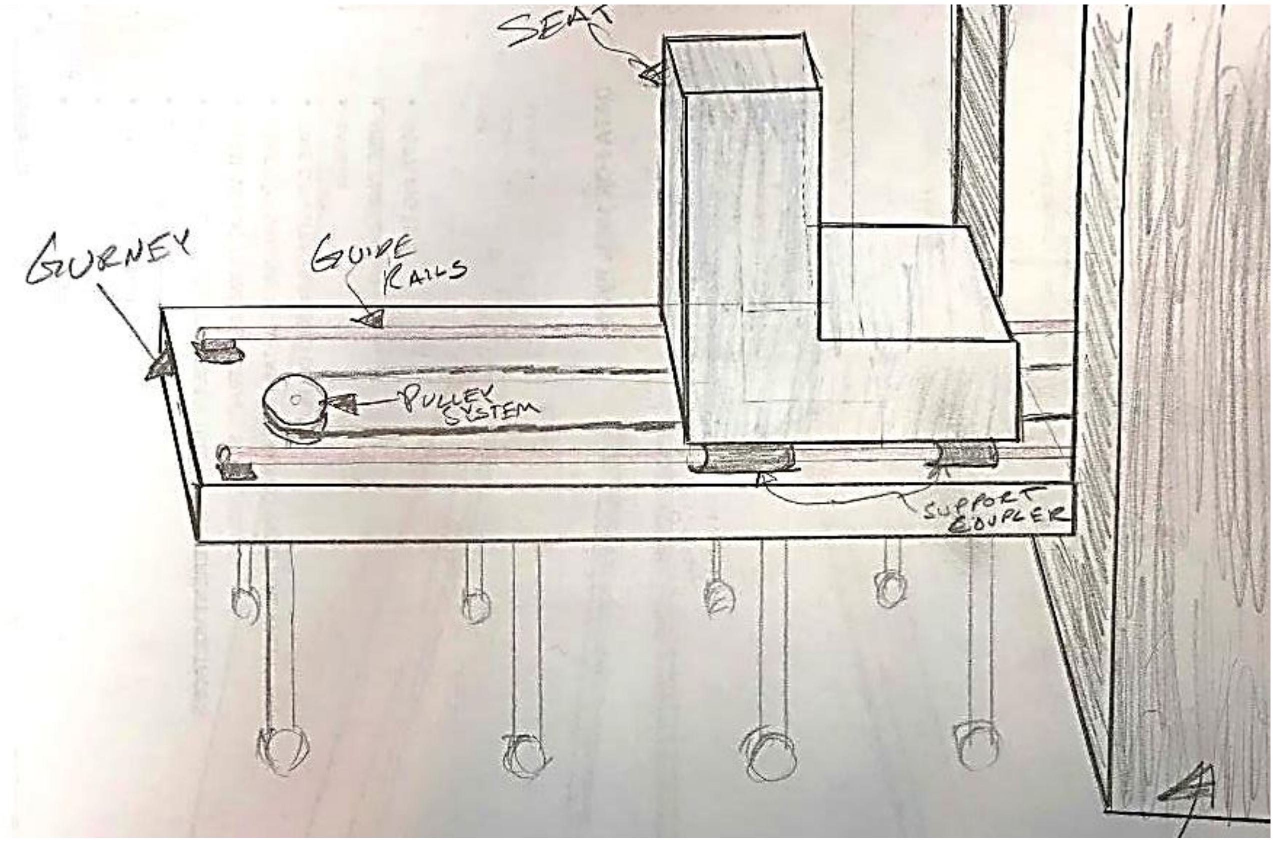
Concept 10.

Concept Pros: Minimal space used, motor is not under seat.

Concept Cons: Complex design, rapid movement in emergency situations would be difficult.

Concept 11:

This design uses a pully system the is powered by a motor. As the motor turns the seat will be guided into the cockpit simulator using two cylindrical guide rails.



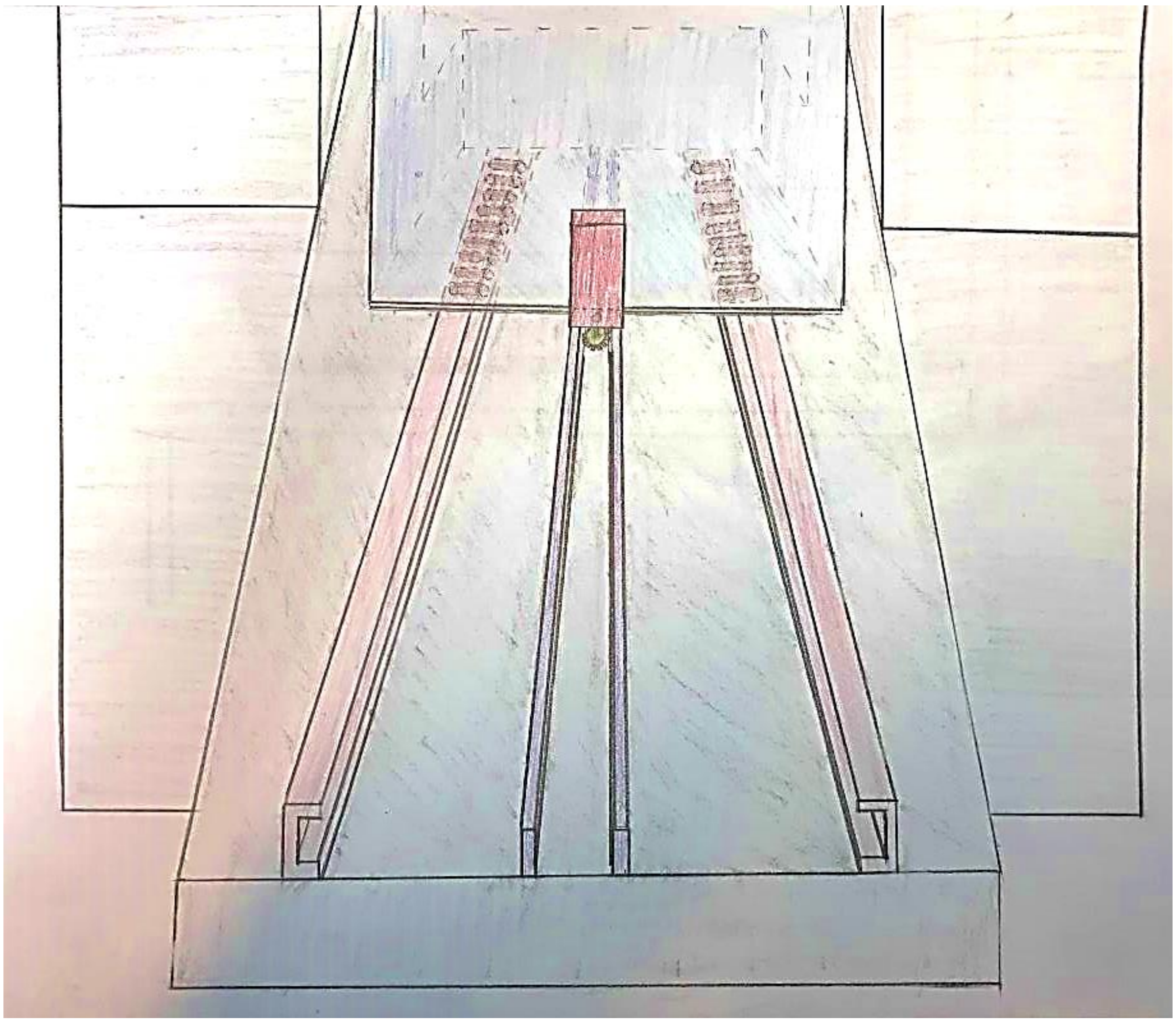
Concept 11.

Concept Pros: Simple design, cheap.

Concept Cons: Not provide large force to seat, belt could slip.

Concept 12:

This concept uses a rack and pinion system. The motor is mounted behind the seat and turns a gear. The gear is placed between two racks the will provide twice as much force as a single rack. The seat is guided using C-beams with rollers attached to the seat sliding inside the beams.



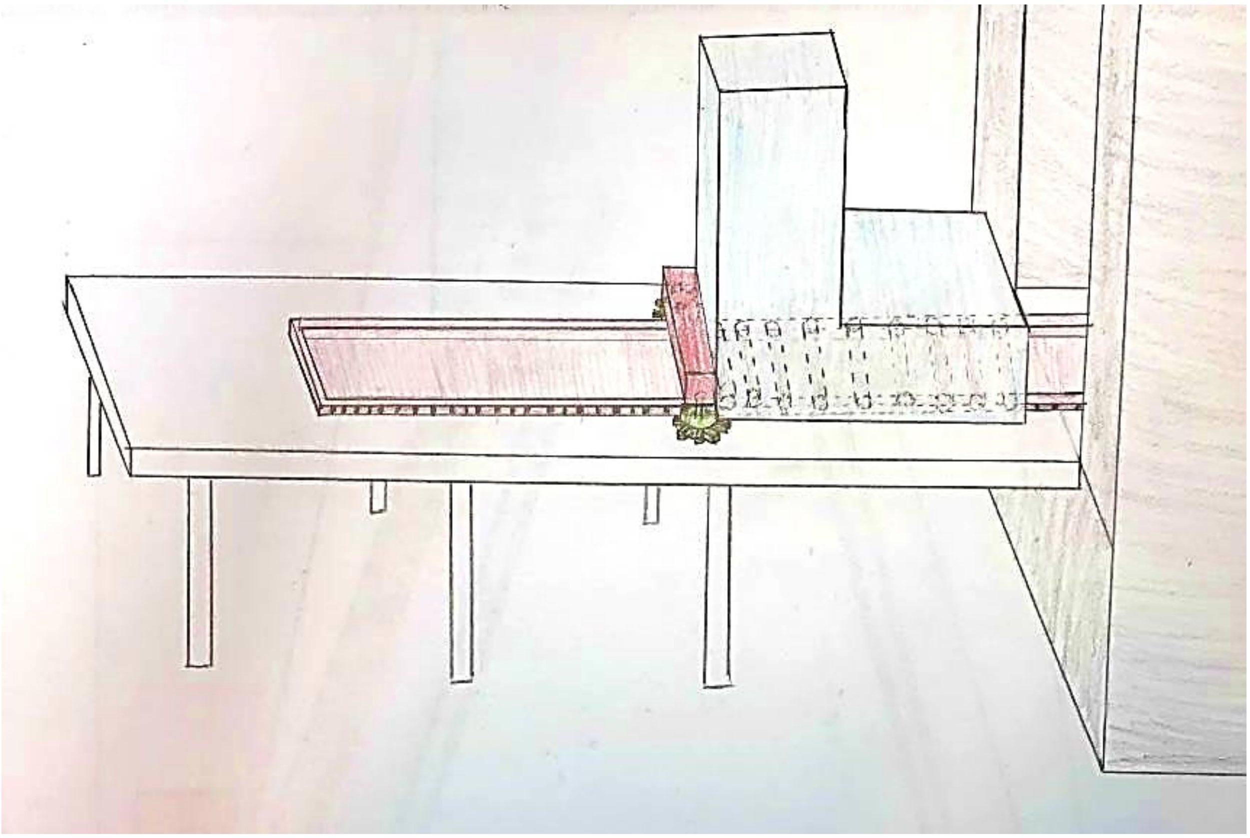
Concept 12.

Concept Pros: Friction is minimized, motor attached to back of seat.

Concept Cons: Space under seat is used, rollers inside of beam would be hard to implement.

Concept 13:

This concept uses a rack and pinion design. Mounted to the back of the seat would be two motors that will each turn a gear that is in mesh with a rack. The seat is guided along with a extruded slot with rollers connected to the seat ensuring linear motion.



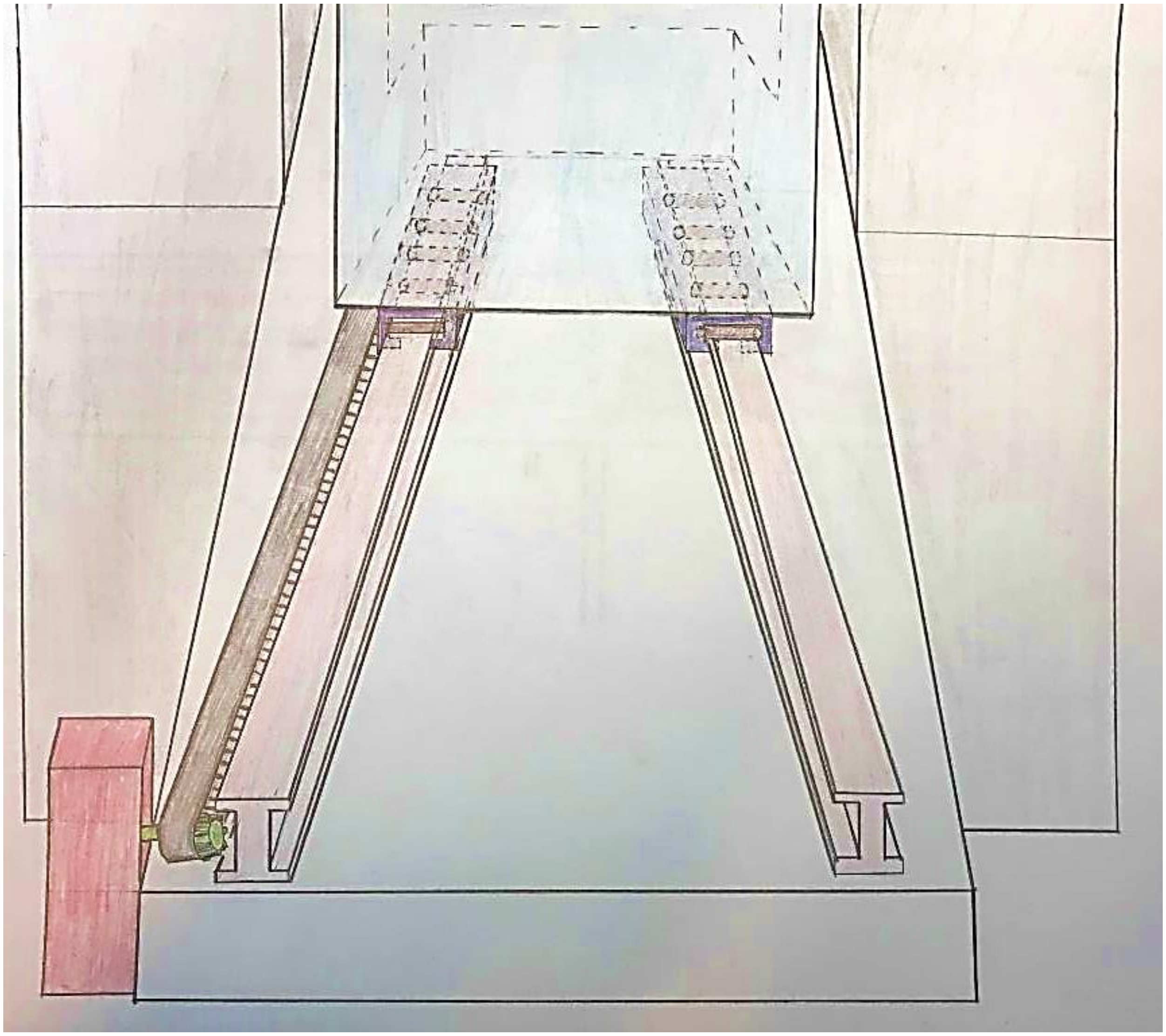
Concept 13.

Concept Pros: Low friction, motors mounted to back of seat.

Concept Cons: Motors will need to work in perfect sync to work.

Concept 14:

This concept uses a motor turning a ribbed belt connected to the seat to provide motion. It is guided along using two I-beams. The seat rides along the beam on rollers on top of the I-beams.



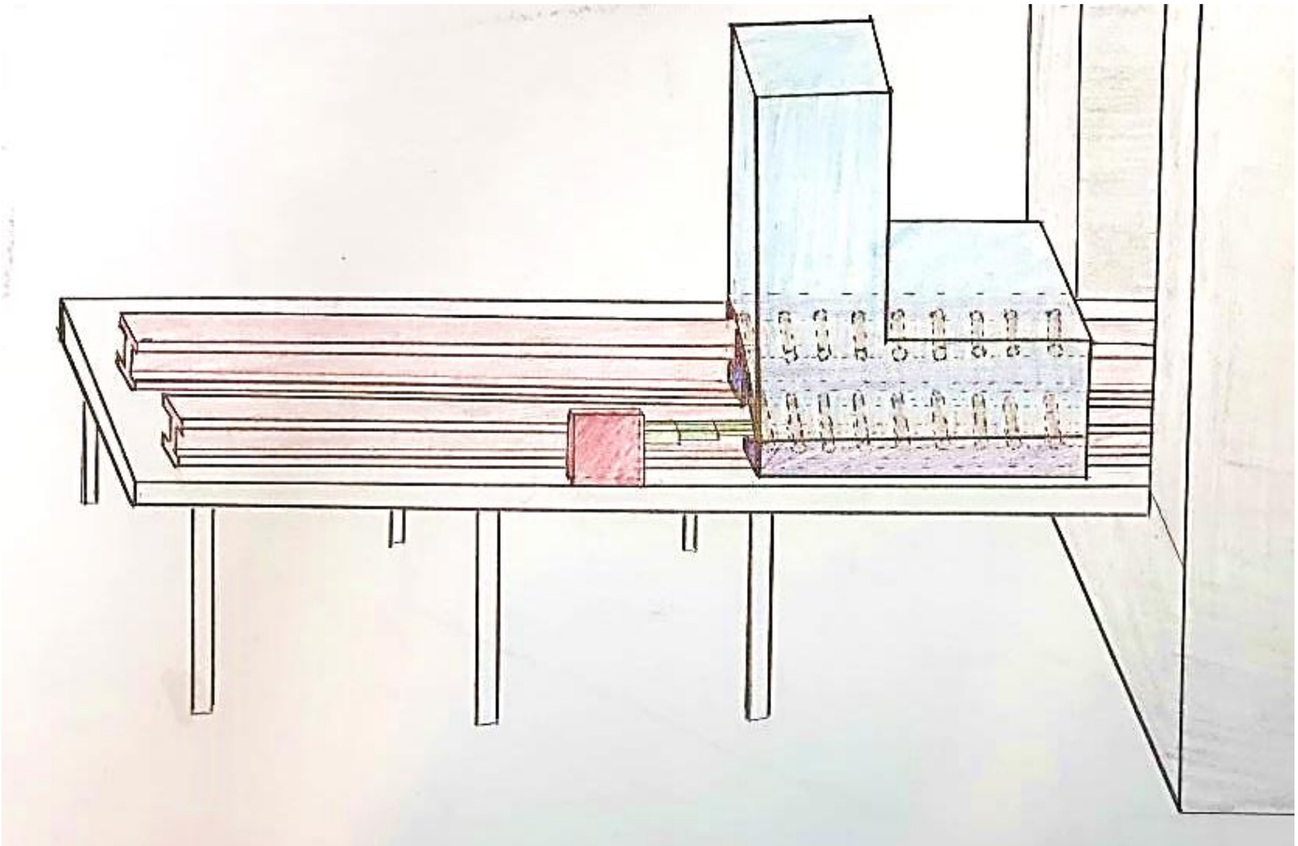
Concept 14.

Concept Pros: Low friction, minimal space under seat used, simple design.

Concept Cons: Belt could slip.

Concept 15:

This concept uses a linear actuator connected to a telescoping rod. It is guided along using two I-beams. The seat rides along the beam on rollers on top of the I-beams.



Concept 15.

Concept Pros: Minimal space under seat used, low friction, large force provided by actuator.

Concept Cons: Telescoping rod may be hard to implement.

1.6 Concept Selection

Functions and customer needs were used to evaluate the fifteen concepts that were generated. A Pugh matrix was used to obtain a quantitative comparison between the designs. The Pugh matrix is a powerful concept selection tool because it allows the designer to compare the concepts against the functions that the design must accomplish. Creating the design requirements promotes discussion that leads to clear, easily quantifiable criteria that furthers the translation of customer needs into design requirements. Design requirements that are not easily quantifiable must then be broken down into more specific and manageable requirements, often bringing new considerations to light. The Pugh matrix also allows certain functions that are critical to the operation of the system to be weighted more than others. Functions that are not essential design parameters do not have to be given as much weight, but are still considered in the overall design. This process narrows down the complexity of choosing between various solutions to a customer need.

One of the main advantages of using a Pugh matrix is that the best aspects of a group of designs can be applied to create one, robust design. The functions can be organized by subsystems for each design, and the best functions of each subsystem are taken to form a single design. A “sanity check” can then be performed using the highest scoring designs from each subsystem. This encourages designers to consider the practicality of implementing designs for certain subsystems and encourages them to review the functions of the system as a whole.

Evaluation Variables

The concepts were broken down into two main components: a drive system and guide system. These components were assessed and broken down further, allowing evaluation variables to be made. These variables were used to assess how each concept performed against one another on a scale from zero to five. The variables for each system allow for a deeper understanding of each concept's strengths and weaknesses. These variables can also show the strong, distinct components for each concept which can also be combined to develop a good, overall design.

For example, the drive system contains the evaluation variable "Machinability." From this, it's easier to see which drive systems for each concept will be easier to machine and produce based on our rating scale. Again, these evaluation variables allow for in depth analysis of each concept and support the concept selection phase in a big way.

Table 3: Pugh matrix used to select drive and guide systems.

Concept	Weight	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Drive System		Bevel	Chain	Human	R&P	Belt	Human	Belt	Actuator	R&P	Worm	Belt	R&P	R&P	Belt	Actuator
Cost	2	1	4	5	3	3	5	3	2	3	2	3	3	3	3	2
User safety	5	3	1	3	2	4	3	4	4	2	4	4	2	2	4	3
Ease of emergency exit	4	2	4	5	3	3	5	4	2	3	0	4	3	3	4	2
Ease use	5	5	5	0	5	5	0	5	5	5	5	5	5	5	5	5
Machinability	3	1	4	4	1	4	4	3	3	1	1	4	1	1	4	3
Maintainability	2	2	3	4	3	2	4	2	3	3	2	2	3	3	2	3
Life span	3	4	4	4	4	3	4	3	3	4	3	3	4	4	3	3
Drive time	4	3	4	2	3	3	2	3	2	3	1	3	3	3	3	2
Drive Complexity	2	3	4	2	1	4	2	4	1	4	3	4	1	1	4	1
Symmetry	3	2	4	4	5	2	4	4	5	1	1	4	4	5	1	1
Space for seat wiring	4	4	1	4	4	4	4	3	3	4	4	1	1	4	4	4
Force applied	3	3	3	1	2	1	1	2	3	3	4	1	3	3	3	4
Peripheral components	1	1	1	5	1	1	5	1	1	1	1	1	1	1	1	1
Totals		119	134	125	126	134	125	140	128	123	107	132	114	129	141	118
Guide System		Wheels	Cyl rails	Wheels	Wheels	Cyl rails	Wheels	Cyl rails	Cyl rails	Cyl rails	Cyl rails	Cyl rails	Roller/C-Beam	Rollers	Roller/I-Beam	Roller/I-Beams
Cost	2	3	2	2	0	2	1	2	2	2	1	2	3	2	3	3
User safety	5	2	3	3	1	2	4	3	3	3	3	3	4	4	4	4
Machinability	2	4	4	4	1	4		4	4	4	2	4	3	4	3	3
Integrate outsourced parts	1	4	4	4	2	4	2	4	4	4	2	4	1	1	1	1
Resistance to deflection	4	2	1	1	4	1	4	1	1	1	1	1	4	5	5	5
Resistance to friction	3	2	4	4	3	4	2	4	4	4	4	4	4	2	4	4
Mounting capability	4	4	3	3	2	3	2	3	3	3	2	3	3	4	3	3
Height clearance	5	4	1	1	4	1	4	1	1	1	1	1	4	3	4	4
Material hardness	2	3	3	3	4	3	2	3	3	3	2	3	4	3	4	4
Fatigue life	3	4	3	3	4	3	2	3	3	3	3	3	4	4	4	4
Totals		96	79	79	82	74	84	79	79	79	65	79	113	108	117	117

Drive System Design Selection

The evaluation variables were weighted from one to five, depending on how critical it is to fulfill the functions and customer needs. The team corroborated to identify safety and ease of use as the most important evaluation variables for the drive system. These variables were given a weight of five. Following safety and ease of use were the next set of important variables: ease of emergency exit, drive time, and space for seat wiring. These variables were given the weight of four. The team continued this process until each variable was weighted according to its criticality for achieving the goals of the system.

The drive system for each concept received an overall score which was calculated by multiplying the variable weight by variable score, and then summing its score for each variable. Although fifteen complete concepts were evaluated, many of the concepts had similar drive systems. These types of drives were broken down into hydraulic actuated, bevel gear driven, worm gear driven, human driven, rack and pinion driven, chain driven, and belt driven.

Using the low scores of the matrix and general intuition, a hydraulically actuated system, a bevel gear driven system, and a worm gear driven system were eliminated. Given the customer desired length and speed of egress, these systems are inferior to the others evaluated.

The human driven systems scored relatively high overall, but they are not actually feasible. The pilot cannot adequately ingress into the simulator given the variable leg lengths of pilots, and the decreasing range of leg motion as the pilot "walks" into the simulator. For this reason, a solely human driven system was eliminated, although the team plans to implement human powered override in case of emergency.

The rack and pinion driven systems also scored relatively high, but very low on more than one evaluation variable. The low machinability along with the complexity of the driving a symmetric system led the team to eliminate rack and pinion driven systems.

The chain and belt driven systems are very similar and can almost be considered the same type of drive system. They also were the two highest scoring types of systems in the Pugh matrix. Because the chain driven system has more safety hazards, the team favored using a belt rather than a chain the driven system. The belt system had the most well-rounded scores with very few "low" scores for any evaluation variable and scored the highest overall.

Guide System Design Selection

The best guide system concept was selected using the same methodology used for the drive system. User safety and height clearance were deemed the most important evaluation variables, receiving a weight of five. Mounting capabilities and resistance to deflection were identified as the next most significant variables, and received a weight of four. This was continued for the remained of the design variables.

Although fifteen concepts were created, their guide systems can be grouped into three categories: cylindrical rails, beams, and wheeled systems. Each of these systems received an individual score specific to its implementation in the respective concept, but there are obvious trends in the scoring of the systems.

Cylindrical rails scored the lowest of the three categories. The main problem that was identified with using cylindrical rails is the ability to stay within the two-inch height clearance. The rails would have to be mounted above the surface, leaving a gap of unused vertical space, which is already in short demand. Furthermore, the rails would have to be made of a rigid, and therefore heavy, material to withstand deflection under loading.

Although implemented in varying fashion, wheeled systems as a category scored slightly higher than the cylindrical rails. Wheeled systems can utilize the entirety of the vertical space, cutting the waste seen in the cylindrical rail design. The downside of using a wheel system comes when analyzing the systems resistance to friction and deflection. Plastic or metal wheels will provide a high frictional force, requiring more work from the drive system.

According to Pugh matrix, beam type guide systems are the optimal choice. Beam systems have a few distinct advantages. The beams can be mounted directly to the gurney, eliminating any waste in space seen in other systems. Furthermore, C or I beam’s will increase the rigidity of the system, ensuring that deflection under loading will be minimized.

Final Design Reasoning

The concepts selected for the drive system and guiding system are concepts 11 and 15 respectively. Concept 11 was chosen by interpreting the Pugh matrix and by also debating which of the top 3 would be the best for our project. This concept uses a pulley system that is mounted below the seat with the wheel face parallel to the gurney; this allows the pulleys to be large in size and produce a large amount of motion with little turning. The large pulleys could utilize a much slower motor which will decrease the size and weight of the overall system. Concept 11 fulfills most of the functions that are related to the drive system such as provide enough force to move seat, maintaining a system height of 2 inches, while also reducing the amount of space used under the seat to allow for wire housing. For the guiding system the process in choosing concept 15 was straightforward. Concept 15's guide system was identical to concept 14 and slightly different from concept 13. These three concepts scored the highest in the Pugh matrix. Concept 15 uses parallel I-beams to guide the seat which are used all over industries that require extensive loading. The two main functions of our guiding system are to ensure the seat moves in and out of the cockpit freely and to support the weight of the seat and the user; concept 15 does both of these things and also requires less analysis, reduces force required for seat motion and all but eliminates deflection of the system. The combining of the two concepts selected will ensure that the overall concept will be the best possible.

Although these two concepts have been selected we will need to continue a more in-depth concept selection of the concepts the Pugh matrix has ranked highest. A more in-depth selection process is required because the difference in the totals for some of the concepts are small. The new concept selection will introduce a 1-3-7 point system that will ensure that the difference in point totals is increased. Also, the new process should be more in-depth and have more factors to rank each concept on. The new concept selection will either assure that the concepts selected are the best choice or tell us which concepts should be selected.

1.7 Project Plan

The project plan sets the schedule for the Spring semester. It includes the detailed design phase and all the necessary deadlines to complete the design before Engineering Design Day on April 12th. Furthermore, the project plan discusses potential ‘bottlenecks’ and major

Table 4: Gantt chart detailing the schedule and milestones of the project until completion.

Team Number: 10	Project: Flight Simulator Cockpit Egress System															Date:		30-Jan-18	
Project Objective: Design a flight simulator egress system for an F-16 cockpit	Timeline																		
	December			January					February				March				April		
Major Tasks	11th	18th	25th	1st	8th	15th	22nd	29th	5th	12th	19th	26th	5th	12th	19th	26th	2nd	9th	12th
Rolling System																			
Request samples of linear rail systems					■	■	■												
Test friction coefficients of rail systems								■	■										
Determine handle and foot grip requirements for pilot motion									■	■									
Detailed CAD design for handle position										■									
Request rail quotes from various vendors								■	■										
Compare and order linear rail system									■	■	■								
Test rail mounting method/performance on prototype											■	■	■						
Validate handle position for ease of use														■	■				
Finalize rail, seat, and handle mounting															■	■	■		
Finalize Locking System																			
Choose method of locking	■	■	■	■	■	■	■												
CAD design for mounting orientation and sizing							■												
Determine force requirements								■	■										
Request quotes from various vendors								■	■										
Compare and order electromagnets									■	■									
Test mounting method/performance on prototype											■	■	■						
Adjust performance to meet customer requirements													■	■					
Finalize electromagnet mounting															■	■	■		
Administrative																			
Design Website						■	■	■	■	■	■	■	■	■					
Meet with Lockheed Martin in person																■	■		
Building									■	■	■	■	■	■	■	■	■		
Debugging															■	■	■		
Completely Working prototype																	■		

Major Milestones

Purchase the roller and guide system– February 5th

The roller and guide system is the foundation of the design. Purchasing these items will constrain the allowable dimensions of the electrical system. The mounting method of the guide system to the gurney must be determined beforehand to determine compatible C beams and rollers.

Choose method of locking – January 22nd

The seat locking method will take in to account the forces exerted on the seat by the pilot while the simulator is in use.

Detailed design of locking system – January 29th

Design chosen seat locking system in ProE and determine method of procurement.

Force calculations – February 5th

The exact forces needed to move the weight of the seat using the belt system will be calculated. The system design will involve a safety factor to safely move the weight of the seat.

Meet with Lockheed Martin in person – TBD

Meet with Lockheed team to discuss chosen parts and how the system will work as whole once all the parts are integrated.

Order parts – February 19th

The deadline to have all parts ordered.

Building – January 29th

Begin piecing together the total system.

Debugging – March 19th

Fully test every operation of the system to verify that it meets the requirements set forth in the target catalogue. Troubleshoot any problems using all available resources, including Lockheed Martin.

Fully functioning prototype – April 2nd

Present the fully functioning prototype.

Potential Problem Areas

Through the course of research and preliminary building, it has become apparent that creating a motor powered system is outside of the scope and budget of the project. The project will progress as a human powered device, with two main components: the rail system and locking system. Each of these systems will be purchased from a vendor, which raises potential bottlenecks in the execution of the building phase. Currently, the team is allotting a month of the ordering and shipping process, mainly based on initial conversations with several vendors. If the part availability were to change, the schedule and project could be affected.

Budget Analysis

If the project proceeds as expected, it will stay well within the $2,000 budget for the project. The linear rails and electromagnet are the two major expenses, accounting for about half of budget. The remainder expenses include the wood that will be used for the low fidelity cockpit mockup, fasteners and other building related supplies. These expenses will not put the team in danger of going over the budget.

Appendices

Appendix A: Code of Conduct

Mission Statement

Team 10 is dedicated to upholding professionalism, allowing for a free flow of communication, and focusing on the successful completion of the project. Each team member will display integrity and respect for each member within the group, and preserve their commitments to honest and quality work.

Roles

Team Leader – Frank Cullen

The team leader is responsible for the successful completion of all objectives. Furthermore, the team leader will track upcoming deadlines and create plans to meet these deadlines. The team leader is responsible for keeping morale high and advocating for teamwork to efficiently solve problems. The team leader will delegate tasks as he sees fit, and be a resource when tasks need a helping hand.

Design Engineer – Andrew Filiault

The design engineer will take charge of the mechanical design of the project and construction of a prototype. He is also responsible for knowing details of the design, and presenting alternatives for each aspect to the team for the decision process. The design engineer will keep design documentation for record.

Research Engineer – Andrew Porter

The research engineer is responsible for gathering any relevant information pertaining to the necessary background knowledge for the design phase. This includes details of designs previously used by our sponsor and their competitors. During the design phase, the research engineer will be responsible for seeking information on new topics as they arise. The research should be summarized into a presentable format for the other group members.

Financial Advisor – Daniel Swope

The financial advisor manages the budget and maintains a record of all credits and debits to project account. Any product or expenditure requests must be presented to the advisor, who is then responsible for reviewing and the analysis of equivalent/alternate solutions. He then relays the information to the team and if the request is granted, orders the selection. A record of these analyses and budget adjustments must be kept.

Historian – Marco Karay

The historian is responsible for creating and maintaining the team website for the project. This includes designing the website, and also keeping it up to date with the latest documents. He will be in charge of taking notes during team meetings, and documenting relevant material to the website.

Communication

Communication amongst the team will be split into two methods. For day to day communication, such as meeting planning, text message will be the main form of communication. For any project documentation, email will be the main form of communication. When communicating with someone outside of the team, a draft of the communication shall be reviewed for grammar by at least one other member. If a team member has a verbal conversation with information pertinent to the project, the team member shall send an email describing the conversation to each team member.

Ethics

Team members are required to be familiar with the NSPE Engineering Code of ethics as they are responsible for their obligations to the public, the client, the employer, and the profession. There will be stringent following of the NSPE Engineering Code of Ethics.

Dress Code

Team members are expected to always maintain a basic level of grooming. There is no dress code for weekly team meetings. All members must be dressed at a minimum of business casual (dress shirt, slacks, dress shoes, belt, tie), with the ability of business professional for all presentations and meetings with sponsor.

Work Schedule and Meeting Times

The primary meeting times of the entire group will be from 2:00 P.M. to 6:00 P.M. every Tuesday and Thursday. If it is deemed necessary, an additional meeting time may be added on Monday at 5:00 P.M. Meetings must be formally scheduled three days in advance, and team members will be expected to attend scheduled meetings.

Decision Making

All decisions pertinent to the project will be made via a four-person majority. Each member must form an opinion on the question at hand, and participate in the vote. The individual team members must always work in the best interest in the team and achievement of the goal of the project. Safety and ethics will be of utmost importance. The following decision process will be made for all major project decisions, as defined by the team:

- Problem Definition – Define the problem and understand it. Discuss among the group.

- Tentative Solutions – Brainstorms possible solutions. Discuss most plausible among group.
- Data/History Gathering and Analyses – Gather necessary data required for implementing Tentative Solution. Re-evaluate Tentative Solution for plausibility and effectiveness.
- Design – Design the Tentative Solution product and construct it. Re-evaluate for plausibility and effectiveness.
- Test and Simulation/Observation – Test design for Tentative Solution and gather data. Re-evaluate for plausibility and effectiveness.
- Final Evaluation – Evaluate the testing phase and determine its level of success. Decide if design can be improved and if time/budget allows for it.

Conflict Resolution

In the event of conflict amongst the team, the following steps will be used:

- Communication of points of interest from both parties, which may include demonstration of active listening by both parties through paraphrasing or other tool acknowledging clear understanding.
- Administration of a vote, if needed, favoring majority rule.
- Team Leader intervention.
- Instructor will facilitate the resolution of conflicts.

Amending the Code the Conduct

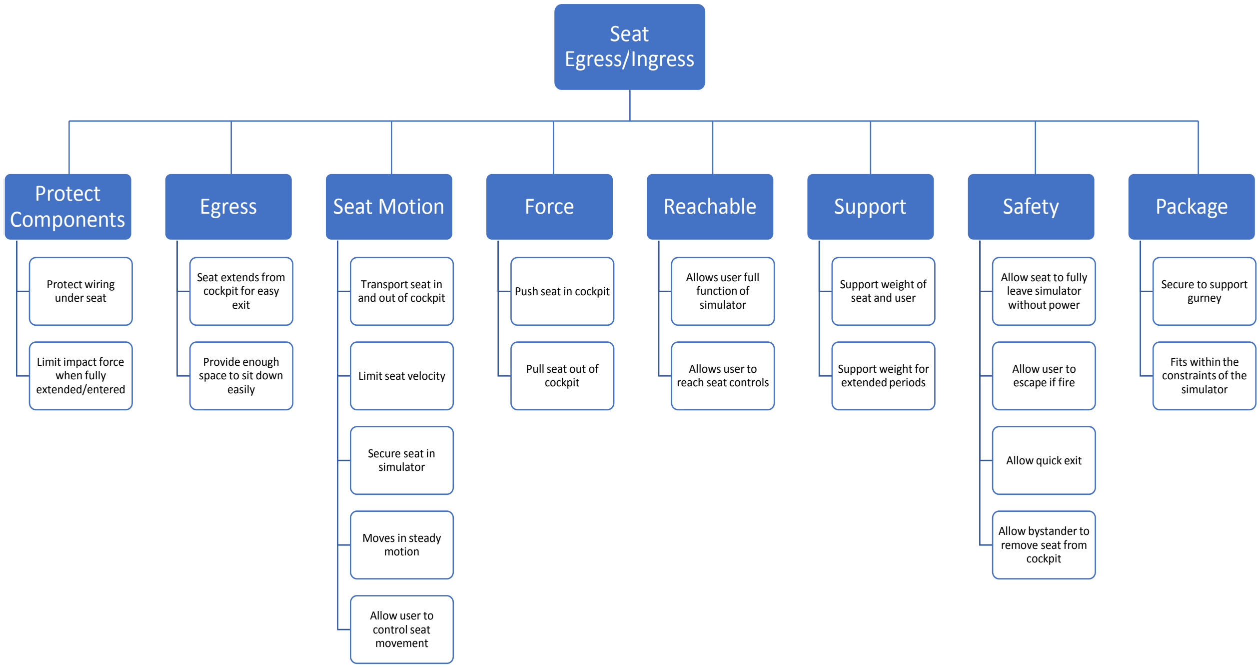
If it is deemed that a revision must be made to this document, all team members must be present. Every team member must agree to the revisions to the Code of Conduct before the document can be officially revised.

Statement of Understanding

By signing this document the members of Team 10 agree to all of the above and will abide by the code of conduct set forth by the group.

Name	Signature	Date
______________________________	_________________________	_________
______________________________	_________________________	_________
______________________________	_________________________	_________
______________________________	_________________________	_________
______________________________	_________________________	_________

Appendix B: Functional Decomposition



Appendix C: Target Catalog

Metric	Measure	Target
Time to complete ingress or egress	Time	15s
Maximum acceleration of system	Acceleration	4.56 ft/s^2
Maximum axial force	Force	338 lbf
Constant acceleration	Jerk	0 ft/s^3
Width clearance under seat	Length	16.1 in.
Clearance to sit in seat (buttock-knee length)	Length	26 in.
Stopping impulse	Force	TBD
Clearance of seat edge to cockpit	Length	47.1 in. – length of cockpit dome
Seat controls within user's reach	Length	28.2 in.
Force required for seat movement	Force	TBD
Change in position on the gurney when the load is applied	Length	0 in.
Change in position on the gurney when the load is applied	Force	TBD
Material deflection under passenger load	Length	TBD
Number of cycles	N/A	36500
Maximum fire escape time	Time	5.0s
Width clearance to fit inside cockpit dome	Length	20.3 in.
Force required for bystander to pull seat out of simulator with one arm	Force	45 lbf
Bystander width workspace clearance	Length	24 in.
Bystander workspace depth	Length	41 in.
Force to manually move seat (feet on ground)	Force	23 lbf

Appendix D: Pugh Matrix

Concept	Weight	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Drive System		Bevel	Chain	Human	R&P	Belt	Human	Belt	Actuator	R&P	Worm	Belt	R&P	R&P	Belt	Actuator
Cost	2	1	4	5	3	3	5	3	2	3	2	3	3	3	3	2
User safety	5	3	1	3	2	4	3	4	4	2	4	4	2	2	4	3
Ease of emergency exit	4	2	4	5	3	3	5	4	2	3	0	4	3	3	4	2
Ease use	5	5	5	0	5	5	0	5	5	5	5	5	5	5	5	5
Machinability	3	1	4	4	1	4	4	3	3	1	1	4	1	1	4	3
Maintainability	2	2	3	4	3	2	4	2	3	3	2	2	3	3	2	3
Life span	3	4	4	4	4	3	4	3	3	4	3	3	4	4	3	3
Drive time	4	3	4	2	3	3	2	3	2	3	1	3	3	3	3	2
Drive Complexity	2	3	4	2	1	4	2	4	1	4	3	4	1	1	4	1
Symmetry	3	2	4	4	5	2	4	4	5	1	1	4	4	5	1	1
Space for seat wiring	4	4	1	4	4	4	4	3	3	4	4	1	1	4	4	4
Force applied	3	3	3	1	2	1	1	2	3	3	4	1	3	3	3	4
Peripheral components	1	1	1	5	1	1	5	1	1	1	1	1	1	1	1	1
Totals		119	134	125	126	134	125	140	128	123	107	132	114	129	141	118
Guide System		Wheels	Cyl rails	Wheels	Wheels	Cyl rails	Wheels	Cyl rails	Cyl rails	Cyl rails	Cyl rails	Cyl rails	Roller/C-Beam	Rollers	Roller/I-Beam	Roller/I-Beams
Cost	2	3	2	2	0	2	1	2	2	2	1	2	3	2	3	3
User safety	5	2	3	3	1	2	4	3	3	3	3	3	4	4	4	4
Machinability	2	4	4	4	1	4		4	4	4	2	4	3	4	3	3
Integrate outsourced parts	1	4	4	4	2	4	2	4	4	4	2	4	1	1	1	1
Resistance to deflection	4	2	1	1	4	1	4	1	1	1	1	1	4	5	5	5
Resistance to friction	3	2	4	4	3	4	2	4	4	4	4	4	4	2	4	4
Mounting capability	4	4	3	3	2	3	2	3	3	3	2	3	3	4	3	3
Height clearance	5	4	1	1	4	1	4	1	1	1	1	1	4	3	4	4
Material hardness	2	3	3	3	4	3	2	3	3	3	2	3	4	3	4	4
Fatigue life	3	4	3	3	4	3	2	3	3	3	3	3	4	4	4	4
Totals		96	79	79	82	74	84	79	79	79	65	79	113	108	117	117

Appendix E: Explanation of Evaluation Variables

Drive System

- Cost – Anticipated cost for all components of the drive system
- User Safety – Possible safety hazards associated with the drive system
- Ease of Emergency Exit – Gauged level of effort required to move a non-working system
- Ease of Use – Level of input required for user to operate
- Machinability – Evaluation of the parts ability to be machined, either "in house" or by a third party. Parts requiring extensive machining received a lower score.
- Maintainability – Ability for the system to be serviced and parts to be replaced
- Lifespan – Estimated duration the concept will be of good use
- Drive Time – Time it takes for the system to reach its destination
- Drive Complexity – How complex the system will be when undergoing motion
- Symmetry – Will the components of the system be symmetrical allowing for efficient movement
- Space for seat wiring – Allow enough room for wiring implementation
- Force applied – Taking into account the applied loading and deflection on each component of the system
- Peripheral components – Placement of outside components on the system

Guide System

- Cost – Anticipated cost for all components of the guide system

- User Safety – Possible safety hazards associated with the guide system
- Machinability – Evaluation of the parts ability to be machined, either "in house" or by a third party. Parts requiring extensive machining received a lower score.
- Integrate Outsourced Parts – Will it require us to incorporate parts from other suppliers
- Resistance to deflection – Ability to withstand forces under certain loading conditions
- Resistance to friction – Ability to withstand opposing forces
- Mounting capabilities – Ease of system to be mounted on to the gurney
- Height clearance – Ability for system to meet height requirements and specifications
- Material Hardness – Resistance to deformation
- Fatigue Life – Endurance capability of the system

Appendix F: Risk Assessment Safety Plan

Project information:

Flight Simulator Ingress Egress System	3/2/2018
Name of Project	Date of submission

Team Member	Phone Number	e-mail
Frank Cullen	407-463-2649	Ftc13b@my.fsu.edu
Daniel Swope	954-937-0764	Ds13f@my.fsu.edu
Andrew Porter	954-249-4245	Agp13c@my.fsu.edu
Andrew Filiault	321-720-6675	Af15n@my.fsu.edu
Marco Karay	727-389-6044	Mak13b@my.fsu.edu
Faculty mentor	**Phone Number**	**e-mail**
Patrick Hollis	850-410-6319	hollis@eng.fsu.edu

I. Project description:

The goal of this project is to create a prototype sliding seat system. The prototype will be a one off model of the F-16 cockpit flight simulator, and the functional prototype is designed to be directly implemented into Lockheed Martin's current configuration. The major components of the prototype are a wooden gurney, a wooden version of the simulator shell, two linear rails with attached gantries and an electromagnet attached to the wooden simulator shell.

II. Describe the steps for your project:

The first step in the project will be to make dimensioned cuts of all pieces of wood that will be used to make the gurney and Simulator shell. Once the cuts are made, fasteners will be used to secure the wood and assemble the gurney and simulator shell. After the gurney is assembled, the linear rails will be mounted to the gurney with fasteners. The seat plate will then be mounted to the gantries using fasteners. The electromagnet will be attached to the simulator shell using fasteners, and will plug into an outside power source.

III. Given that many accidents result from an unexpected reaction or event, go back through the steps of the project and imagine what could go wrong to make what seems to be a safe and well-regulated process turn into one that could result in an accident. (See examples)

The first major incident that could occur is injury due to cutting the wood. A miter saw will be used for the cutting, which has an exposed blade when the blade is near the wood. The loss of fingers and hands is an imminent threat if action is not taken. Both hand and battery powered drivers will be used to properly install the fasteners. While applying force, the head of the driver can slip and contact the user's hand or arm. Furthermore, a hammer will also be used for the assembly of the gurney, which carries the risk of contacting a hand if proper aim is not used. During the preparation and assembly of components, debris may be launched in the air, becoming a hazard to the face or eyes.

IV. Perform online research to identify any accidents that have occurred using your materials, equipment or process. State how you could avoid having this hazardous situation arise in your project.

The primary source of accidents related to the manufacturing of this project include accidents using miter saws and hammers. The main concern with miter saws is when users keep their hands too close to the blade and do not use the blade safety shields that the saw manufacturers install on their saws. To avoid this, the operator should keep his hands at least 6 inches away from any moving blade and make sure that all safety guards are installed before use. It's also important to wait for the blade to stop moving before reaching in to the cutting area. The hammer poses a risk to the operator's hand that is supporting the tools that are Being hit with the hammer. This risk can be minimalized by selecting a hammer that is right weight and size for the job. The striking face of the hammer must also be at least 0.5 inches larger than the face of the tool being struck.

V. For each identified hazard or "what if" situation noted above, describe one or more measures that will be taken to mitigate the hazard. (See examples of engineering controls, administrative controls, special work practices and PPE).

To avoid injury prior to using any tools all jewelry will be taken off, this includes watches, bracelets, necklaces, etc. Eye protection is required always. Closed toe shoes, pants, and a shirt are required to use any equipment or to be in the lab. The saw requires two individuals to operate to help secure wood and avoid mistakes. Before using the saw the wood should be Mounted securely and, on a level, stable surface. While the saw is in use the user will keep a minimum distance of 6 inches from the blade. If the wood being cut has any visible deformities the cut will be made in such a location that does not coincide with the deformity. To avoid flying debris all material must be mounted securely or clamped down using a vice or clamps.

VI. Rewrite the project steps to include all safety measures taken for each step or combination of steps. Be specific (don't just state "be careful").

The First step in the project will be to make dimensioned cuts of all pieces of wood that will be used to make the gurney and simulator shell. In doing this, we will utilize gloves and maintain a safe distance away while performing this cutting motion on the wooden pieces as it's exposed to a sharp blade. Once cuts are made, fasteners will be used to secure the wood and assemble the gurney and simulator shell. We will do this keeping fingers and hands a safe distance away while integrating these components. After the gurney is assembled, the linear rails will be mounted to the gurney with the fasteners taking precaution again keeping a safe distance and keeping your hands and fingers from being clenched or stuck during the mounting operation. We will also utilize more than once individual to keep the weight balanced. This process will go hand in hand with mounting the seat plate to the gantries using fasteners. The electromagnet will then be attached using these fasteners, and it will plug into an outside source. This is done through the assistance of another team member, as well as utilizing gloves for finger protection.

VII. Thinking about the accidents that have occurred or that you have identified as a risk, describe emergency response procedures to use.

If an emergency occurs, the first task will be to assess the situation. If there is an injury, the priority should be to provide immediate aid to the injured party and to alert the appropriate individuals. If the injury necessitates, contact authorities. If the emergency is a fire, immediately pull the fire alarm, evacuate the area and call authorities. In every incident, the faculty mentor will be contacted and informed of the situation.

VIII. List emergency response contact information:

- Call 911 for injuries, fires or other emergency situations
- Call your department representative to report a facility concern

Name	Phone Number	Faculty or other COE emergency contact	Phone Number
		Dr. Shayne McConomy	(850)-410-6624
		Dr. Patrick Hollis	(850)-410-6319
		Dr. Emmanuel Collins	(850)-410-6373

IX. Safety review signatures

- Faculty Review update (required for project changes and as specified by faculty mentor)
- Updated safety reviews should occur for the following reasons:
  1. Faculty requires second review by this date:
  2. Faculty requires discussion and possibly a new safety review BEFORE proceeding with step(s)
  3. An accident or unexpected event has occurred (these must be reported to the faculty, who will decide if a new safety review should be performed.
  4. Changes have been made to the project.

Team Member	Date	Faculty mentor	Date
Andrew Porter	3/1/18		
Frank Cullen	3/1/18		
Daniel Swope	3/1/18		
Marco Karay	3/1/18		
Andrew Filiault	3/1/18		

Report all accidents and near misses to faculty mentor.