FAMU-FSU College of Engineering

Virtual Design Review 2
Team 505

Danfoss Stepper Motor Lifecycle Fixture

11/14/2024

Team Introductions

Bradford Andrews
Mechatronics Engineer

Albert Auer
Mechanical Design Engineer

Presenter

Chaney Bushman
Manufacturing and Test Engineer

Joseph Garvie
Systems Engineer

Presenter

Mason Herbet
CAD Designer

Presenter

FAMU-FSU College of Engineering

Sponsor and Advisors

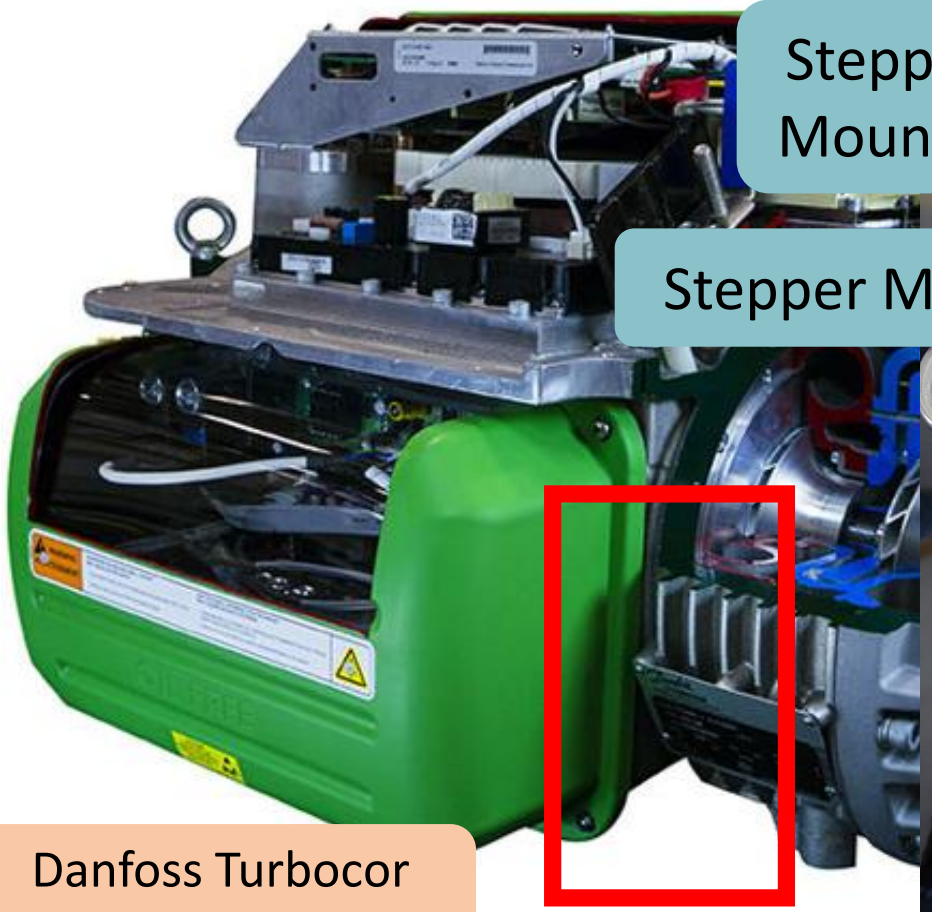
Sponsor
Cole Gray
Senior Mechanical Design Engineer

Academic Advisor
Patrick Hollis, Ph.D.
Associate Professor & Undergraduate Coordinator

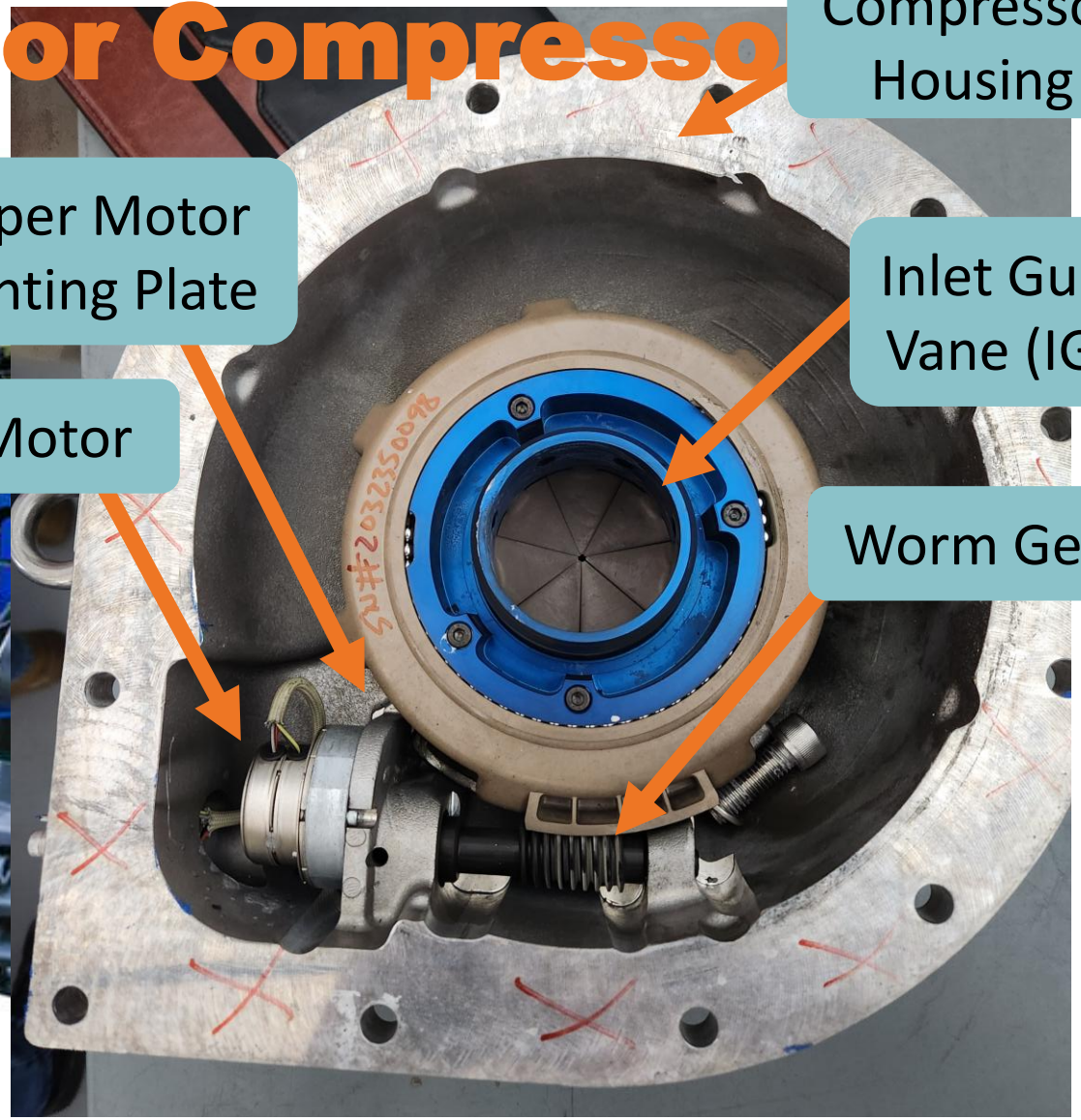
Academic Advisor
Shayne McConomy, Ph.D.
Senior Design Professor

Mason Herbet

Danfoss Turbocor Compressor



Danfoss Turbocor
TG Series



FAMU-FSU College of Engineering

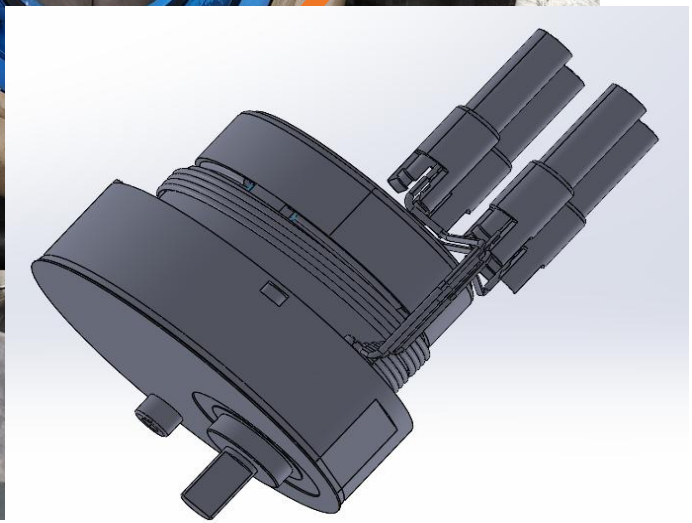
Component Reference

Inlet Guide Vane (IGV)

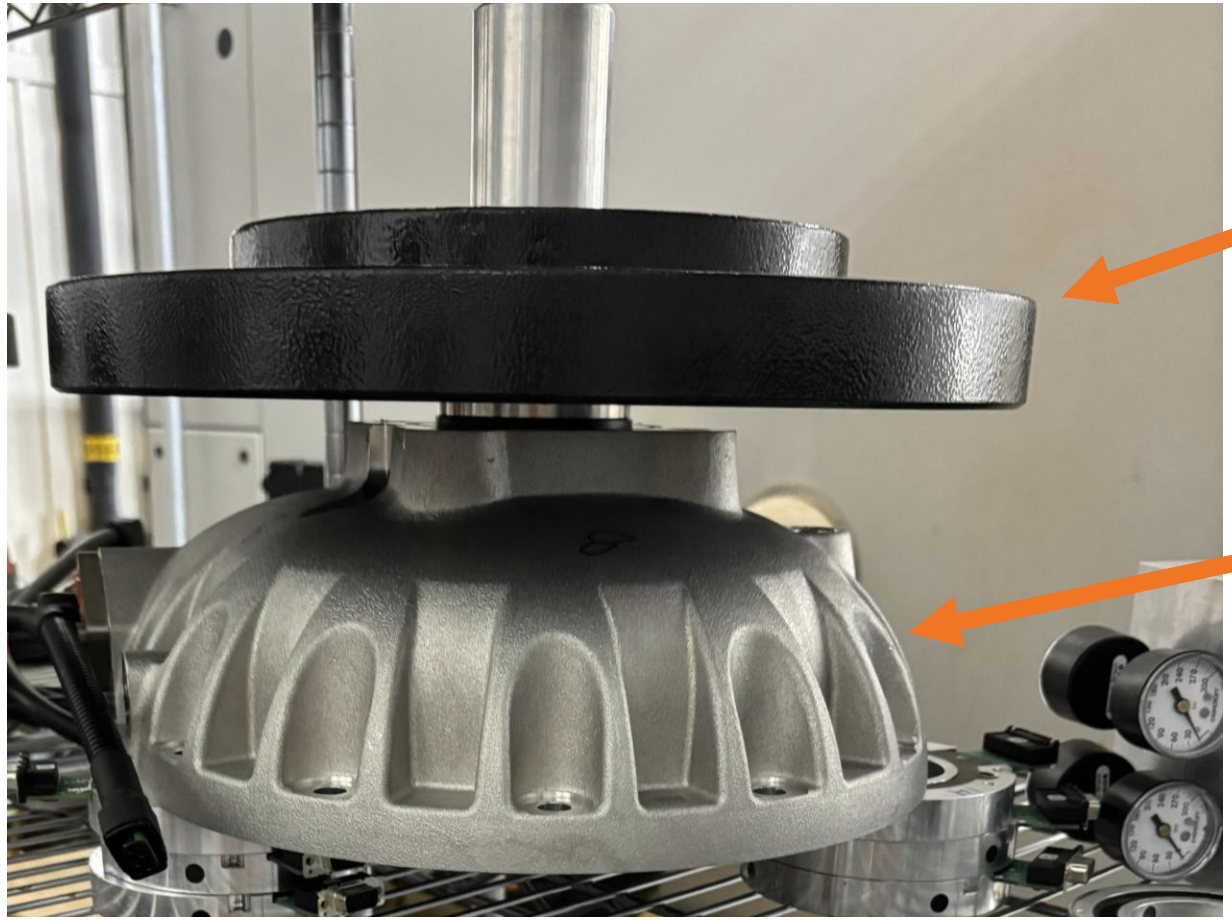
- Controls the fluid flow at the intake of the compressor
- Composed of rotating blades driven by a gear train from a stepper motor

Stepper Motor

- Drives the gear train and controls the angle at which IGV blades are positioned



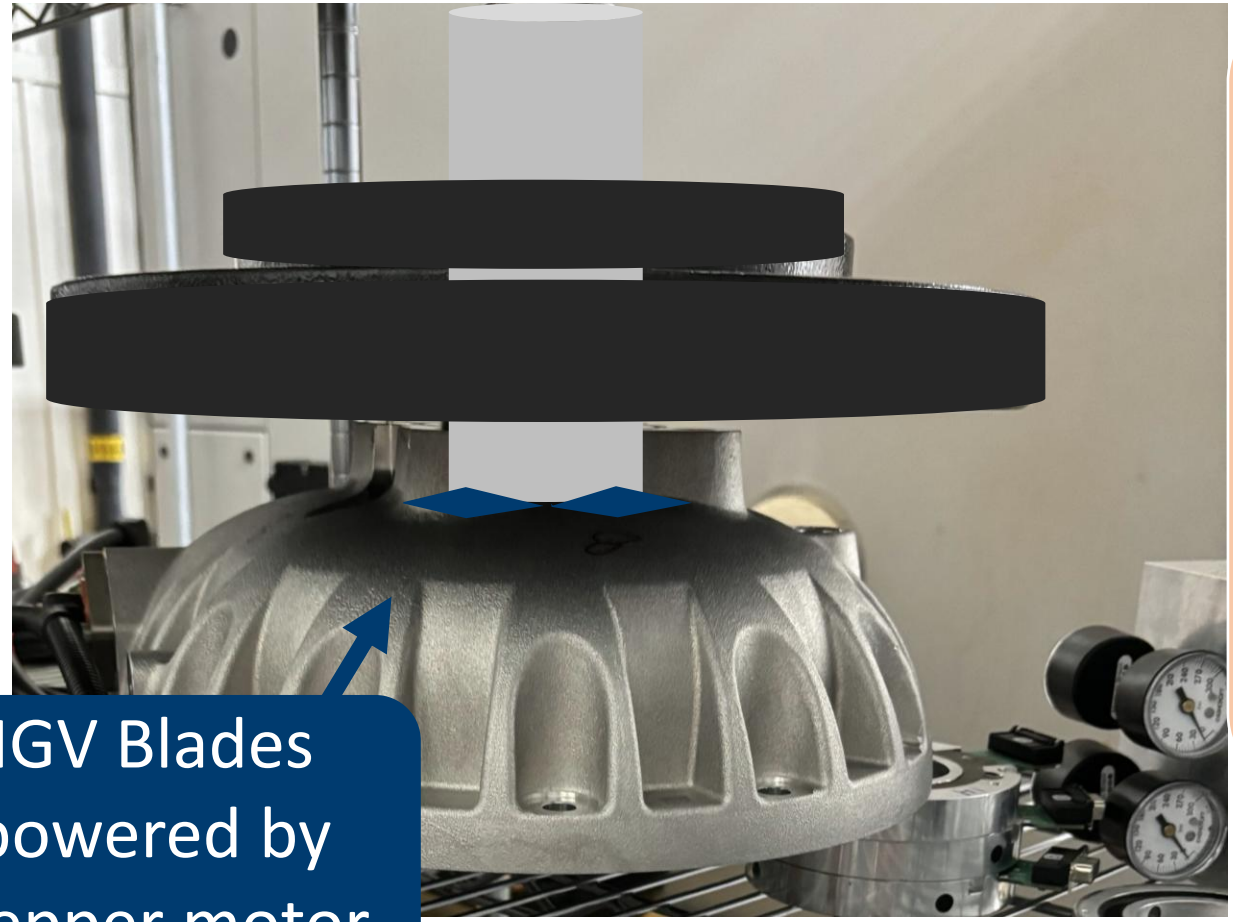
Current Test Procedure



Various Weight Plates

IGV Housing

Current Test Procedure



- Stepper motor drives a gear train which turns IGV blades
- Adds undesirable friction forces to stepper motor
- Inaccurate representation of resistance loading

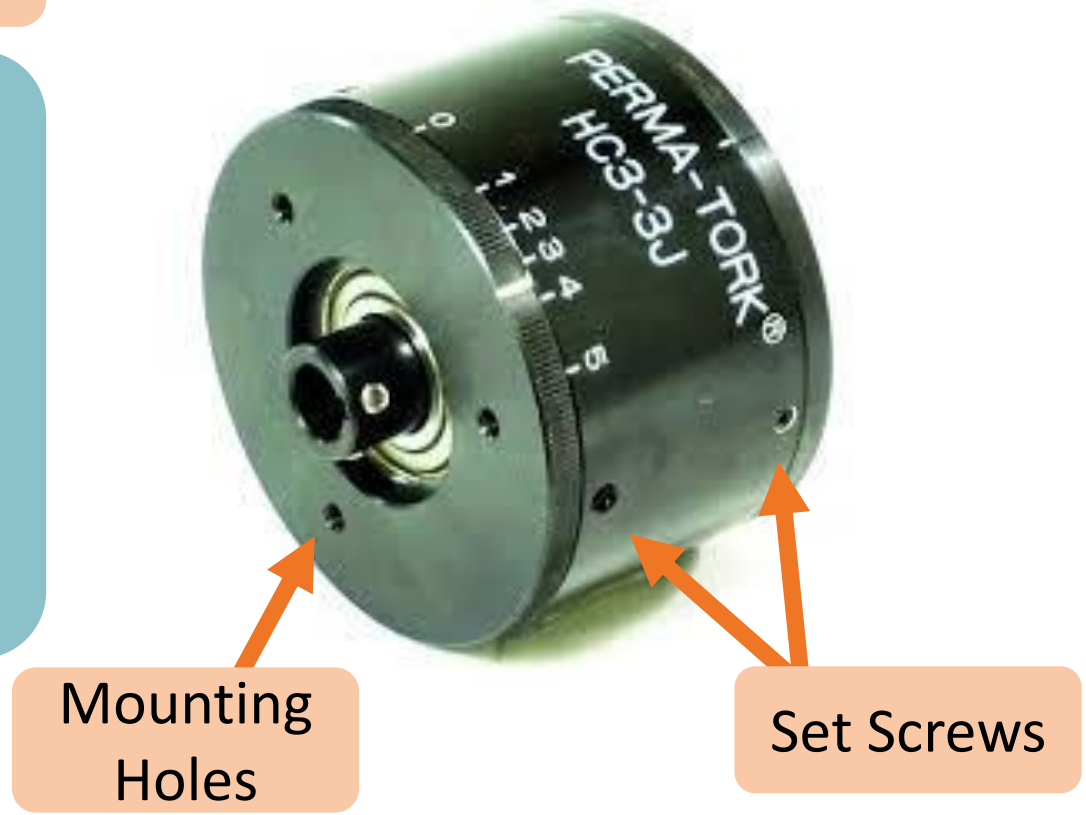
Objective

The objective of this project is to design and produce a stepper motor lifecycle test fixture for Danfoss Turbocor to improve user-friendliness and reliability over their current testing procedure.

Given Components

Perma-Tork

- Model HC3-3J
- Twist to adjust torque from 0.03-0.45NM
- Set Screws to lock torque value
- Verify using torque wrench



FAMU-FSU College of Engineering

Given Components

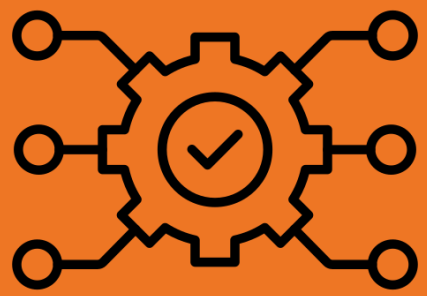
Flexible Coupler

- Set screws on each end
- Flexible metal midsection
- Absorbs minor misalignments

Key Goals

User-Friendliness

Reliability



Automation

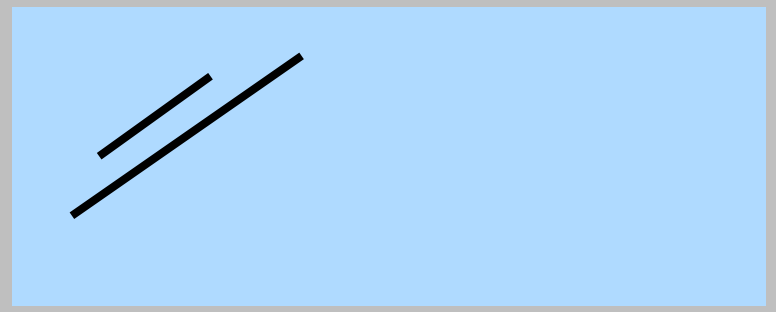
Accuracy

Joseph Garvie

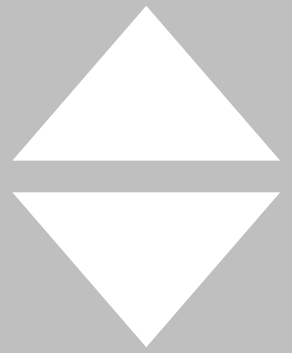
Critical Fixture Functions

User Interface

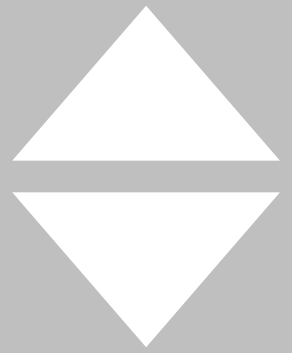
Display Test Results



Adjust Speed

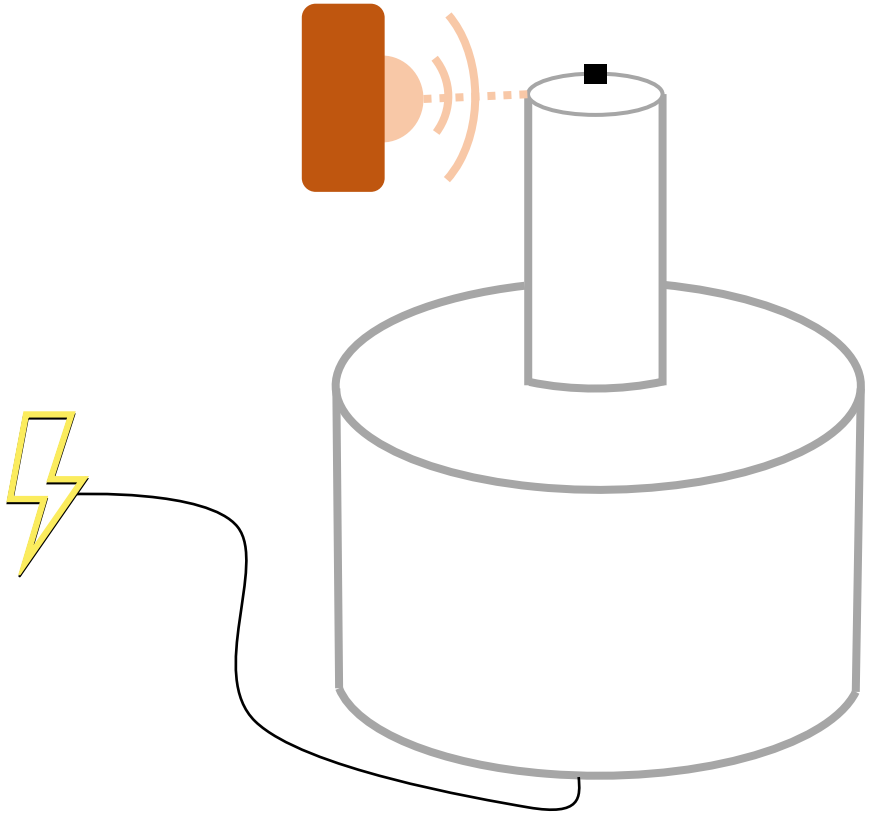


Adjust Cycle Time



Automation

Track Cycles & Rotations
Detect Failure
Deactivate Motor Upon Failure



FAMU-FSU College of Engineering

Critical Targets

User Interface

- **Adjust Cycle Time**
  - A cycle to vary from 0-300 seconds
- **Adjust Speed**
  - 1 – 1000 pulses per second
- **Display Test Results**
  - - Cycle count
  - - Rotation count

Critical Targets

Automation

- Detect Failure
  - Actual rotation time > Expected
- Deactivate Motor Upon Failure
  - 0 Volts
- Track Cycles & Rotations
  - 98% accuracy

Concept Generation

3 High Fidelity Concepts

5 Medium Fidelity Concepts

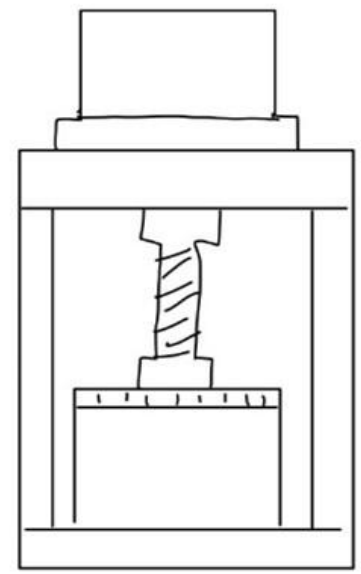
Concepts completely satisfy critical functions and maximize user-friendliness

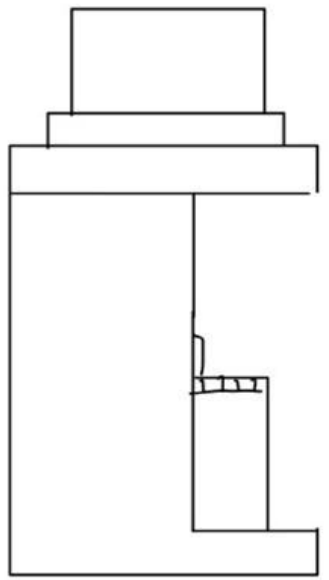
Concepts completely satisfy critical functions

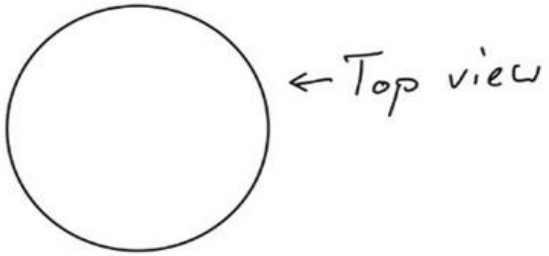
Joseph Garvie

Medium Fidelity Concepts

- Swivel Frame
- StepperLife Pro
- Tower Tester
- Hysteresis Brake
- Torque Master





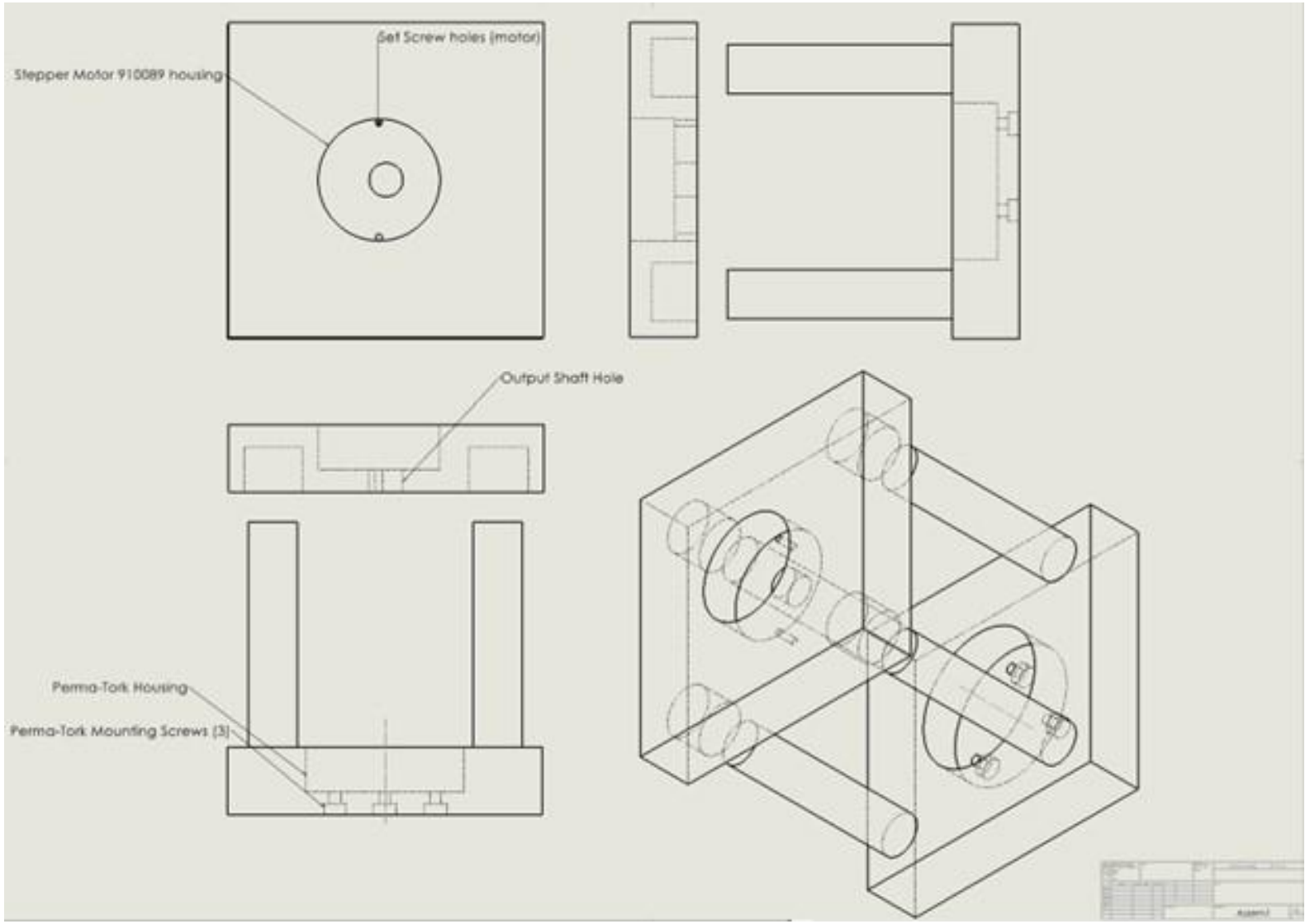


FAMU-FSU College of Engineering

Joseph Garvie

Medium Fidelity Concepts

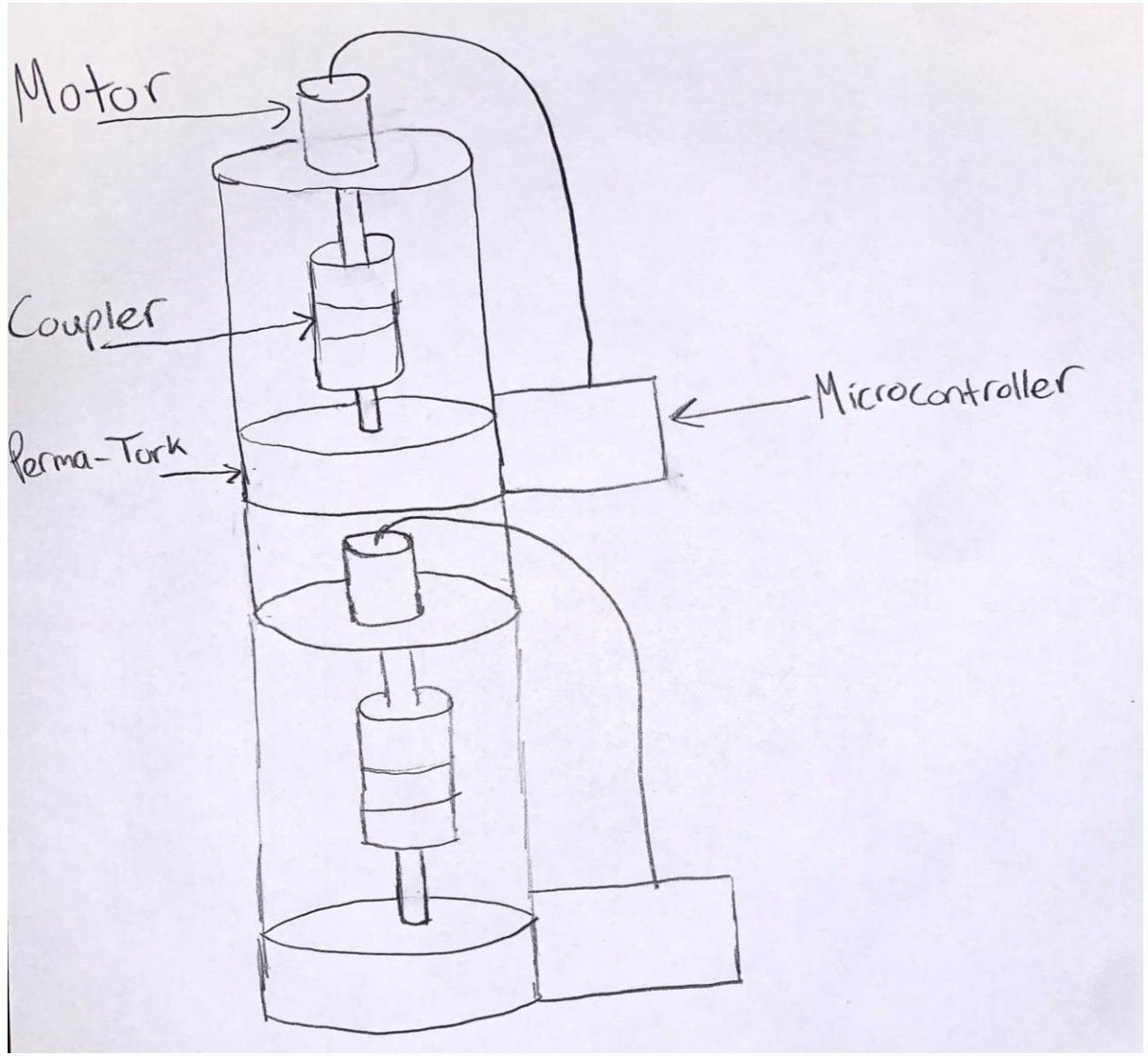
- Swivel Frame
- StepperLife Pro
- Tower Tester
- Hysteresis Brake
- Torque Master



FAMU-FSU College of Engineering

Medium Fidelity Concepts

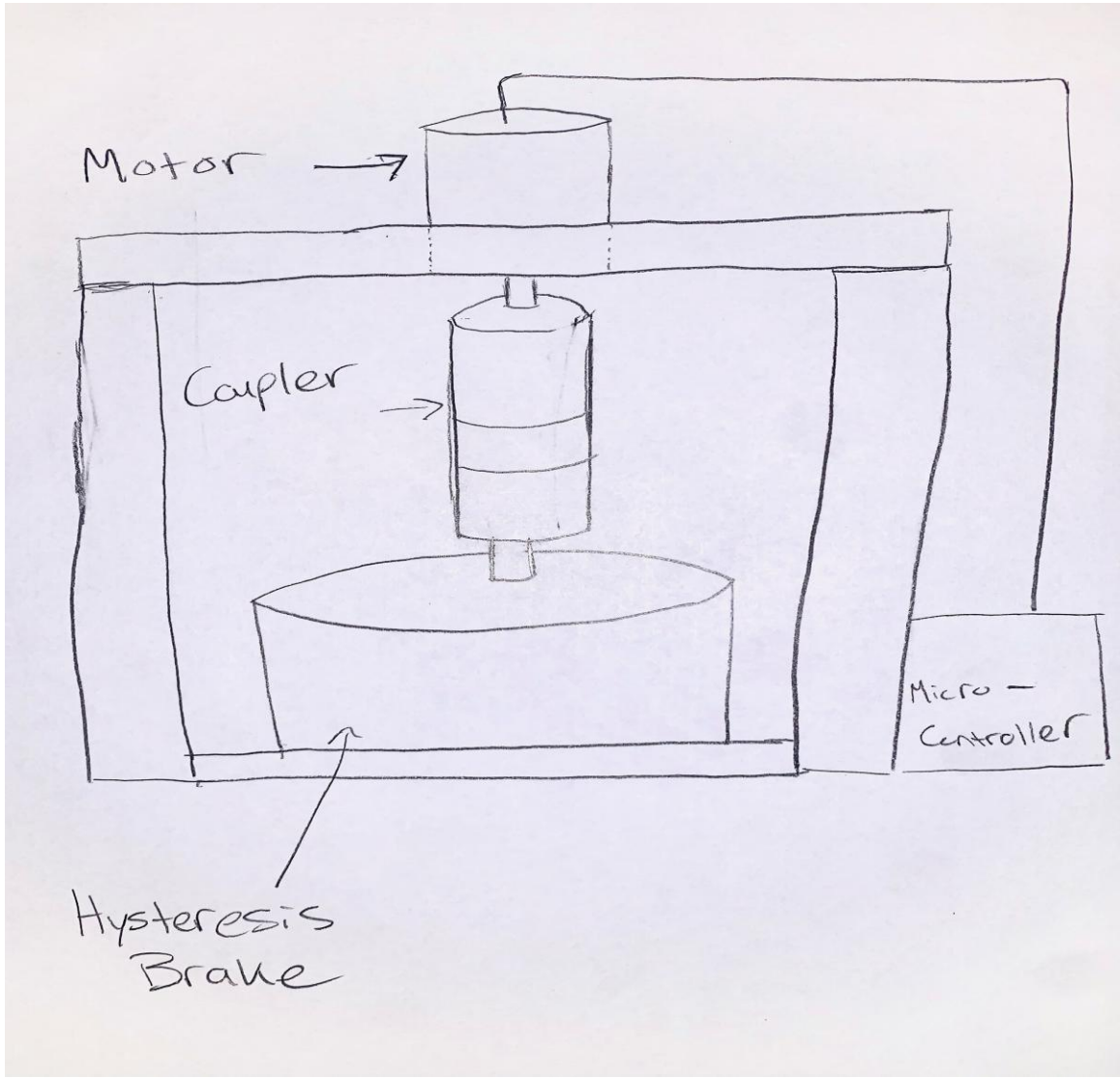
- Swivel Frame
- StepperLife Pro
- Tower Tester
- Hysteresis Brake
- Torque Master



Joseph Garvie

Medium Fidelity Concepts

- Swivel Frame
- StepperLife Pro
- Tower Tester
- **Hysteresis Brake**
- Torque Master

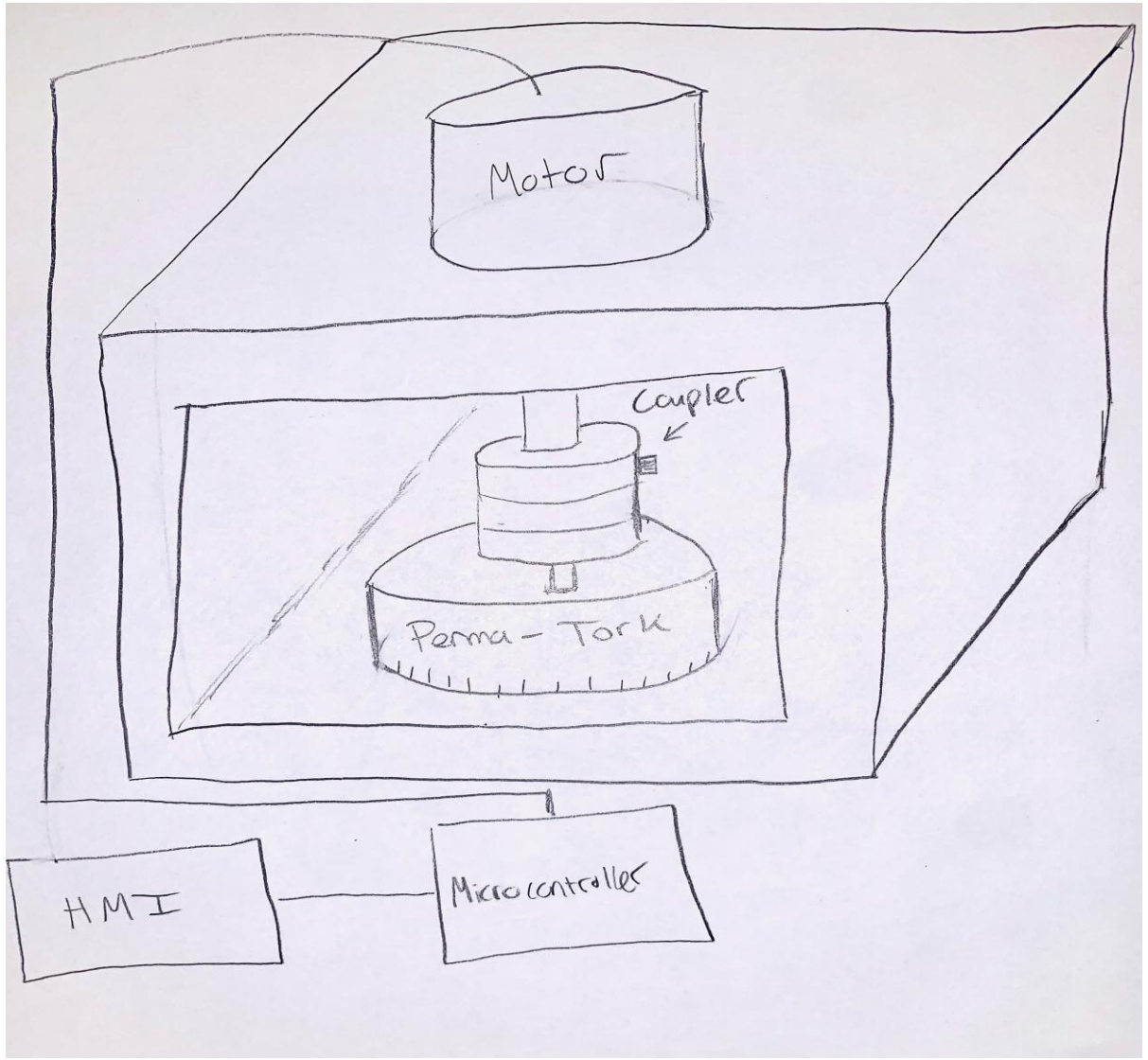


FAMU-FSU College of Engineering

Joseph Garvie

Medium Fidelity Concepts

- Swivel Frame
- StepperLife Pro
- Tower Tester
- Hysteresis Brake
- Torque Master

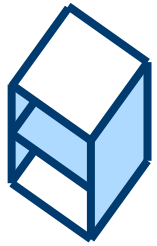


FAMU-FSU College of Engineering

High Fidelity Concepts

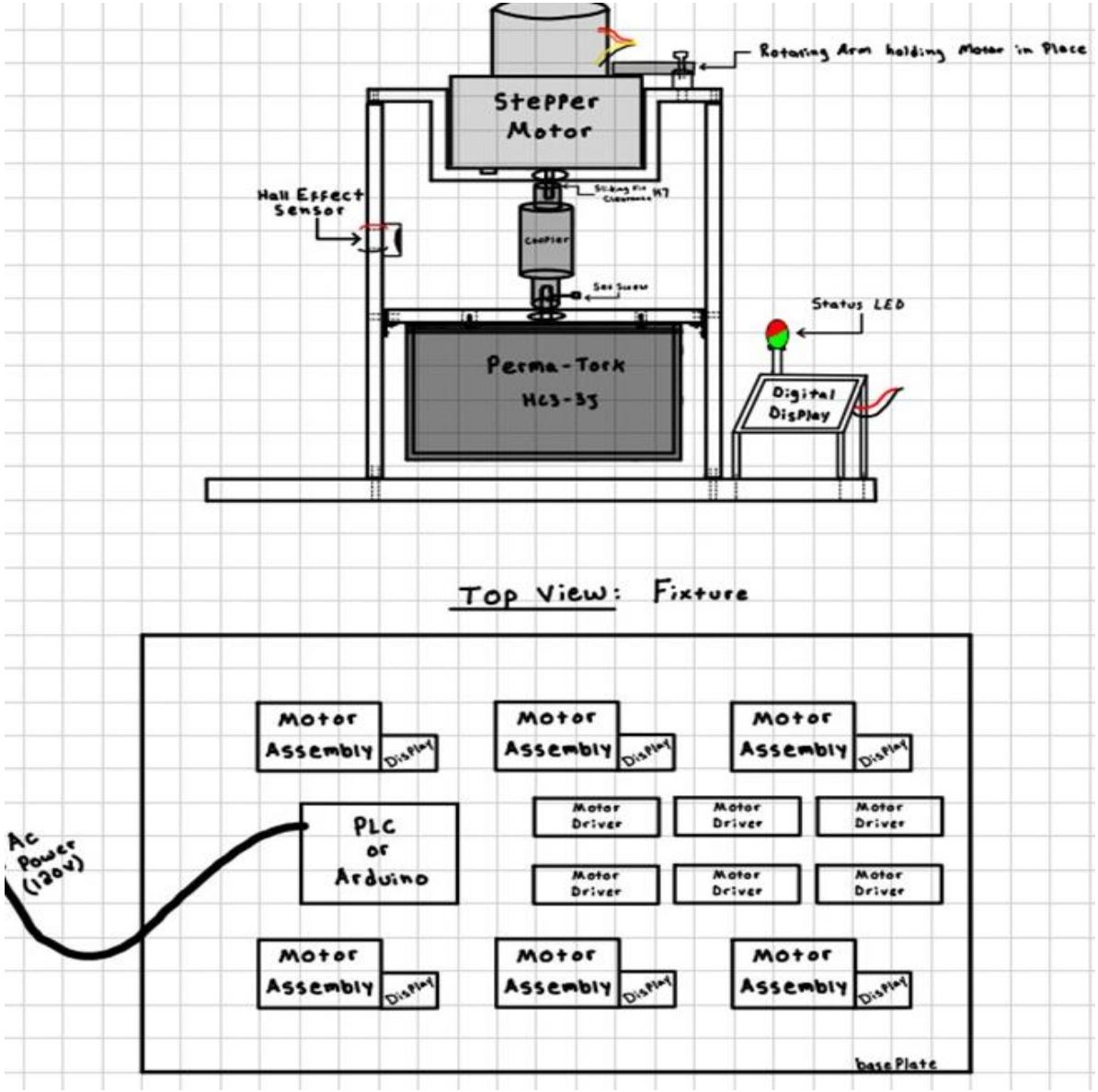
Joseph Garvie

H-Frame



Modular Skeleton

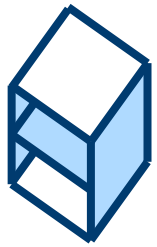
Solo C-Frame



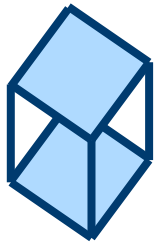
FAMU-FSU College of Engineering

High Fidelity Concepts

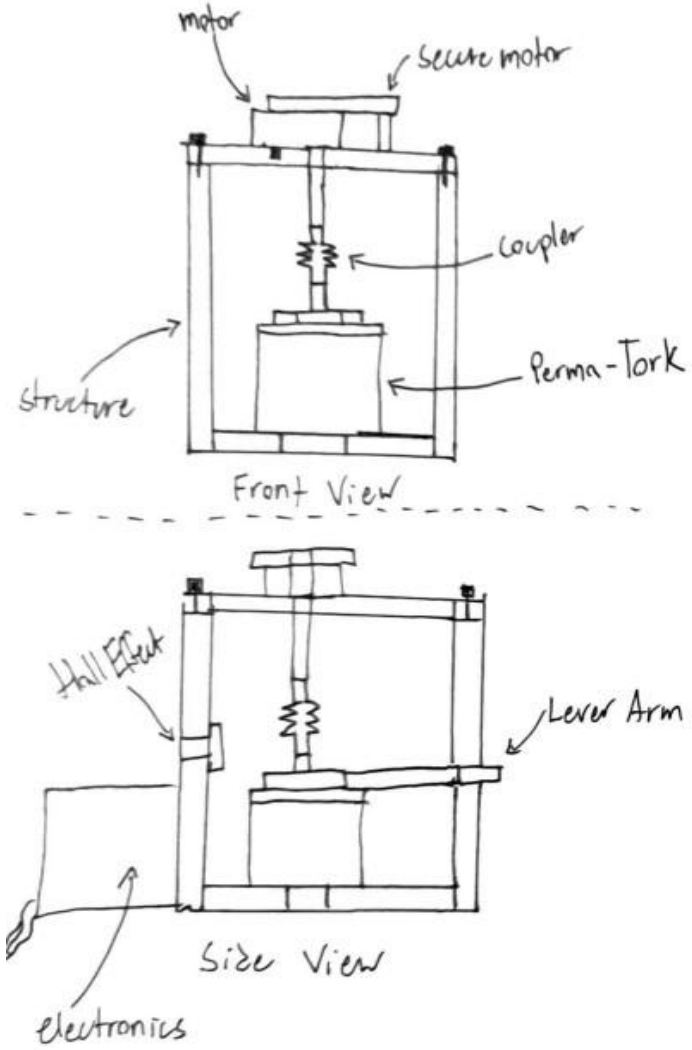
H-Frame

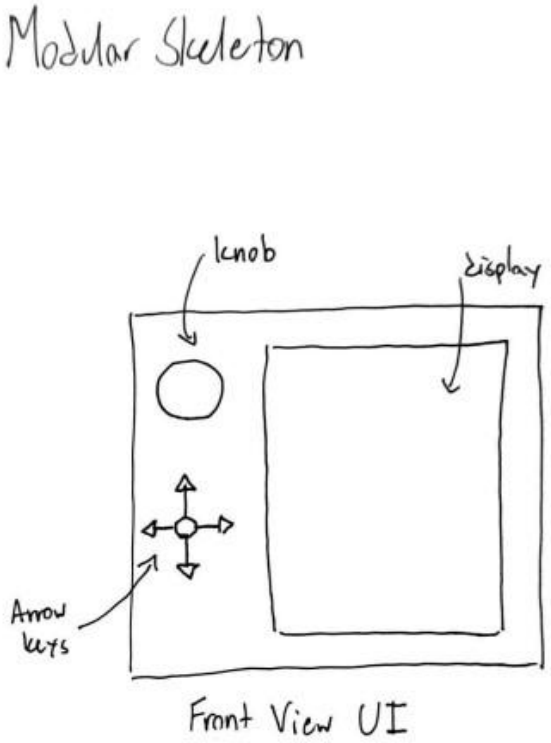


Modular Skeleton



Solo C-Frame

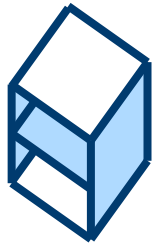




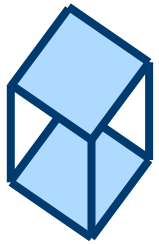
FAMU-FSU College of Engineering

High Fidelity Concepts

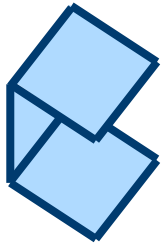
H-Frame

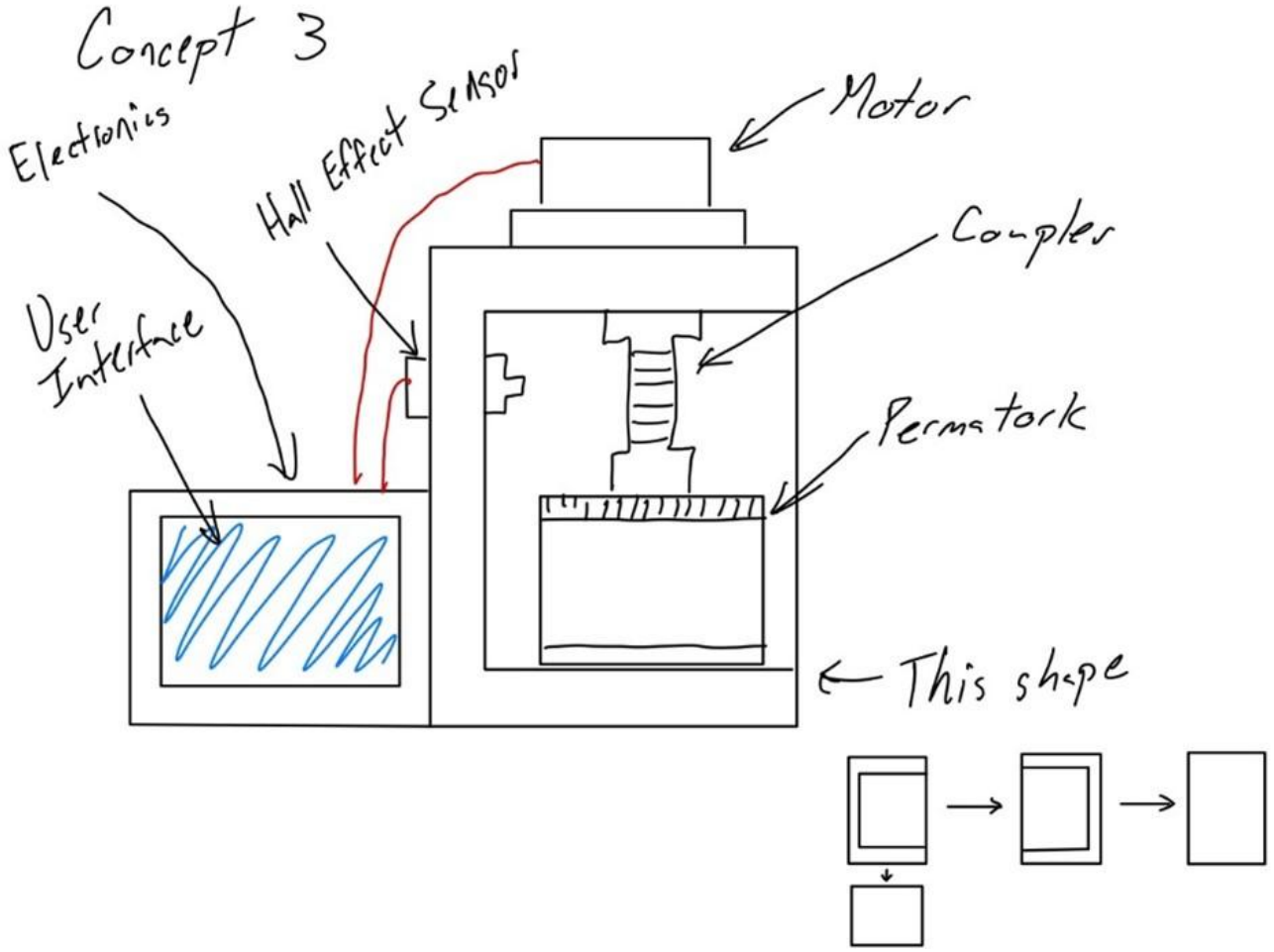


Modular Skeleton

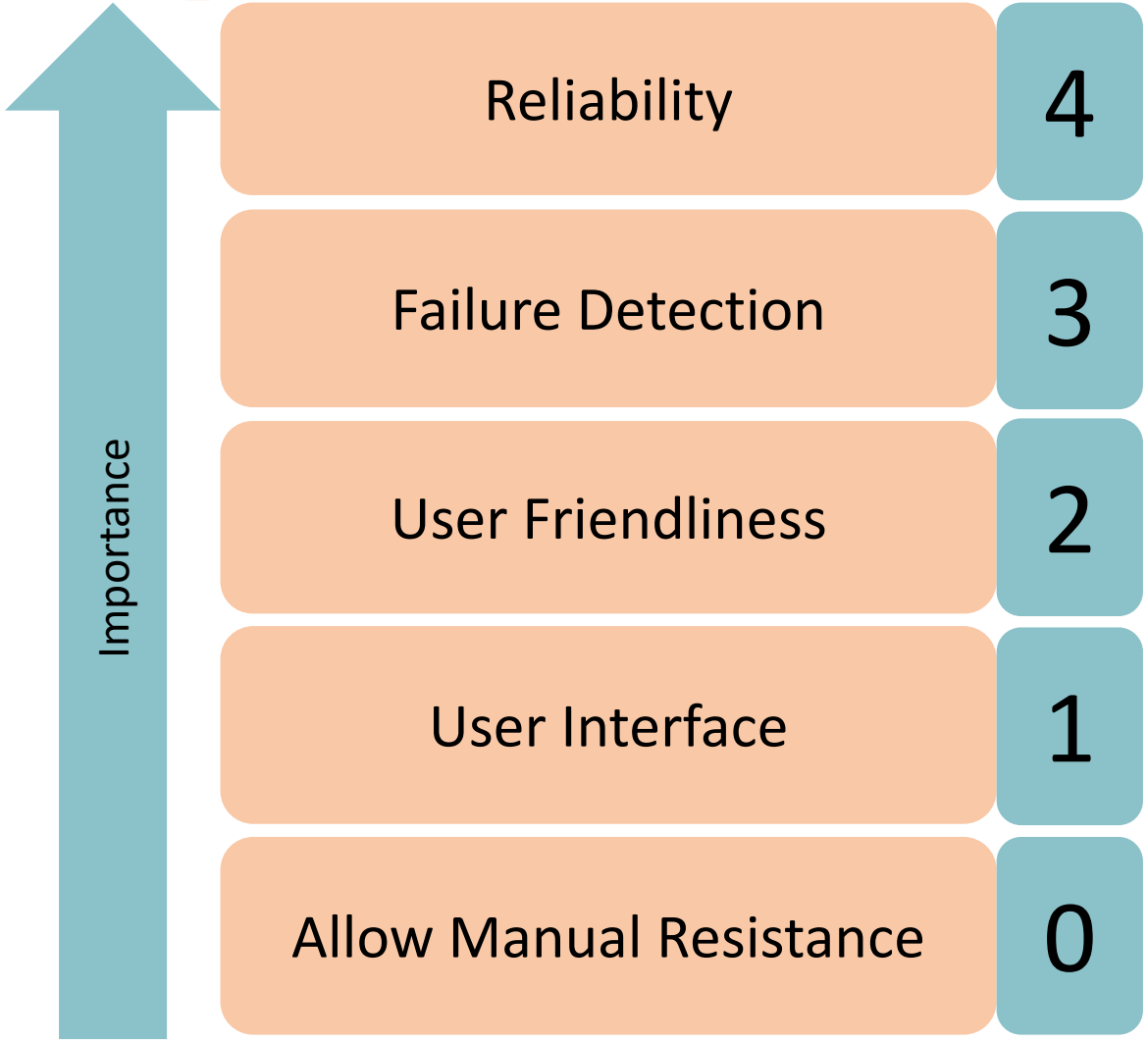


Solo C-Frame





Concept Selection – Binary



*Customer requirements were derived from analysis of customer needs for functional decomposition

Concept Selection - HOQ

Engineering Characteristic															
Improvement Direction		↑	↓	↑	↓	↑	↑	↑	-	-	-	↑	↑	↑	↓
Units		Pa	# Steps	in^2	lb	oz-in	oz-in	oz-in	Total #	P/F	P/F	in^2	in^2	in^2	in^3
Customer Requirements	**Importance Weight Factor**	**Rigidity**	**Test Prep Steps**	**Allowing Resistance Load Adjustment**	**Weight**	**Secure Stepper Motor**	**Secure Resistance Torque Device**	**Secure Coupler**	**Track Cycles and Rotations (Actual)**	**Display Test Parameters**	**Display Test Results**	**Allow for Resistance Torque Verification**	**Coupler Clearance**	**Allow for Motor Replacement Clearance**	**Size**
User Interface	1	0	5	0	0	0	0	0	3	5	5	0	0	0	3
Failure Detection	3	1	1	0	0	3	3	3	5	1	1	0	0	0	0
Allow Manual Resistance Load Adjustment	0	5	3	5	1	1	5	1	0	0	0	3	3	1	3
User Friendliness	2	0	5	3	5	3	5	5	1	3	3	5	5	5	5
Reliability	4	5	0	1	3	5	5	5	5	0	1	1	1	1	1
Raw Data		23	18	10	22	35	39	39	40	14	18	14	14	14	17
Relative Weight %		7.26	5.68	3.15	6.94	11.04	12.30	12.30	12.62	4.42	5.68	4.42	4.42	4.42	5.36
Rank Order		5	7	14	6	4	2	2	1	10	7	10	10	10	9

Albert Auer

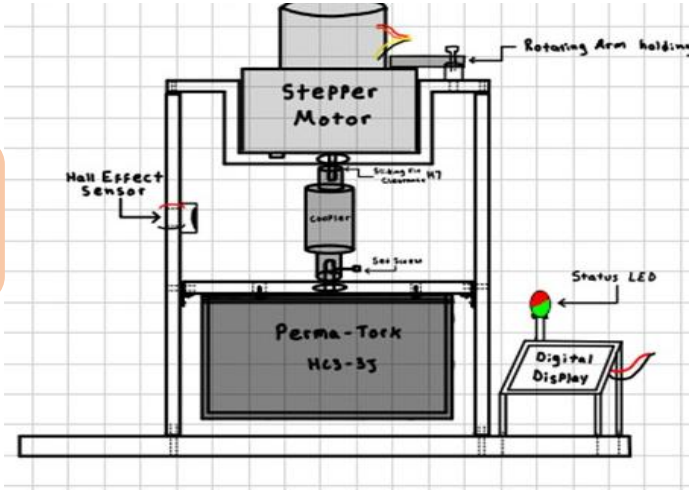
Concept Selection – Pugh Charts

		Concepts				Concepts				
Engineering Characteristics	IGV Assembly	Modular Skeleton	Solo C-Frame	StepperLife Pro	Swivel Frame	Pro	Torque Master	H-Frame	Modular Skeleton	Solo C-Frame
Track Cycles and Rotations (Actual)	- DATUM -	+	-	-	+		+	+	+	+
Secure Coupler		-	-	+	-		-	+	+	+
Secure Resistance Torque Device		+	+	-	+		-	+	+	+
Secure Stepper Motor		-	-	-	-		-	-	+	-
Rigidity		-	-	-	+		+	+	-	+
Total Pluses		0	0	0	0		2	4	4	4
Total Satisfactory		3	2	3	1		3	1	1	1
Total Minuses		2	3	2	4		0	0	0	0
Keep?	Yes	Yes	No	Yes	No		No	Yes	Yes	Yes

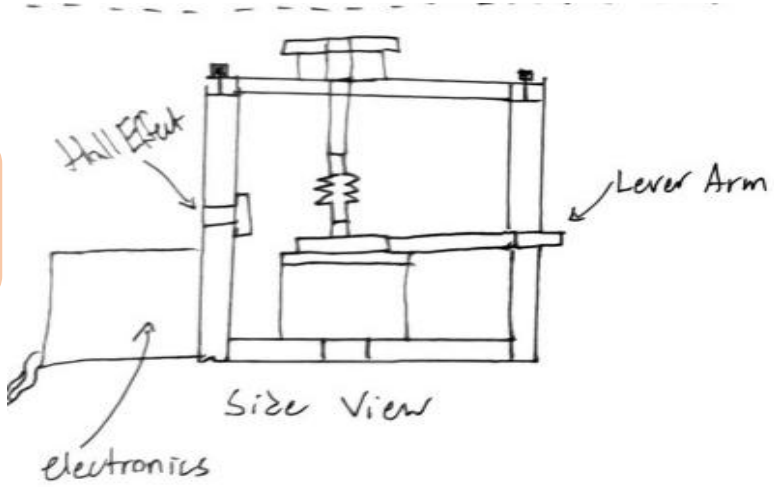
FAMU-FSU College of Engineering

Concept Selection – Final Designs

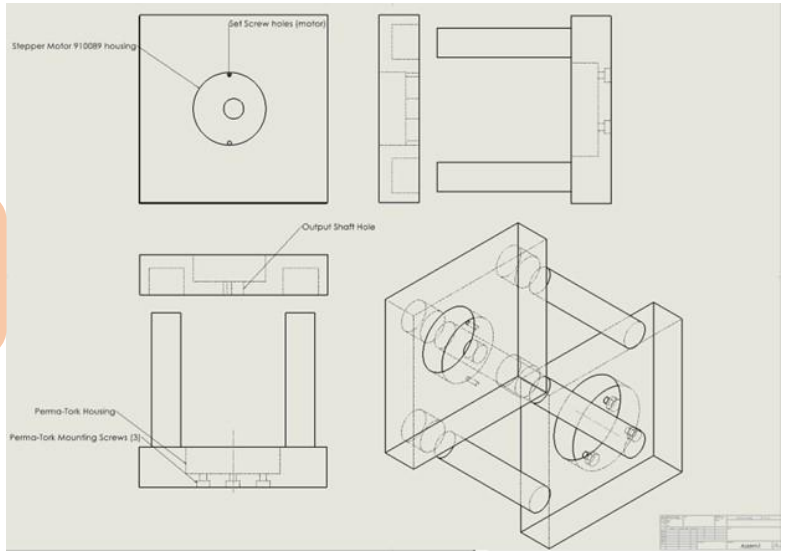
H-Frame



Modular Skeleton



StepperLife Pro



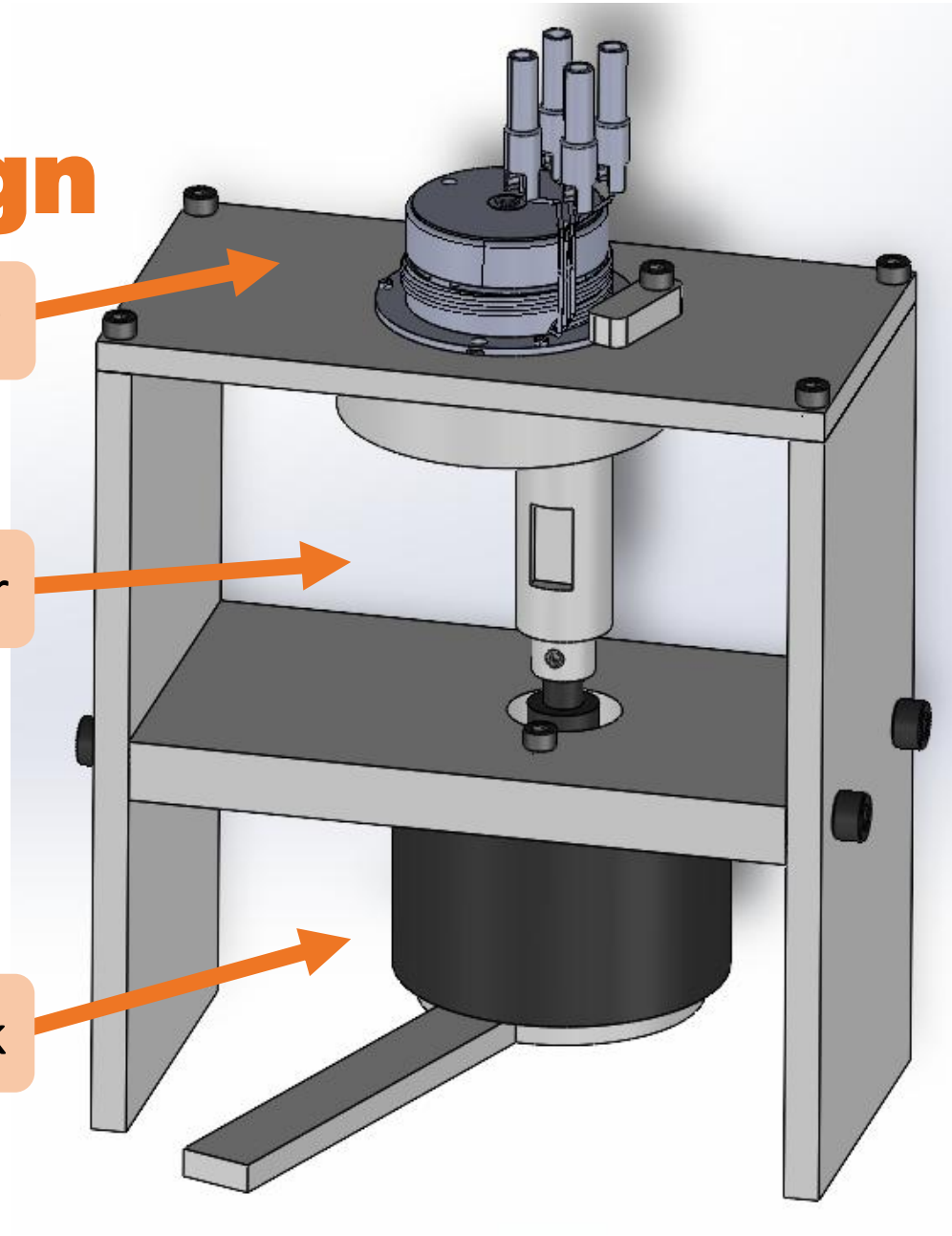
FAMU-FSU College of Engineering

Concept Selection - AHP

H-Frame	0.394
Modular Skeleton	0.367
StepperLife Pro	0.240

Consistency Ratio
0.034

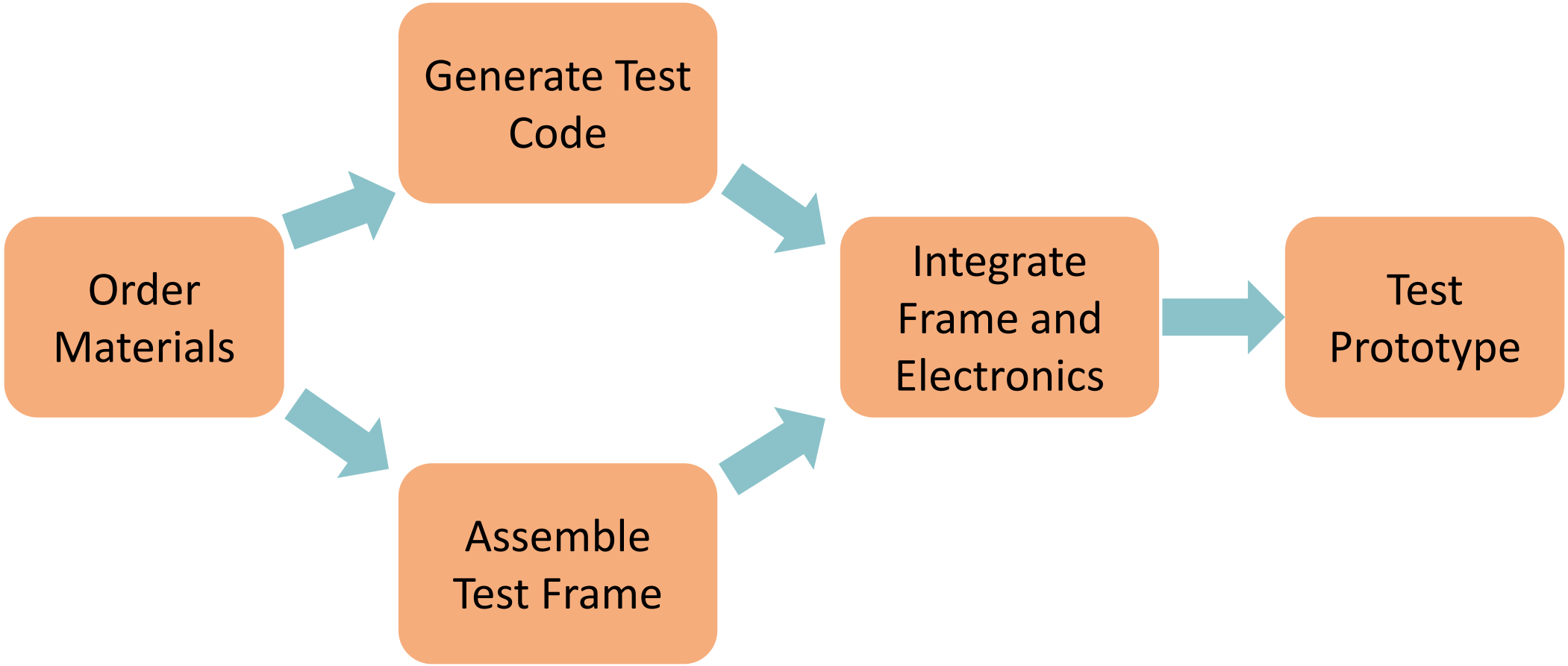
H-Frame CAD Design



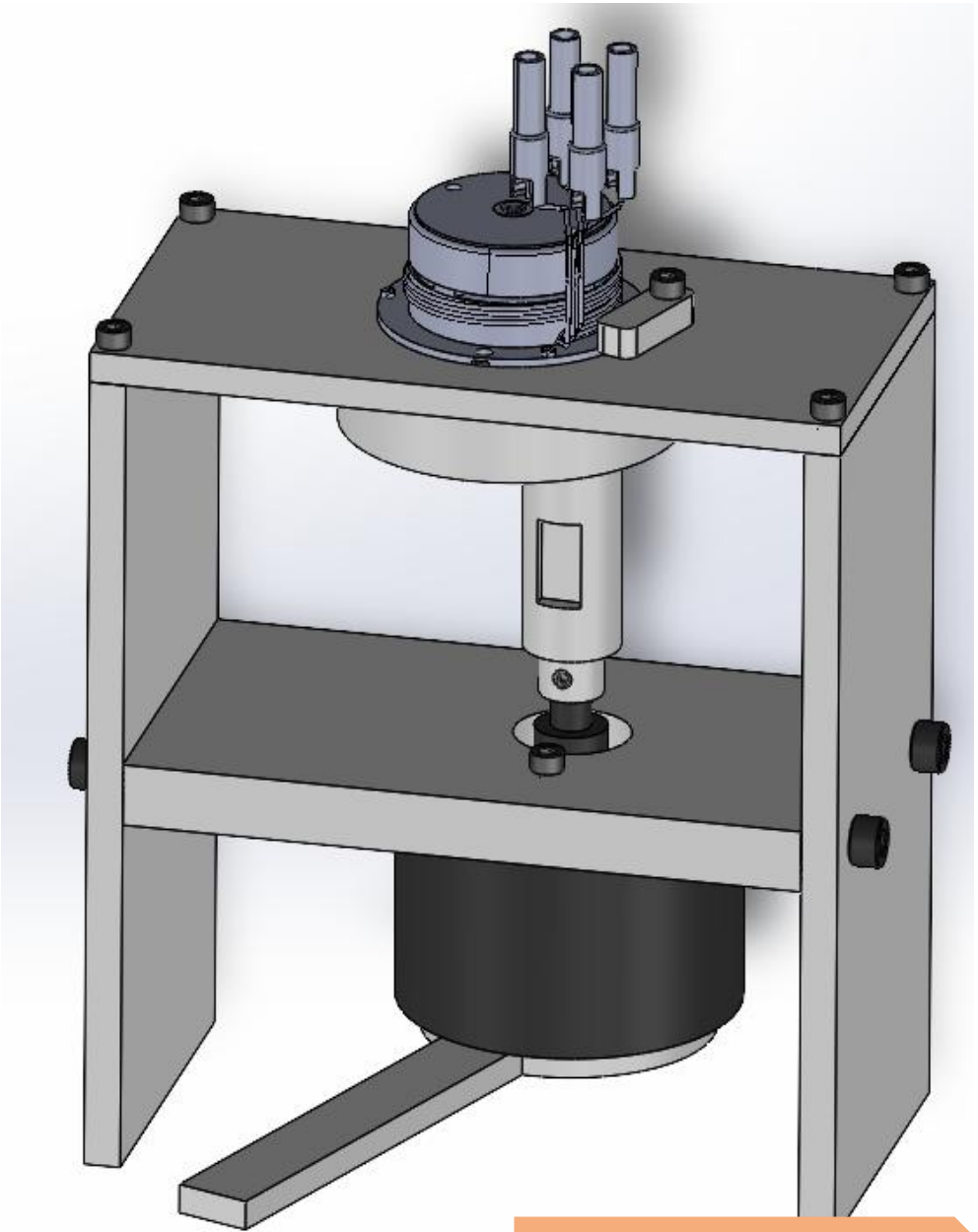
***New Sponsor changes include:**

- No bottom lever
- Use given coupler with an attachment for magnet
- Hinged plexiglass on front and back for safety

Future Work


Generate Test Code
Order Materials
Integrate Frame and Electronics
Test Prototype
Assemble Test Frame

Questions?



H-Frame