Manufacturing Status Review

SIERRA NEVADA CORPORATION

University of Colorado Boulder

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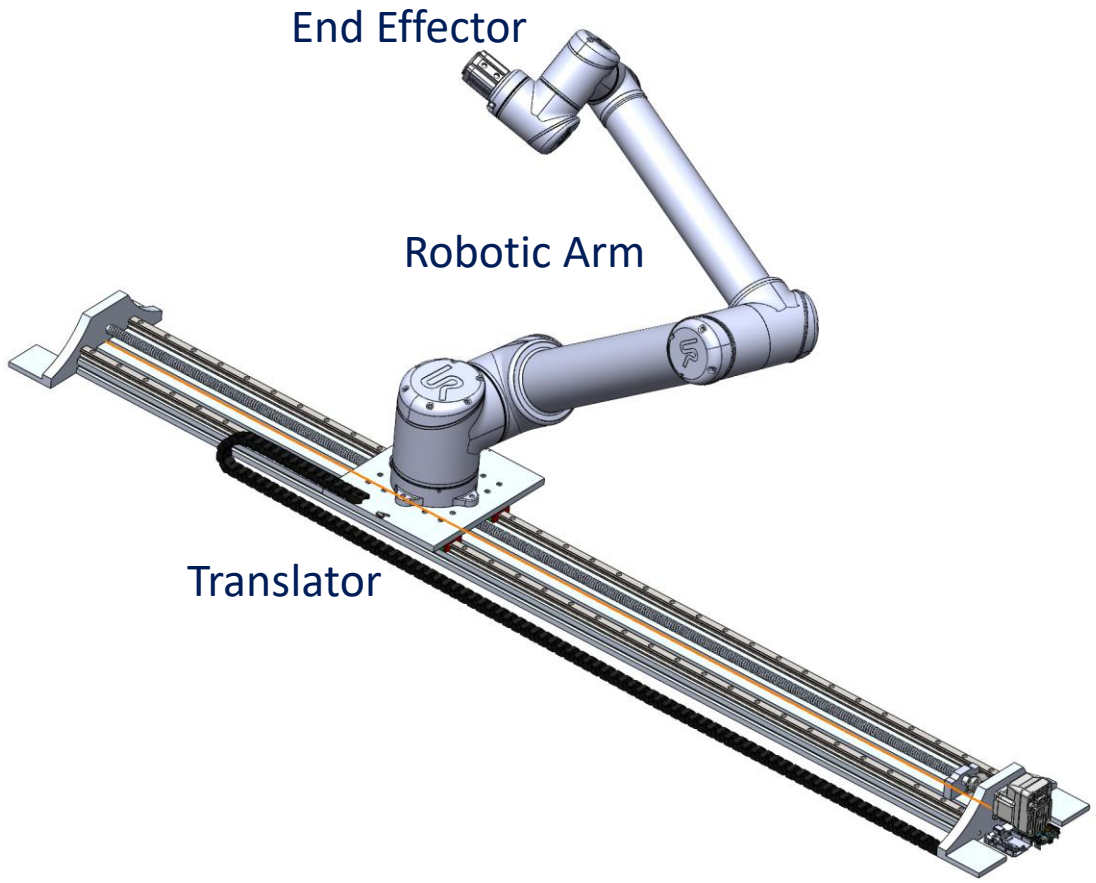
Advisor: Dr. Neogi

Section 1

Project Overview | Purpose | Objectives | CONOPS | FBD

Purpose

- Prove the feasibility of using Intra-Vehicular Robotics (IVR) to identify and distribute NASA cargo bags
- Demonstrate task management in an un-crewed environment
- Use robotics for cargo management tasks anticipated on a space habitat
- Use a robotic arm to capture and release bags in specified positions



Objectives

Level	Translator	Robotic Arm	End Effector	
Level 1	Platform that is **capable of being mounted to the rail system** of size 2.15m x 0.3m.	Robotic arm can **move to a desired pose** under a given command without colliding with simulated LIFE module environment.	End effector is able to take a command to **operate the bag capture mechanism**.	Phase I Feb 19
Level 2	Translator is able to **integrate with the robotic arm** including power and communication systems.	Robotic arm can plan and **move to a specified pose while the base is being moved** by the translator.	**End effector can capture bag with operator input** and maintain hold while translating and rotating the arm.	Phase II Mar 19
Level 3	**Translate robotic arm up to 2 meters** in one direction given a control input with 1 cm of accuracy.	**Robotic system can capture a bag and release it at a specified location**, with a remote operator determining pick up and drop off location.	**End effector receives input from the robotic arm** to be aligned, capture, and control a bag instead of a remote operator.	Phase III Apr 16
Level 4	**Translation is automated** and repeatable; sensor suite returns position data to the system/user to refine position during operations.	The system will complete a cargo transportation task by **identifying, locating, capturing, and releasing a bag with no manual inputs** from an operator.	The end effector is **correctly aligned to capture a bag based on the coordinate location** returned by the imaging sensors.	Phase III Apr 16

CONOPS

Stage 1: Capture

A) Identify a cargo bag and return location coordinates

B) Position arm to attach to bag

C) Engage magnetic end effector

D) Rotate to required pose

Stage 2: Translation

A) Begin motorized translation

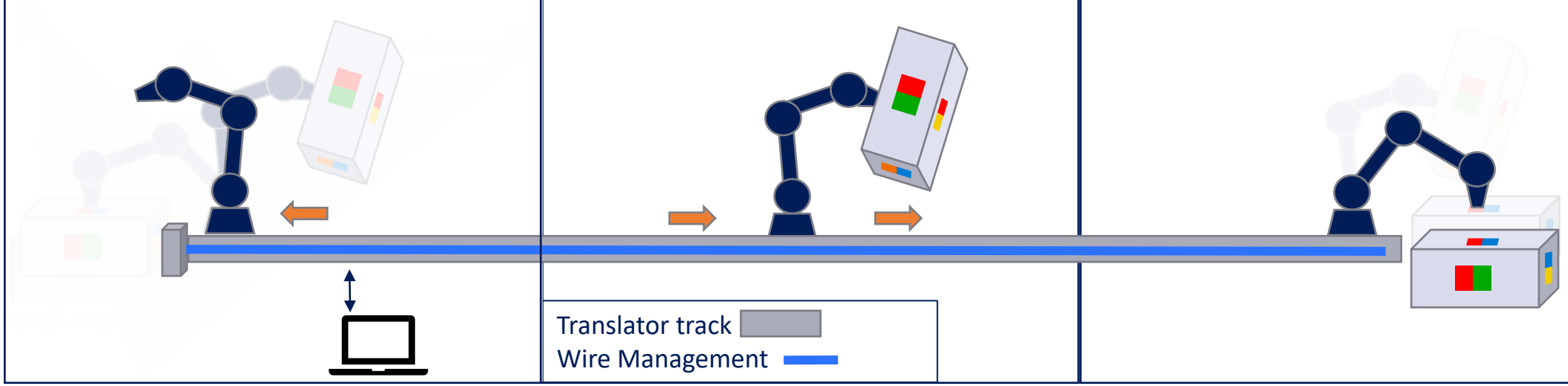
B) Stop translation at drop off location

Stage 3: Release

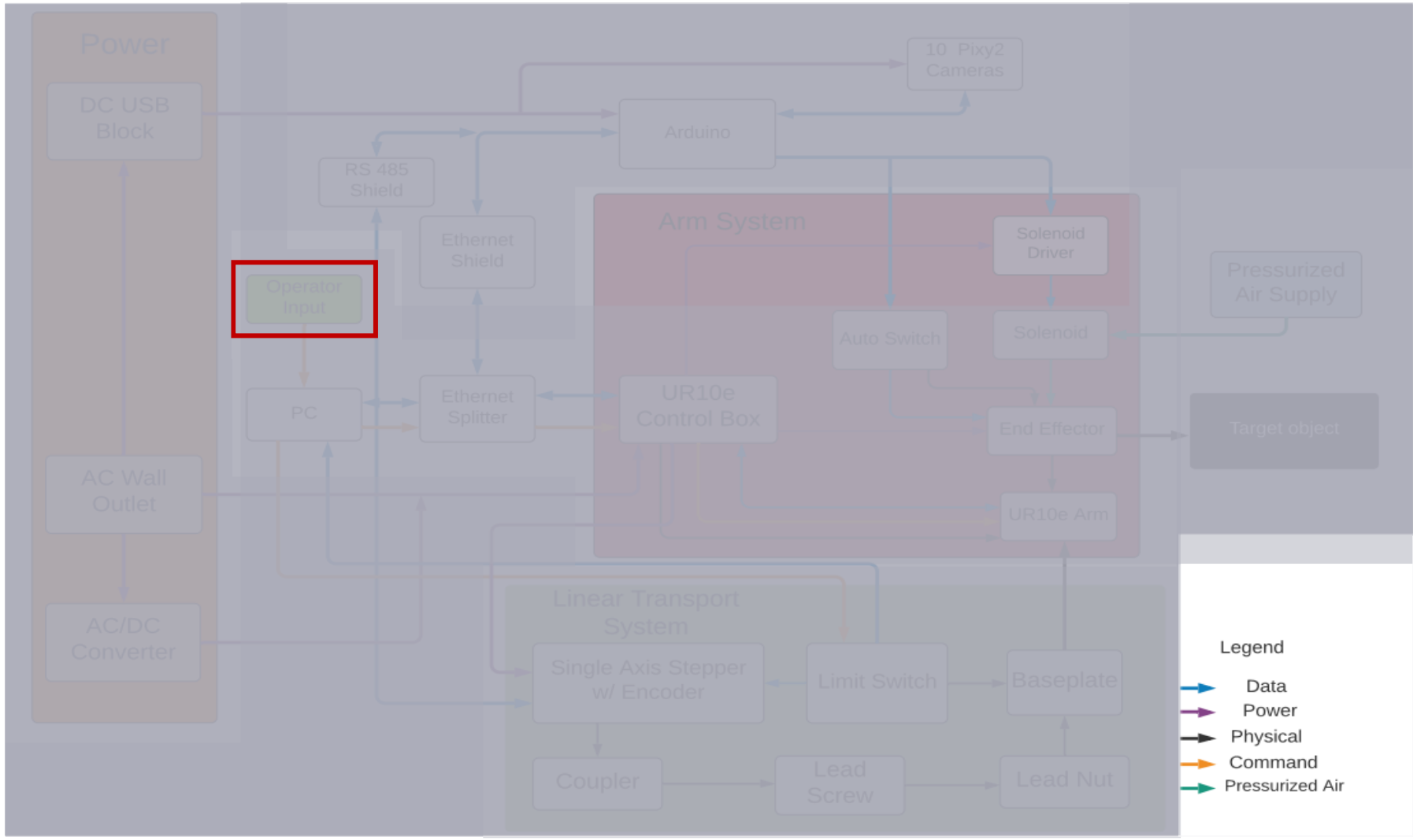
A) Rotate to drop off pose

B) Disengage end effector

C) Return to origin and restart process



FBD


Power
DC USB Block
AC Wall Outlet
AC/DC Converter
10 Pixy2 Cameras
Arduino
RS 485 Shield
Ethernet Shield
Operator Input
PC
Ethernet Splitter
Arm System
Solenoid Driver
Auto Switch
Solenoid
UR10e Control Box
End Effector
UR10e Arm
Pressurized Air Supply
Target object
Linear Transport System
Single Axis Stepper w/ Encoder
Limit Switch
Baseplate
Coupler
Lead Screw
Lead Nut
Legend
Data
Power
Physical
Command
Pressurized Air

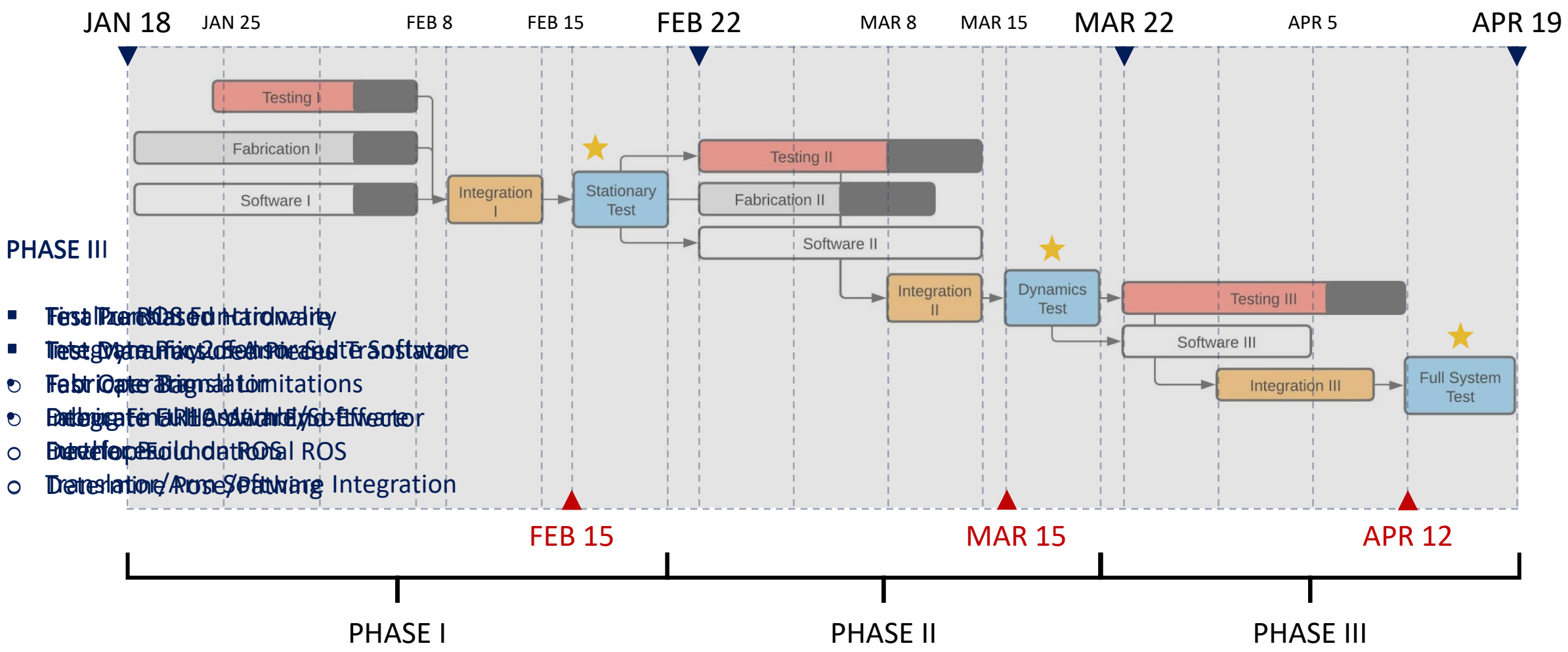
Section 2

Schedule

Gantt Chart

Current Progress

Gantt Chart – Critical Path



PHASE III

- Test Pre-Built Hardware
- Test Manufactured Hardware
- Fabrication Iteration
- Debug Fabrication Issues
- Develop Control ROS
- Determine Rose Pathway

- Test Pre-Built Software
- Test Manufactured Software
- Fabrication Iteration
- Debug Fabrication Issues
- Develop Control ROS
- Translation/Pose Software Integration

Test Description

Stationary Test (Phase I)

A) Position arm to attach to bag

B) Engage magnetic end effector

C) Rotate to required pose

Dynamics Test (Phase II)

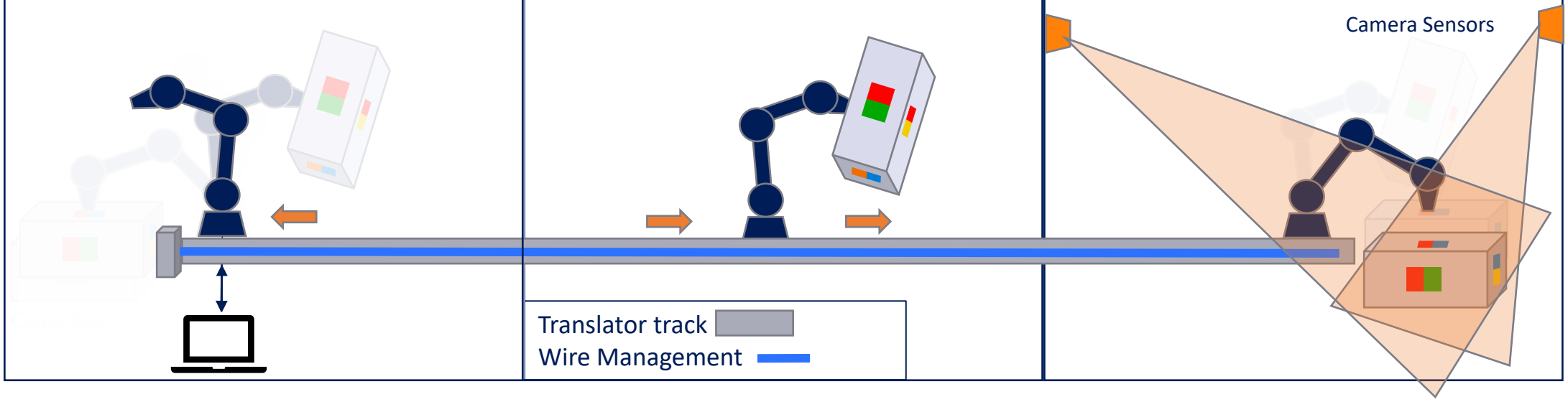
D) Begin motorized translation

E) Stop translation at drop off location

Full Systems Test (Phase III)

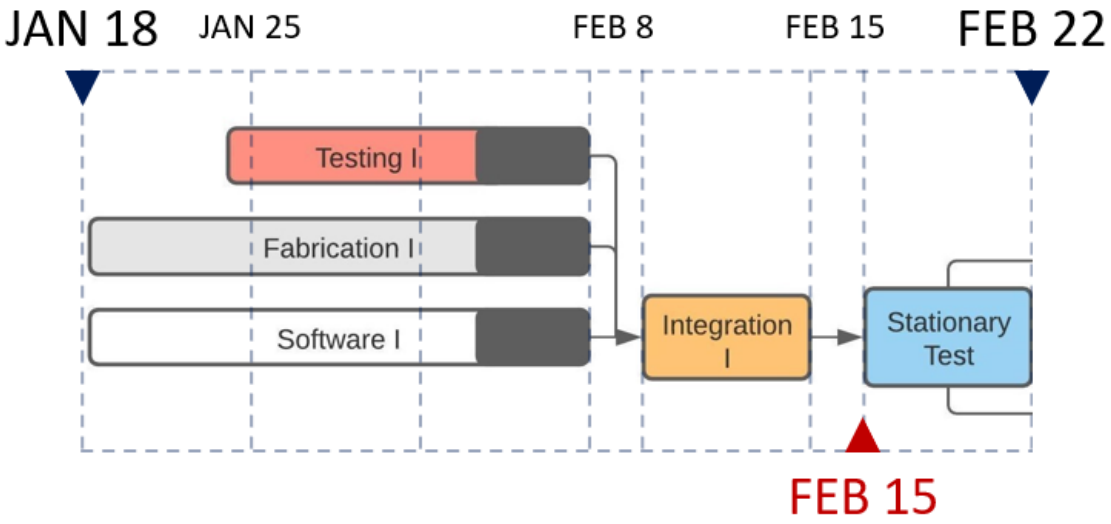
F) Cameras identify the bag

G) One full cycle of operations



Current Progress

★ Milestones ■ Margin
■ Testing ■ Fabrication ■ Software ■ Integration
○ Incomplete ✓ Complete



TESTING	IN PROGRESS, MAJOR CONCERN: FABRICATION DELAY
FABRICATION	IN PROGRESS
SOFTWARE	IN PROGRESS, MAJOR CONCERN: ROS COMPLICATIONS
INTEGRATION	NOT STARTED
STATIONARY TEST	NOT STARTED

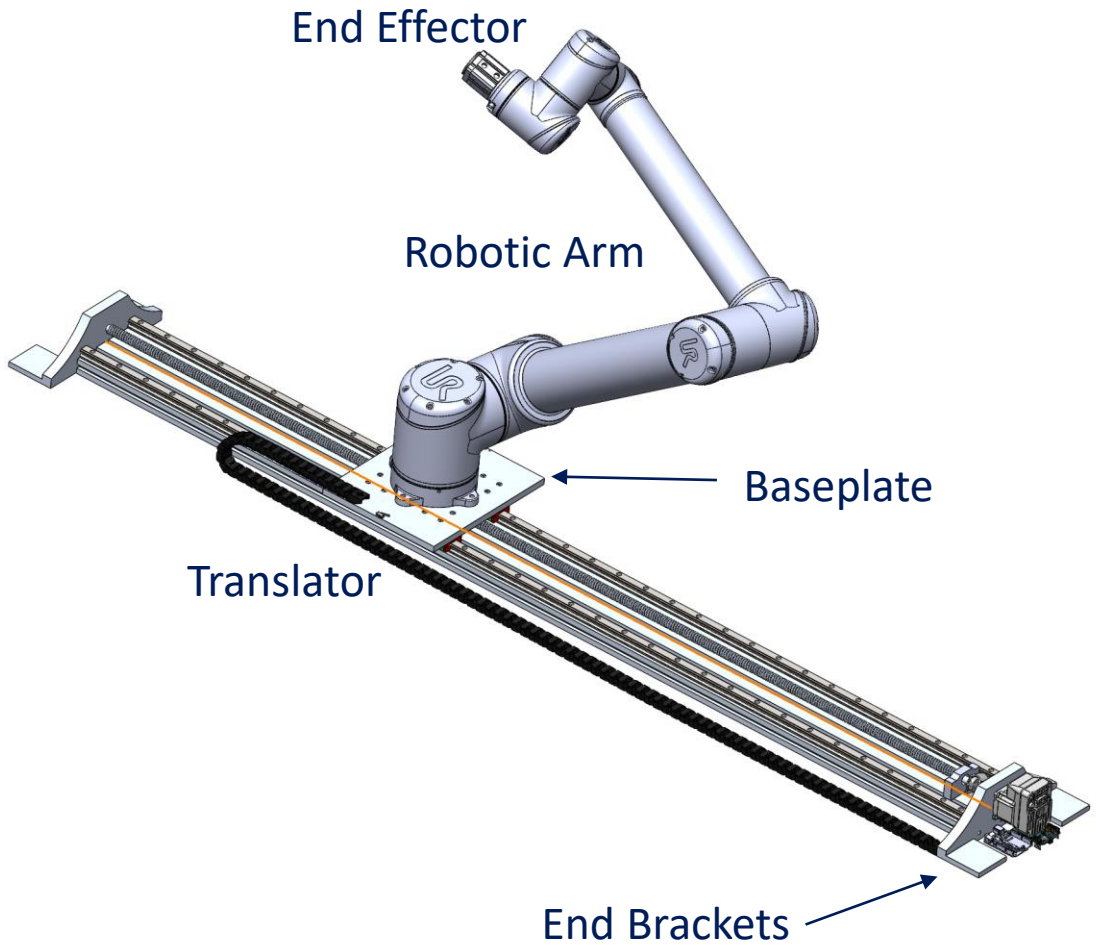
Task Type	Task	Date
Translator Robotic Arm	○ Integrate Arm to Linear Stage Base Plate	○ Feb 15
End Effector	○ Mount End Effector ○ Integrate Pressure, Power, Data Lines	○ Feb 15 ○ Feb 15
Software	○ Formulate Task Planning Architecture	○ Feb 15
Cargo Bag	○ Fabricate Cargo Bag	○ Feb 8

Major Changes Since CDR: Extended Fabrication Stage By 1 Week

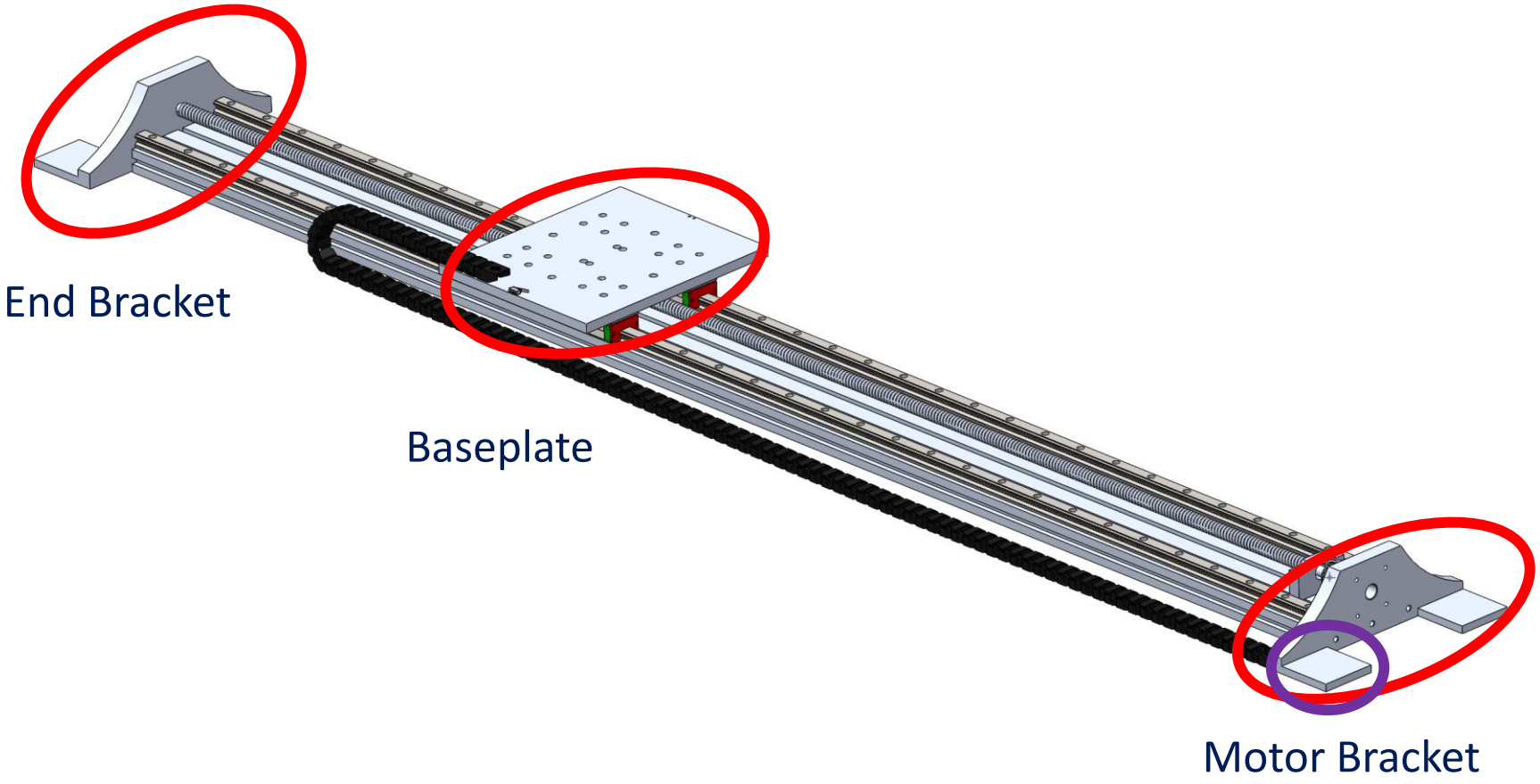
Section 3

Task Overview

Component	Description	Status
Baseplate	• Manufactured by: Machine Shop	In Progress
End Bracket	• Manufactured by: Machine Shop	In Progress
Software	• Manufactured by: RIVeR	In Progress
Electronics	• Manufactured by: RIVeR	In Progress



Manufactured Parts



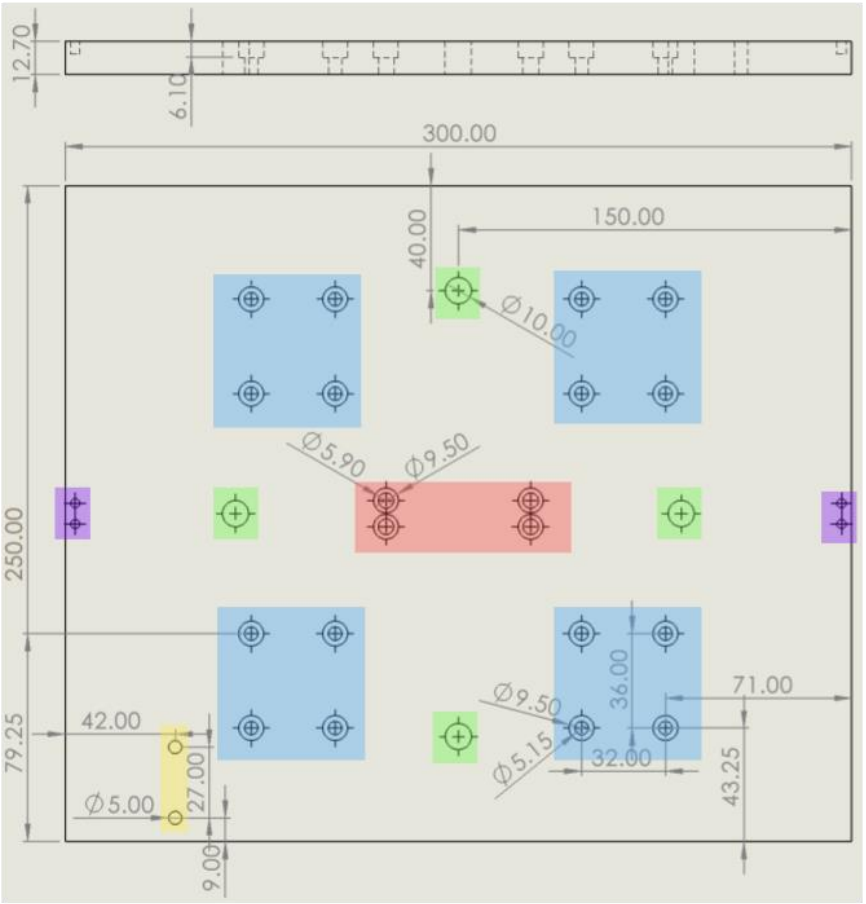
Plan for Fabrication

1. Examine purchased parts
2. Submit designed parts(Red Circles) to machine shop
3. Weld additional plates to brackets(Purple Circle)
4. Assemble designed parts with remainder of system

All Manufactured Part made from Aluminum 6061 because:

- Strong enough to support our load
- Cheap enough to stay within budget

Drawing of Baseplate



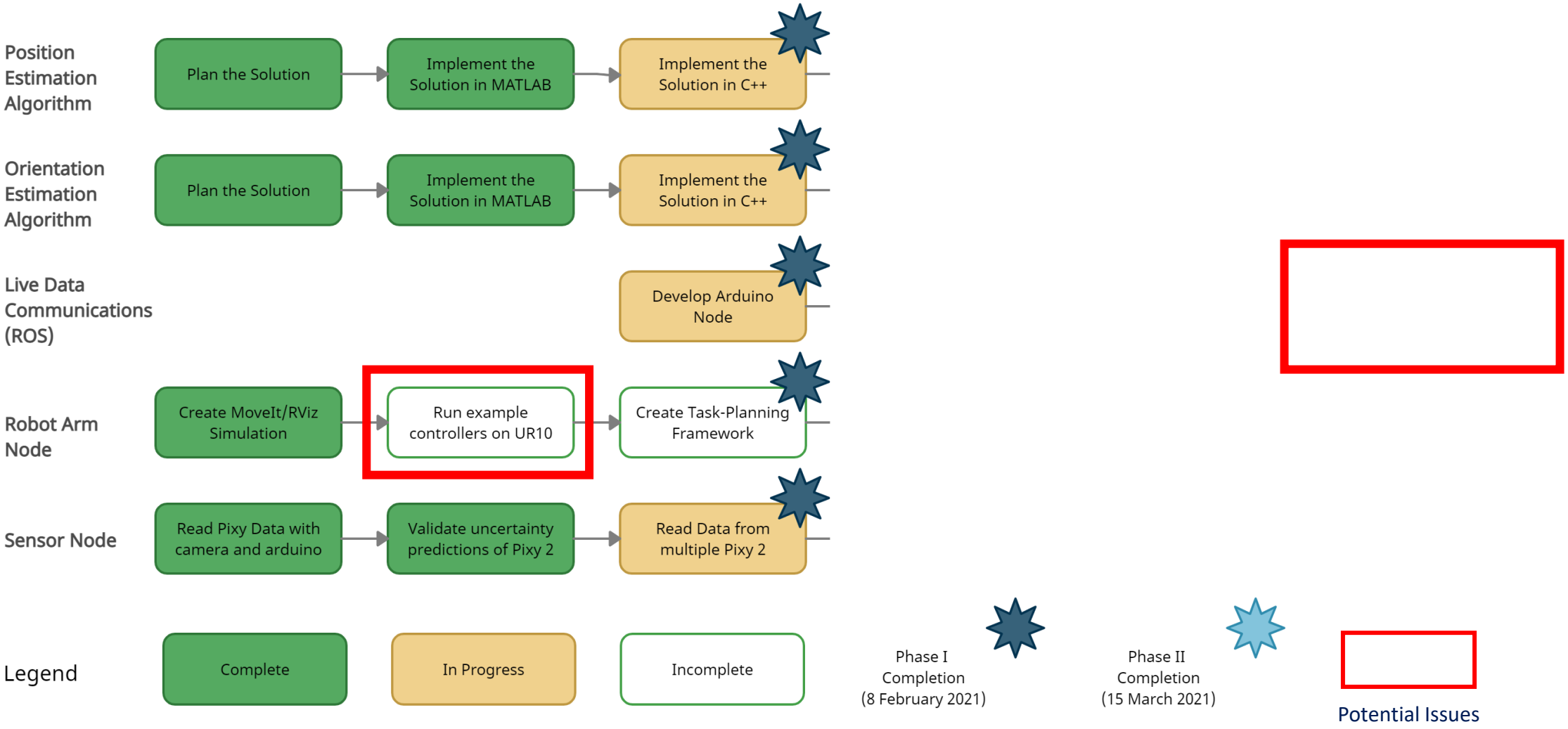
Side View

Top View

Connections:

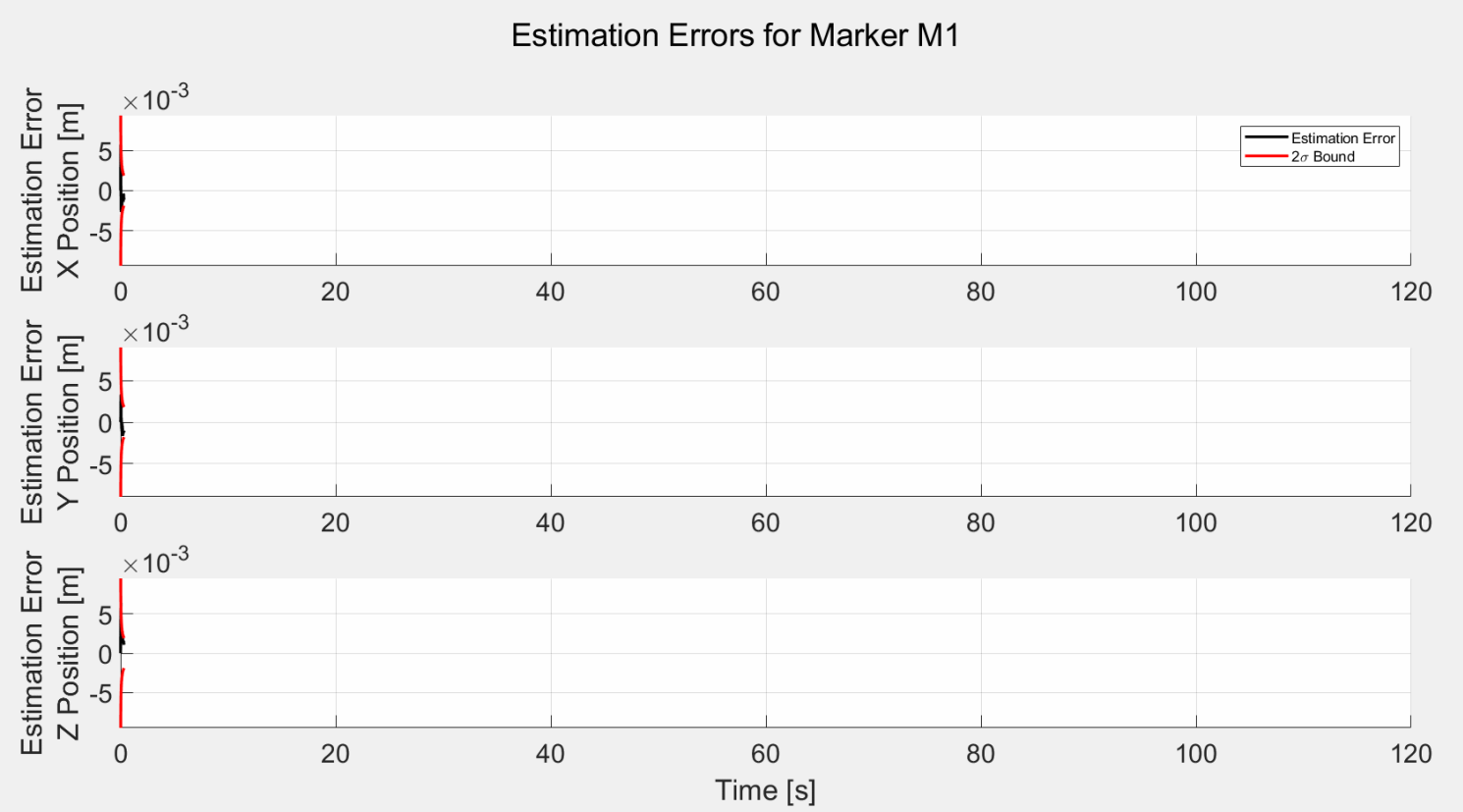
- Blue: Holes for baseplate and Linear bushings connection below
- Green: Holes for robotic arm bolts
- Red: Holes for baseplate to lead nut connection
- Purple: Hole to place limit switches
- Yellow: Holes to mount solenoid valve

Software Manufacturing

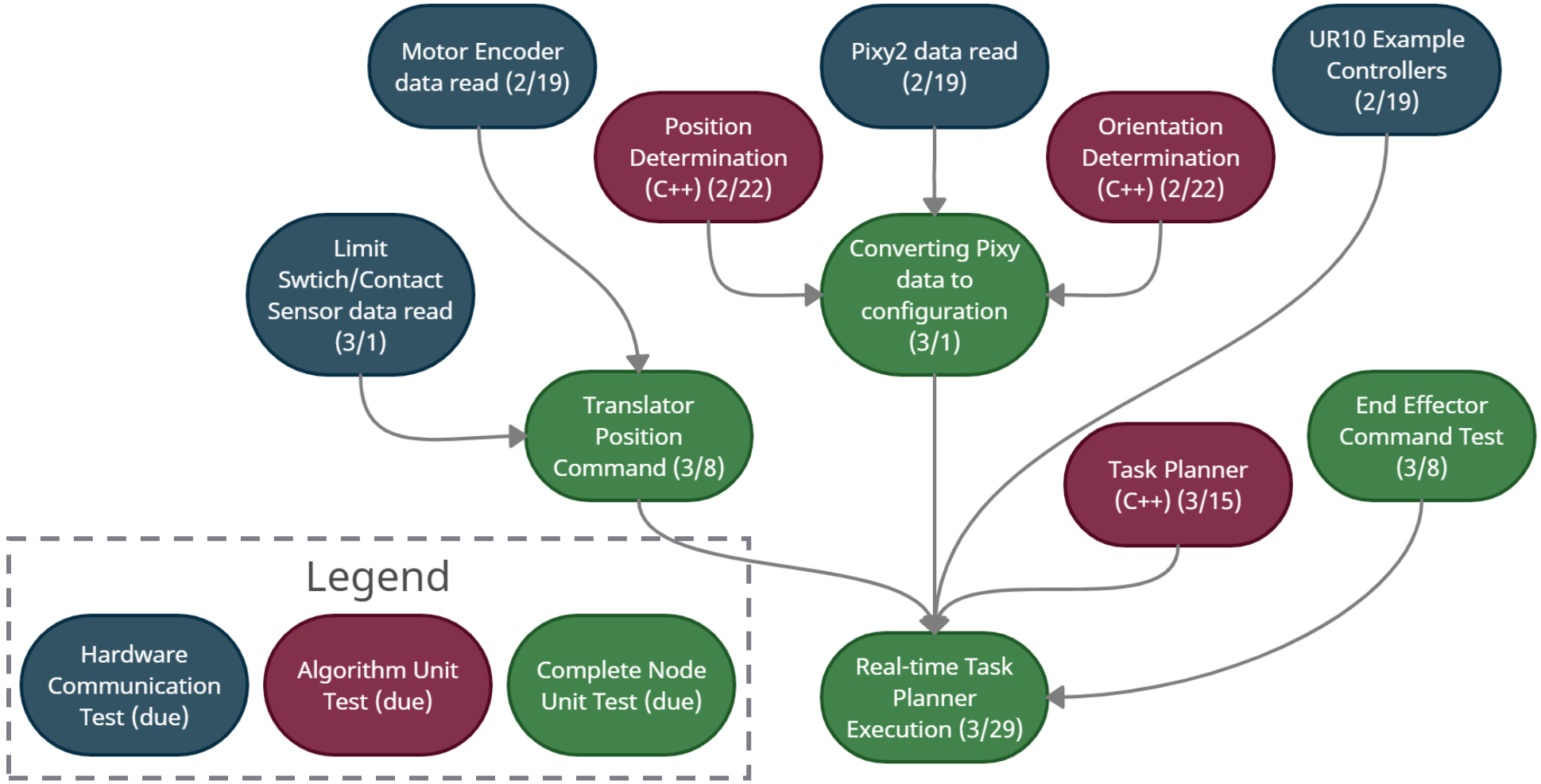


Bag Marker Position Estimation Algorithm

- **At CDR:** Batch estimation solution
- **Now:** Extended Kalman Filter (EKF)
  - Continuous, live estimation
  - More precise solution
  - Capable of estimating uncertainty
  - Capable of calibrating the sensor positions



Software Validation Plan



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Electronics Plan

1. Test Supply Voltages	
Component	**Expected Voltage**
UR-10 Control Box	24 VDC
AC/DC Converter	24 VDC
USB Power	5 VDC

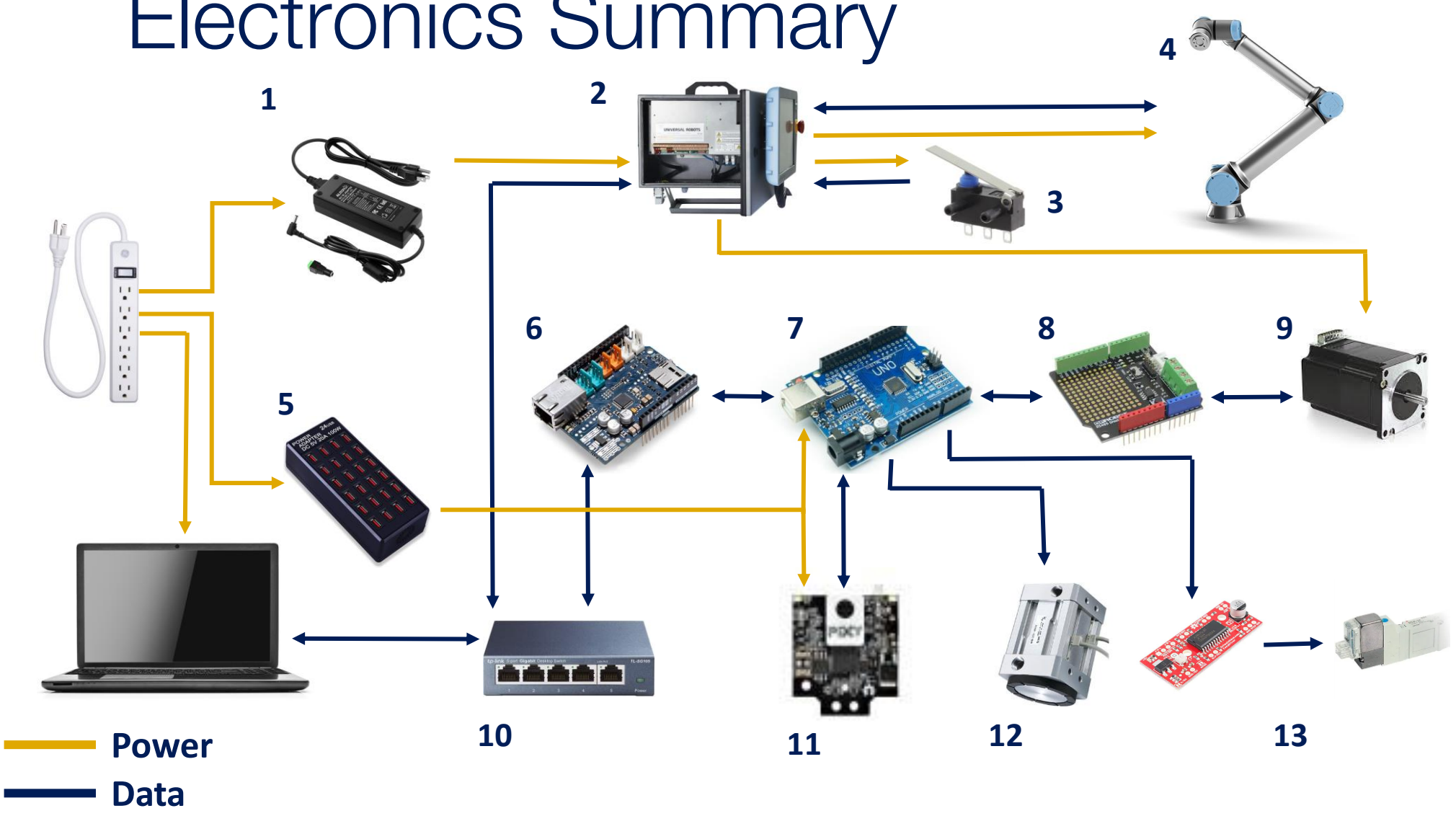
2. Verify Signals/Program with PC	
Component	**Connection Type**
Pixy 2	USB
Arduino	USB
UR-10	Ethernet
Solenoid	USB

3. Integrate Components with Arduino	
Component	**Arduino Pins**
Stepper Motor	1,2
Solenoid	3
Auto Switch	4
Ethernet Shield	10,11,12,13
Pixy2 Bus	A4,A5

4. Cut Wires	
Wire Type	**Purpose**
24 Gauge	Pixy2 I2C
24 Gauge	Power
Micro USB	Pixy2 Power
Ethernet	Data

5. Integrate System	
UR-10 Control Box	Solenoid
AC/DC Converter	Auto Switch
USB Power	Stepper Motor
10 Pixy 2 Cameras	RS-485 Sheild
Arduino	Ethernet Shield
PC	Ethernet Tree

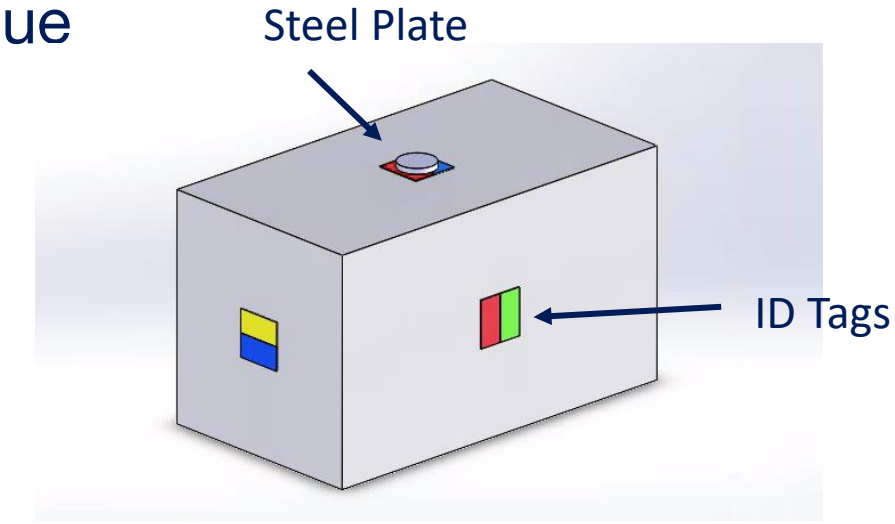
Electronics Summary



#	Component
1	Power Supply
2	UR Control Box
3	Limit Switch
4	UR-10
5	USB Power
6	Ethernet Sheild
7	Arduino Uno
8	RS-485 Sheild
9	Stepper Motor
10	Ethernet Tree
11	Pixy 2
12	Auto Switch
13	Solenoid

Cargo Bag Manufacturing

- Begin testing with rigid foam core box
- Improve fidelity as time allows
  - Complete full systems test with rigid 'bag' and then improve bag model
  - Work our way up to a true NASA cargo bag
- Stainless Steel plates: Attached with super glue
- ID tags: printed squares glued onto box



Overall Status

Component	Current Tasks	Status	Key Dates
Manufacturing (Machine Shop)	Measure Components Fabricate Test Stand	Started	Job Order Submission: Feb 5
Software	C++ Position Algorithms Command EEF Actuator Sample Arduino Comm Node	Started	Feb 8 Feb 8 Feb 15
Electronics	Assemble Arduino Connections Set up Cable Track	Not Started	Feb 15 Feb 15
Cargo Bag	Fabrication	Not Started	Complete By: Feb 8

Biggest Concerns:

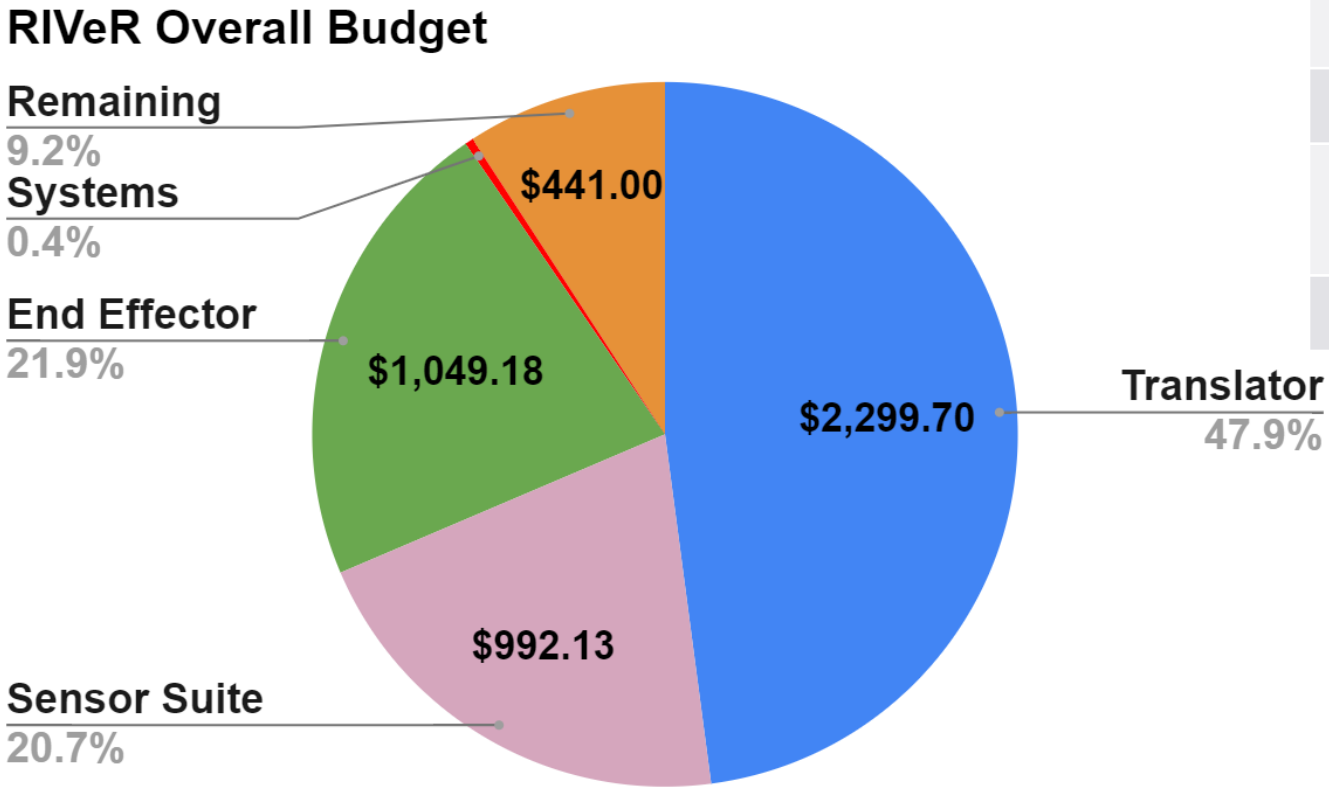
- Schedule Delays
- Assembly challenges
- Sofware integration across components and debugging

Section 4

Budget

Cost Plan

Budget



Subsystem	CDR Cost	Current Cost	Allocated Amount	Budget Margin
Translator	$1617.40	$2,299.70	$2500	$200.30
End Effector	$998.17	$1,049.18	$1200	$150.82
Sensor	$729.23	$992.13	$1082.01	$89.88
Systems	17.99	$17.99	17.99	$0
RIVeR Total	**$3,362.79**	**$4,224.73**	**$4800**	**$441.00**

Special Thanks

Sierra Nevada Corportation and Loren McDaniel

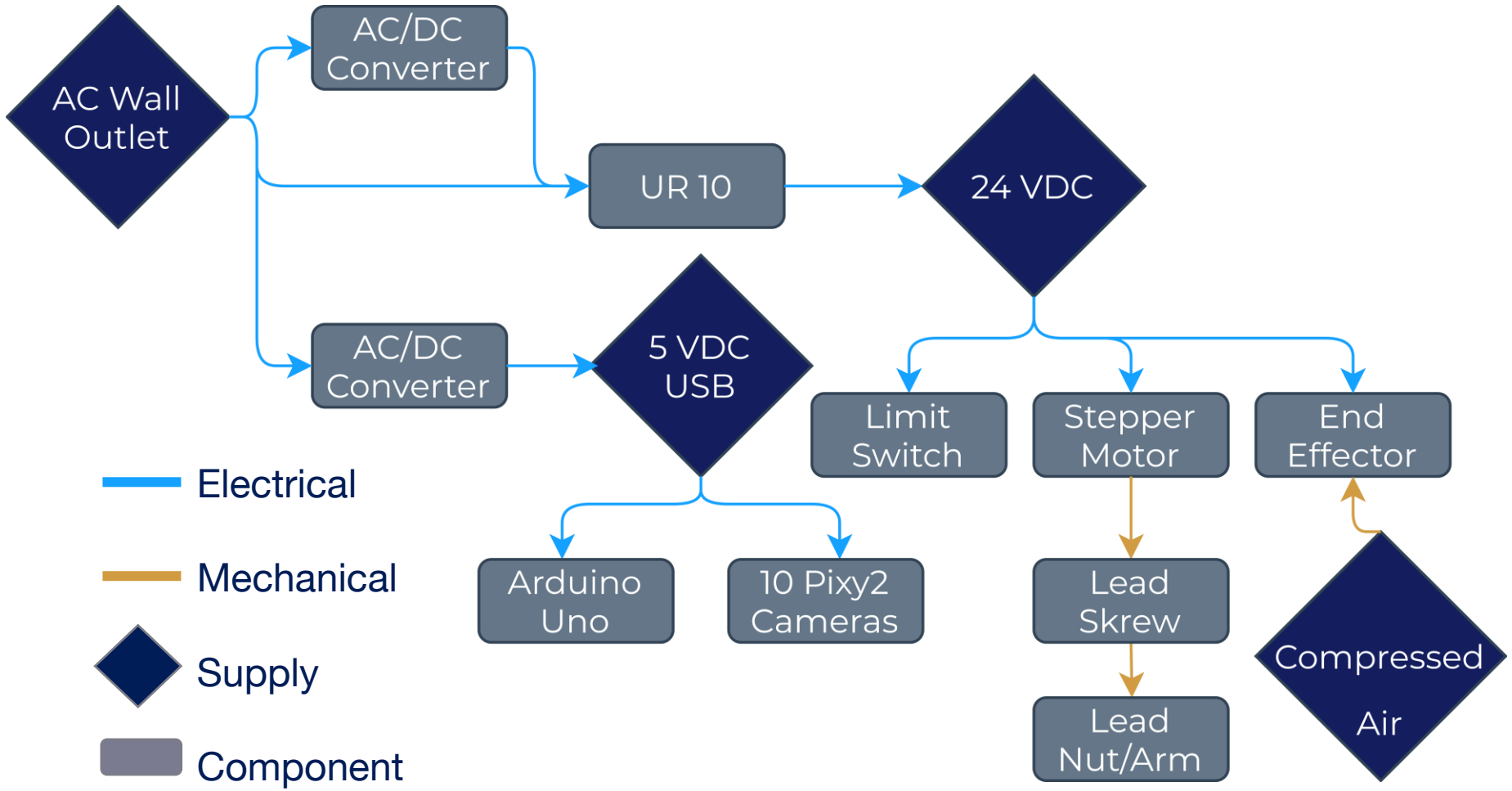
Dr. Neogi

CU Boulder Aerospace Department

PAB

Back Up

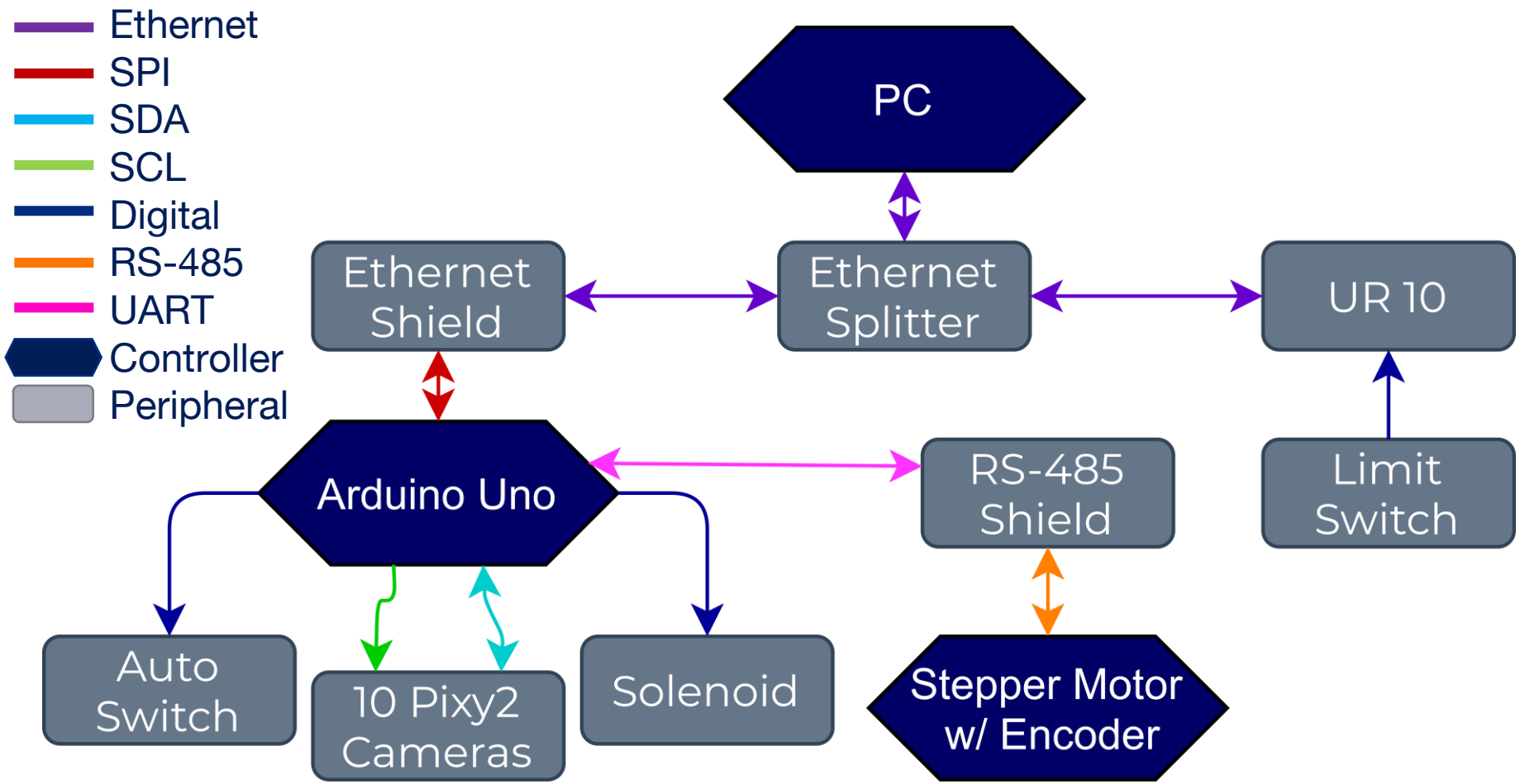
Power Budget



24 VDC	
Component	Power
UR 10	48 W
AC/DC	72 W
Limit Switch	-4.8 W
Stepper Motor	-72 W
End Effector	-20.72 W
Total	22.48 W

5 VDC - USB	
Component	Power
AC/DC	100W
Arduino	-.25 W
Pixy2s	-7 W
Total	92.75 W

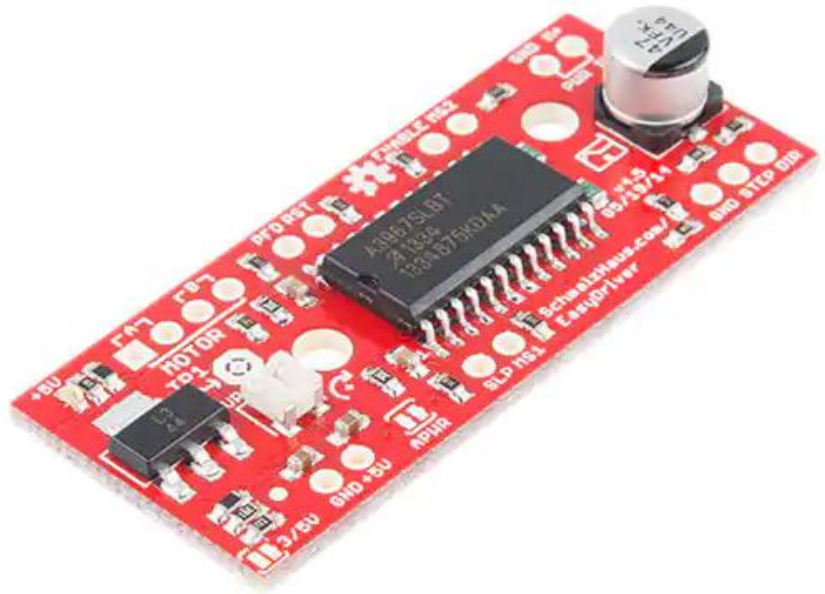
Data Budget



Component	Data Rate
10 Pixy2Cameras	1.15 Mbps
Stepper Motor	9.6 Kbps
Arduino Uno	2 Mbps
EthernetShield	100 Mbps
UR-10	100 Mbps
EthernetSplitter	1000 Mbps
PCRequirement	200 Mbps

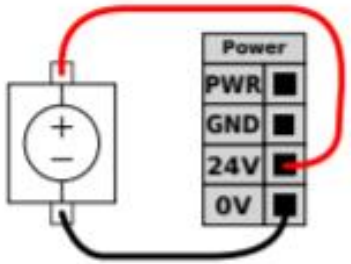
Solenoid Driver

- ROB-12779
  - Arduino Compatible
- Will use digital Logic from Arduino
- Enable line to Solenoid
- Powered from 24 V
  - Included with End Effector in power budget



Extra Power to UR-10

If more current is needed, an external power supply can be connected as shown below.



- 24V 3A Power Supply Attached
  - Adds to 2 A included
- Total Power From 24V Rail
  - 5 A
  - 120 W
- Includes free wire adapter

USB Power

- Arduino
  - Includes 1 Meter USB 2.0
  - .05 A 5 VDC
- Pixy 2 Cameras
  - Micro USB
  - 1 Meter Included
  - .14 A 5 VDC
- USB Power Supply
  - 2.4 A per port for multiple devices

Power Budget Cont.

24VDC Rail				
Part	**Current [A]**	**Voltage[VDC]**	**Number of Parts**	**Power[W]**
Power Supply	3	24	1	72
UR-10	2	24	1	48
Stepper Motor	-3	24	1	-72
Limit Switch	-0.1	24	2	-4.8
MHM 25	-0.8233333333			-20.72
Total	1.076666667			22.48

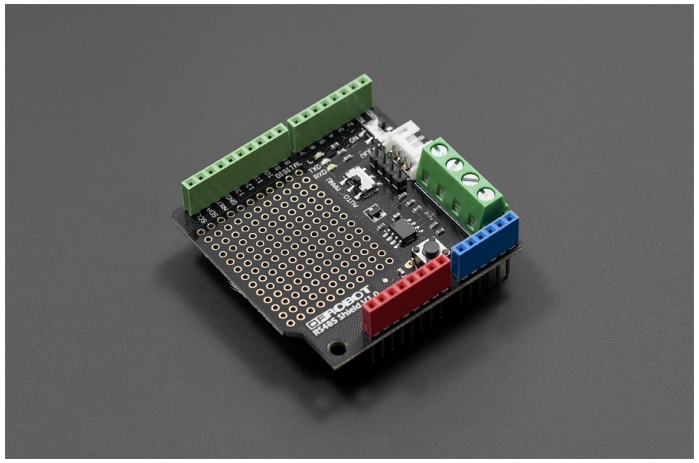
5 VDC Rail				
Part	**Current [A]**	**Voltage[VDC]**	**Number of Parts**	**Power[W]**
USB Power Supply	20	5	1	100
Arduino	-0.05	5	1	-0.25
Pixy2	-0.14	5	10	-7
Total				92.75

MHM 25 Breakdown				
Part	**Current [A]**	**Voltage[VDC]**	**Number of Parts**	**Power[W]**
D-M9PWV	-0.04	24	2	-1.92
Solenoid Driver	-0.75	24	1	-18
Solenoid	-0.01458333333	24		-0.35
Solenoid SY	-0.01875	24		-0.45
Total	-0.8233333333			-20.72

Voltage Rails	Parts
24 V	MHM 25, Stepper, Limit Switch
12 V	
5 V	Pixy 2, Arduino
30 V	

Stepper Motor

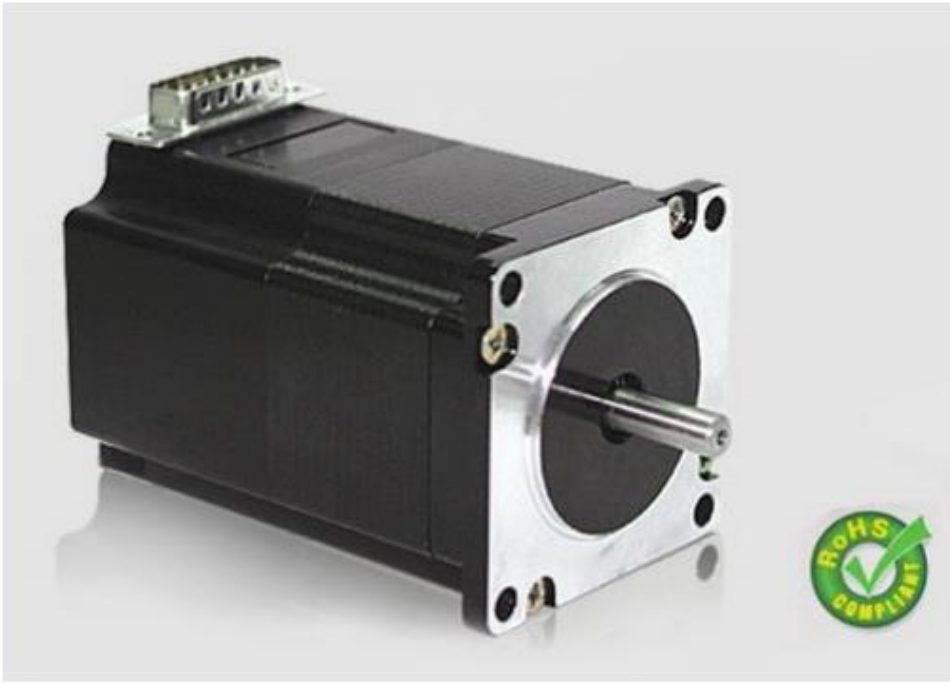
- RS-485
  - Differential signal
- Arduino used as PLC
  - Serial commands converted from UART to RS-485
  - Receives corrected encoder data
- RS-485 Shield



Silverpak 23C and 23CE

INTEGRATED STEP MOTOR, DRIVER AND CONTROLLER(CE)

(23CE With optional encoder feedback – closed loop)

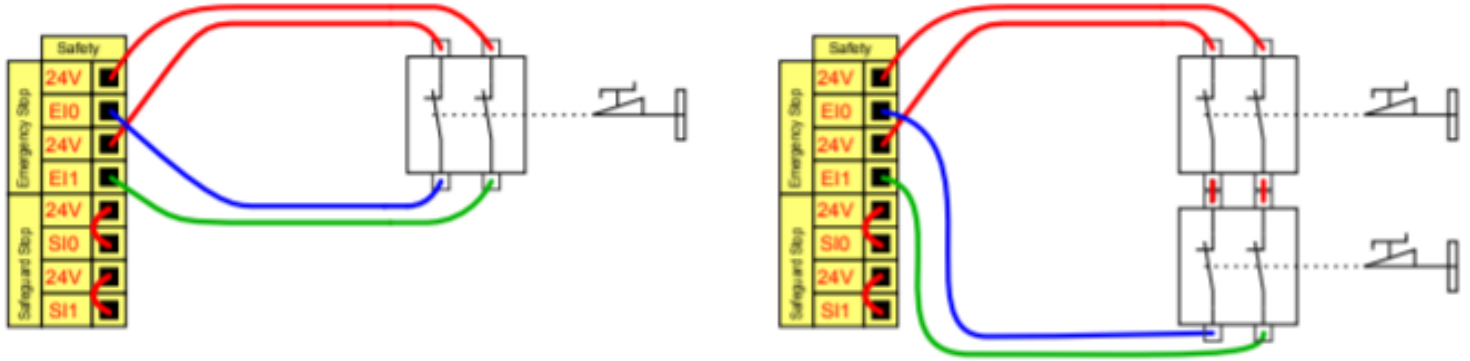


Limit Switch

- 2 Limit Switches
- Connected to emergency stop
- 2 Pin outs
- 24V limit switch selected.

4.3.2.2 Connecting emergency stop buttons

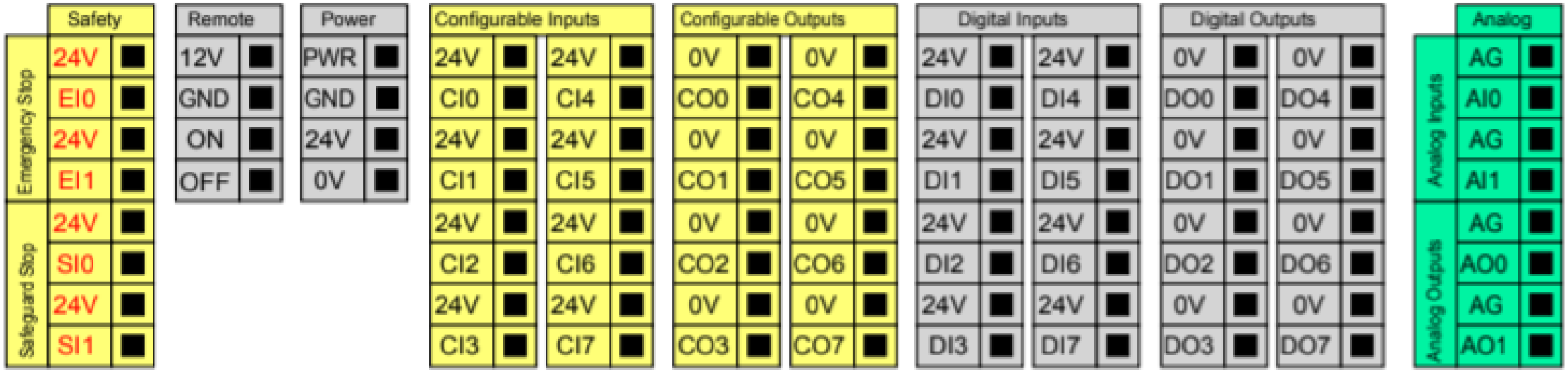
In most applications it is required to use one or more extra emergency stop buttons. The illustration below show how one or more emergency stop buttons.



Wiring

- 75 ft needed
  - 180 ft accounted for
- 24 Gauge Wire Selected
- 30 T2 connectors to split I2C and power lines

UR-10 Electronics Interface

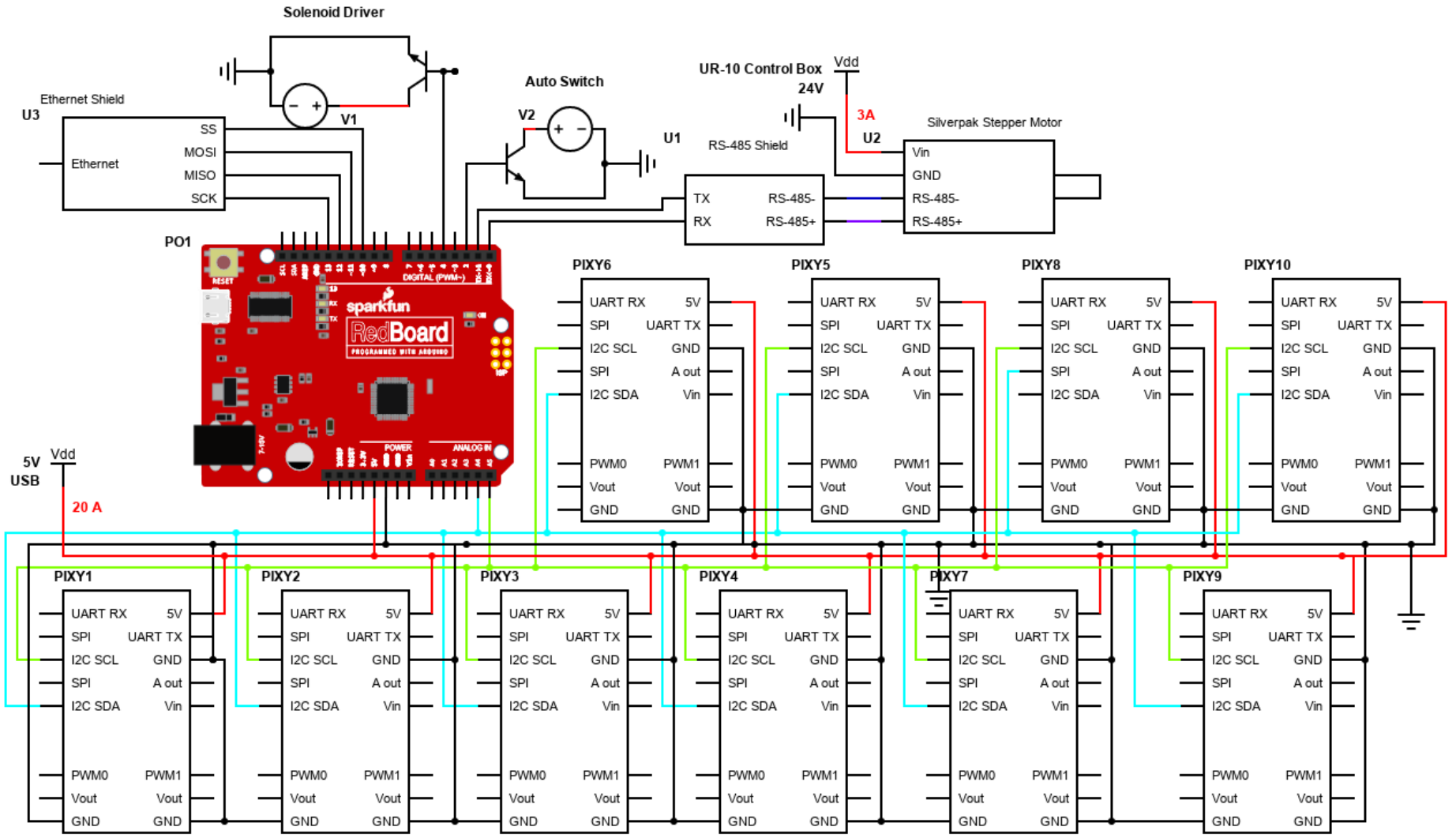


Arduino Uno Pin Out

Pin	Function	Device
RX0 (Pin 1)	UART RX	RS-485 Shield
TX0 (Pin 2)	UART TX	RS-485 Shield
Digital 3	Logic High/Low	Solenoid Driver
Digital 4	Logic High/Low	Auto Switch
Digital 10	SS	Ethernet Shield
Digital 11	MOSI	Ethernet Shield
Digital 12	MISO	Ethernet Shield
Digital 13	SCK	Ethernet Shield
Analog 4	SDA	Pixy2 Cameras
Analog 5	SCL	Pixy2 Cameras

Electronics Diagram

SDA
SCL
Power
Ground



Translater Item Tracking

Translater	Cost	Needed	Spares	Total	Shipping	Total Cost	Status
Motor	$643.00	1	0	1	$17.45	$660.45	Delivered
Linear Stage	$749.99	1	0	1	$0.00	$749.99	Delivered
Limit Switch	$3.06	2	0	2	$0.00	$6.12	Delivered
Stepper Motor Power Supply	$19.99	1	0	1	$0.00	$19.99	Delivered
Bumper Pads	$10.97	1	0	1	$0.00	$10.97	Delivered
AL 6061 1/2"	$183.74	1	0	1	$42.44	$226.18	Delivered
Al 6061 1.75"	$106.03	1	0	1	$0.00	$106.03	Delivered
Rubber Washer	$6.07	1	0	1	$0.00	$6.07	Delivered
Linear Coupler 1/2" - 1/4" Zinc Plate Steel	$26.62	1	0	1	$0.00	$26.62	Delivered
UR10 Baseplate	$154.64	1	0	1	$22.51	$177.15	Delivered
Precision Bubble Leveler	$13.29	2	0	2	$0.00	$26.58	Not Ordered
Cable Carrier	$108.84	1	0	1	$0.00	$108.84	Transit
Cable Mounting Brackets	$8.44	1	0	1	$0.00	$8.44	Transit
Strut Channel - Zinc Plate Steel	$28.78	4	0	4	$0.00	$115.12	Transit
Hex Head Screw (x5)	$10.20	4	1	5	$0.00	$10.20	Transit
Hex Nut (x5)	$4.73	4	1	5	$0.00	$4.73	Transit
							Transit
					Overall	**$2,263.48**	

End Effector Item Tracking

End Effector	Cost	Needed	Spares	Total	Shipping	Total Cost	Status
Manual Dump Valve	$50.85	1	0	1	$0.00	$50.85	Delivered
Filter/Regulation Combo	$32.20	1	0	1	$0.00	$32.20	Delivered
Electronic Dump Valve	$131.65	1	0	1	$0.00	$131.65	Delivered
Coupler w/ wall mount bracket	$6.40	2	0	2	$0.00	$12.80	Delivered
Pressure Gauge	$11.00	1	0	1	$0.00	$11.00	Delivered
Single Solenoid Valve	$64.52	1	0	1	$0.00	$64.52	Delivered
Solenoid Valve Silencers	$3.50	2	0	2	$0.00	$7.00	Delivered
Speed Controller Valve	$7.03	2	0	2	$0.00	$14.06	Delivered
1/4" Tube to 10-32 straight connector (inter	$4.12	2	8	10	$0.00	$41.20	Delivered
1/4" Tube to 1/4 NPT Elbow	$2.82	2	8	10	$0.00	$28.20	Delivered
Magnetic Gripper	$491.45	1	0	1	$0.00	$491.45	Delivered
Solid State Sensors	$44.62	2	0	2	$0.00	$89.24	Delivered
1/4" Polyurethane Tubing, Black, 20 meters	$24.00	1	0	1	$0.00	$24.00	Delivered
Solenoid Driver	$14.95	1	0	1	$7.99	$22.94	Delivered
Manual Dump Valve Coupler	$5.49	1	0	1	$0.00	$5.49	Delivered
					Overall	$1,026.60	

Sensor and System Item Tracking

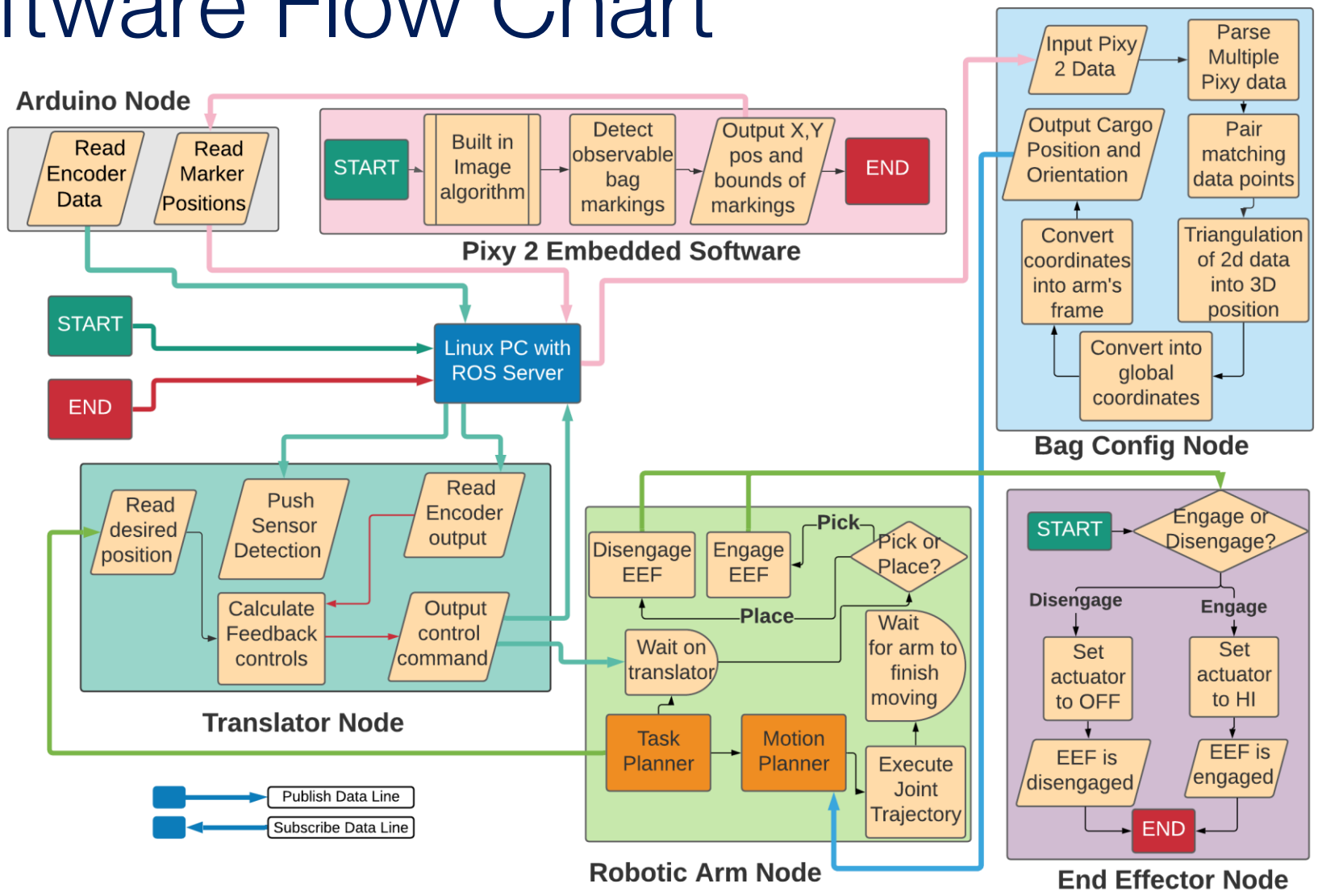
Sensors	Cost	Needed	Spares	Total	Shipping	Total Cost	Status
Tracking Camera	$55.00	10	0	10	$0.00	$550.00	Delivered
Microcontroller - Arduino UNO R3	$23.00	1	0	1	$0.00	$23.00	Delivered
Arduino Ethernet Shield	$24.40	1	0	1	$0.00	$24.40	Delivered
T Type Connector	$10.65	3	0	3	$0.00	$31.95	Delivered
24 Gauge Wire	$13.99	1	0	1	$0.00	$13.99	Delivered
USB Power	$39.99	1	0	1	$0.00	$39.99	Delivered
High-Pressure Pipe	$1.49	9	0	9	$0.00	$13.41	Transit
PVC Pipe	$6.33	6	0	6	$0.00	$37.98	Transit
PVC Pipe Fitting	$0.45	33	0	33	$0.00	$14.85	Transit
Snap-Link Socket with Plate	$4.49	10	0	10	$0.00	$44.90	Not Ordered
Snap-Link Ball with Plate	$4.99	10	0	10	$0.00	$49.90	Not Ordered
					Overall	**$844.37**	

Systems	Cost	Needed	Spares	Total	Shipping	Total Cost	Status
Ethernet Tree	$17.99	1	0	1	$0.00	$17.99	Delivered
					Overall	**$17.99**	

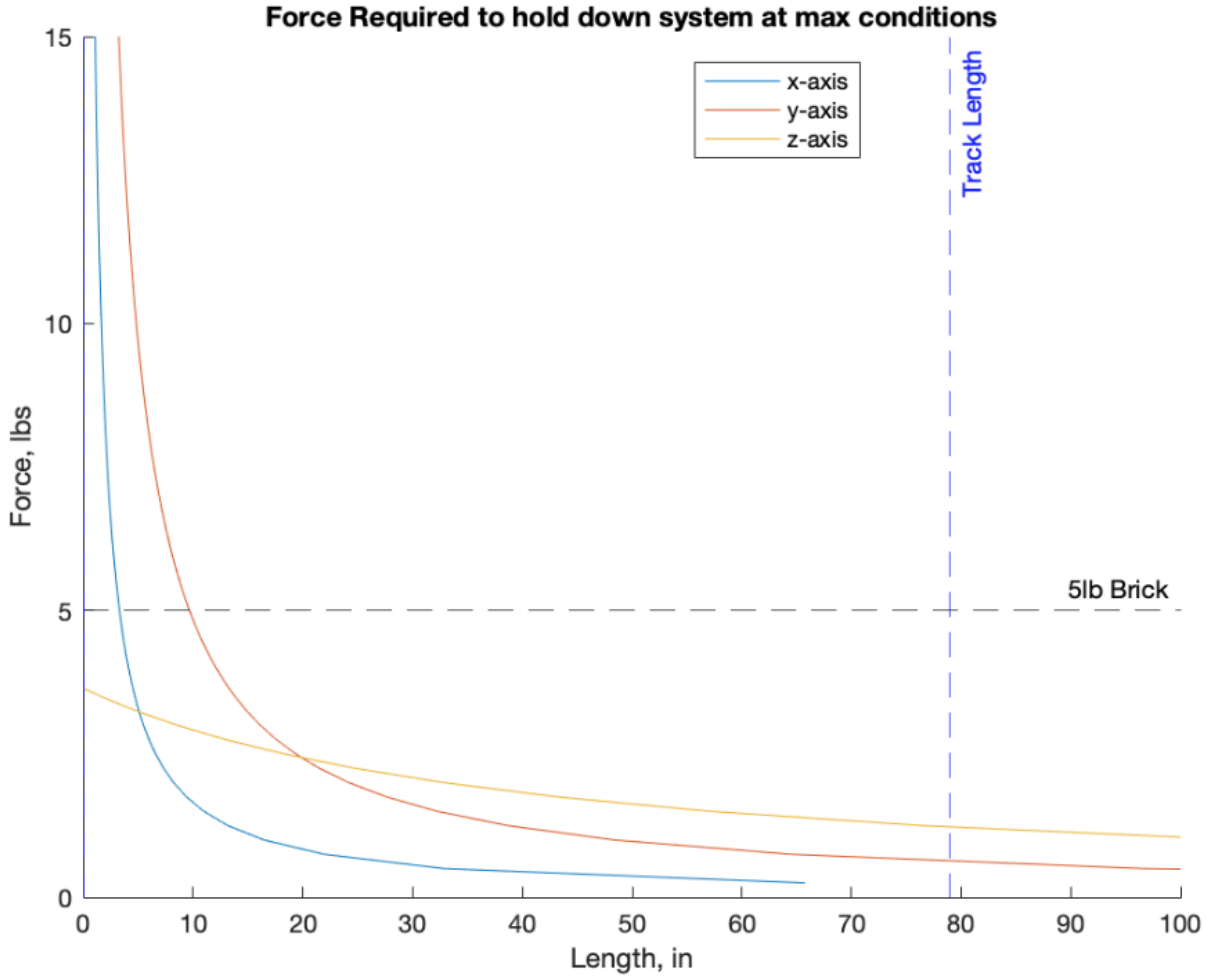
Software Test Descriptions

- Hardware Communication Tests
  - Motor Encoder data read: Read the position of the translator into ROS
  - Pixy2 data read: Read the position of observed markers from multiple Pixy2 cameras into ROS
  - UR10 Example Controllers: Command the UR10 using Universal Robotics Driver example controllers
  - Limit Switch/Contact Sensor data read: Read binary outputs from limit switches and contact sensors
- Algorithm Unit Tests
  - Position Determination: Verify the correctness of the position determination algorithm using isolated unit tests in C++
  - Orientation Determination: Verify the correctness of the Orientation determination algorithm using isolated unit tests in C++
  - Task Planner: Verify the feasilbility and correctness of the output task sequence by varying input queries
- Complete Node Unit Tests
  - Converting Pixy data to configuration: Read in pixy data from multiple cameras simultaneously then be able to output the best fit configuration of the bag that the markers are representing
  - Translator Position Command: Send a desired linear position to the translator node and verify the translator moves to the desired position
  - End Effector Command Test: Send an "engage" or "disengage" command to the end effector and verify the end effector engages or disengages
  - Real-time Task Planner Execution: Execute a task sequence from the Robot Arm Node and verify that all components execute sub actions correctly

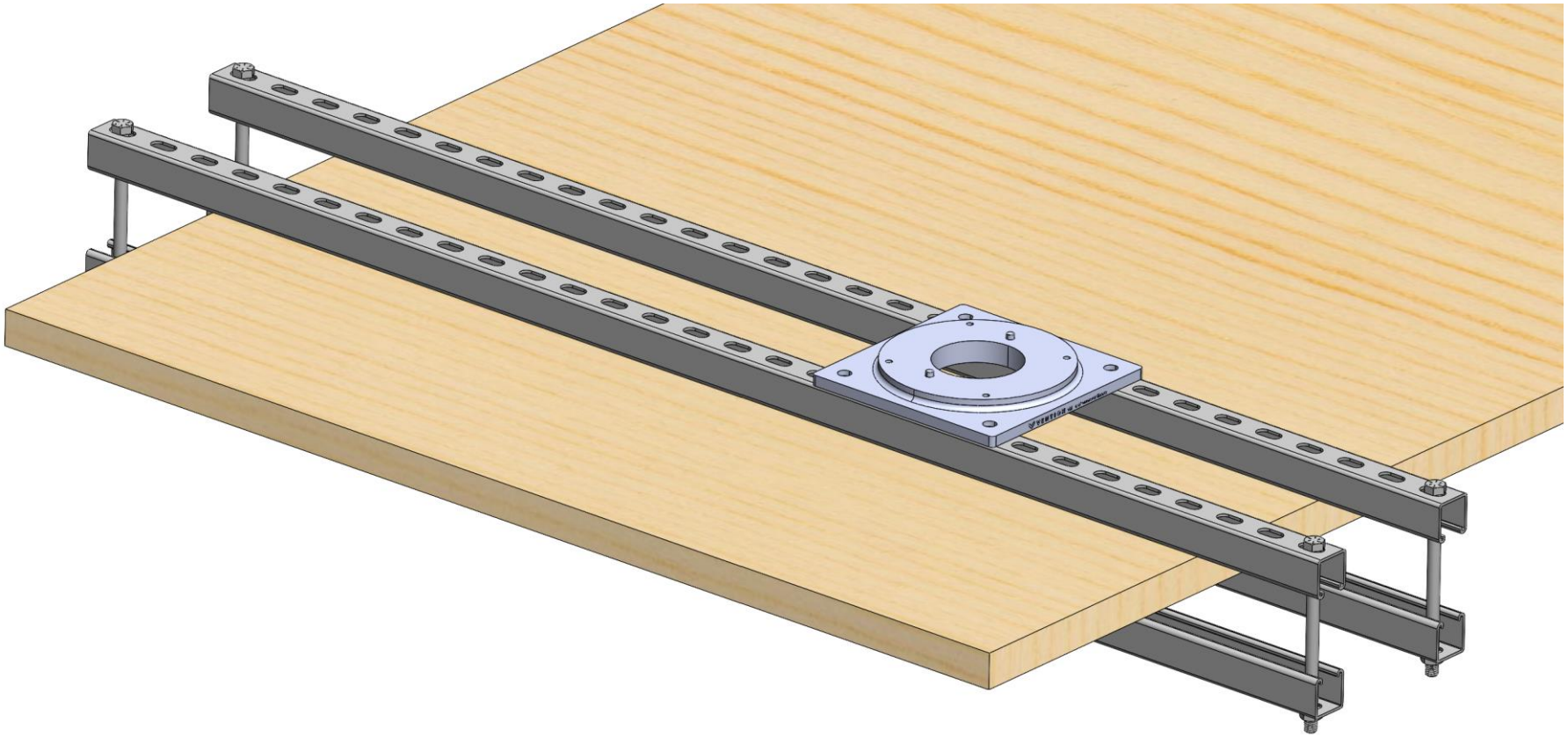
Software Flow Chart



Feasibility of Mounting



Robotic Arm Stationary Mount



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RViz Demonstration