Model Based Systems Quadruped

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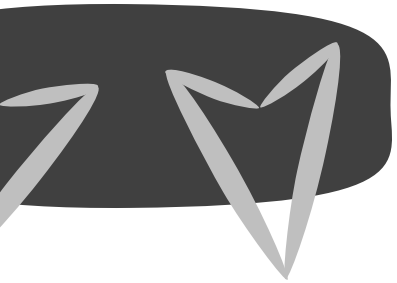
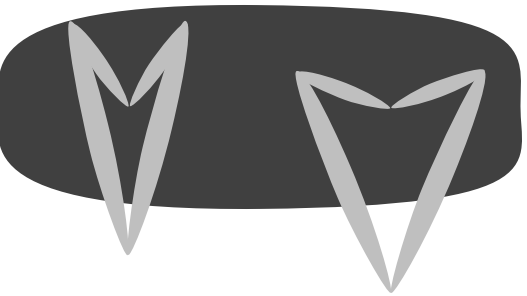


Model Based Systems Quadruped



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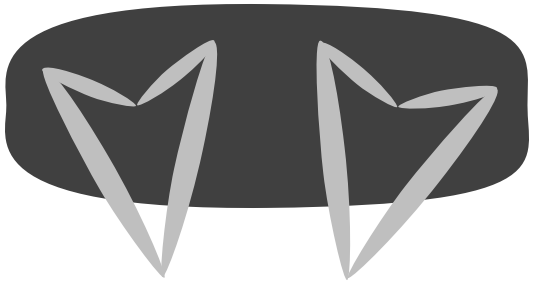
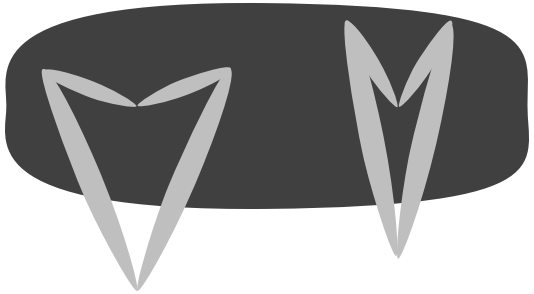


Model Based Systems Quadruped



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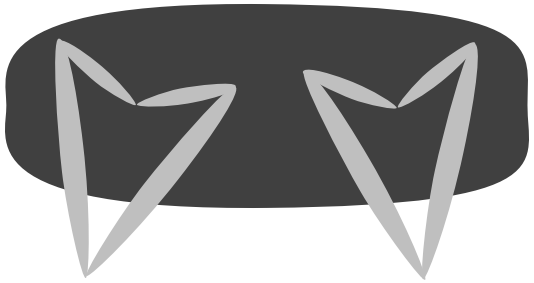

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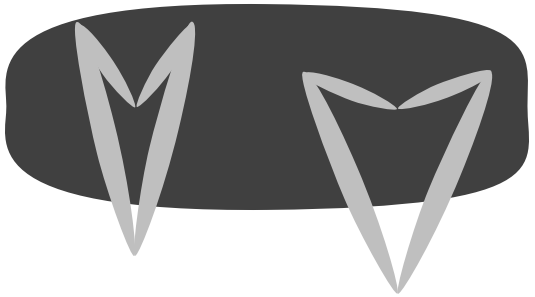

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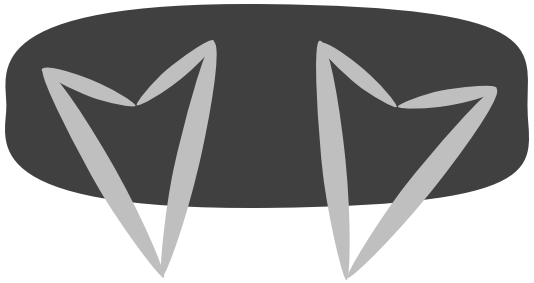
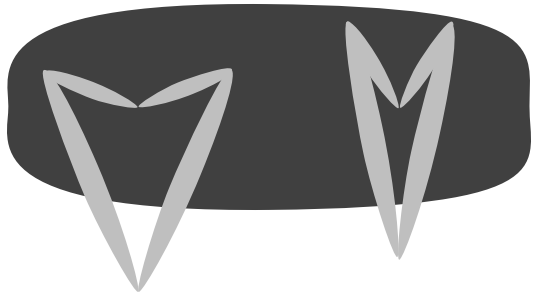
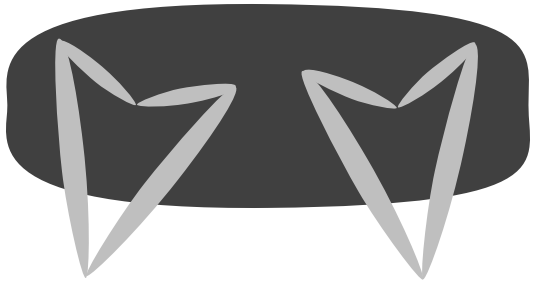


Model Based Systems Quadruped



Model Based Systems Quadruped



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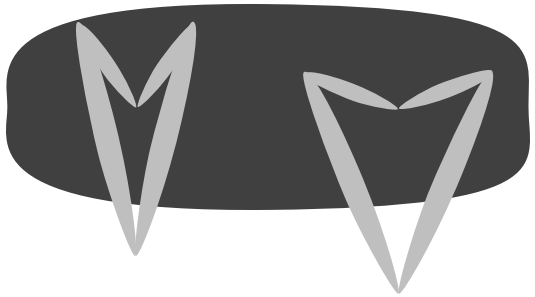

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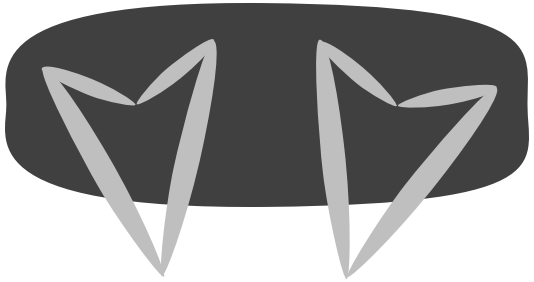

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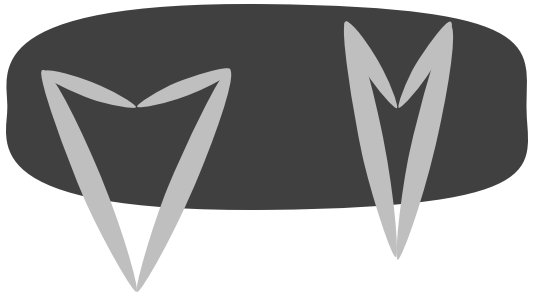

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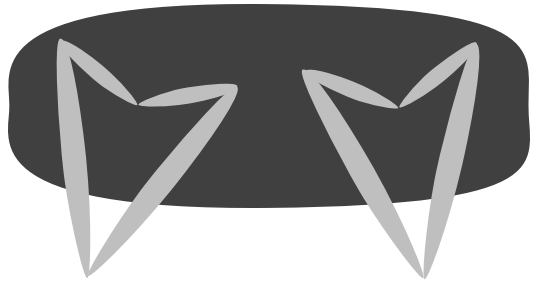

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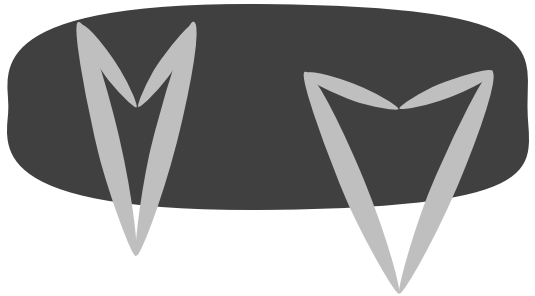

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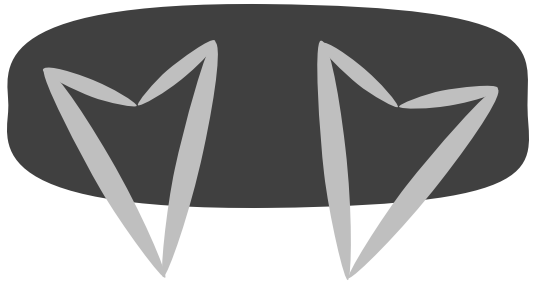
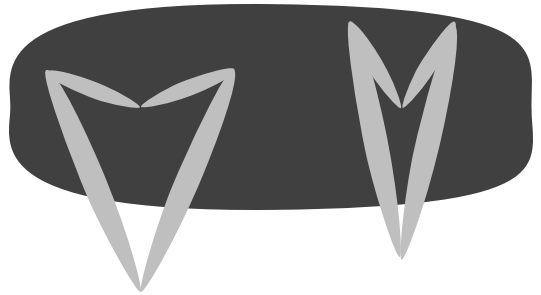
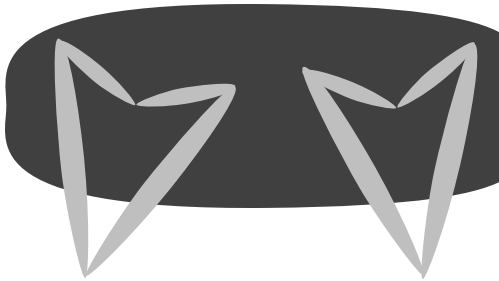


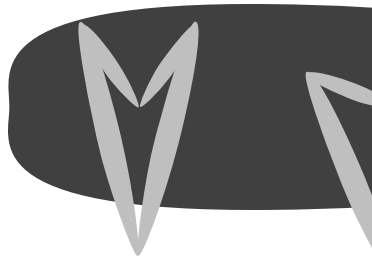
Model Based Systems Quadruped



Model Based Systems Quadruped



Model Based Systems Quadruped



Model Based Systems Quadruped

Model Based Systems Quadruped

Model Based Systems Quadruped

Team Introductions

Milton Bouchard
Modeling Engineer

Michael Dina
Systems Engineer

Onoriode Onokpise
User Interface Engineer

Jackson Raines
Testing Engineer

Zachary Shapiro
Testing Engineer

Sponsors and Advisor

CISCOR

Center for Intelligent Systems, Control, and Robotics

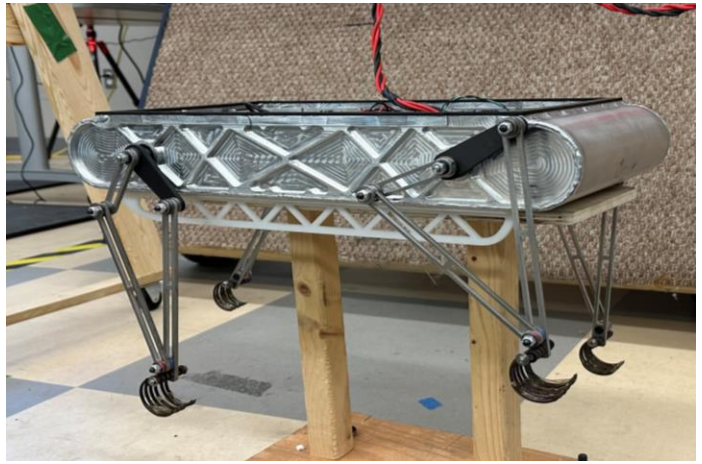
Dr. Jonathan Clark
Sponsor

Dr. Patrick Hollis
Advisor

Dr. Shayne McConomy
Sponsor

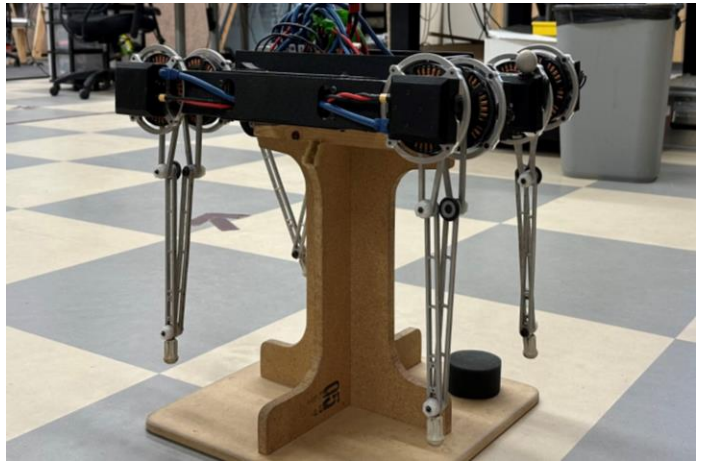
Objective

The objective of this project is to develop a software tool that expedites the design and construction of quadrupedal robots. The tool will use the knowledge gained from robots previously built at CISCOR.



ET-Quad

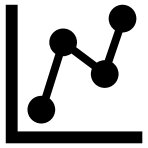
RHex



Minitaur

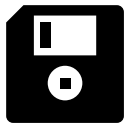
Key Goals

Develop a tool to assist new quadrupedal robot development



Return critical parameter values

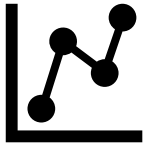
Reduce development time



Act as a database of knowledge for robot development

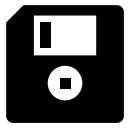
Key Goals

Develop a tool to assist new quadrupedal robot development



Return critical parameter values

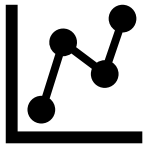
Reduce development time



Act as a database of knowledge for robot development

Key Goals

Develop a tool to assist new quadrupedal robot development



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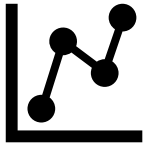

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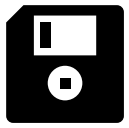
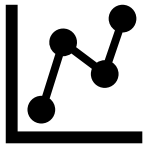


Act as a database of knowledge for robot development

Key Goals

Develop a tool to assist new quadrupedal robot development

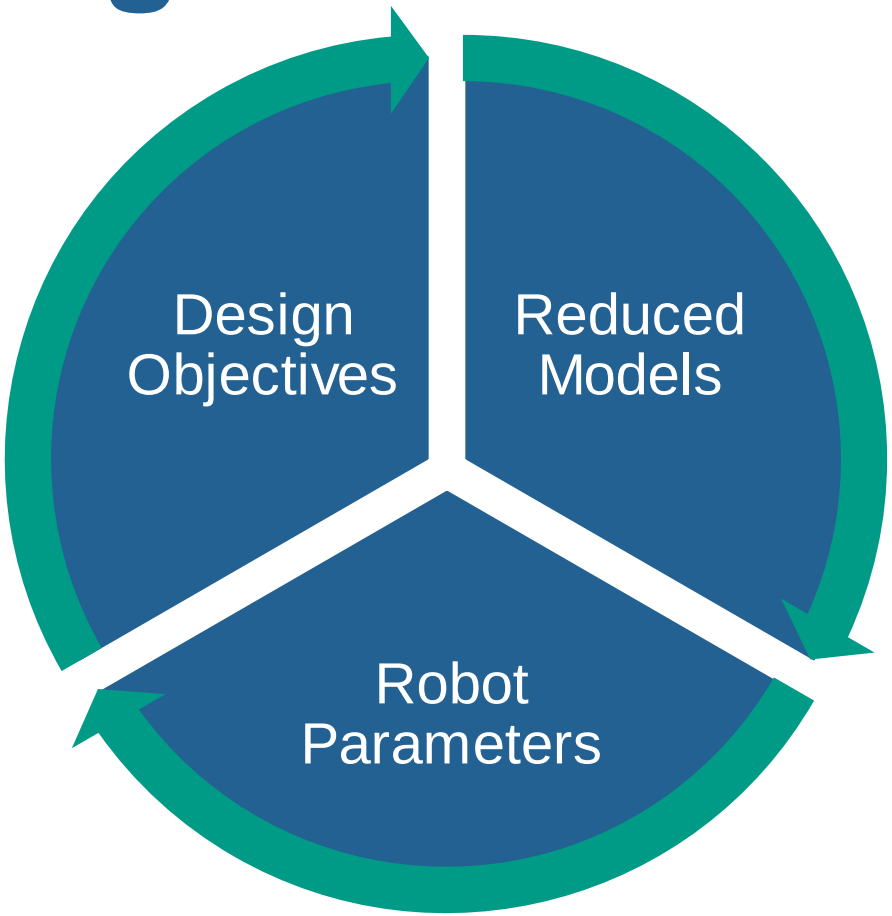


Return critical parameter values

Reduce development time

Act as a database of knowledge for robot development

CISCOR Design Process



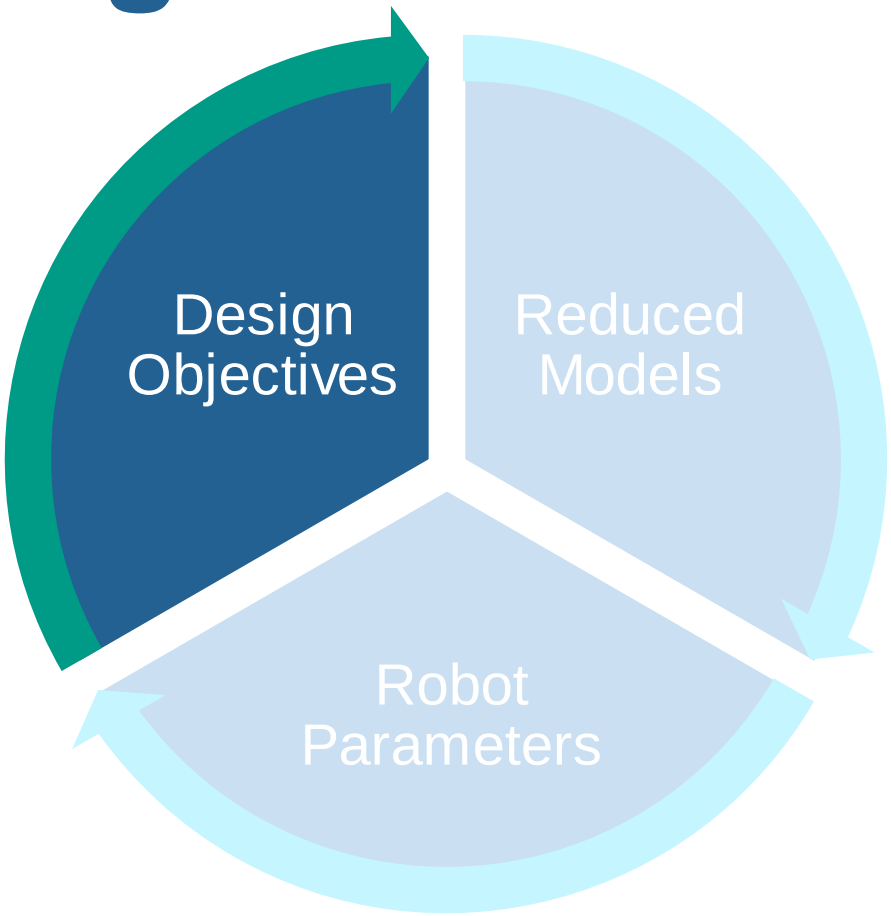
Use Case

7.51 kg

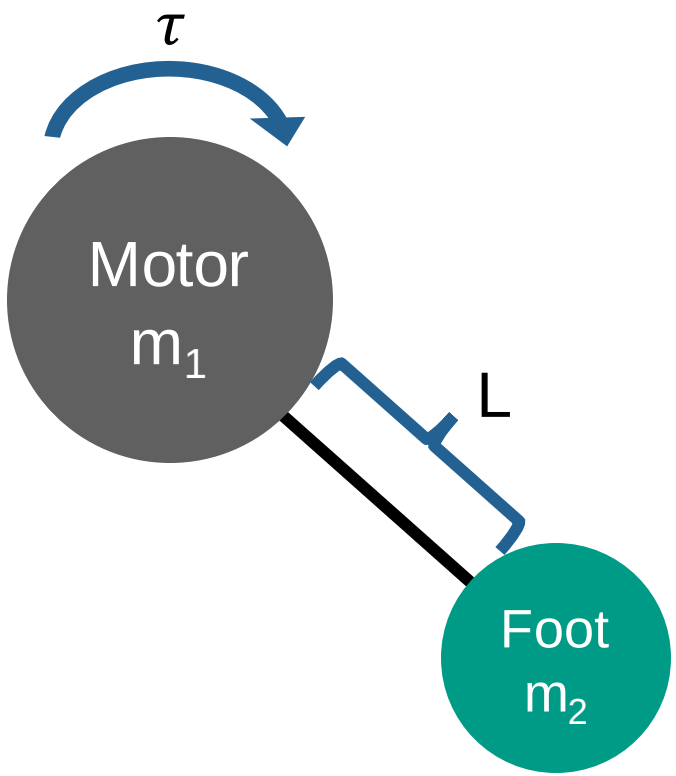
$\sim\frac{1}{10}$ mass scale

0.8 kg

CISCOR Design Process

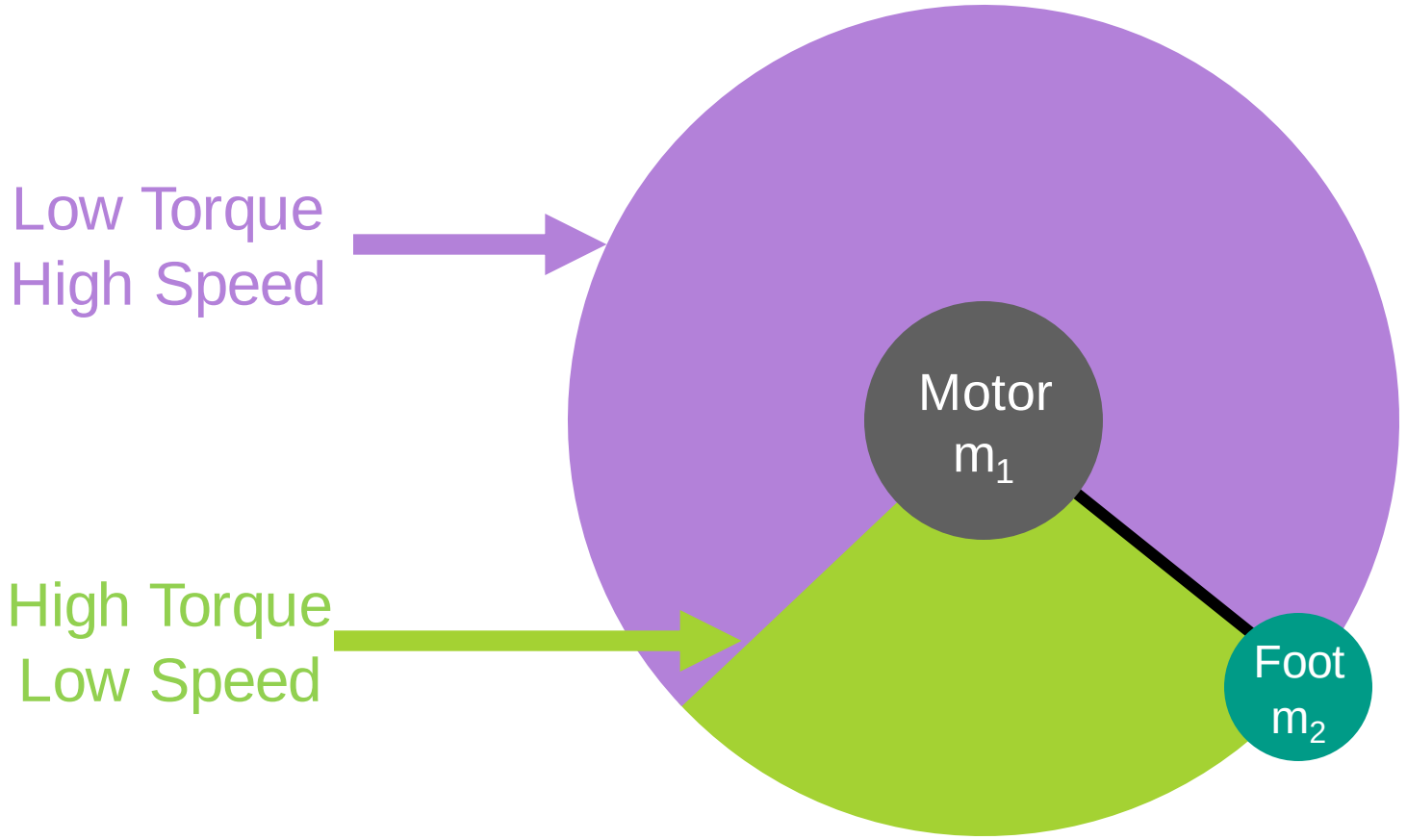


Starting Motor Model - Simple

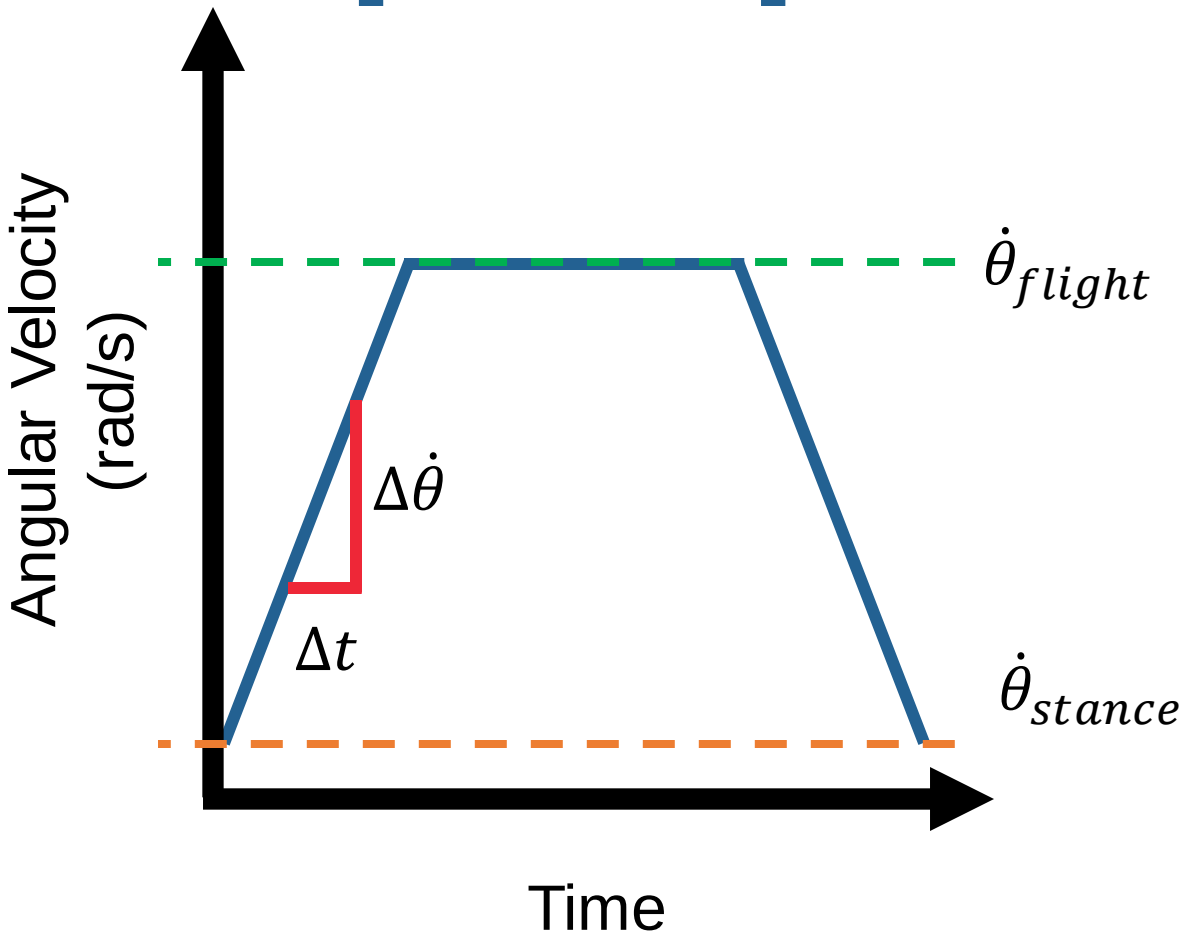


RHex

Two Phases - Stance

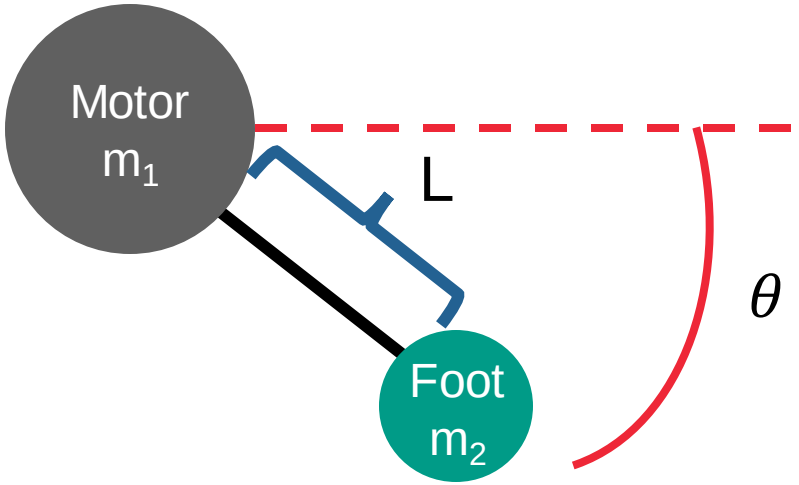


Torque Required

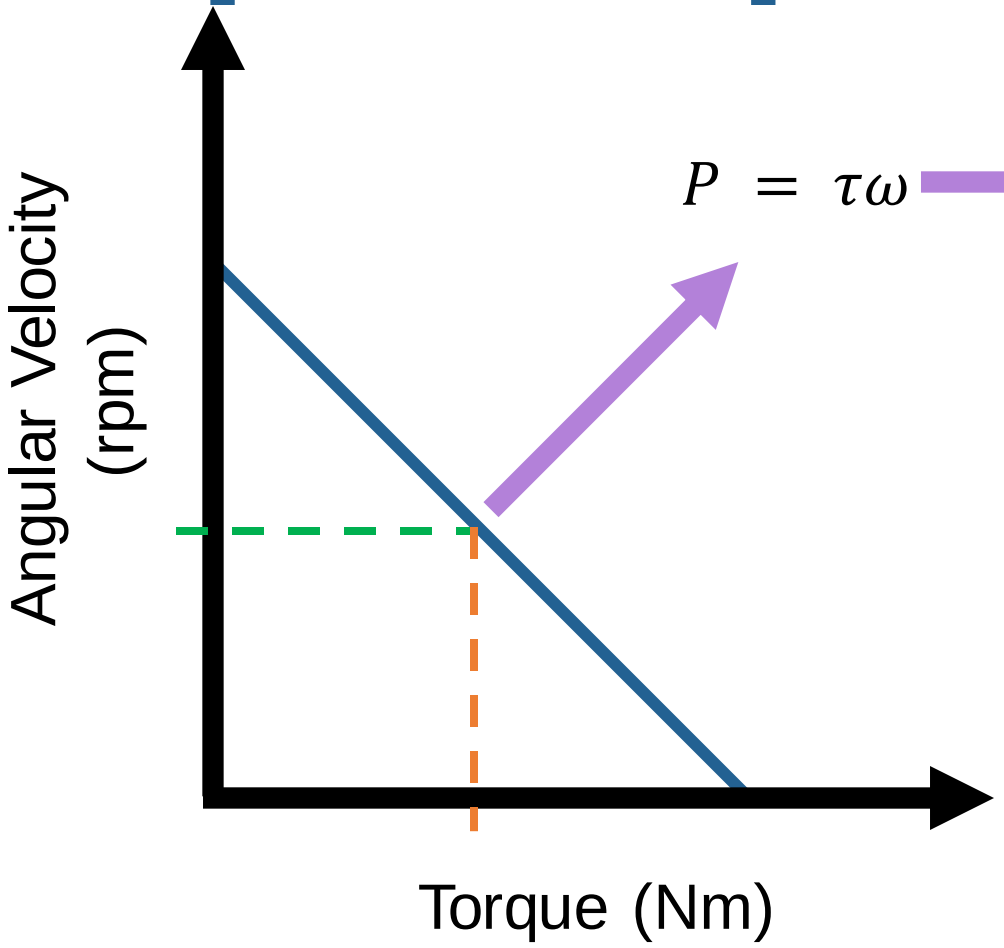


$$\tau_{stance} = m_1 L g \cos\theta$$

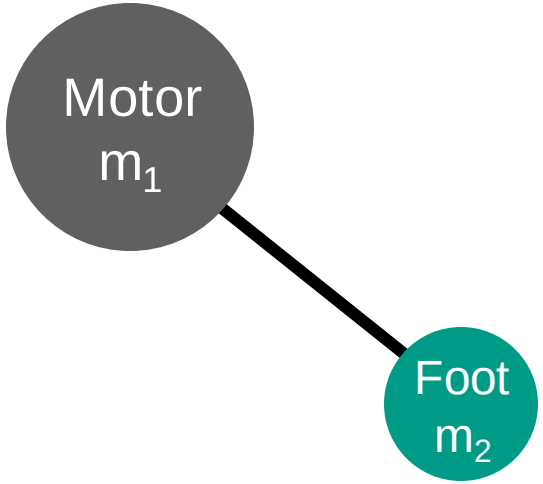
$$\tau_{flight} = m_2\left(\frac{2\pi f_{stride}(f_{flight} - f_{stance})L^2}{\Delta t}\right)$$



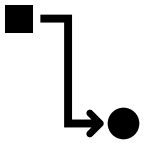
Speed-Torque Curve



$$P = \tau\omega \rightarrow P \propto m \rightarrow m_{motor} \cong 0.2m_{total}$$

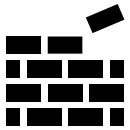


Primary Scope



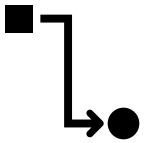
Complete process from the input to the output

Focus on ET-Quad database



Set framework for improvement and future complexity

Primary Scope



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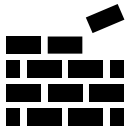

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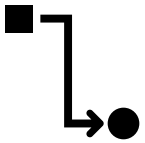

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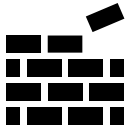

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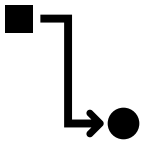

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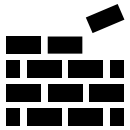
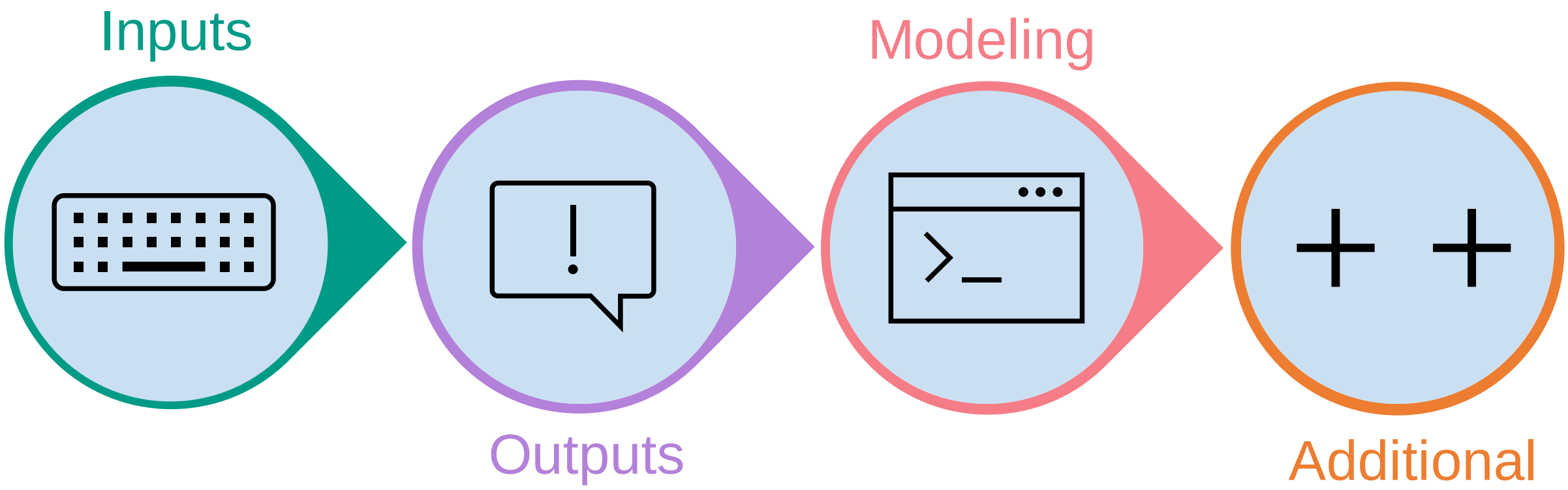


Set framework for improvement and future complexity

Targets and Metrics

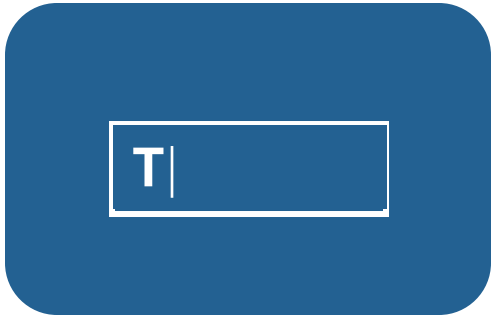


Concept Generation

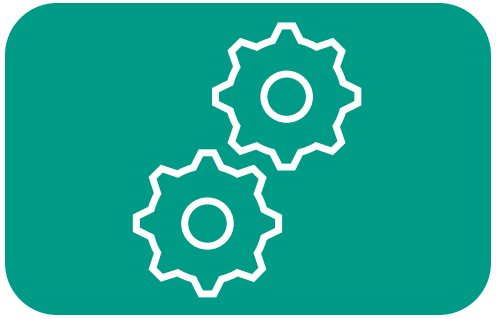
Brainstorming

Forced Analogy

Medium Fidelity



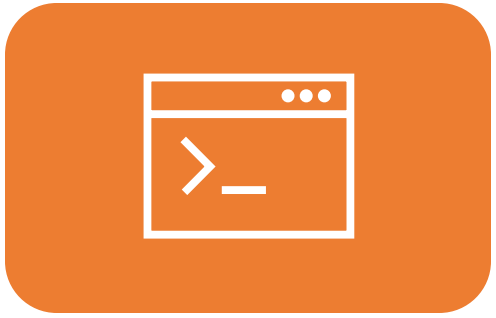
MATLAB Textbox



Simscape Model

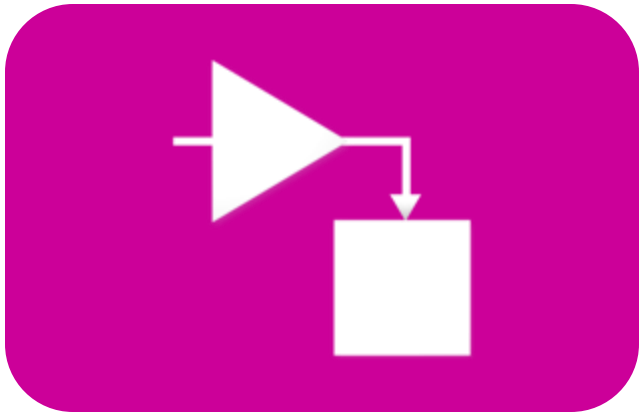
MATLAB GUI with information Dashboard

Racing Car Game Selection



MATLAB command line

High Fidelity



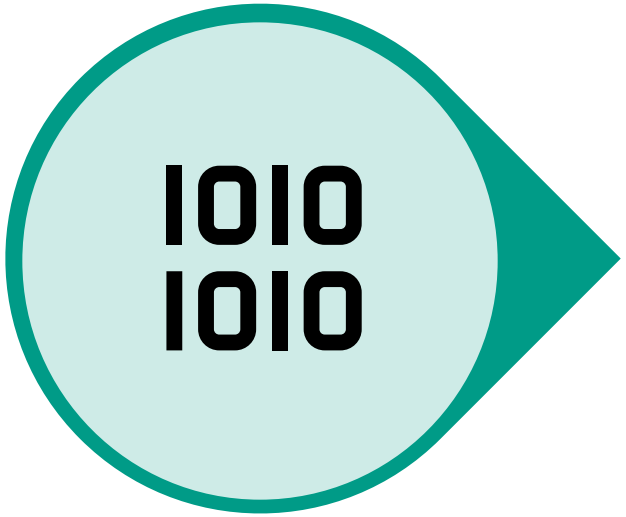
MATLAB to
Simulink

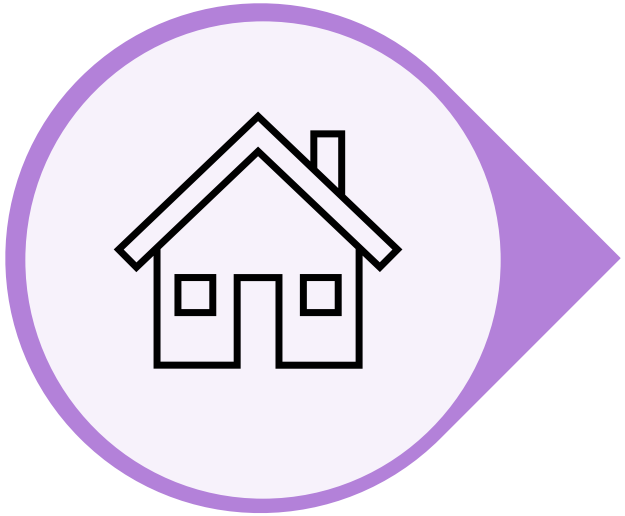
MATLAB GUI
with Dropdowns

System
Composer GUI

Concept Selection

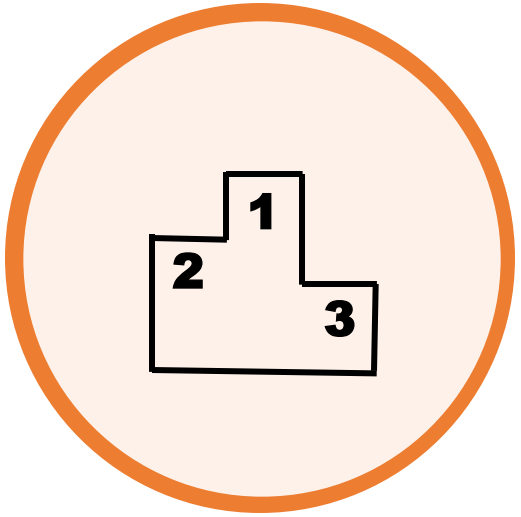
Pairwise Comparison





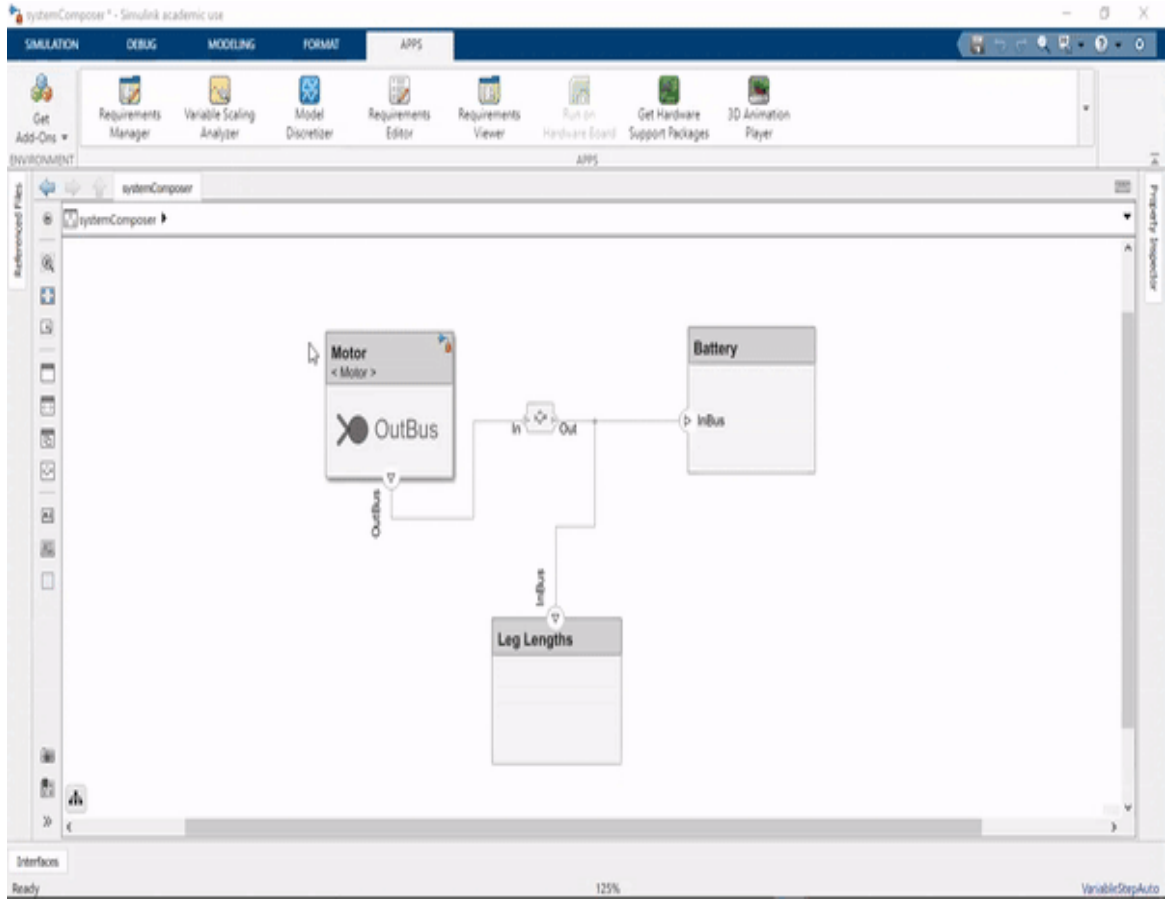
House of Quality

Pugh Chart



Analytical Hierarchy

Final Selection

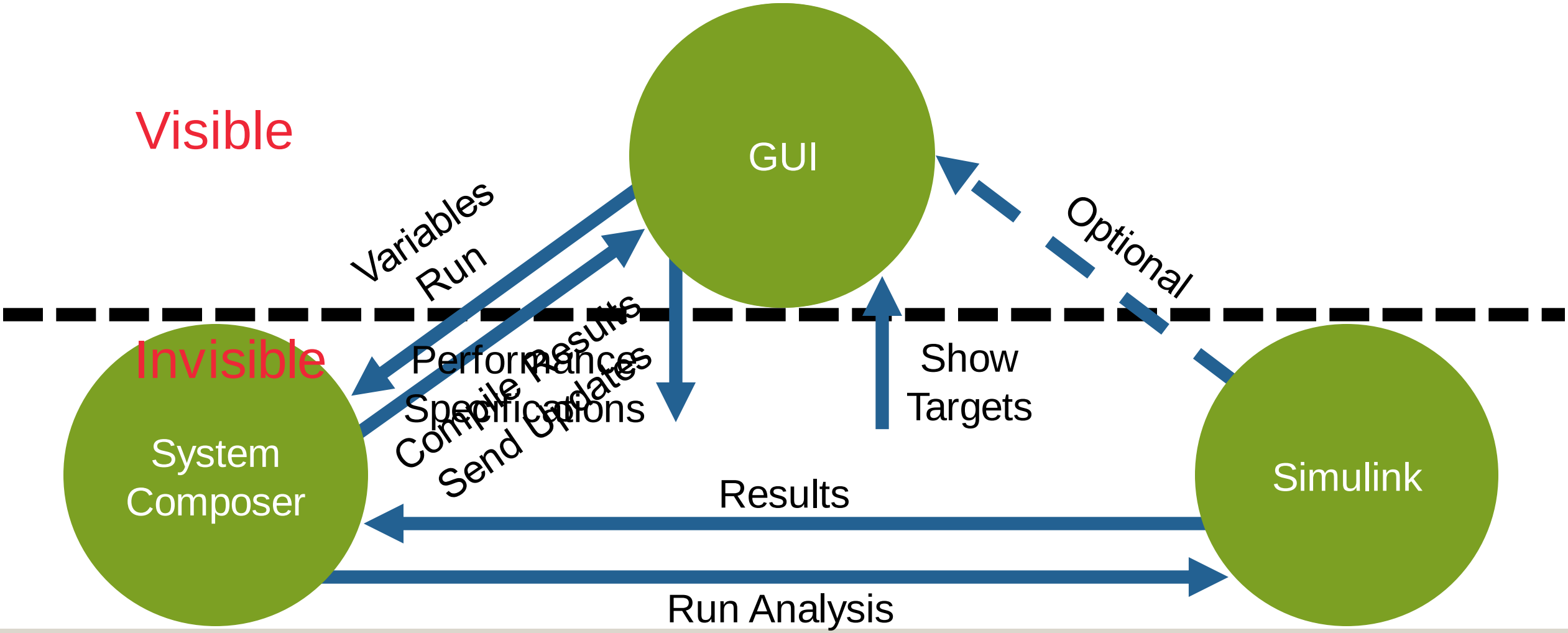


System Composer GUI

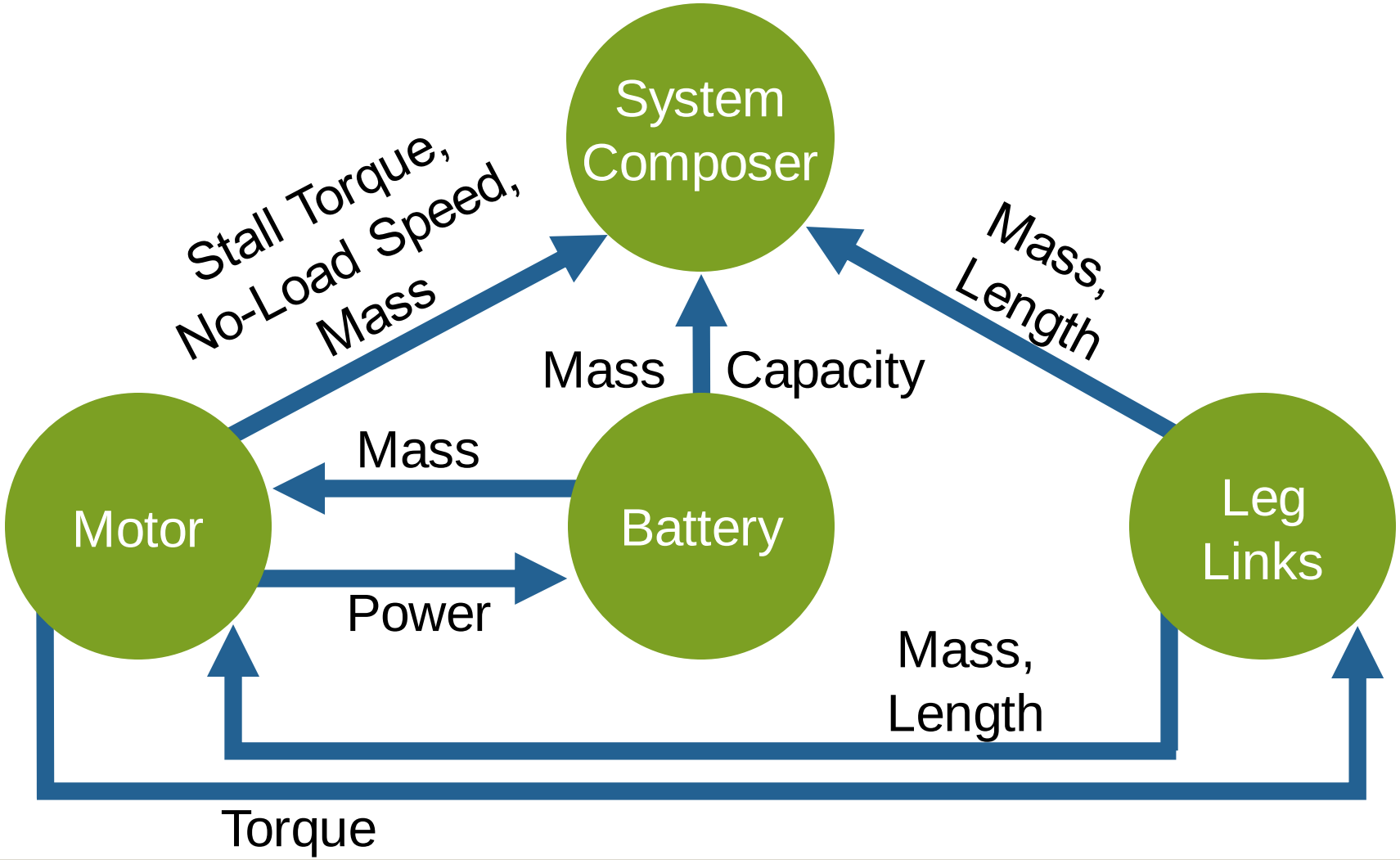
Accepts constraints from user in the form of performance characteristics

Attach Simulink models to specific functions

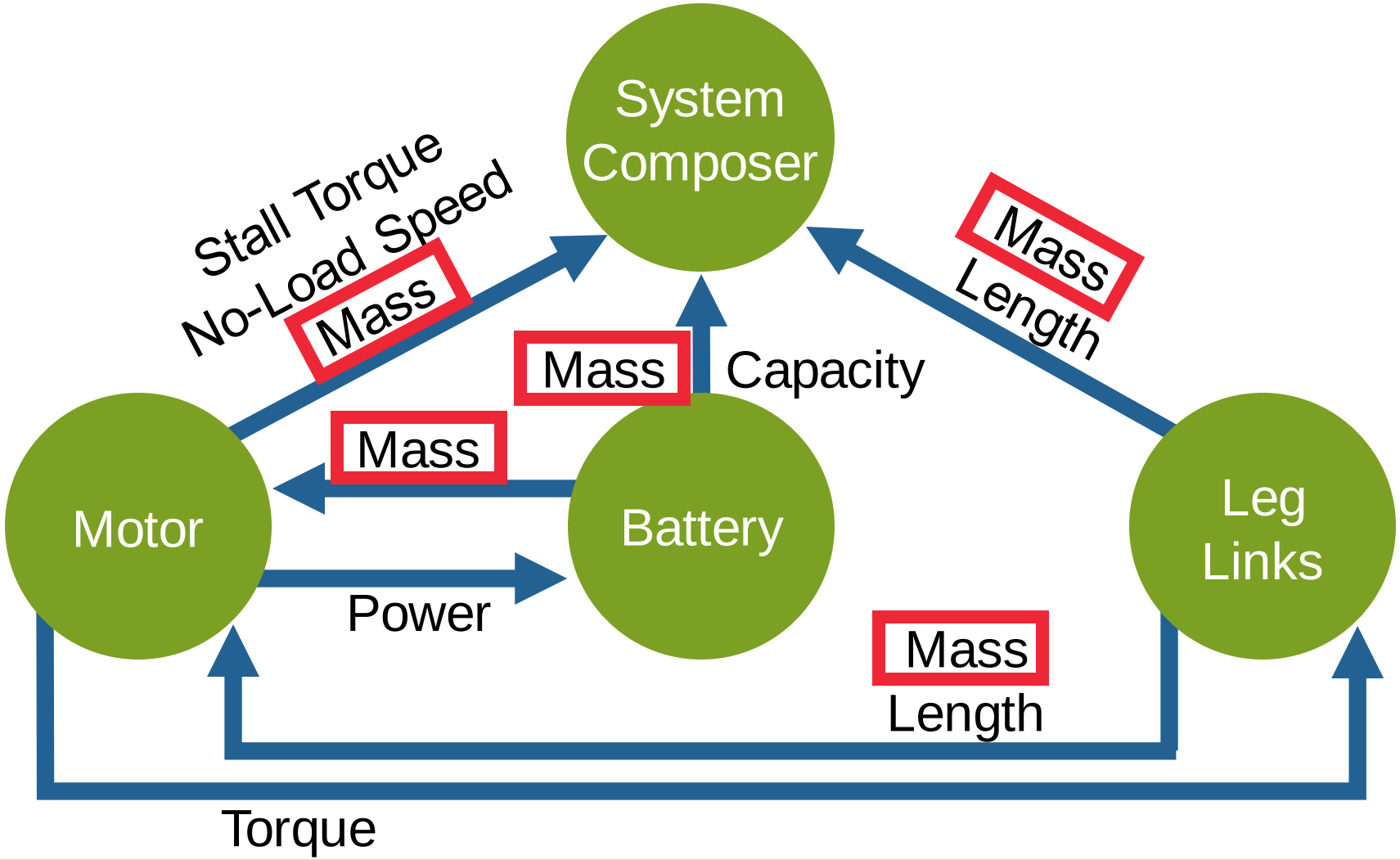
Software Architecture



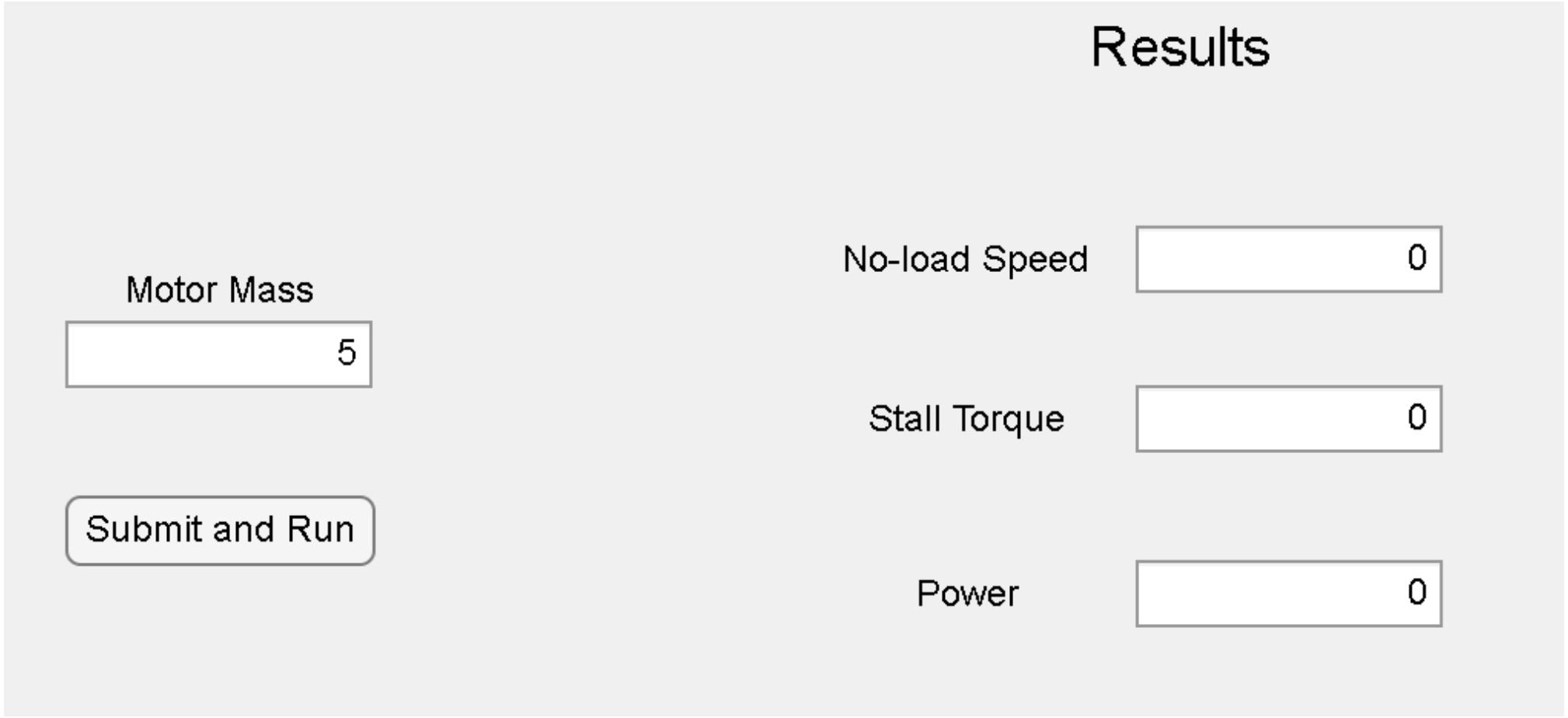
System Composer Architecture



System Composer Architecture



First Functional GUI



Results

Motor Mass

5

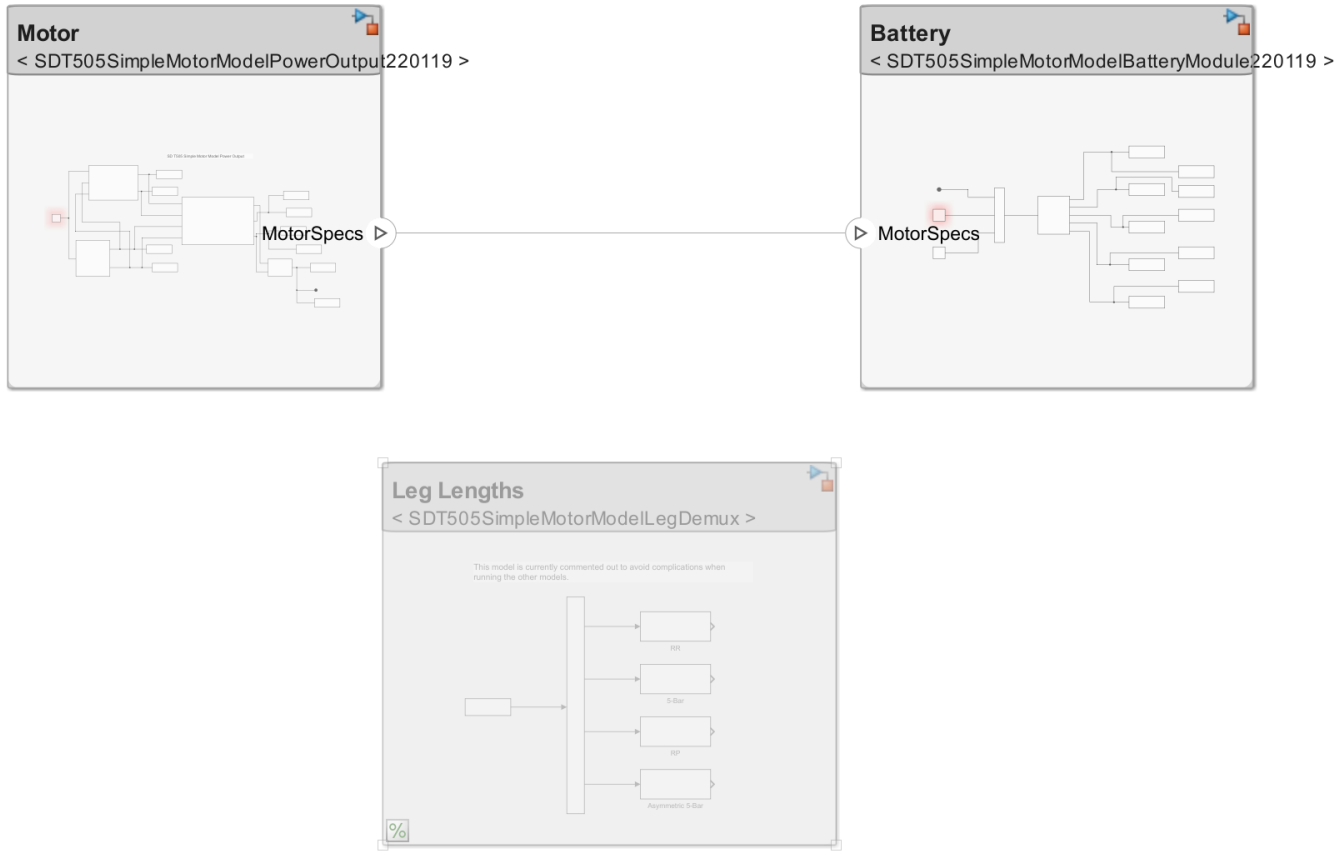
Submit and Run

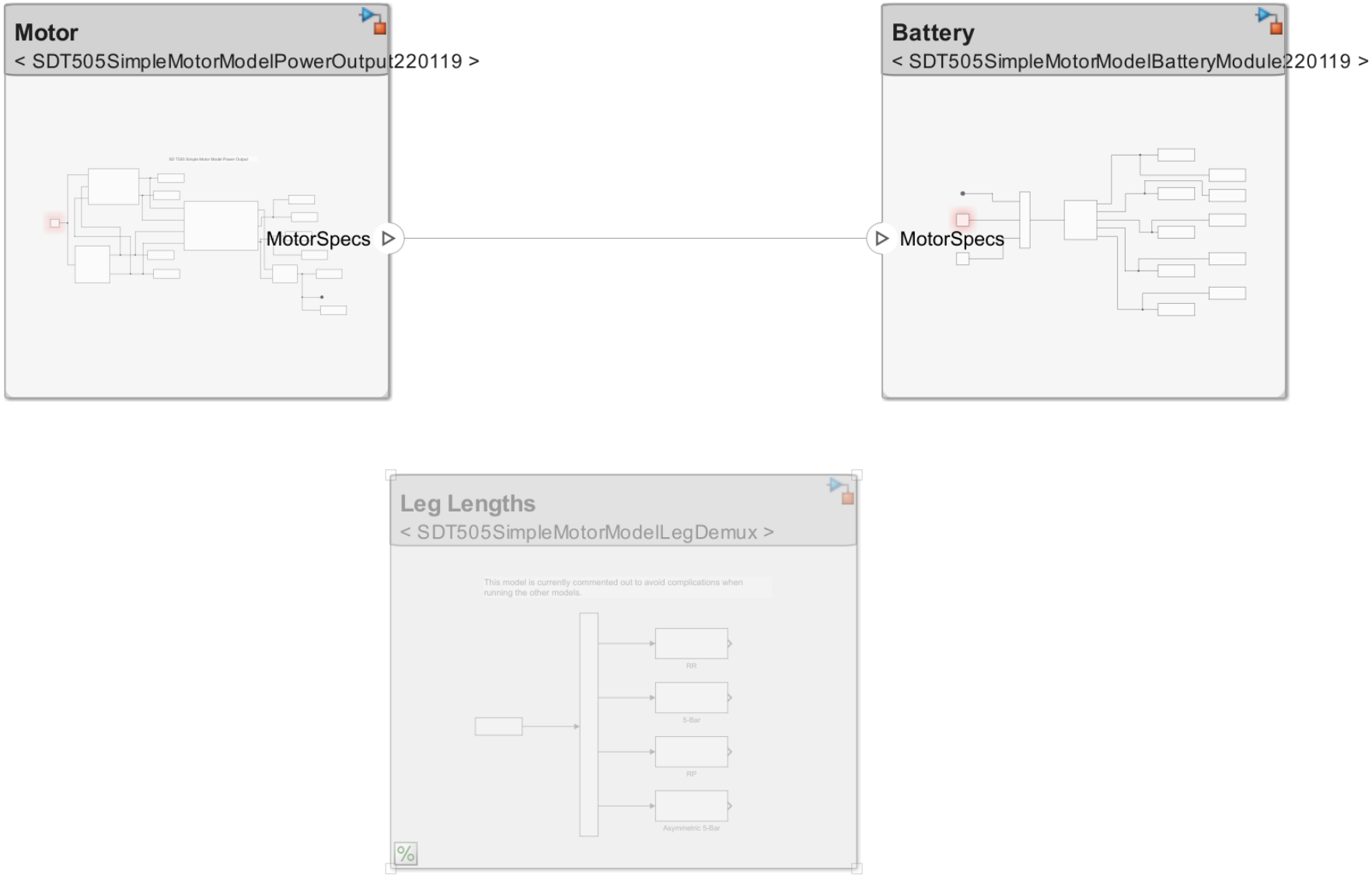
No-load Speed 0

Stall Torque 0

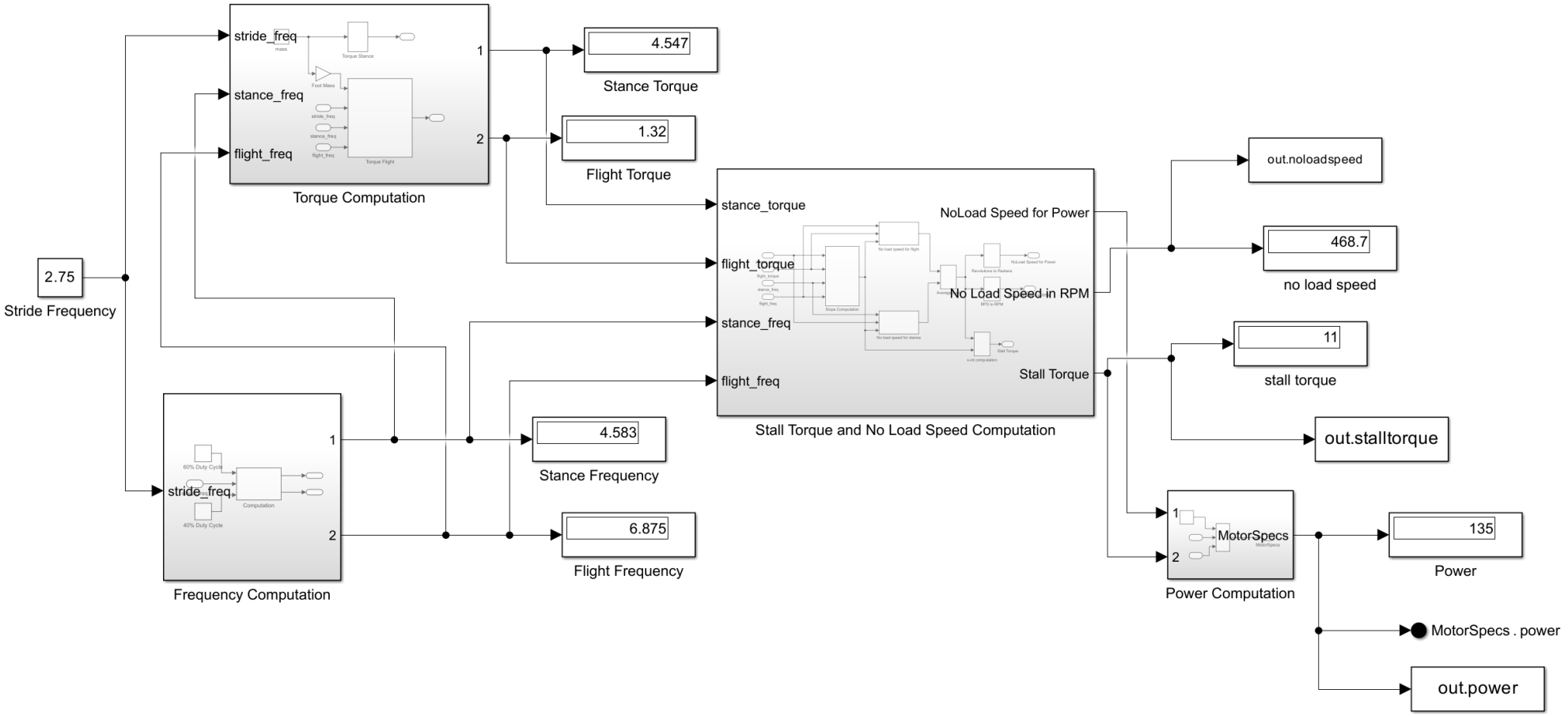
Power 0

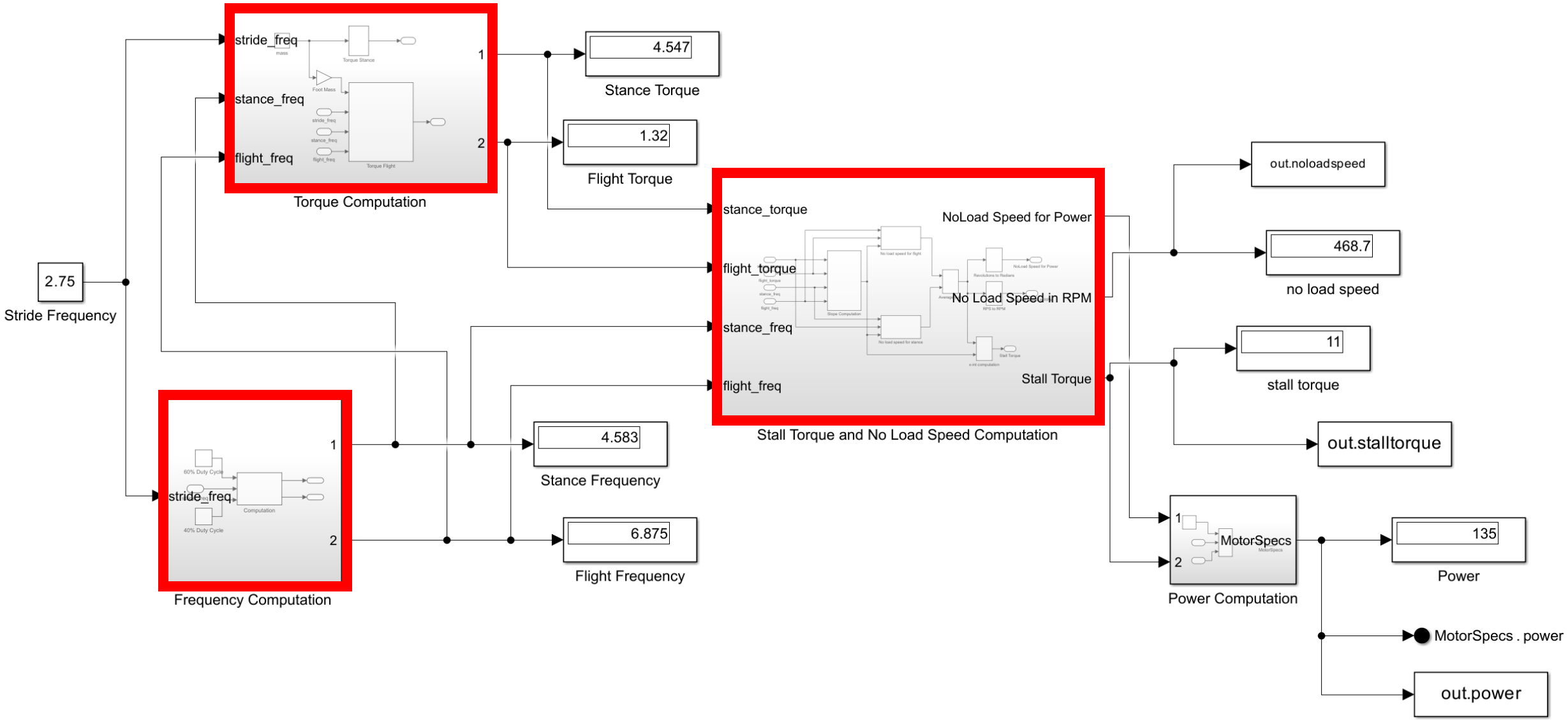
System Composer Interface

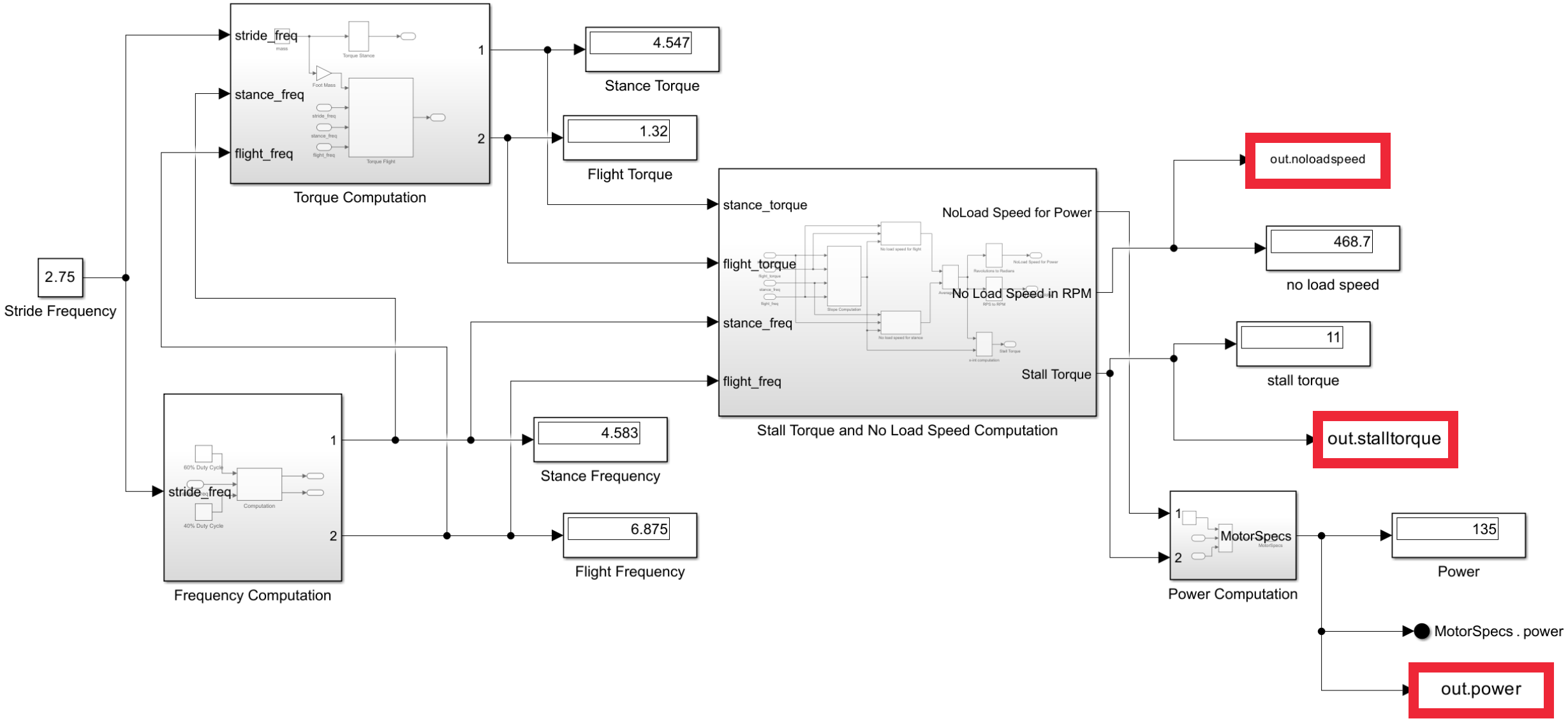



Motor
< SDT505SimpleMotorModelPowerOutput220119 >
MotorSpecs
Battery
< SDT505SimpleMotorModelBatteryModule220119 >
MotorSpecs
Leg Lengths
< SDT505SimpleMotorModelLegDemux >
This model is currently commented out to avoid complications when running the other models.
RR
5-Bar
RP
Asymmetric 5-Bar

Simulink Motor Model




stride_freq
stance_freq
flight_freq
1
2
Torque Computation
4.547
Stance Torque
1.32
Flight Torque
2.75
Stride Frequency
stance_torque
flight_torque
stance_freq
flight_freq
NoLoad Speed for Power
No Load Speed in RPM
Stall Torque
Stall Torque and No Load Speed Computation
out.noloadspeed
468.7
no load speed
11
stall torque
out.stalltorque
4.583
Stance Frequency
6.875
Flight Frequency
stride_freq
Frequency Computation
MotorSpecs
Power Computation
135
Power
MotorSpecs . power
out.power


stride_freq
stance_freq
flight_freq
1
2
Torque Computation
4.547
Stance Torque
1.32
Flight Torque
2.75
Stride Frequency
stance_torque
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flight_freq
NoLoad Speed for Power
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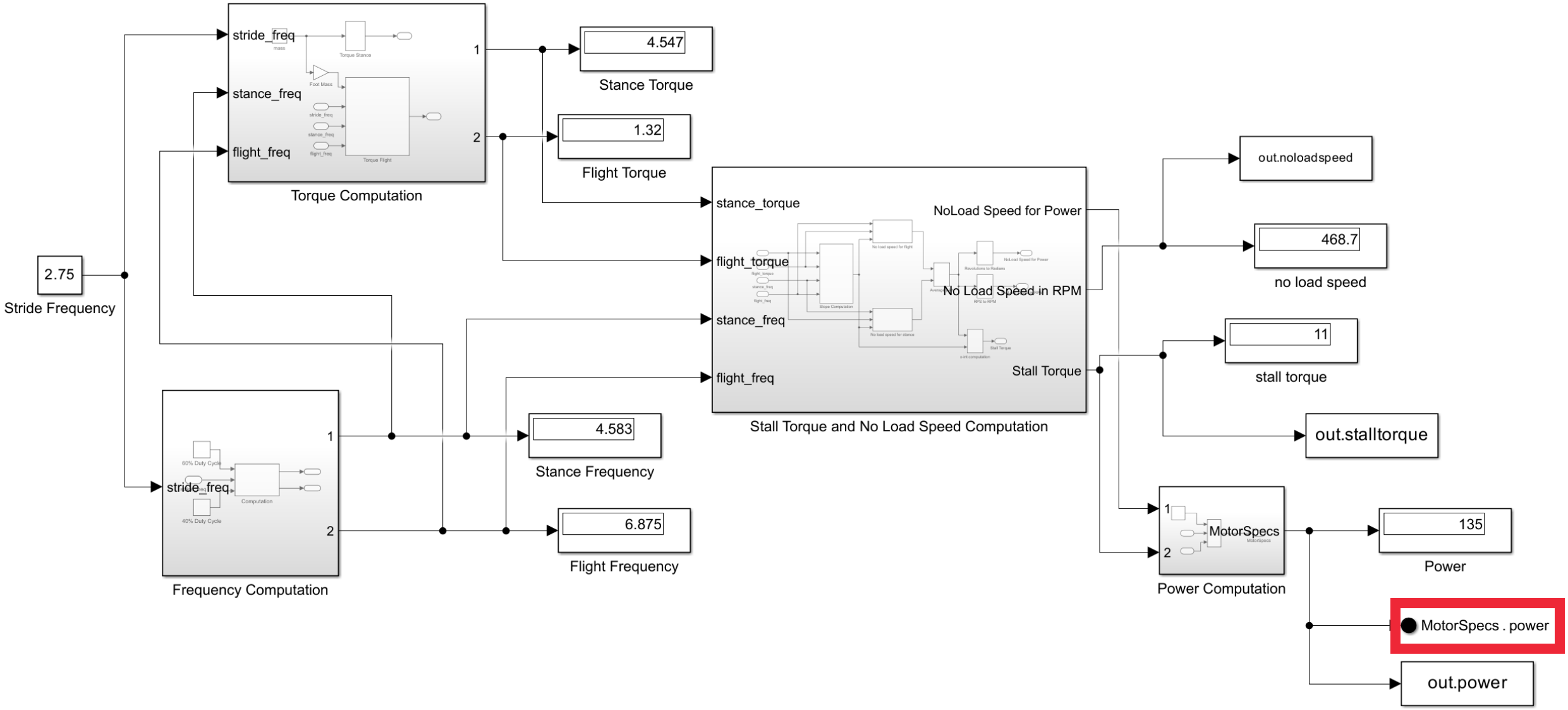
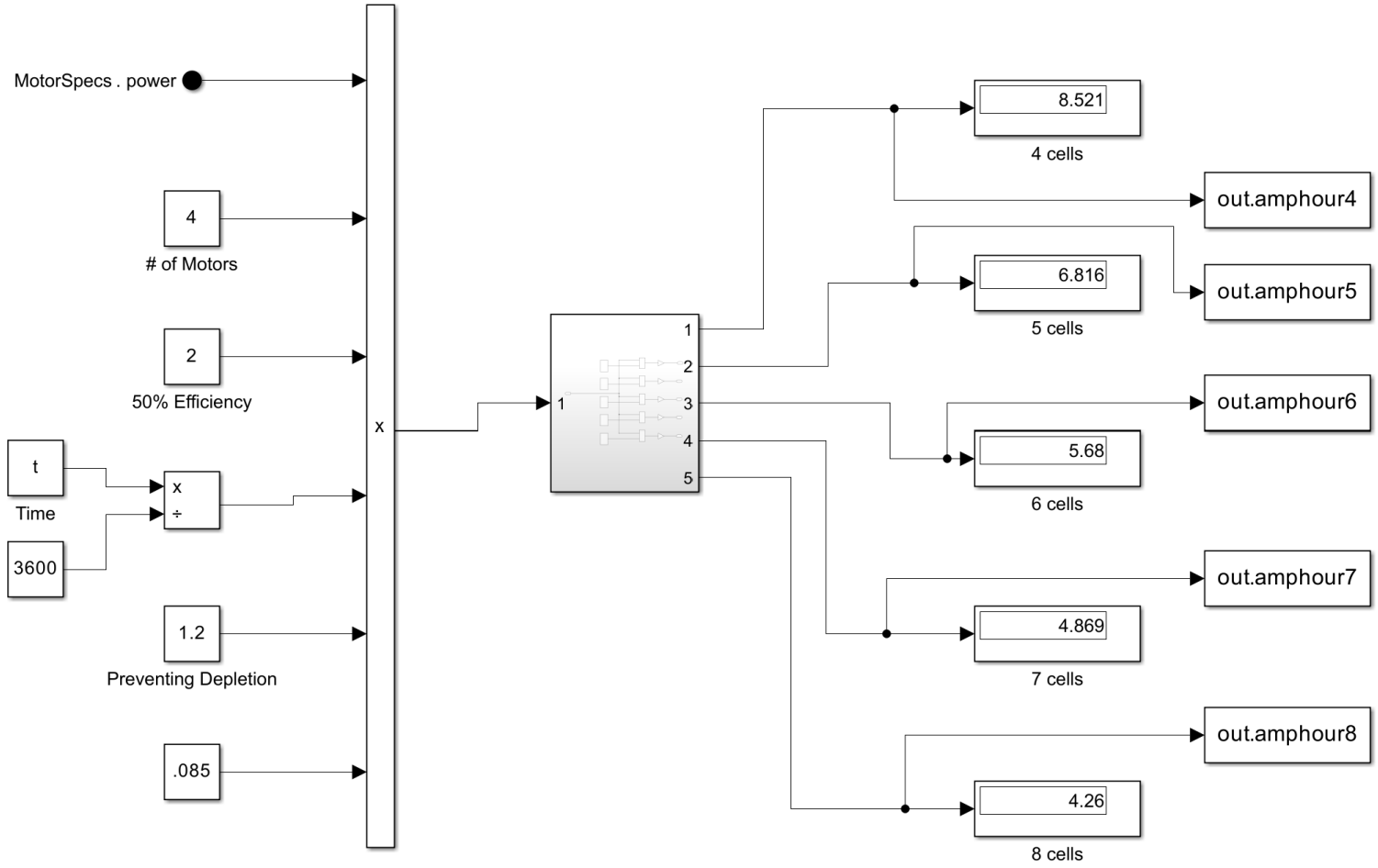
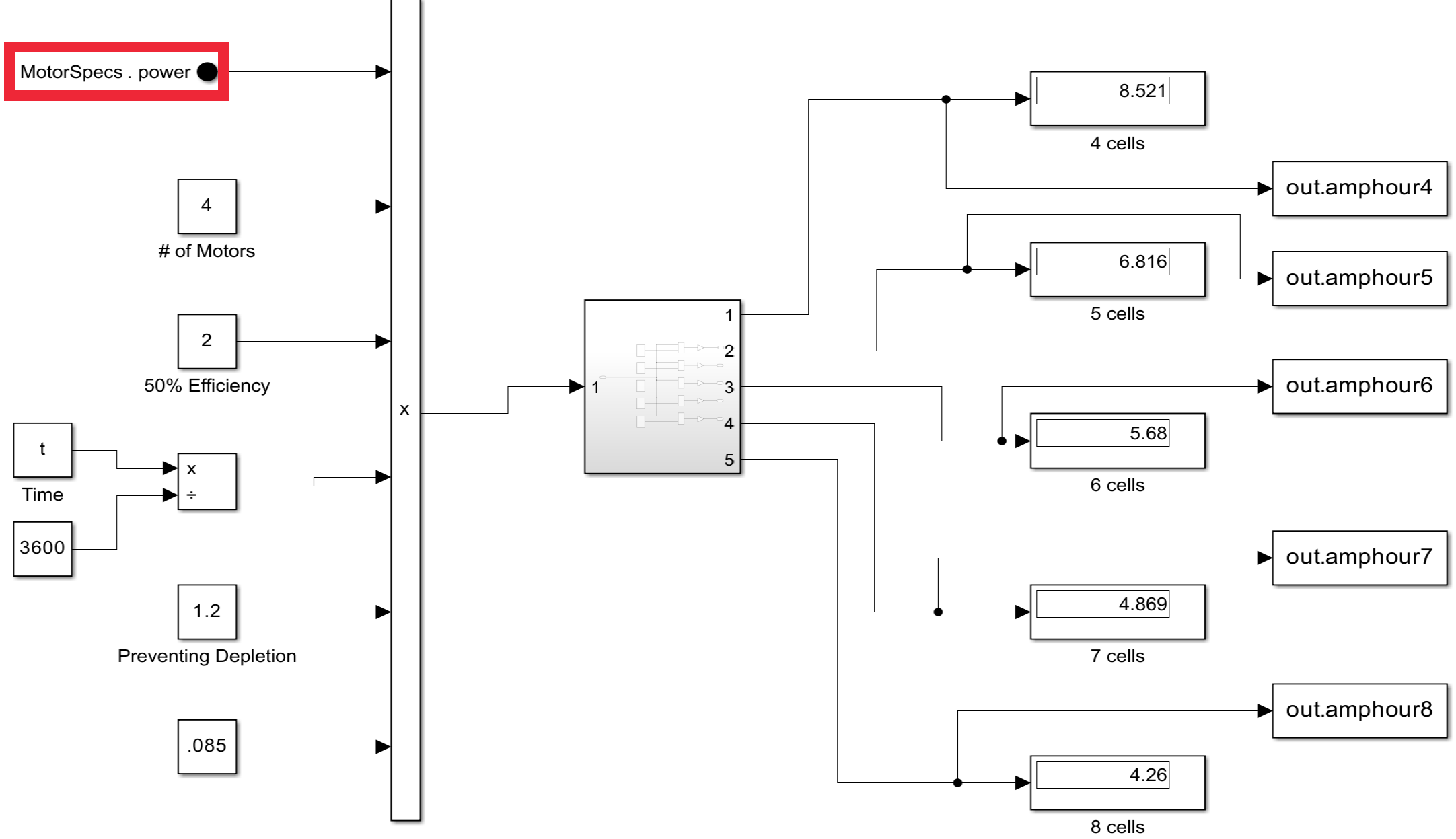
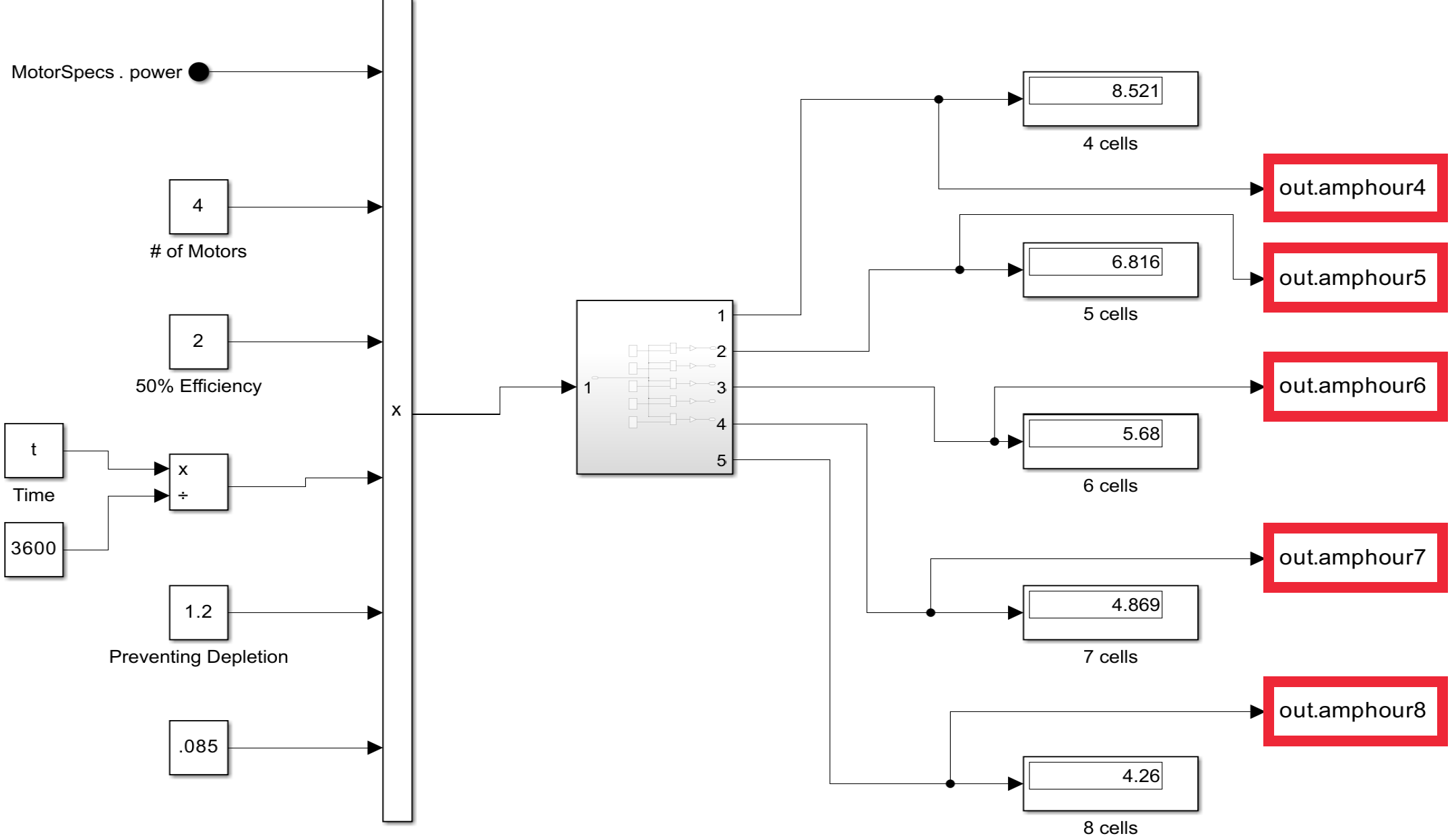
Stance Frequency
6.875
Flight Frequency
stride_freq
Frequency Computation
MotorSpecs
Power Computation
135
Power
MotorSpecs . power
out.power


stride_freq
stance_freq
flight_freq
1
2
Torque Computation
4.547
Stance Torque
1.32
Flight Torque
2.75
Stride Frequency
stance_torque
flight_torque
stance_freq
flight_freq
NoLoad Speed for Power
No Load Speed in RPM
Stall Torque
Stall Torque and No Load Speed Computation
out.noloadspeed
468.7
no load speed
11
stall torque
out.stalltorque
4.583
Stance Frequency
6.875
Flight Frequency
Frequency Computation
MotorSpecs
Power Computation
135
Power
MotorSpecs . power
out.power

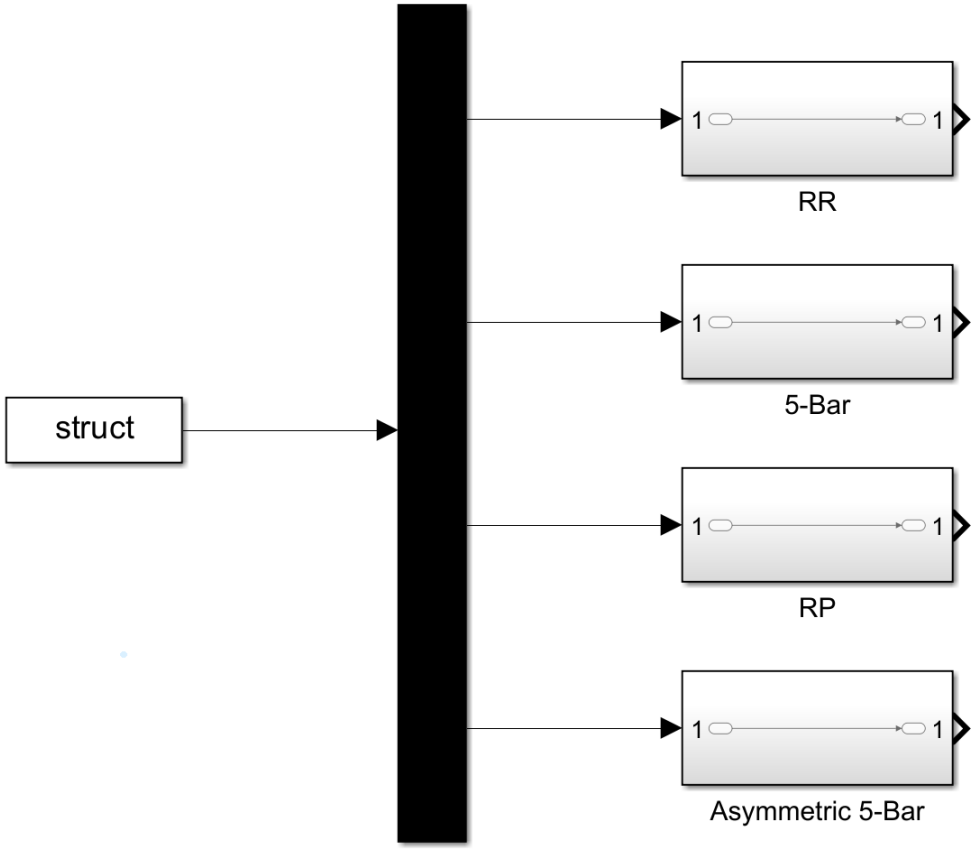
Simulink Battery Model

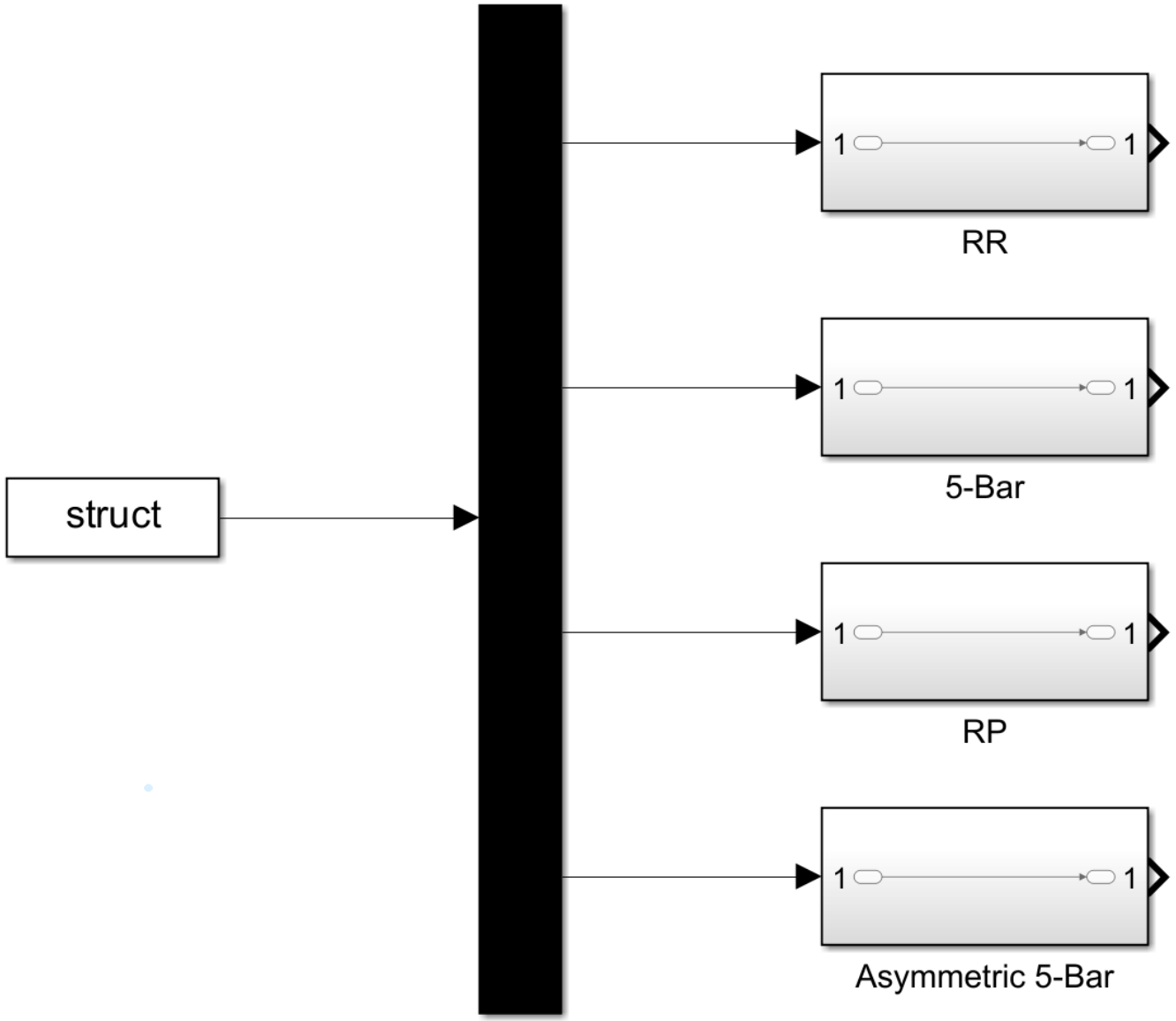



MotorSpecs . power
4
# of Motors
2
50% Efficiency
t
Time
x
÷
3600
1.2
Preventing Depletion
.085
x
1
1
2
3
4
5
8.521
4 cells
out.amphour4
6.816
5 cells
out.amphour5
out.amphour6
5.68
6 cells
out.amphour7
4.869
7 cells
out.amphour8
4.26
8 cells


MotorSpecs . power
4
# of Motors
2
50% Efficiency
t
Time
x
÷
3600
1.2
Preventing Depletion
.085
x
1
1
2
3
4
5
8.521
4 cells
6.816
5 cells
5.68
6 cells
4.869
7 cells
4.26
8 cells
out.amphour4
out.amphour5
out.amphour6
out.amphour7
out.amphour8

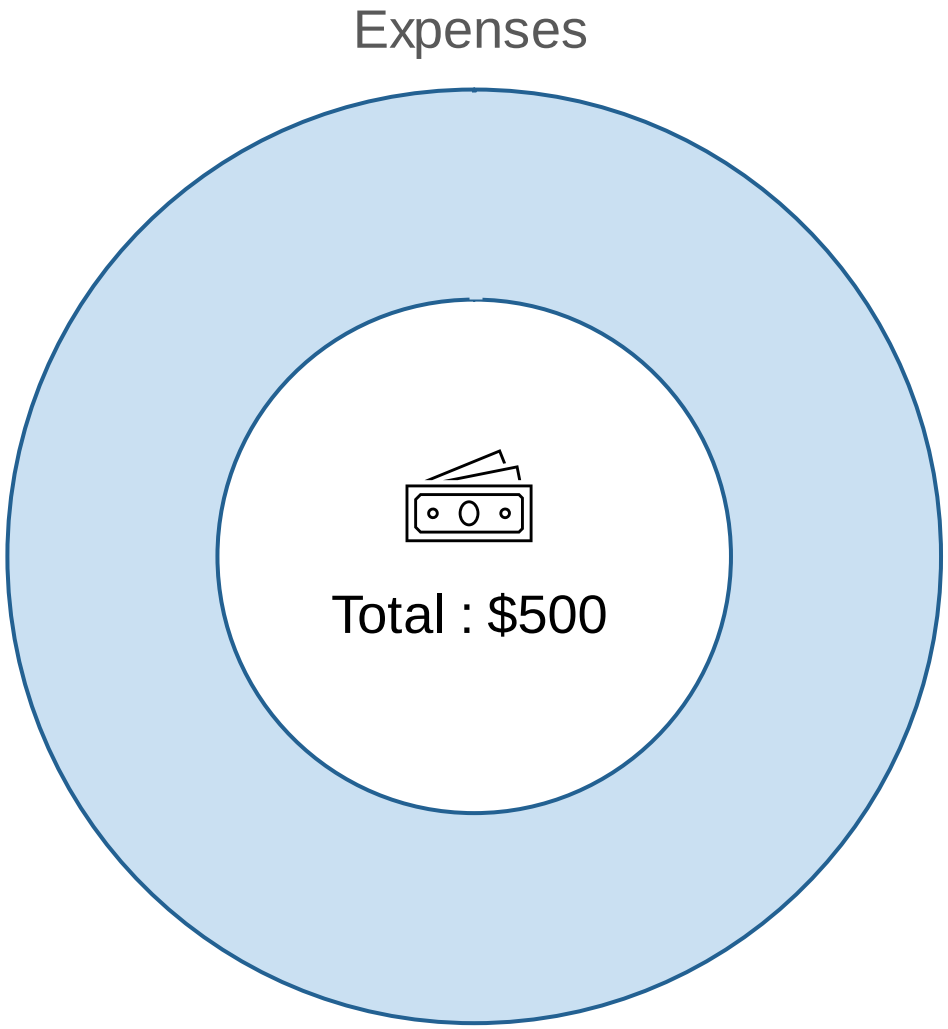
Simulink Leg Length Model




struct
1
1
RR
1
1
5-Bar
1
1
RP
1
1
Asymmetric 5-Bar

Budget Report

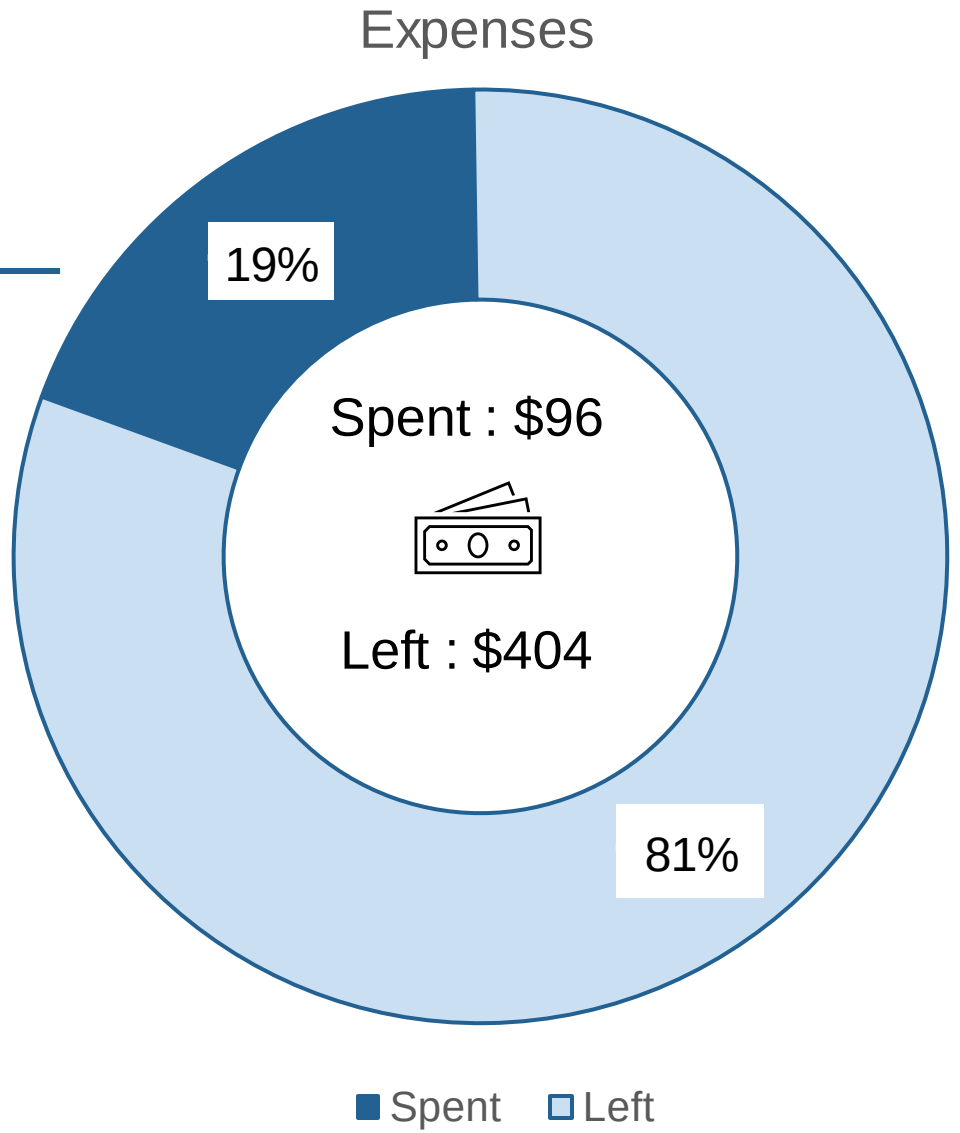
Project funding comes from $500 provided by CISCOR



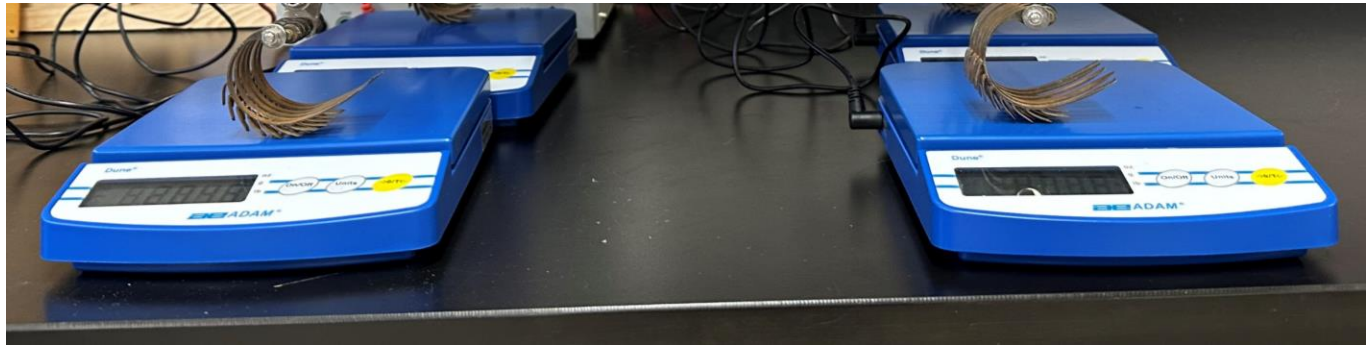
Budget Report

Compact Bench Scale

$96 (19%) spent purchasing a scale to weigh robot parts



Database Creation



- Total robot mass
  - ✓ Used for verification
- Leg mass, battery mass, and sensor package mass
  - ✓ Help with mass budget
- Battery Mass
  - ✓ Used for linear approximations
- Motor mass
  - ✓ Used for verification

Model Validation

For a robot with a total body mass of 7.5kg:

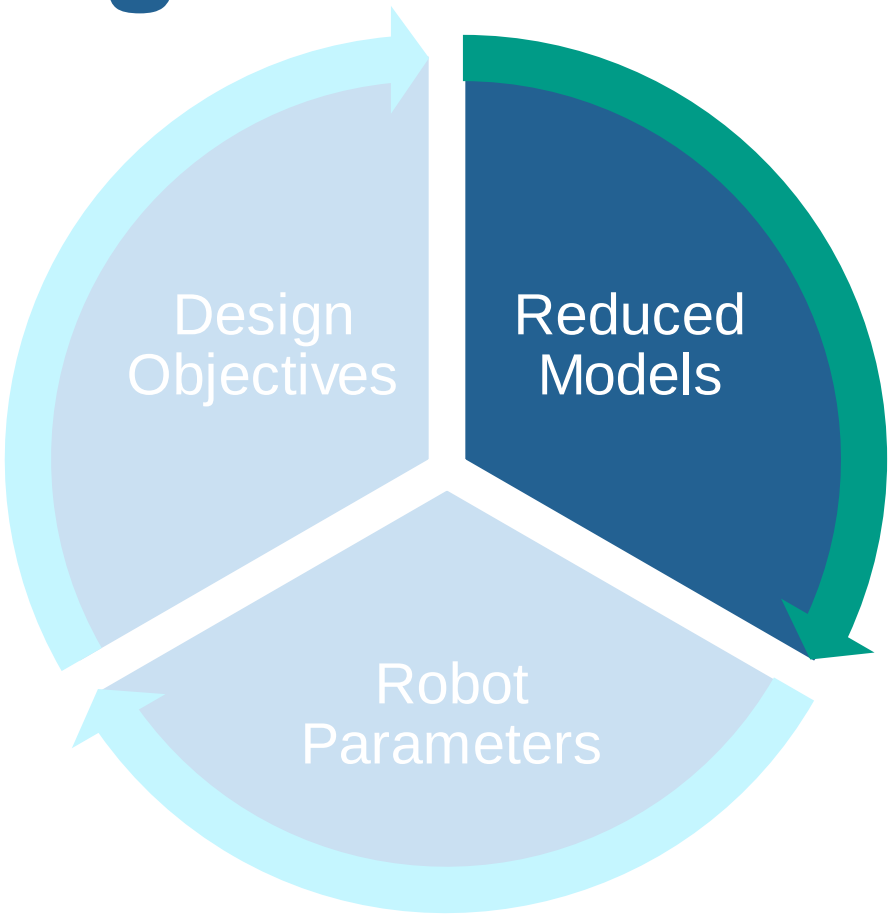
Stall Torque

Torque required at joint	±10%	Margin of Error
18.35 Nm	20.401 Nm	10% Margin of Error

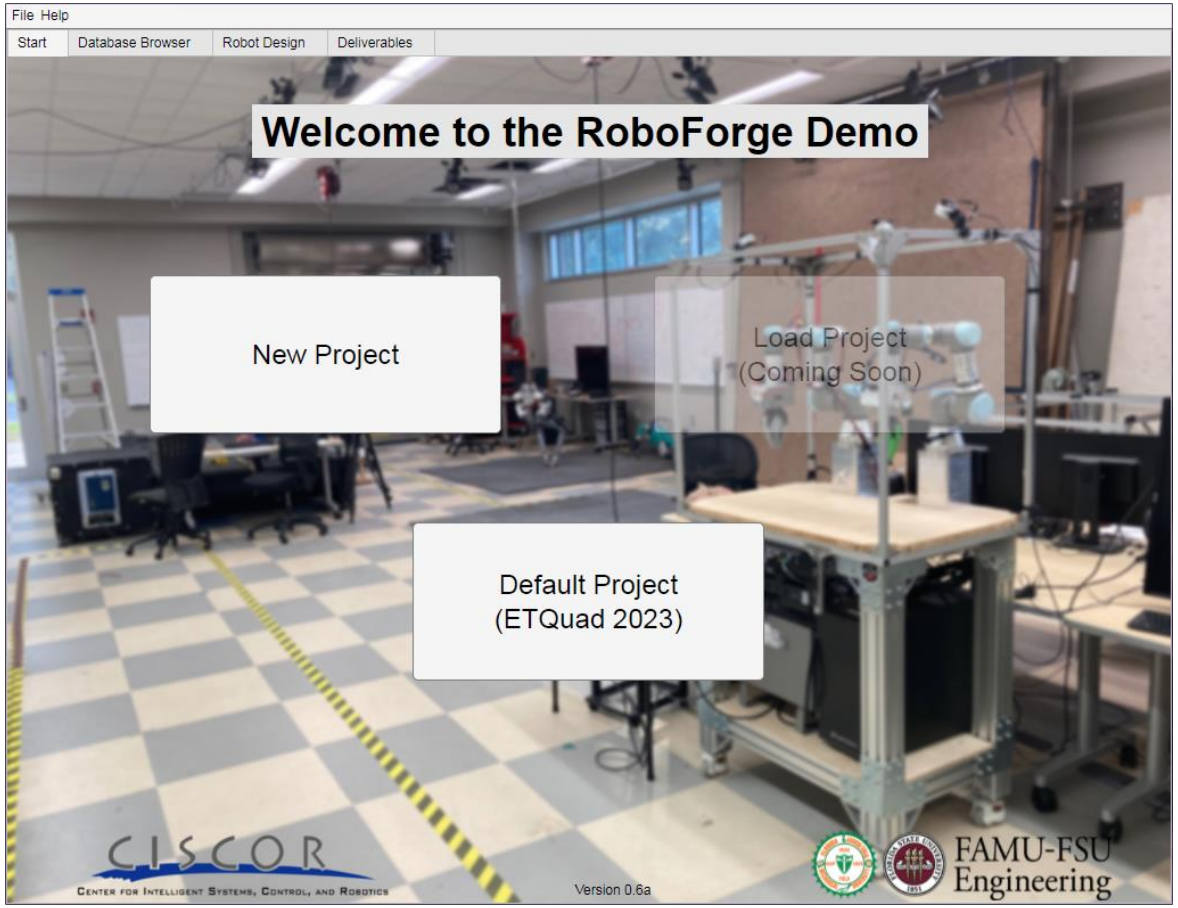
Model Predicted

Actual

CISCOR Design Process



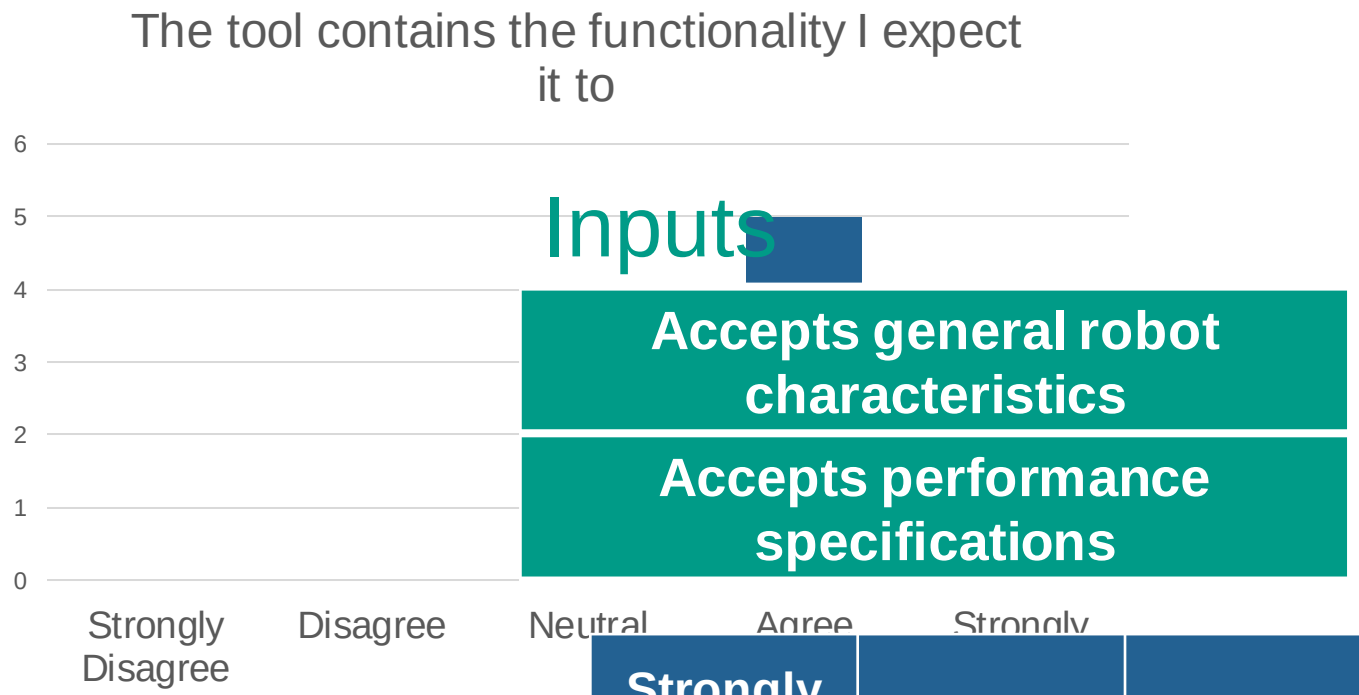
RoboForge


File Help
Start
Database Browser
Robot Design
Deliverables
Welcome to the RoboForge Demo
New Project
Load Project
(Coming Soon)
Default Project
(ETQuad 2023)
CISCOR
Center for Intelligent Systems, Control, and Robotics
Version 0.6a
FAMU-FSU
Engineering

Validation

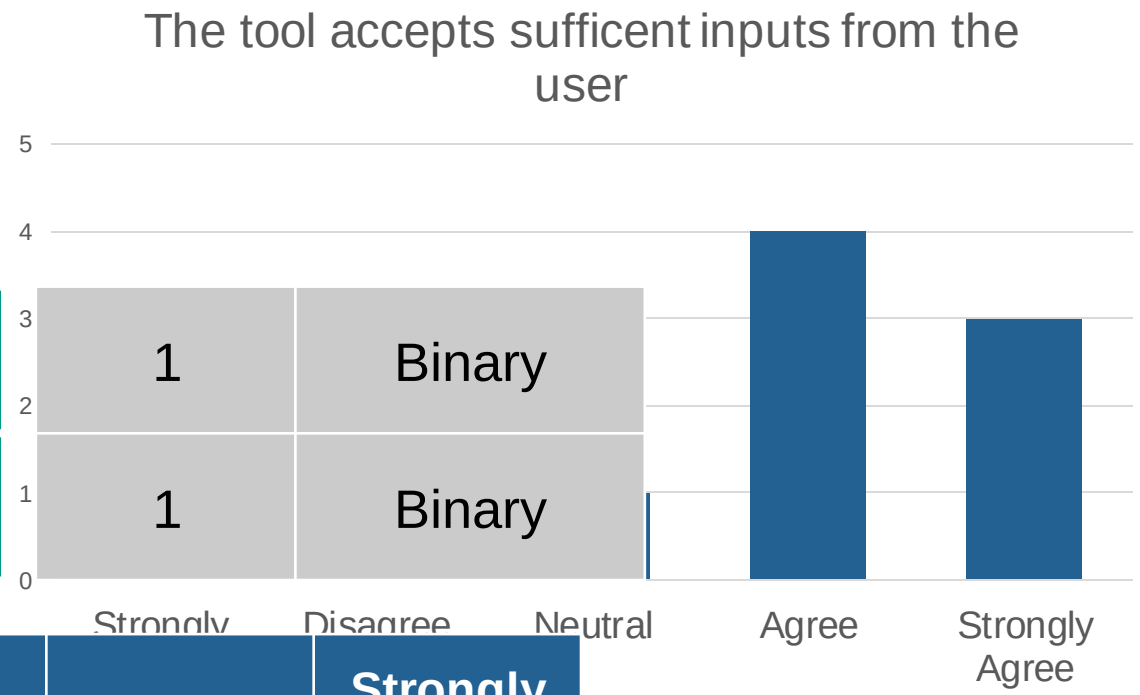
Inputs	Accepts general robot characteristics	1	Binary
	Accepts performance specifications	1	Binary
Outputs	Produces and stores critical targets catalog	1	Binary
Modeling	Calculate critical targets based on user input	1	Binary

Validation



Inputs

Accepts general robot characteristics	1	Binary
Accepts performance specifications	1	Binary

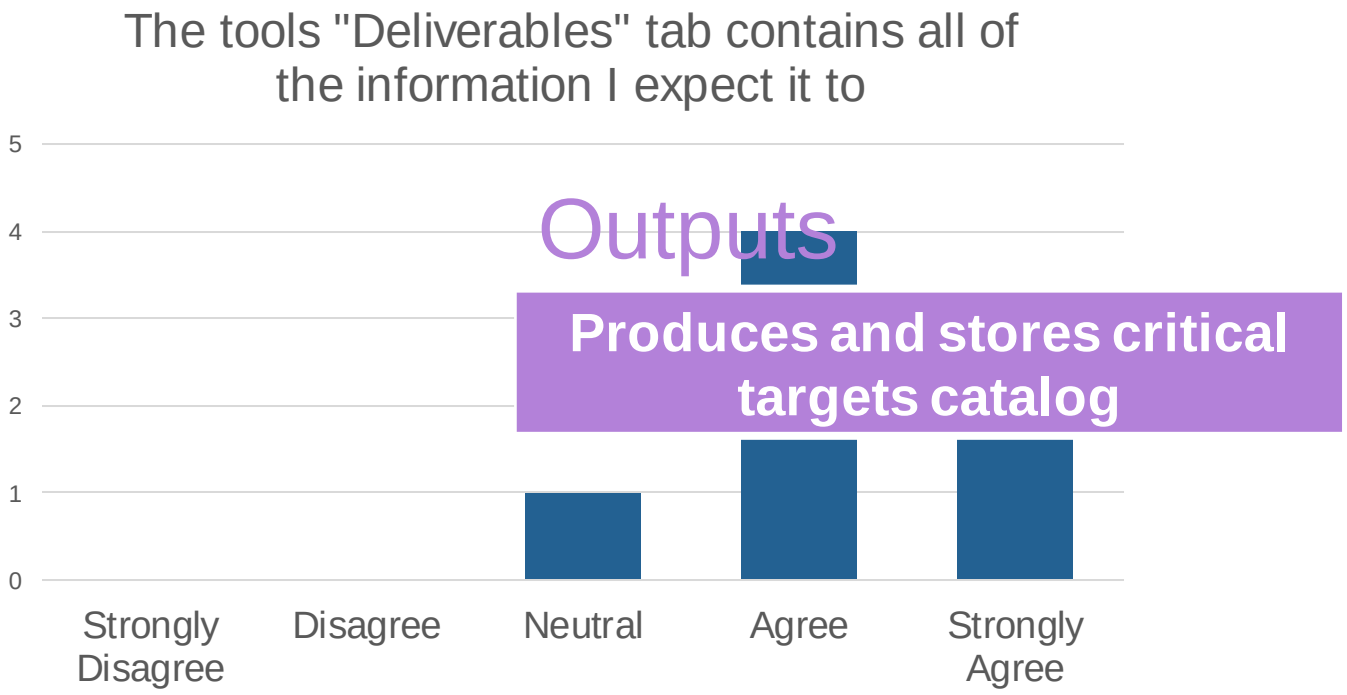


4.3

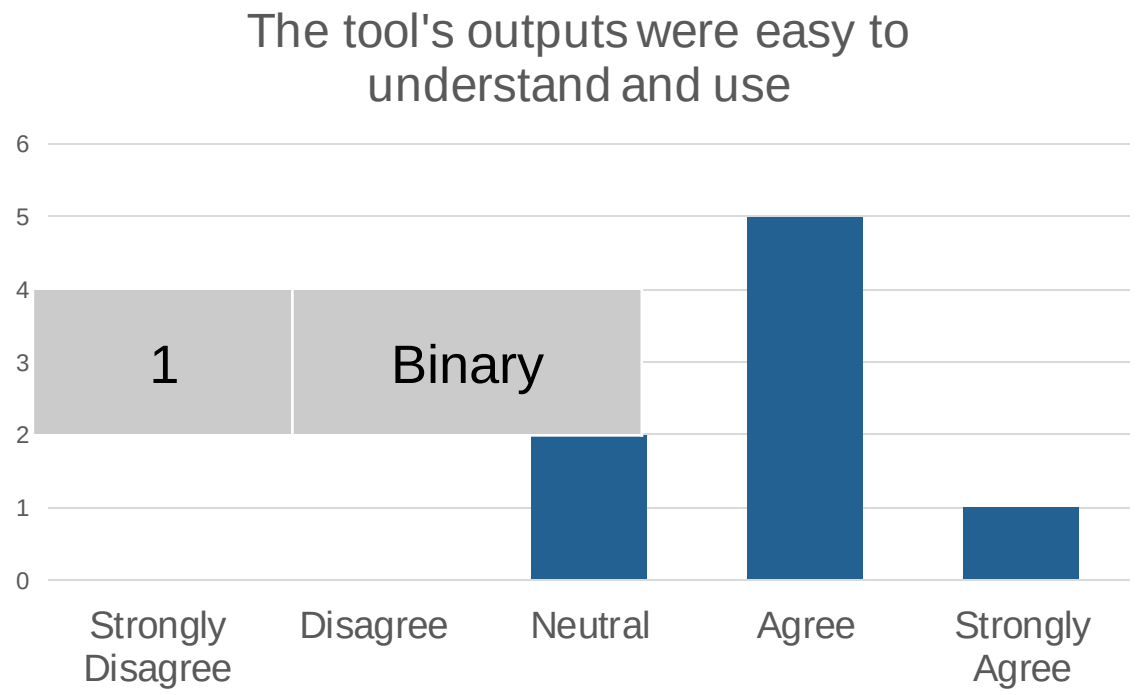
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	5

25

Validation

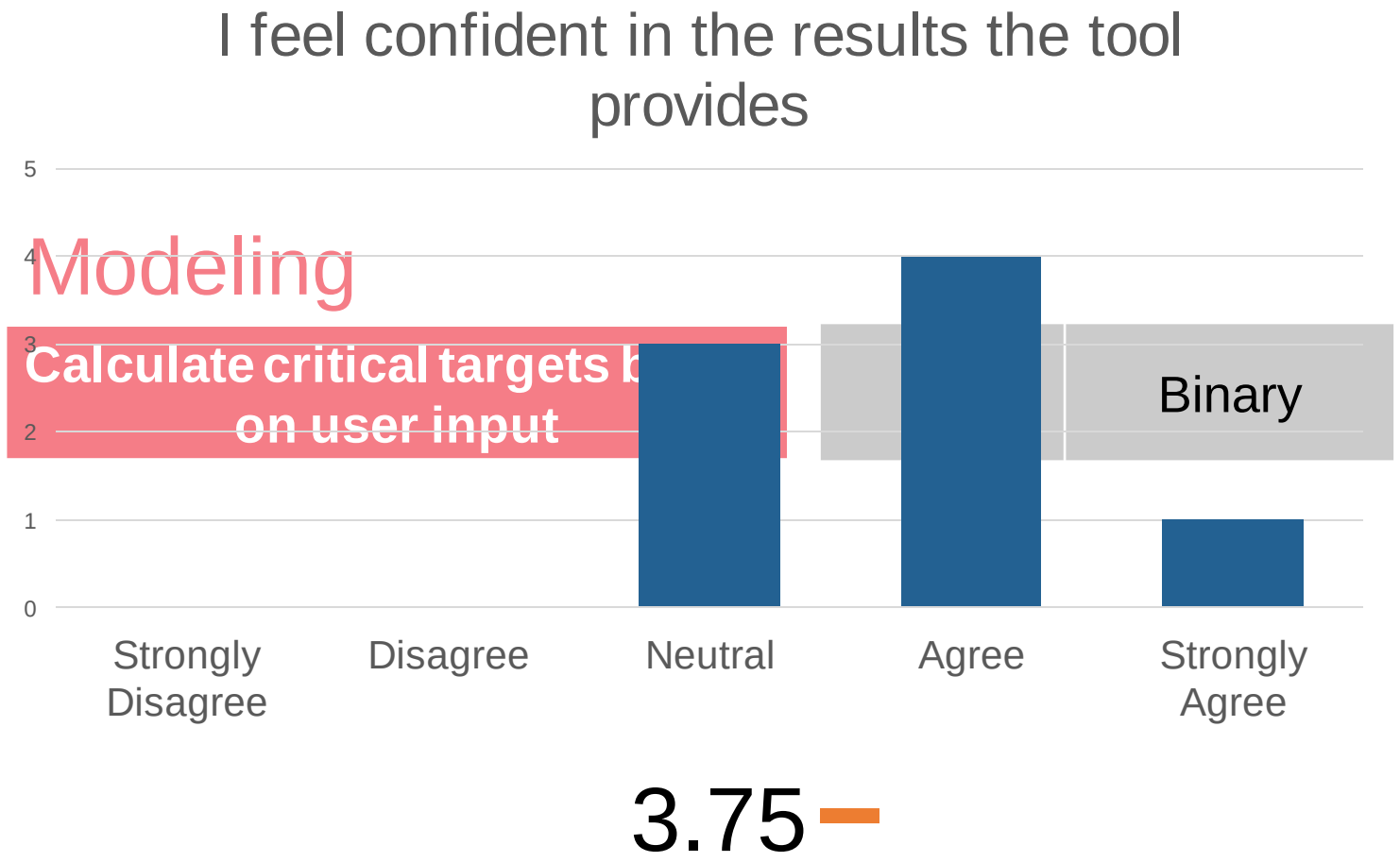


4.25 ✓



3.88 –

Validation


I feel confident in the results the tool provides
5
4
3
2
1
0
Modeling
Calculate critical targets b
on user input
Binary
Strongly Disagree
Disagree
Neutral
Agree
Strongly Agree
3.75

Lessons Learned

Software documentation difficulties

Project documentation

Properly defining scope while mitigating ambition

Lessons Learned

Software documentation difficulties

Project documentation

Properly defining scope while mitigating ambition

Lessons Learned

Software documentation difficulties

Project documentation

Properly defining scope while mitigating ambition

Lessons Learned

Software documentation difficulties

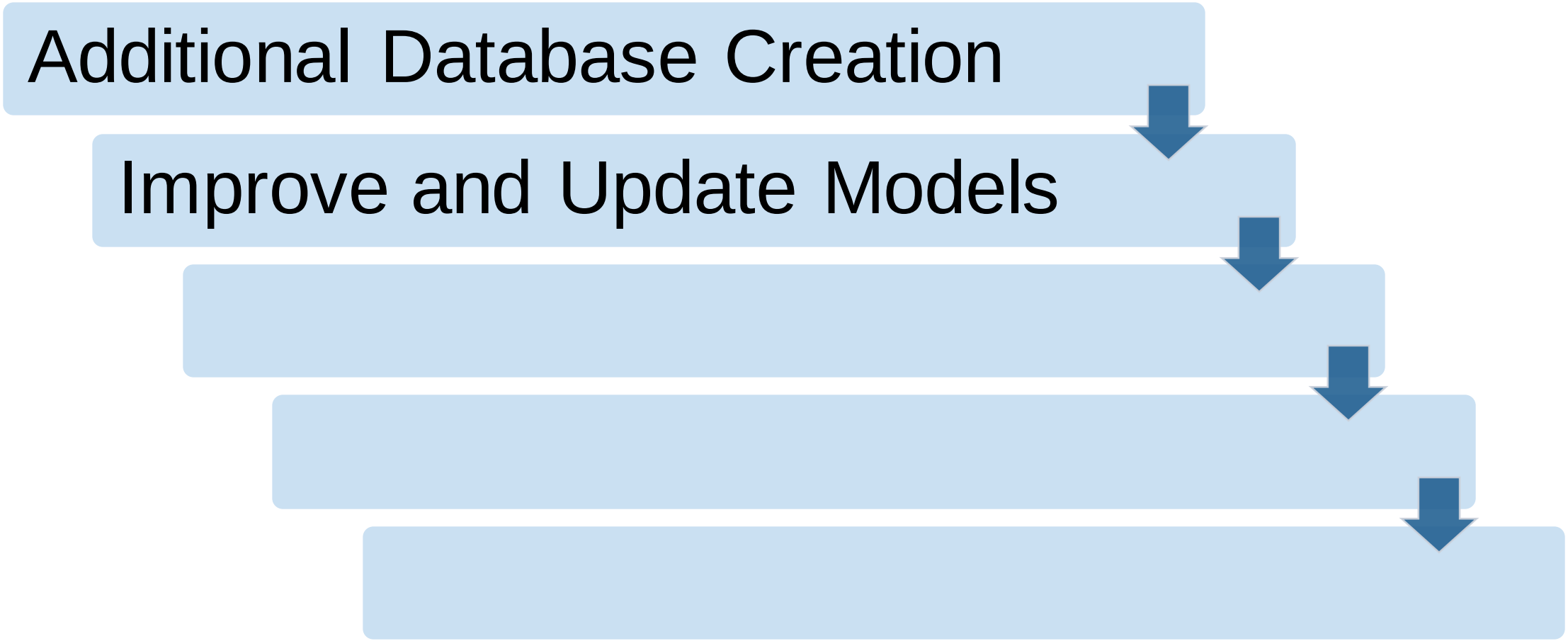
Project documentation

Properly defining scope while mitigating ambition

Suggestions for Improvement

- Additional Database Creation

Suggestions for Improvement



Suggestions for Improvement

- Additional Database Creation
- Improve and Update Models
- Enhance User Interface

Suggestions for Improvement

- Additional Database Creation
- Improve and Update Models
- Enhance User Interface
- Sensitivity Analysis

Suggestions for Improvement

- Additional Database Creation
- Improve and Update Models
- Enhance User Interface
- Sensitivity Analysis
- Design Optimization

LinkedIn Profiles

Milton Bouchard
Modeling Engineer

Michael Dina
Systems Engineer

Onoriode Onokpise
User Interface Engineer

Jackson Raines
Testing Engineer

Zachary Shapiro
Testing Engineer