Team 19 : Construction Marking Robot

Interim Design Review

Team Members: Justin Gibbs, Kelsey Howard, Brandon Roberts, Derrick Portis, and Christian Baez

Sponsor: Mark Winger, PSBI

Advisors: Dr. Collins, Dr. Gupta

Date: November 19, 2015

Presentation Outline

- Introduction
- Our Approach
  - Converting layout file to coordinates
  - Sending data to robot
  - Localization
  - Marking Mechanism
  - Obstacle Avoidance
- Planning for the Future

Introduction

Background

- Productivity in the Construction Industry has been low since the recession
- The Team's Sponsor, Mark Winger of PSBI saw the inclusion of more technology into the industry as a solution
- One area where this could be proven:
  - Manual layout of floorplans on site
    - Inefficient in terms of time duration
    - Prone to high error propagation due to human error and miscommunication amongst multiple contractors
    - The inclusion of a robot to assist in this process could save the industry both time and money by working more efficiently and accurately

Project Scope

- The scope of this project is to implement a "proof of concept" marking robot which can:
  - Receive a CAD file of a floorplan and mark it out on concrete
  - Do so within ½" accuracy
  - Navigate autonomously and avoid obstacles
  - Generate an error report

Need Statement

"The ***construction industry*** is in need of a means of **increasing efficiency and productivity** as well as **reducing the amount of time and error** that goes into laying out floor plans ***manually.***"

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Goal Statement

"Implement a '**<u>proof of concept</u>**' high **<u>precision marking robot</u>** that will lay out the preliminary ***floor plan of a construction site,*** increasing **<u>efficiency and productivity</u>** of the layout process."

Objectives

- Add functionality to robot to receive a CAD file of a floor plan and convert it into useable coordinates
- Design, fabricate, and implement a marking mechanism
- Make the robot able to navigate autonomously, avoid obstacles, and generate an error report

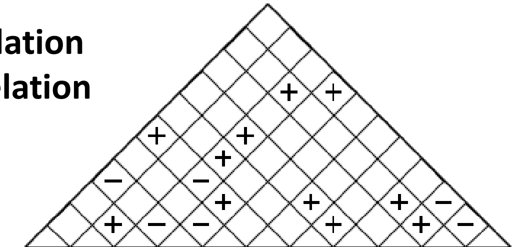
Design Requirements

- The final product must be:
  - Able to make marks within ½ ” accuracy
  - Easily portable
  - Able to mark on concrete
  - Able to mark across 100 sq. ft. within 10 minutes
  - Able to navigate autonomously

House of Quality

- Most Important Engineering Characteristics:
  - Autonomy
  - Weight
  - Battery Life
  - Rate of Coverage
  - Precision
- Selling Points:
  - Functionality (Able to complete exact task)
  - Speediness

+ : Positive Correlation
- : Negative Correlation



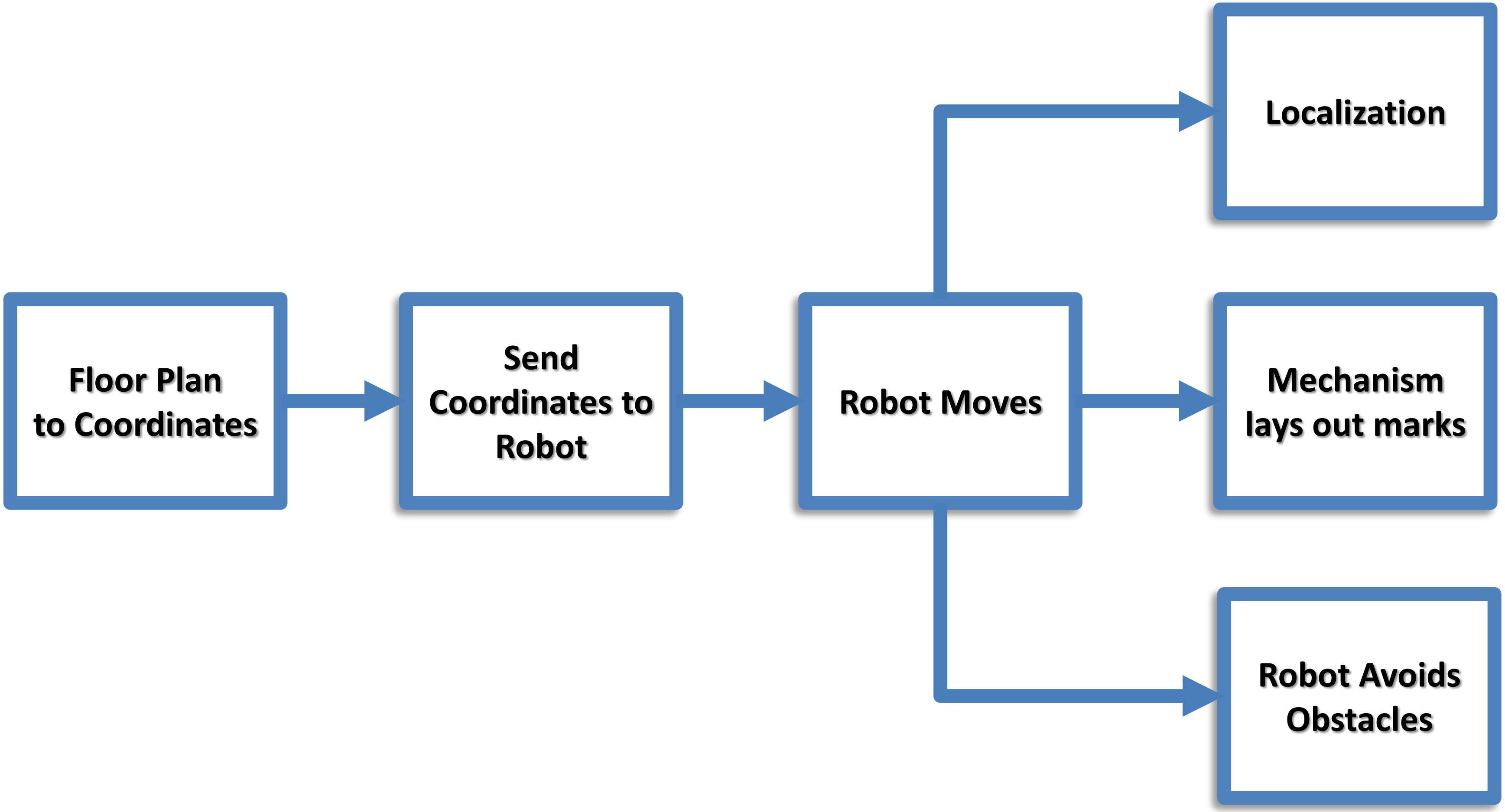
Rank on a scale of 1-10 (highest)

Engineering Characteristics													
Customer Requirements	**Customer Importance**	Rate of Coverage	Material	Weight of Device	Battery Life	Precision	Total Area Coverage	Number of Colors	Size	Set up Time	Number of User Controls	Autonomy	**Selling Points**
Functionality	**10**	10			10	10	7	7				10	540
Easy to Operate	**7**			3						10	10	3	182
Lightweight	**7**		3	10					7				140
Safety	**7**			3									21
Portability	**7**		3	10					7				140
Price	**3**		7		10							7	72
Durability	**3**		10		3								39
Aesthetically Pleasing	**1**		3										3
Serviceability	**3**										7		21
Speediness	**10**	10		3	7	10	3	3	7	10	7	10	700
	Importance Weighting	200	96	212	209	200	100	100	168	170	191	242	

Our Approach

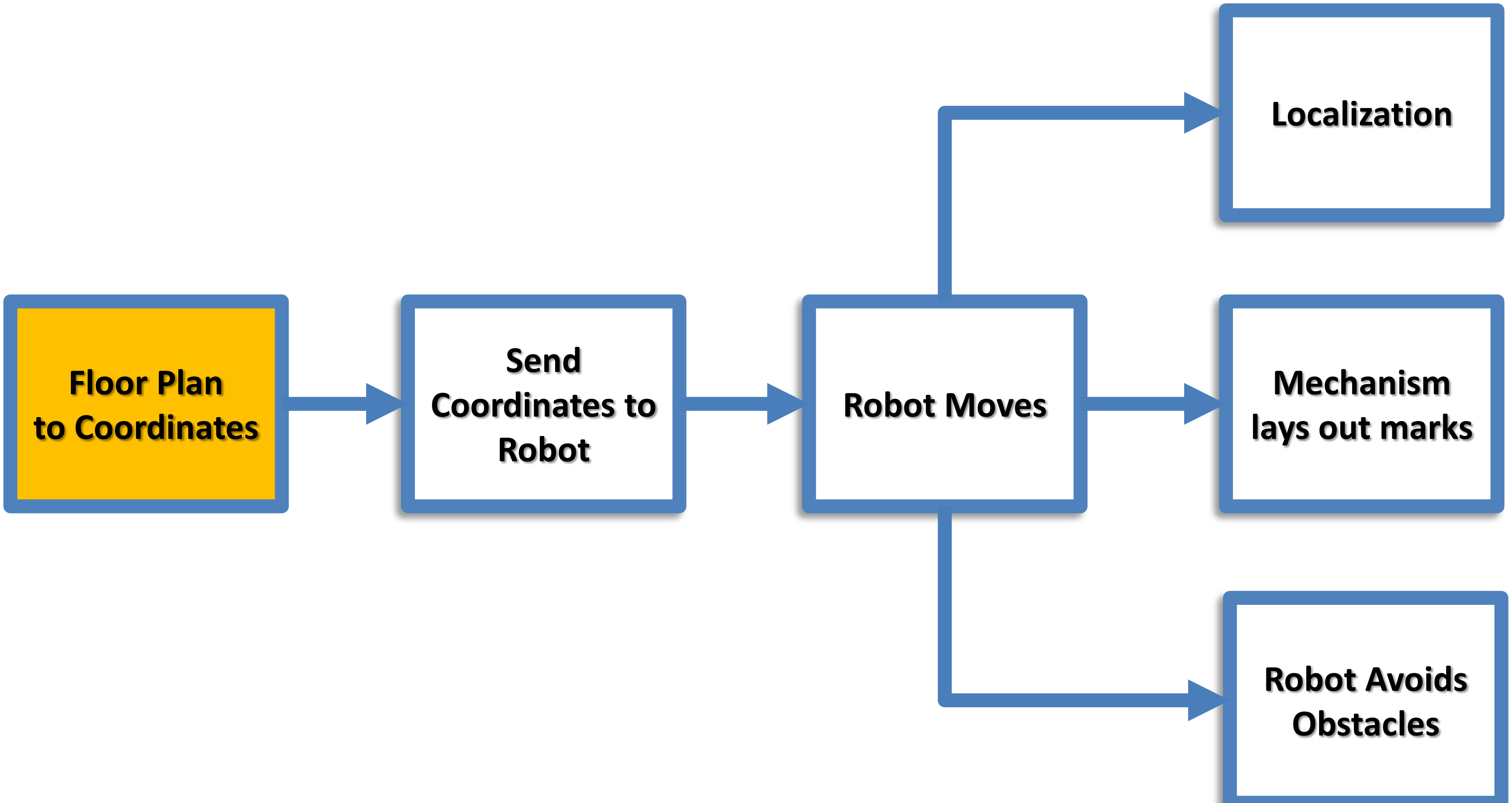
Justin Gibbs

Our Approach



Derrick Portis

Our Approach



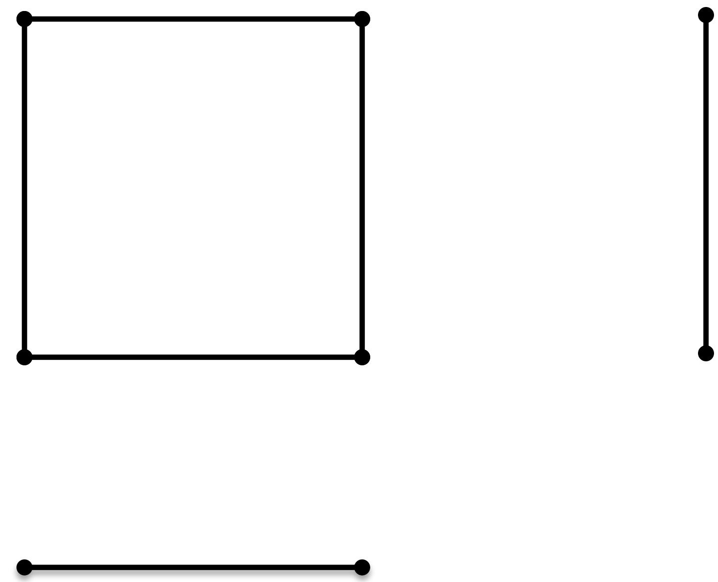
Derrick Portis

Converting the Floor Plan

- Turning the CAD file into a usable coordinate file
  - dxf -> txt
  - Makes file understandable to the robot
- Coordinates will aid the robot to move in space
- Robot must be able to recognize when to mark
- Generating more densely populated coordinate points
  - Greater precision
  - Minimize marking line loss due to obstacle avoidance

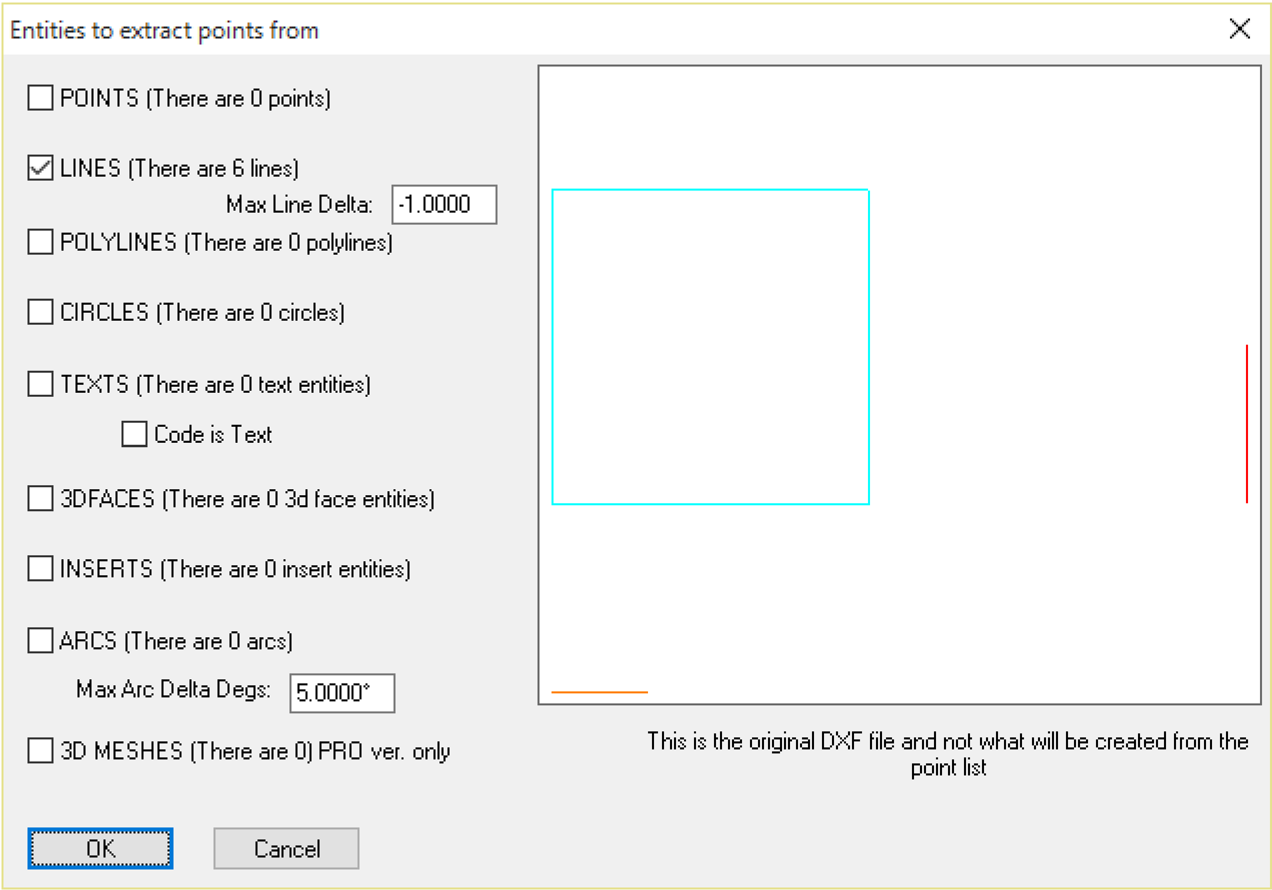
Converting the Floor Plan

- **<u>Ransen Software : Pointor</u>**
  - Reads in CAD (dxf file type)
  - Analyzes the CAD structure
  - Replaces lines with endpoint coordinates
  - Generates a point list of coordinates
  - Able to export point list to a text file



Converting the Floor Plan

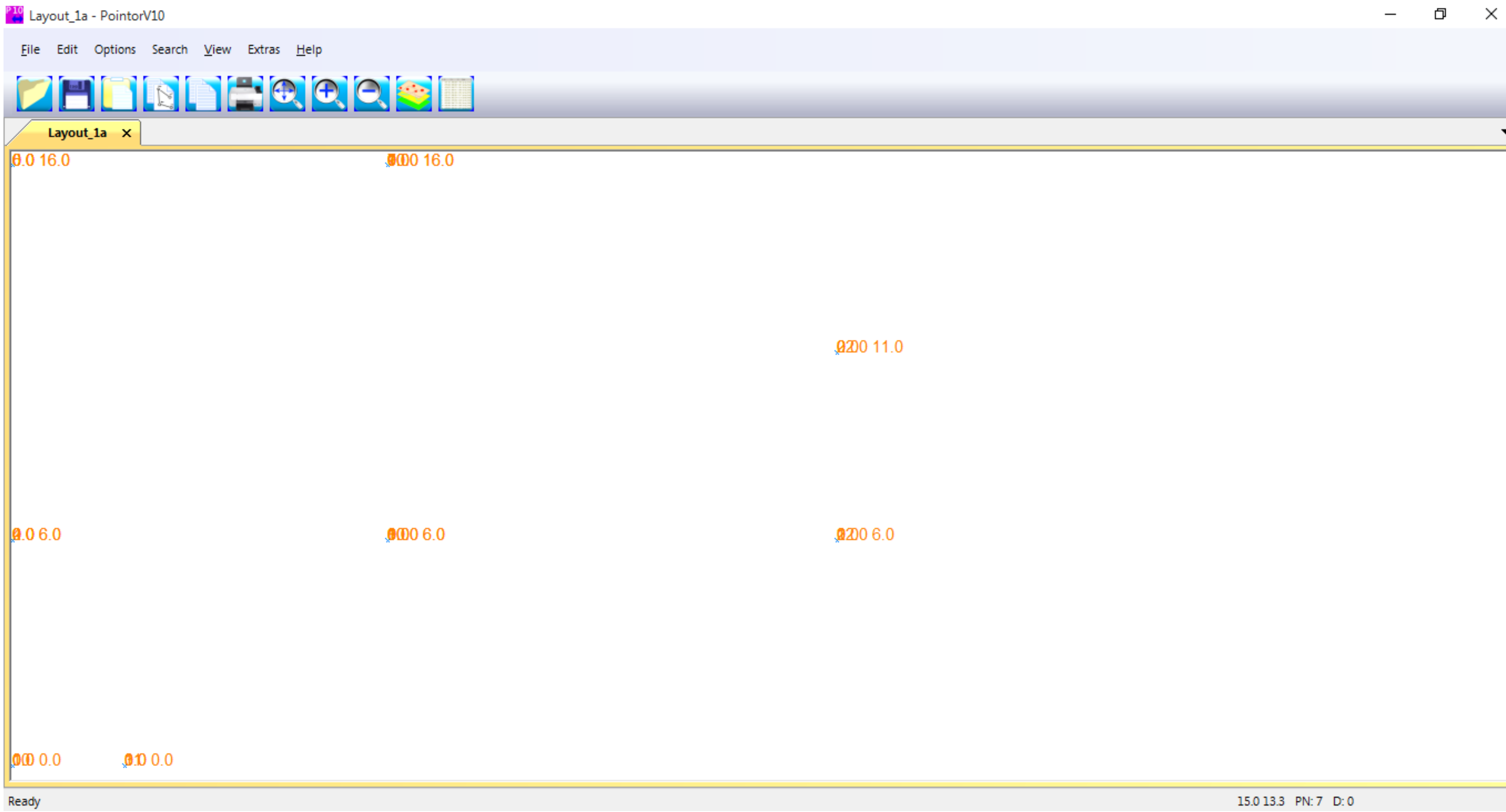
Ransen Software : Pointor



Derrick Portis

PSBI
Construction Marking Robot

Converting the Floor Plan



Derrick Portis

PSBI
Construction Marking Robot

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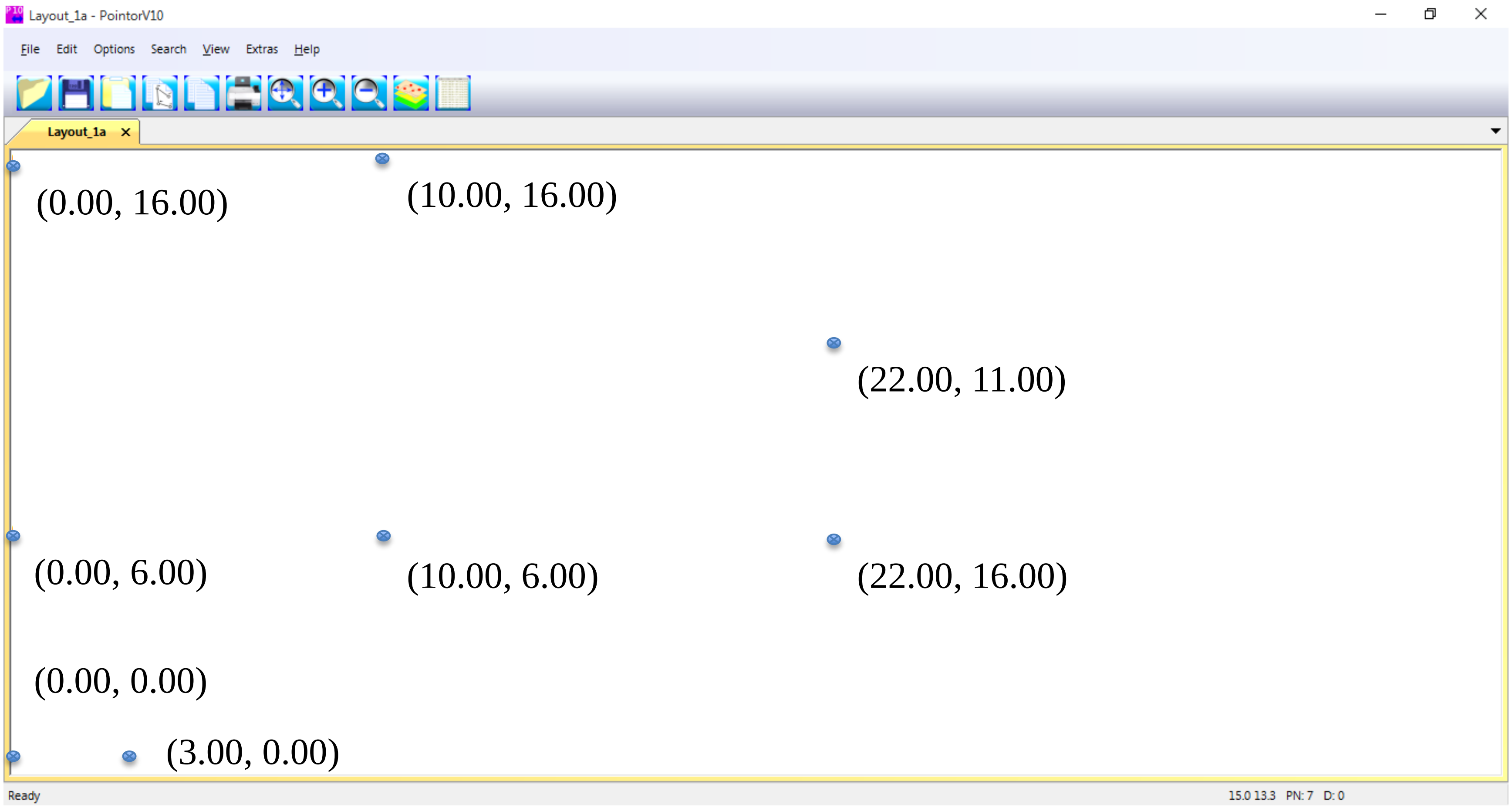


Converting the Floor Plan

- Coordinates come in pairs
  - Endpoints of a line
- Repeating coordinates occur when multiple lines have the same endpoint
  - i.e. Corner or square

Point list: Layout_1a

Code	X	Y	Z	Desc	Flags
0	22.0000000000	11.0000000000	0.0000000000	0	
1	22.0000000000	6.0000000000	0.0000000000	0	
2	0.0000000000	6.0000000000	0.0000000000	0	
3	10.0000000000	6.0000000000	0.0000000000	0	
4	0.0000000000	6.0000000000	0.0000000000	0	
5	0.0000000000	16.0000000000	0.0000000000	0	
6	0.0000000000	16.0000000000	0.0000000000	0	
7	10.0000000000	16.0000000000	0.0000000000	0	
8	10.0000000000	6.0000000000	0.0000000000	0	
9	10.0000000000	16.0000000000	0.0000000000	0	
10	0.0000000000	0.0000000000	0.0000000000	0	
11	3.0000000000	0.0000000000	0.0000000000	0	

Output of Pointor Program

Point Propagation

Initial Data Points

```
0 22.000000000 11.000000000
1 22.000000000 6.000000000
```

↓

Density Propagation Program

Point Propagation

Initial Data Points

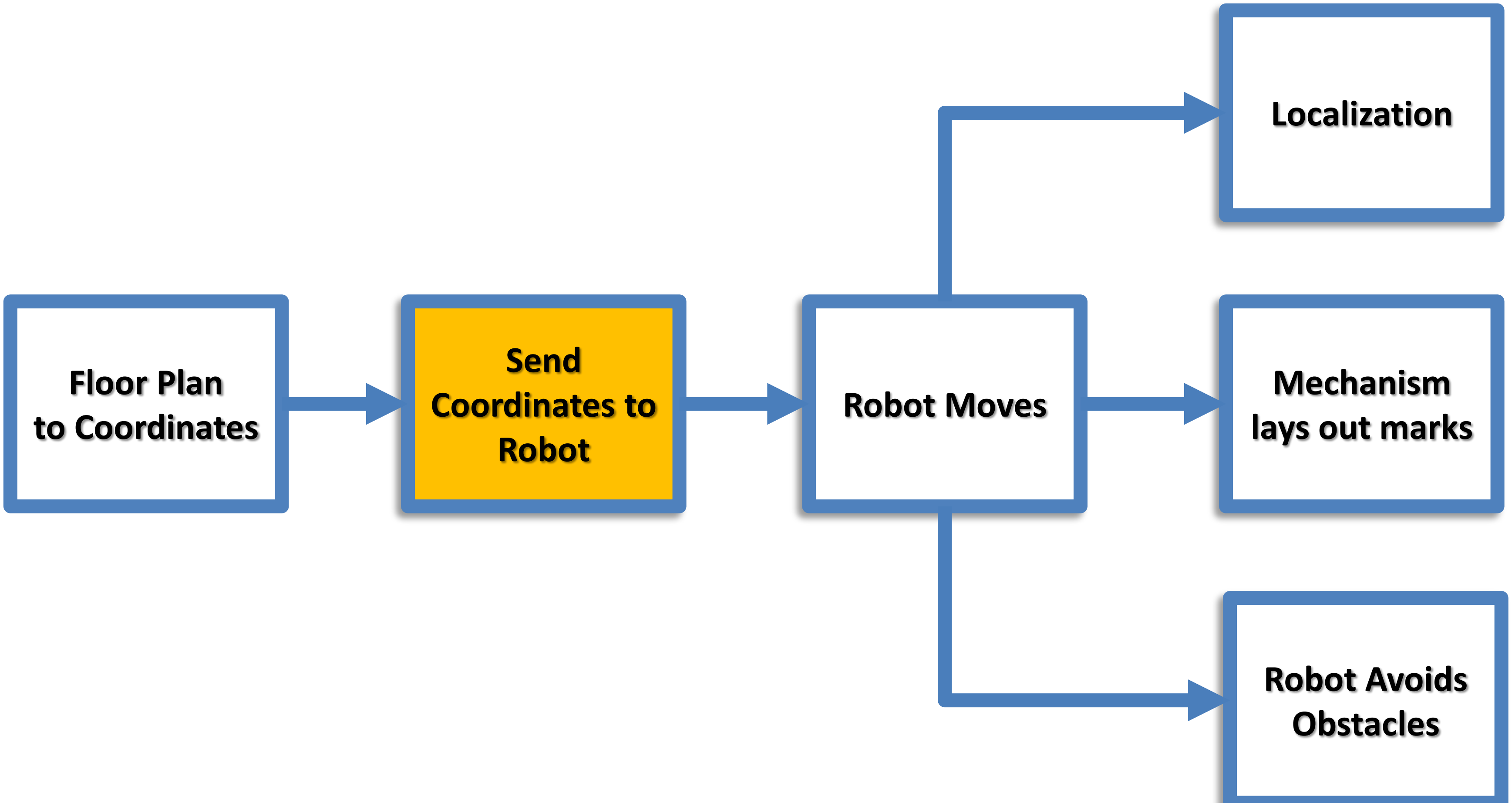
```
0 22.000000000 11.000000000
1 22.000000000 6.000000000
```

Density Propagation Program

Propagated Data Points

```
Start point (22.00, 11.00)
Intermed point: (22.00, 10.50)
Intermed point: (22.00, 10.00)
Intermed point: (22.00, 9.50)
Intermed point: (22.00, 9.00)
Intermed point: (22.00, 8.50)
Intermed point: (22.00, 8.00)
Intermed point: (22.00, 7.50)
Intermed point: (22.00, 7.00)
Intermed point: (22.00, 6.50)
End point (22.00, 6.00)
```

Our Approach



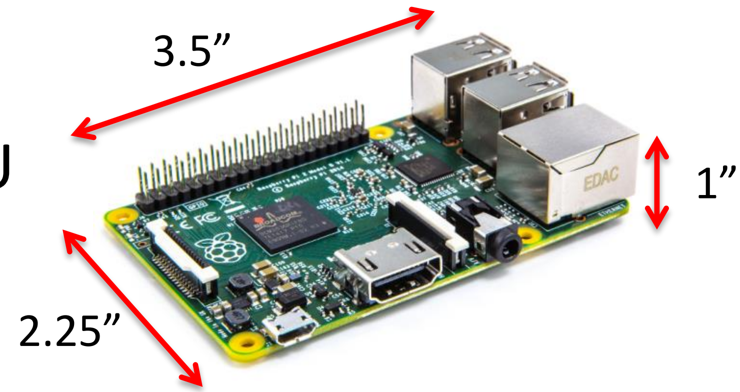
Derrick Portis

Software and Hardware Integration

- Needed for robot to read text file
- The marking attachment, robot, and external localization device have to be able to communicate with one another
- Microprocessor has the programming capability and power to control everything

Raspberry Pi 2

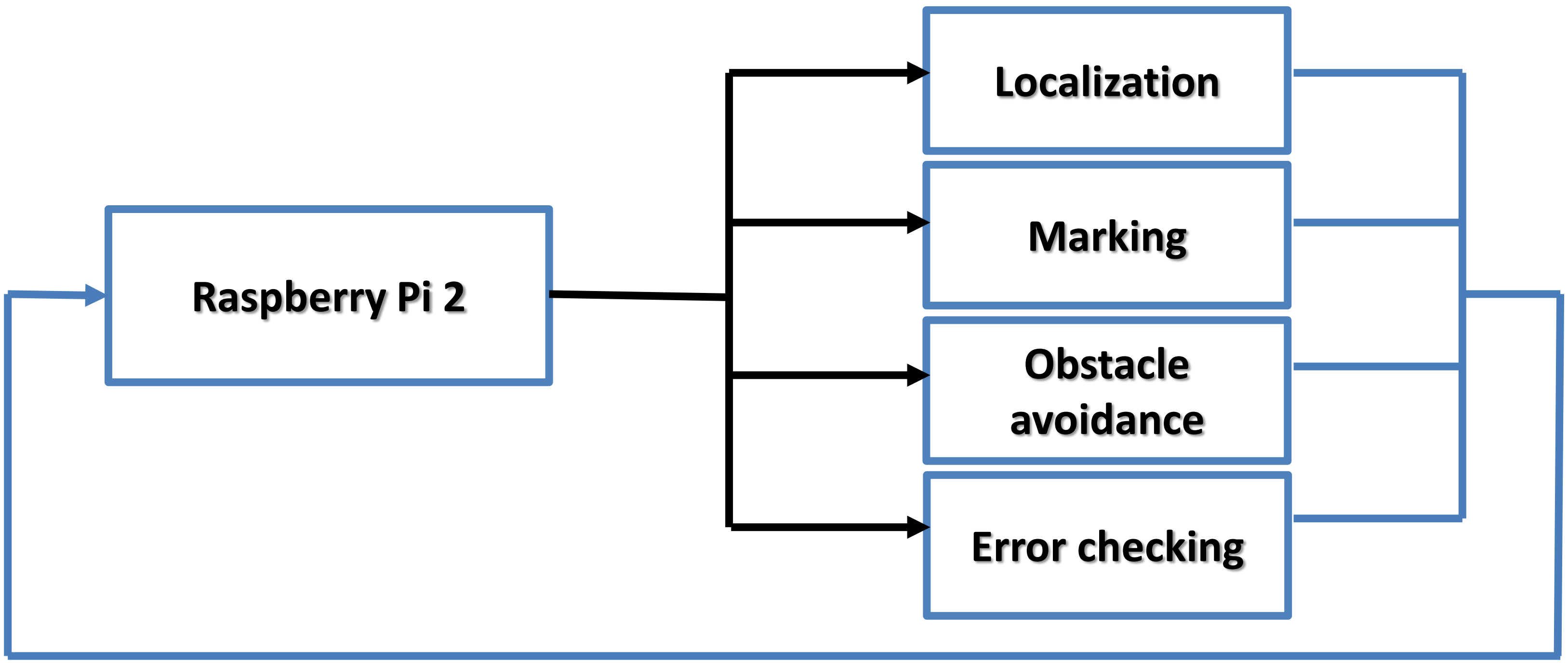
- Specifications
  - 900MHz quad-core CPU
  - 1 GB RAM
  - 40 GPIO pins



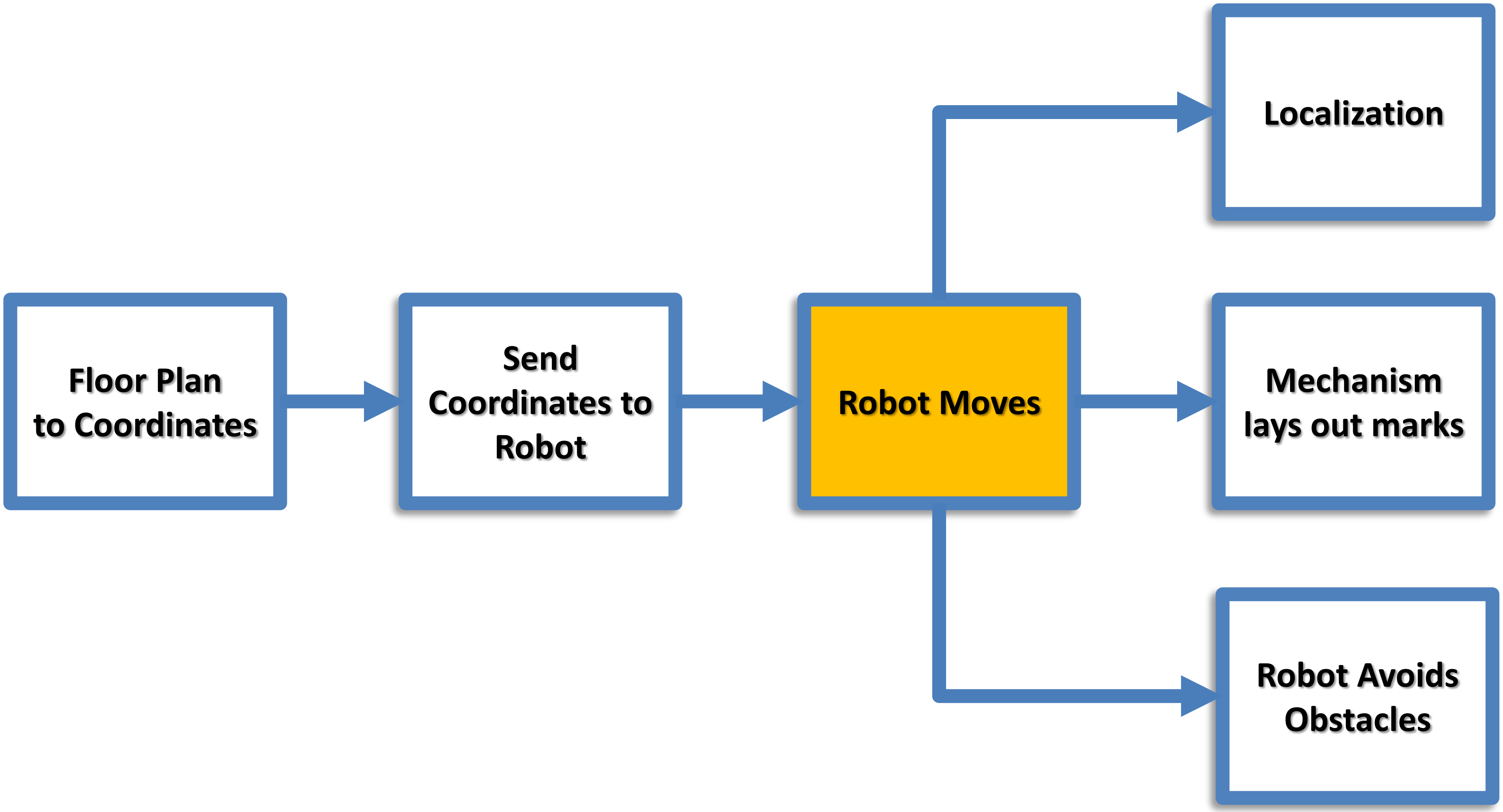
- Will run high level code that sends text file to robot
- Controlling marking mechanism and executes movement functions in response to external sensors
- Will operate on Windows 10 IoT Core OS to run programs and executable files

Software and Hardware Integration

- Raspberry Pi 2 will be the medium for the system

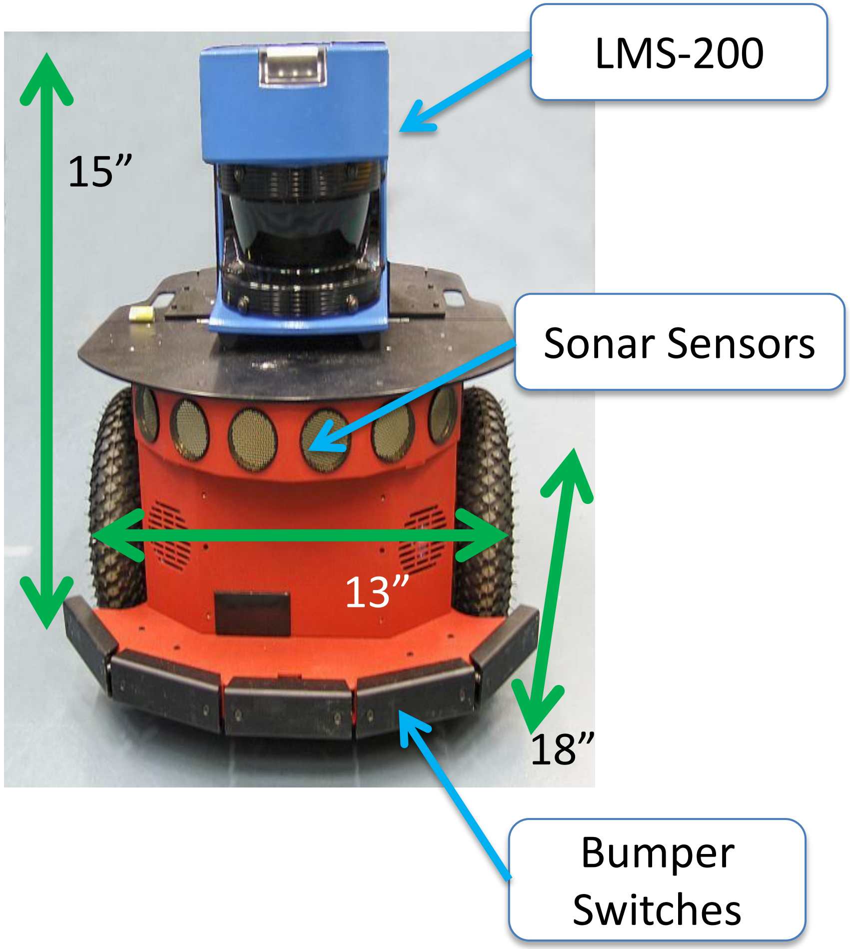


Our Approach

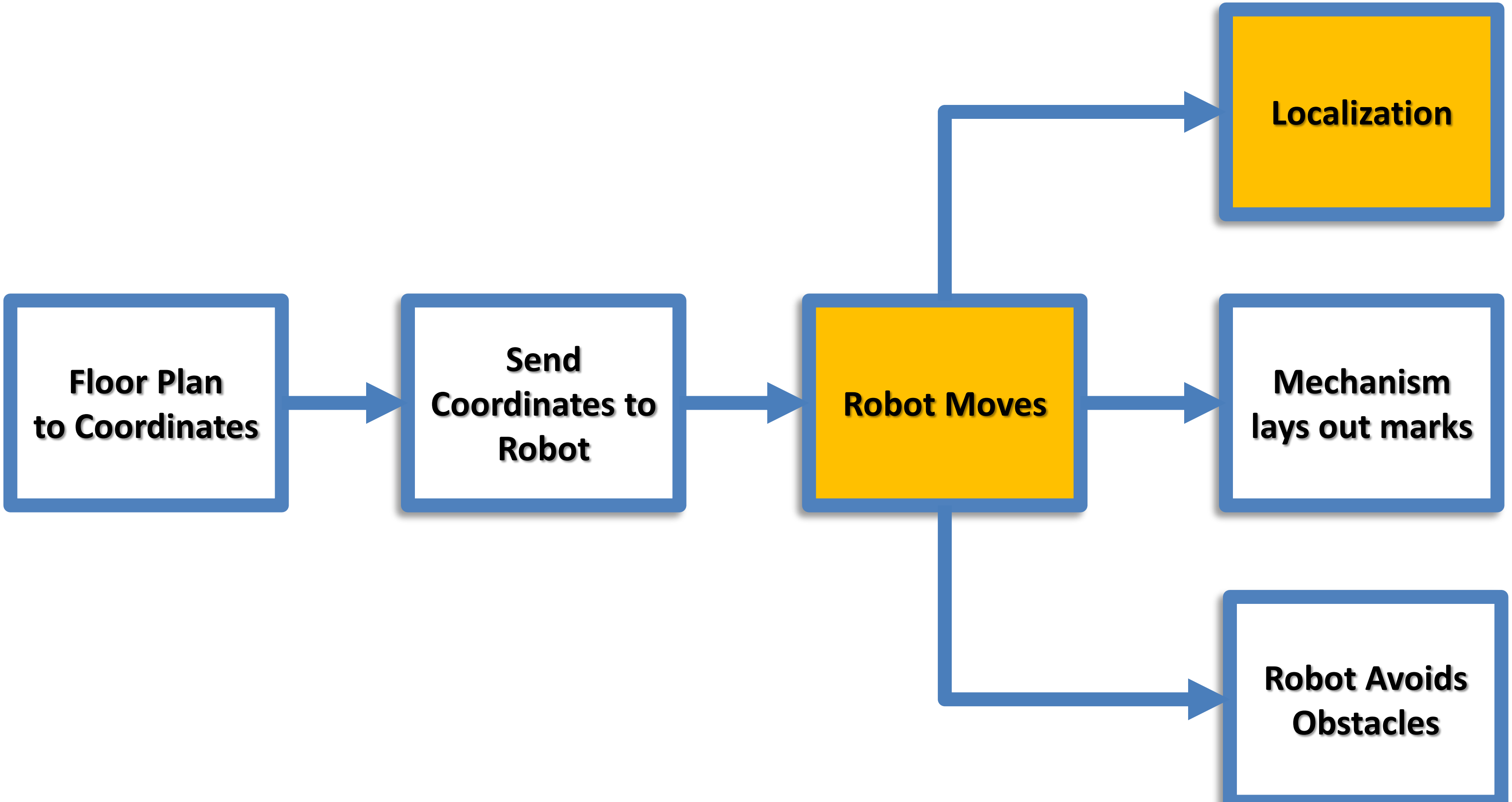


Pioneer 2-DX

- Provided by CISCOR
- Differentially steered
  - Driven by two DC Motors
- Router for wireless communication
- Laser range finder for obstacle detection (shown in blue)
- Robot total weight = 13.5 kg
- Runs on real-time operating system (QnX Neutrino RTOS)
- Approximately 13” W x 17” L x 9” H



Our Approach

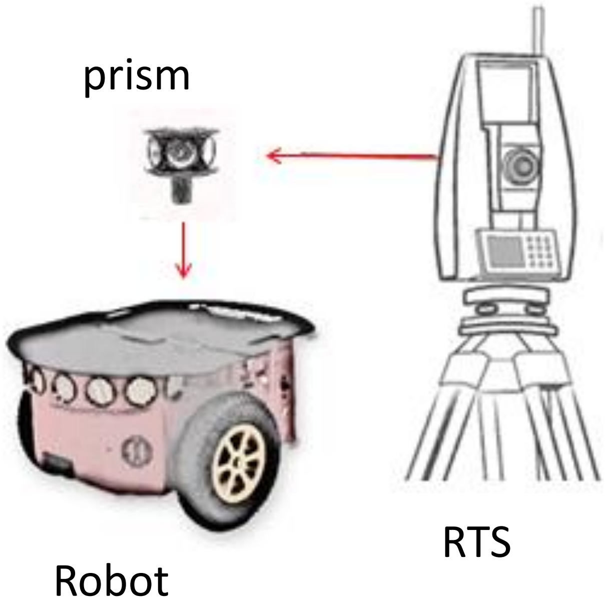


Localization

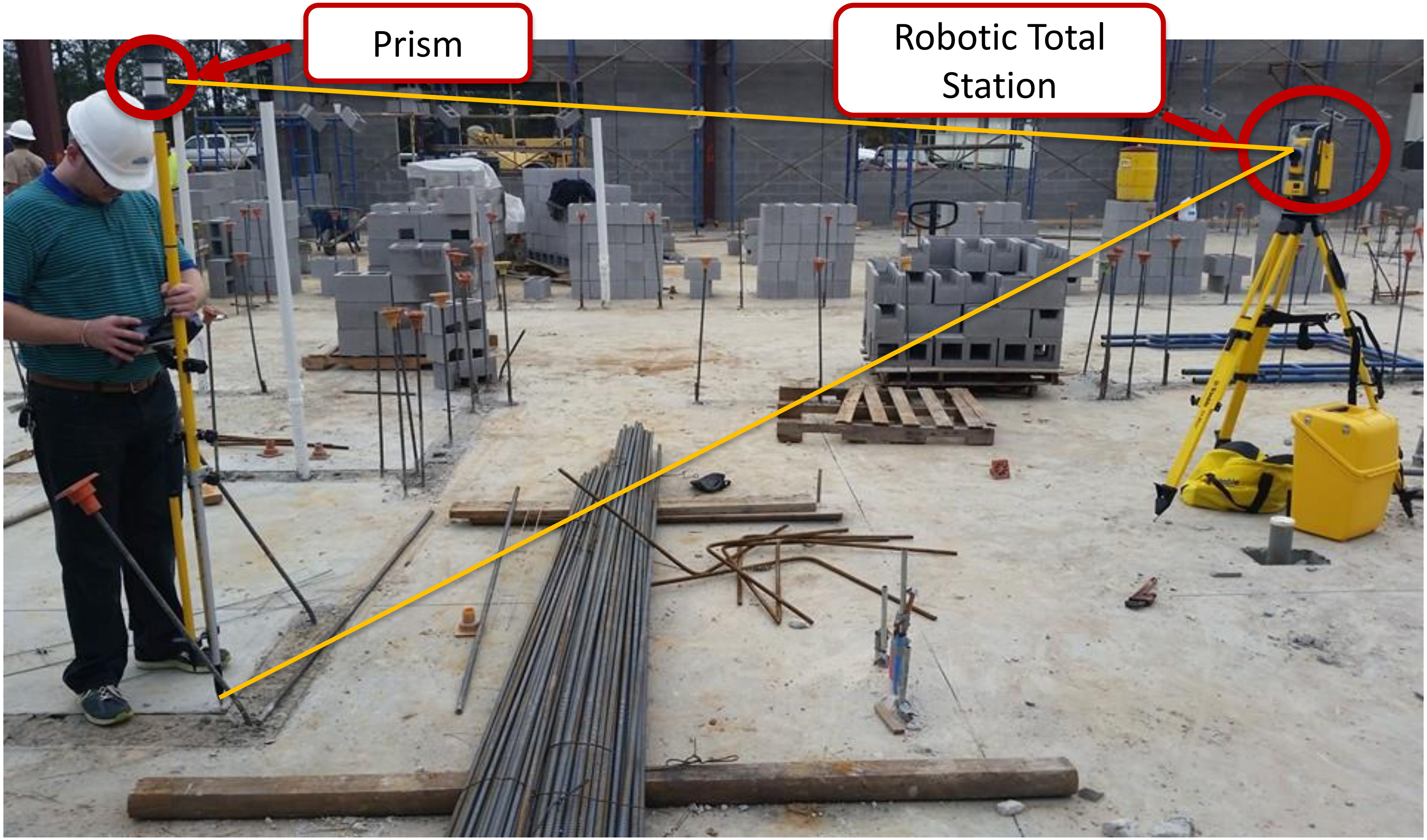
- For accurate movement, the robot needs to be aware of where it is
- Possible options
  - Wheel encoders
  - Visual sensors
  - GPS
  - ***Not adequate for needed accuracy***
- Localization Requirements
  - Continually checks robots position
  - Provides high accuracy relative to layout
  - Removes error propagation

Robotic Total Station

- Features
  - Calibrates via triangulation with two structures of known location
  - Tracks and measures the ***exact position*** of an external prism
    - Measures horizontal and vertical angles as well as slope distance
  - Verifies points are being marked ***accurately***
  - Contains file of layout in internal memory
  - 20Hz update rate

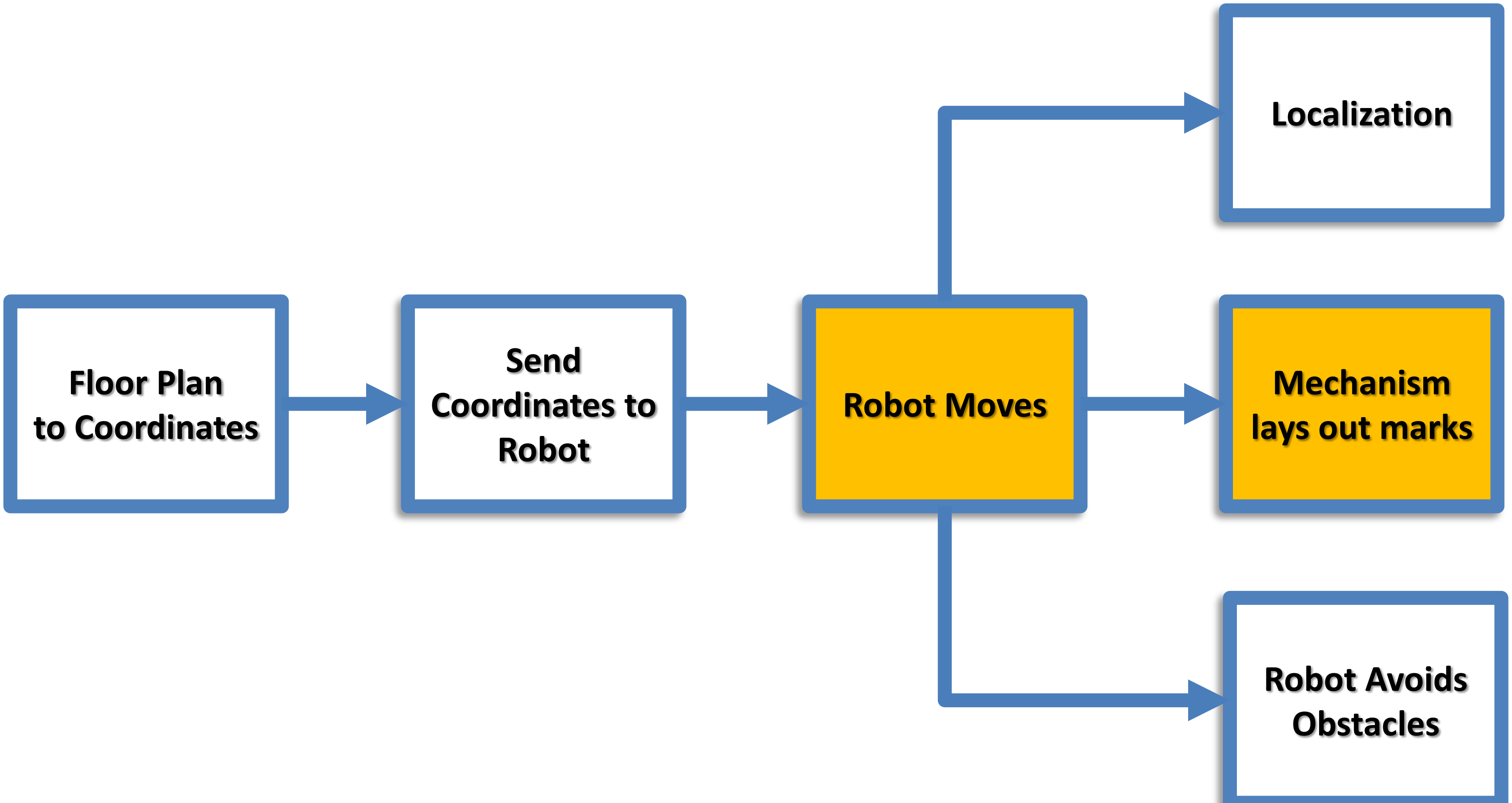


Using the Robotic Total Station

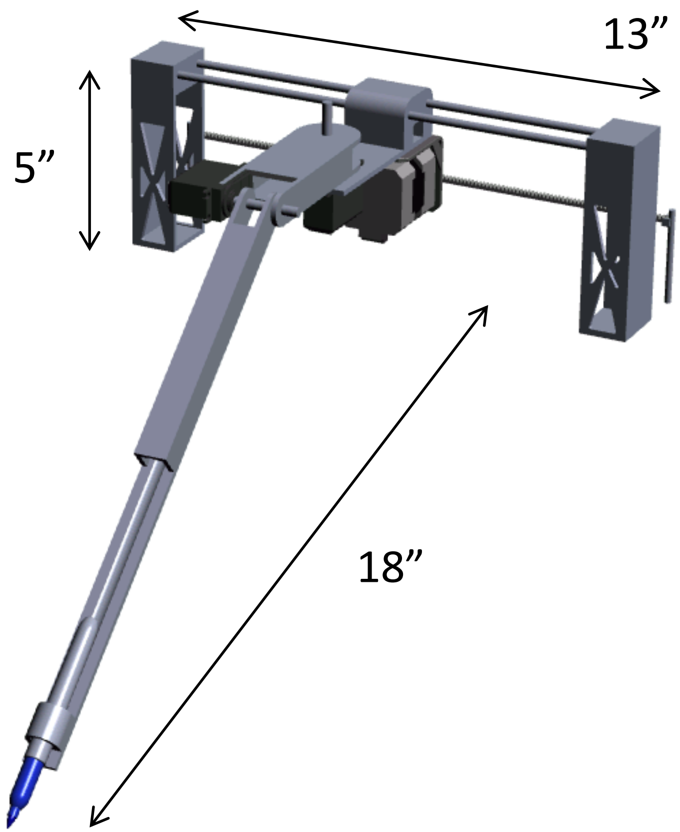


Trimble S6 RTS Setup

Our Approach

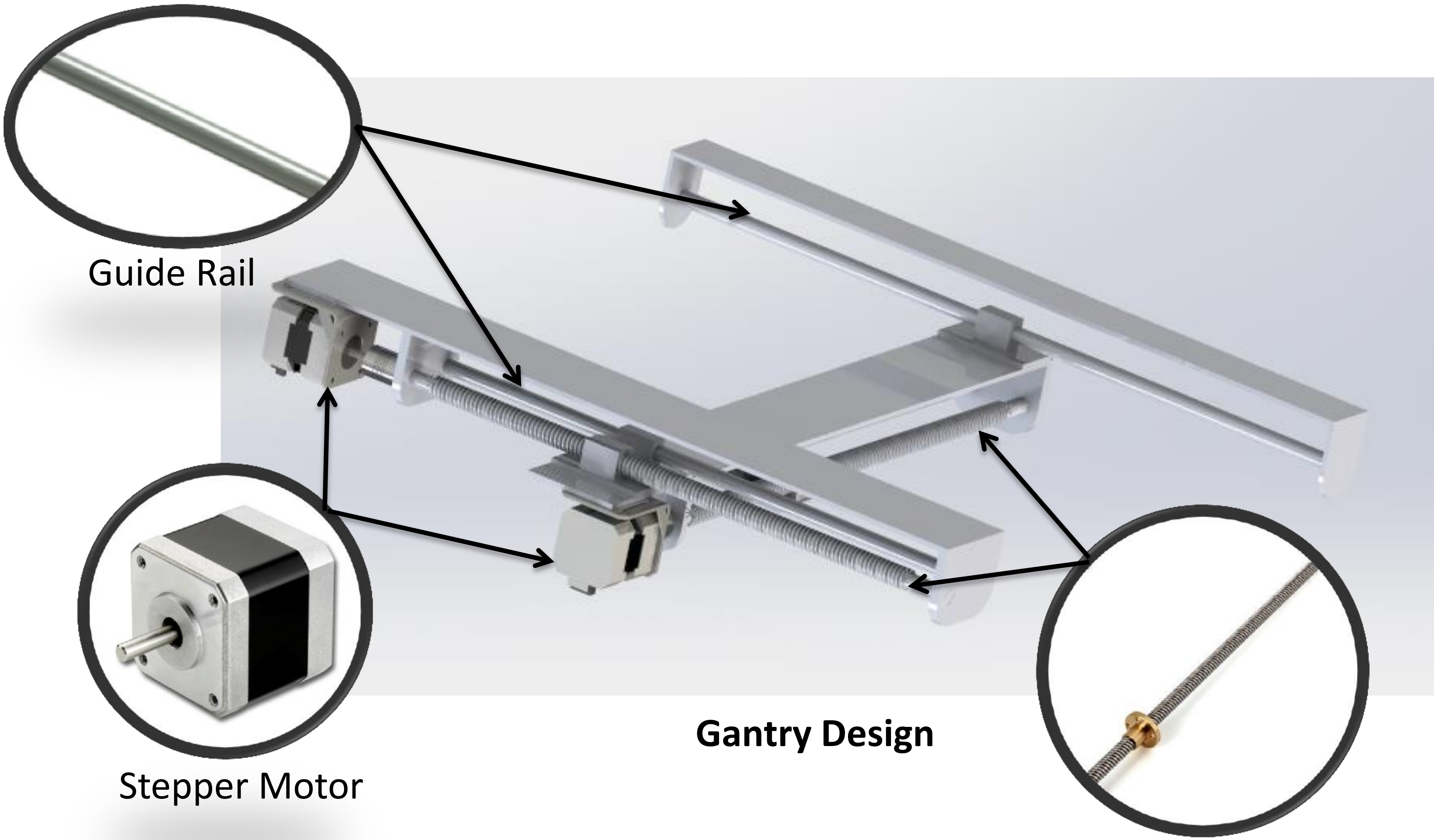


Previous Design



- 2 servo motors
- Provides greater reach
  - Movement in 2 directions
  - Marks outside of tread
- Stepper motor attached to rack and pinion
- Issues with design:
  - Too simplistic to fulfill objectives
  - No plan for multiple colors
  - Will not properly apply pressure on marker

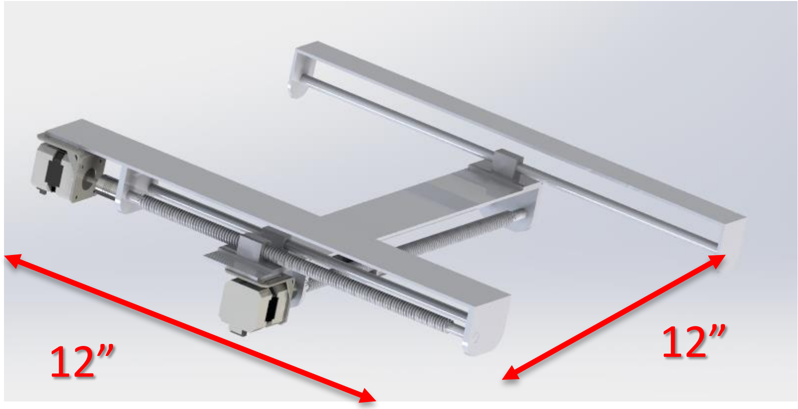
New Concept



Gantry Design

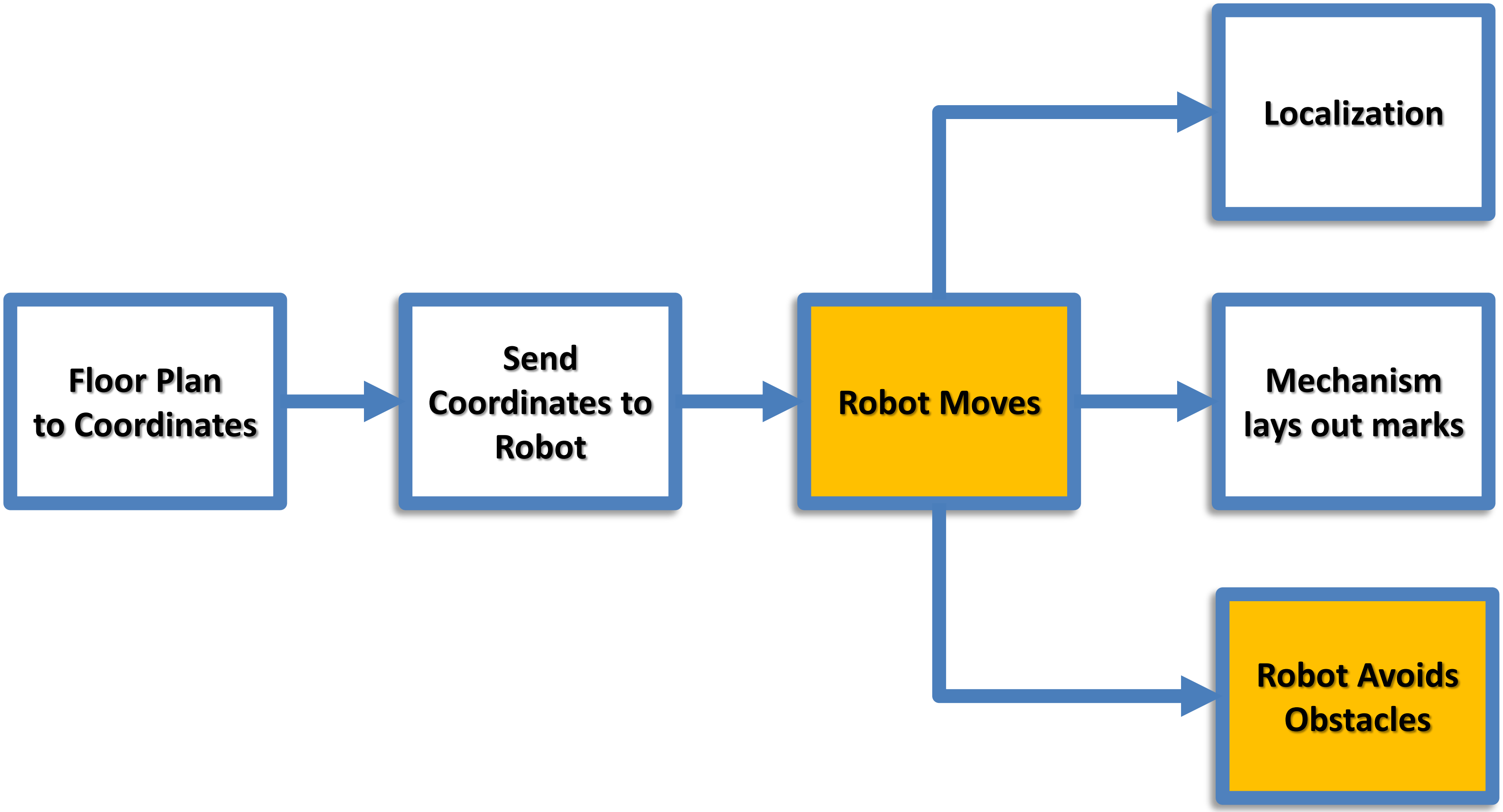
New Concept

- Gantry design comprised of two linear translation systems
- System will be made up of a lead screw driven by a stepper motor, guided by linear rails
- Improvements from old design:
  - Modular design allows for changing markers in the future
  - More accurate marker placement
  - Can draw various shapes with more ease

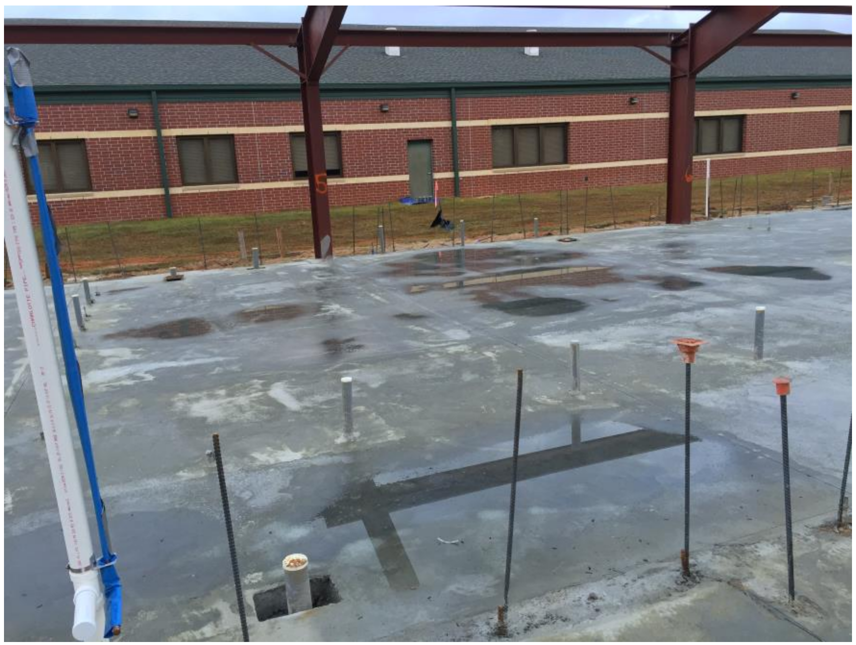


Gantry Design

Our Approach



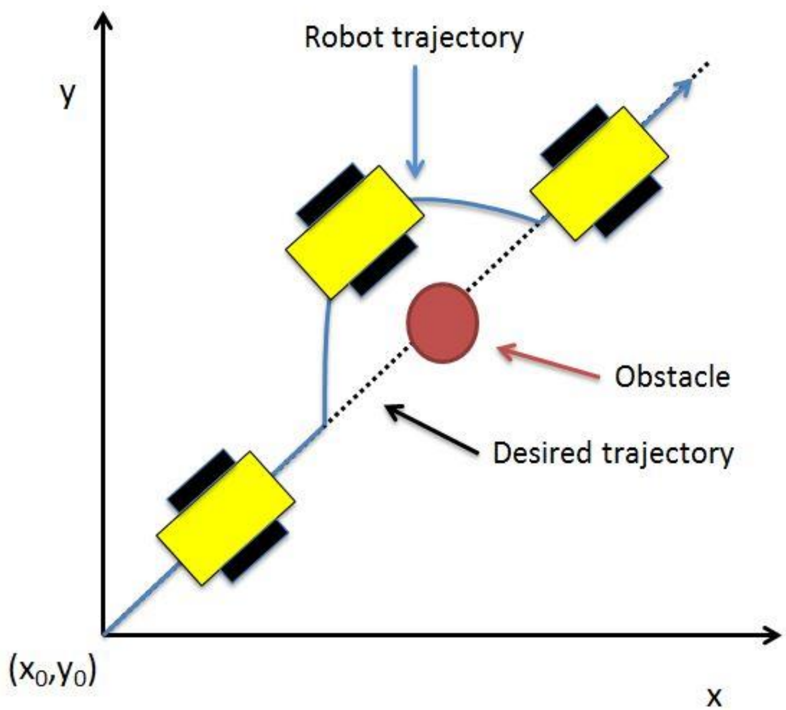
Obstacle Avoidance



Typical construction site

- Typical obstacles:
  - Rebar
  - Electrical conduits
  - PVC pipes
  - People
  - Trash
- Robot needs to avoid these obstacles

Obstacle Avoidance Approach



- Initial approach
  - Robot wants to follow desired path
  - Will adjusts its path when an obstacle is detected
  - Will return to desired path at closest, safest point
  - Distance sensor used to detect obstacles
  - Radius of influence
    - 1.5 feet

Obstacle Detection

Sick LMS 200

Laser Measurement System

- More accurate than sonar and IR sensors
- Internal mirror rotates 180°
- May need to adjust the vertical orientation for the near future

Angular resolution chart

Angular resolution	0.25°	0.5°	1.0°
Max Scanning angle	100°	180°	180°
Max # of measure values	401	361	181

Obstacle Detection

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Sick LMS 200

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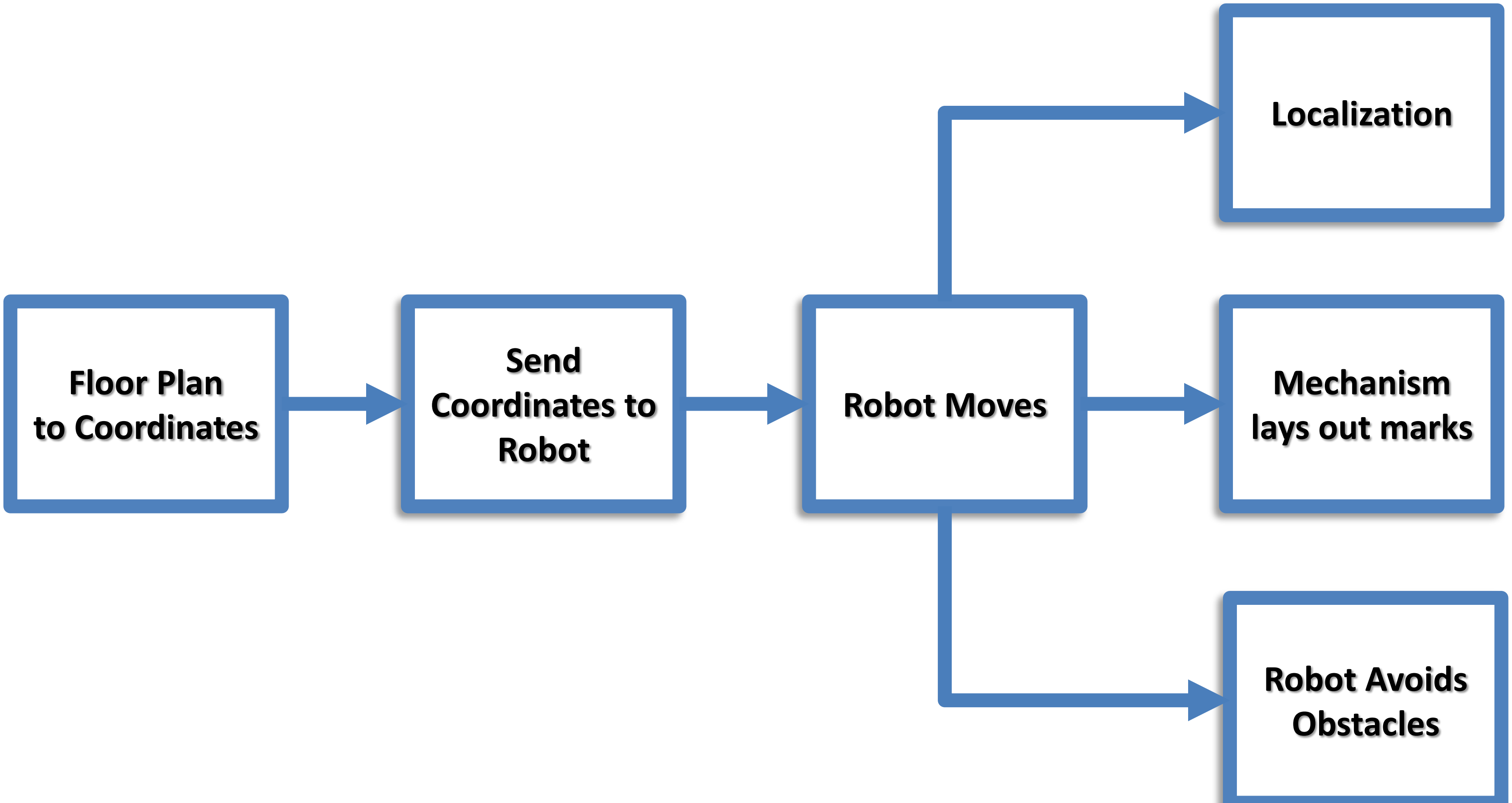
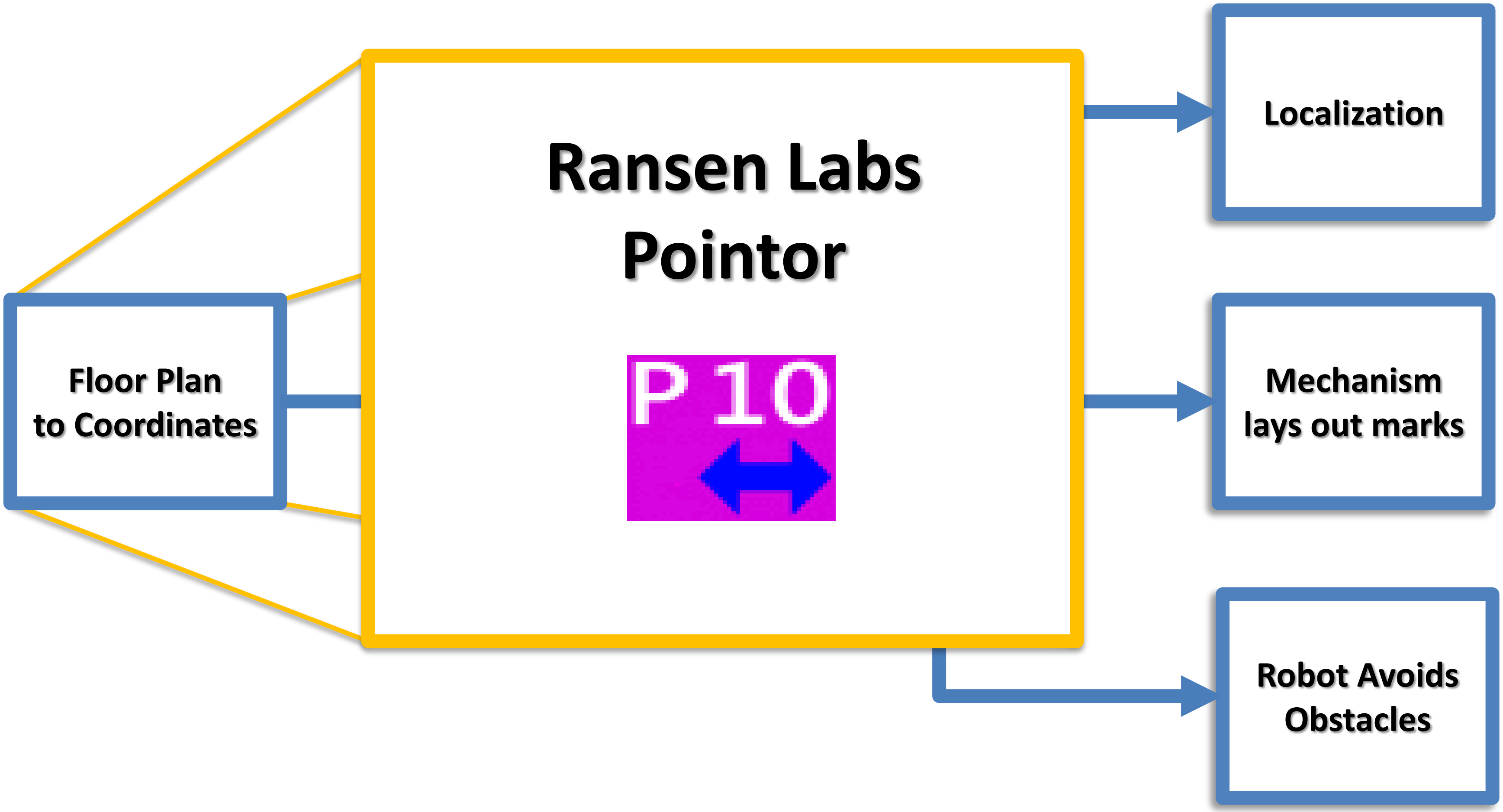
Justin Gibbs

Summary


Floor Plan to Coordinates
Send Coordinates to Robot
Robot Moves
Localization
Mechanism lays out marks
Robot Avoids Obstacles

Summary


Ransen Labs
Pointor
P 10
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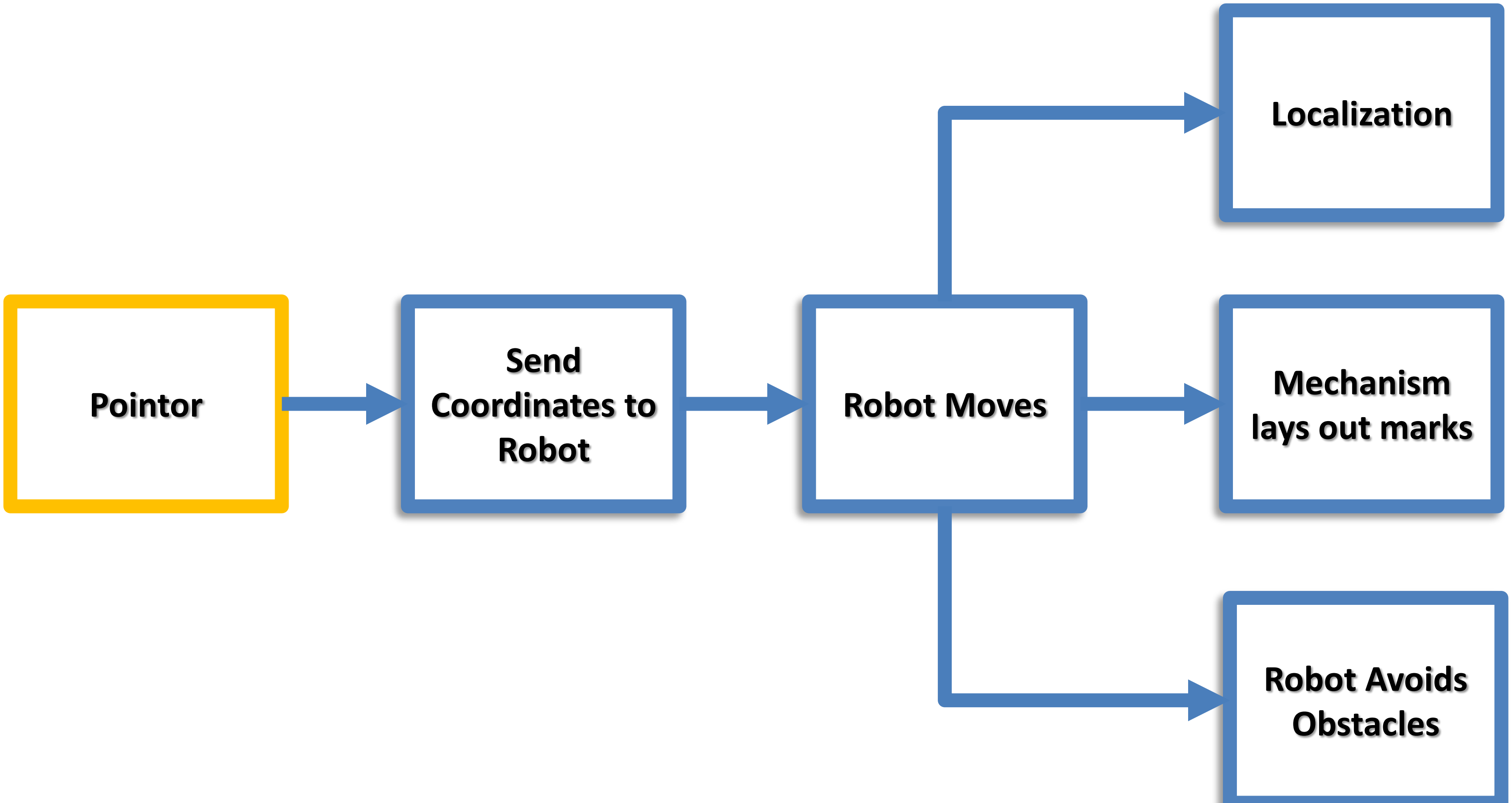
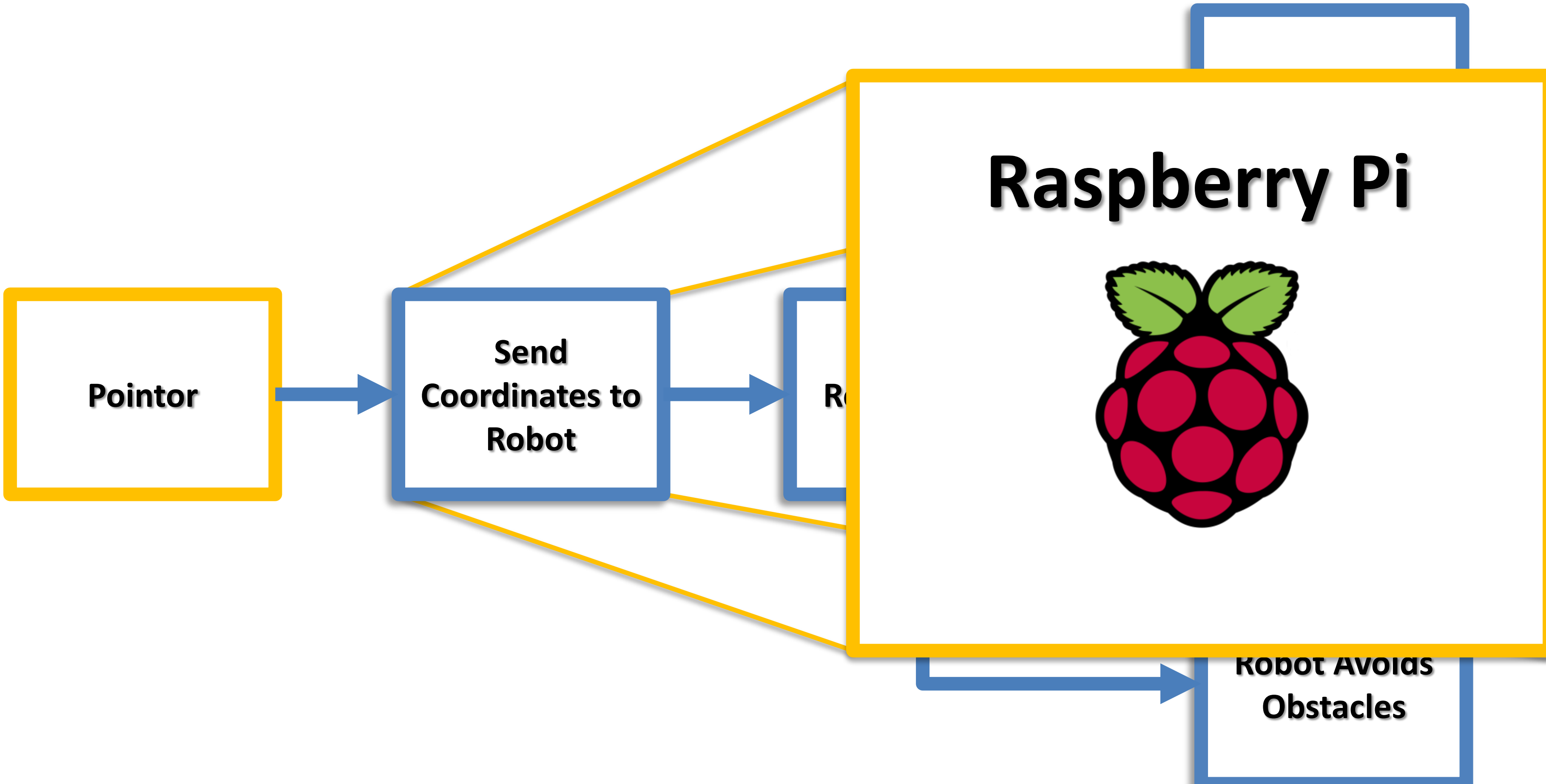


Brandon Roberts

Summary


Pointor
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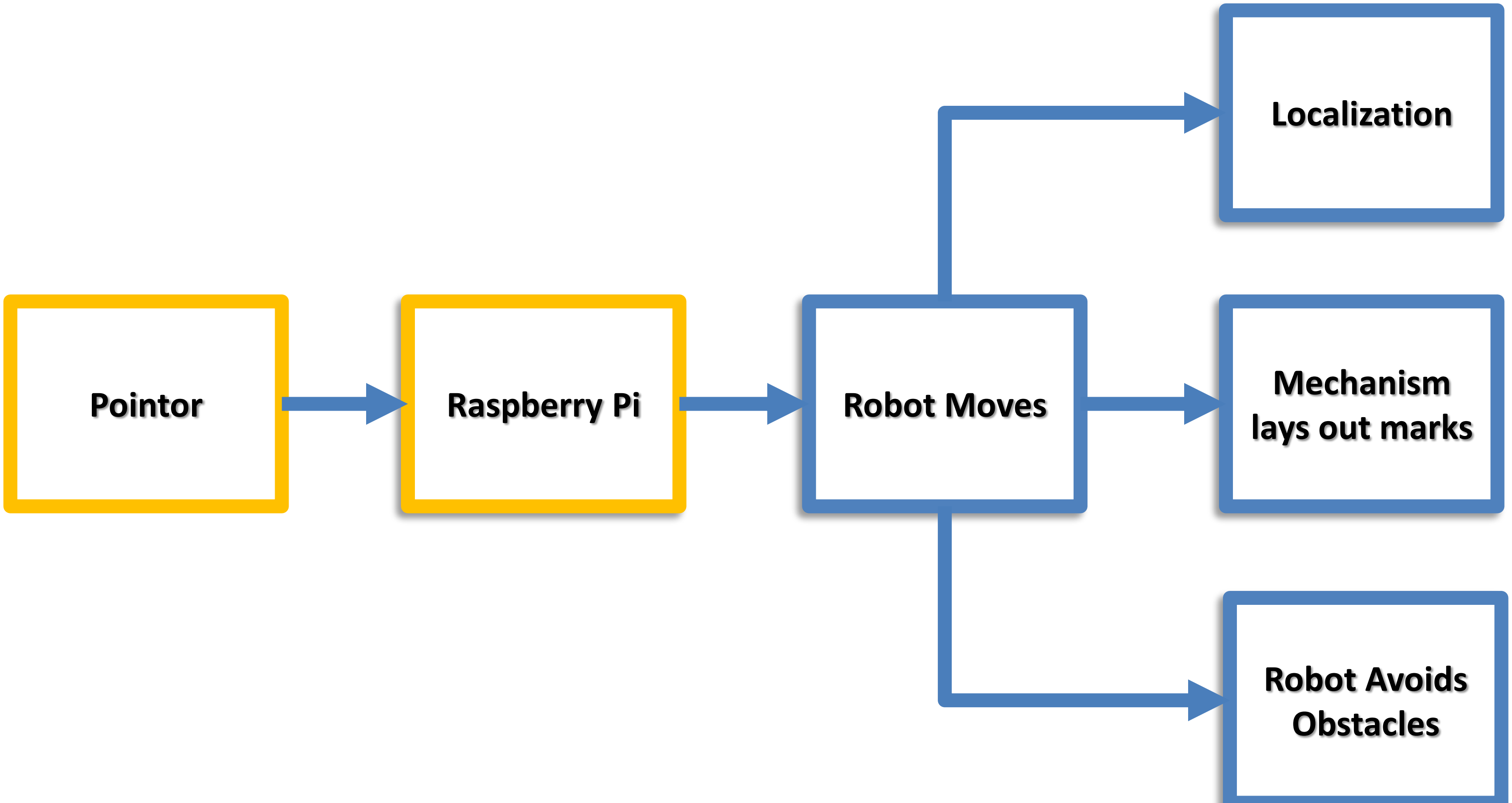

Pointor
Raspberry Pi
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Summary

Pioneer 2DX

Robot Moves

Localization

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Robot Avoids Obstacles

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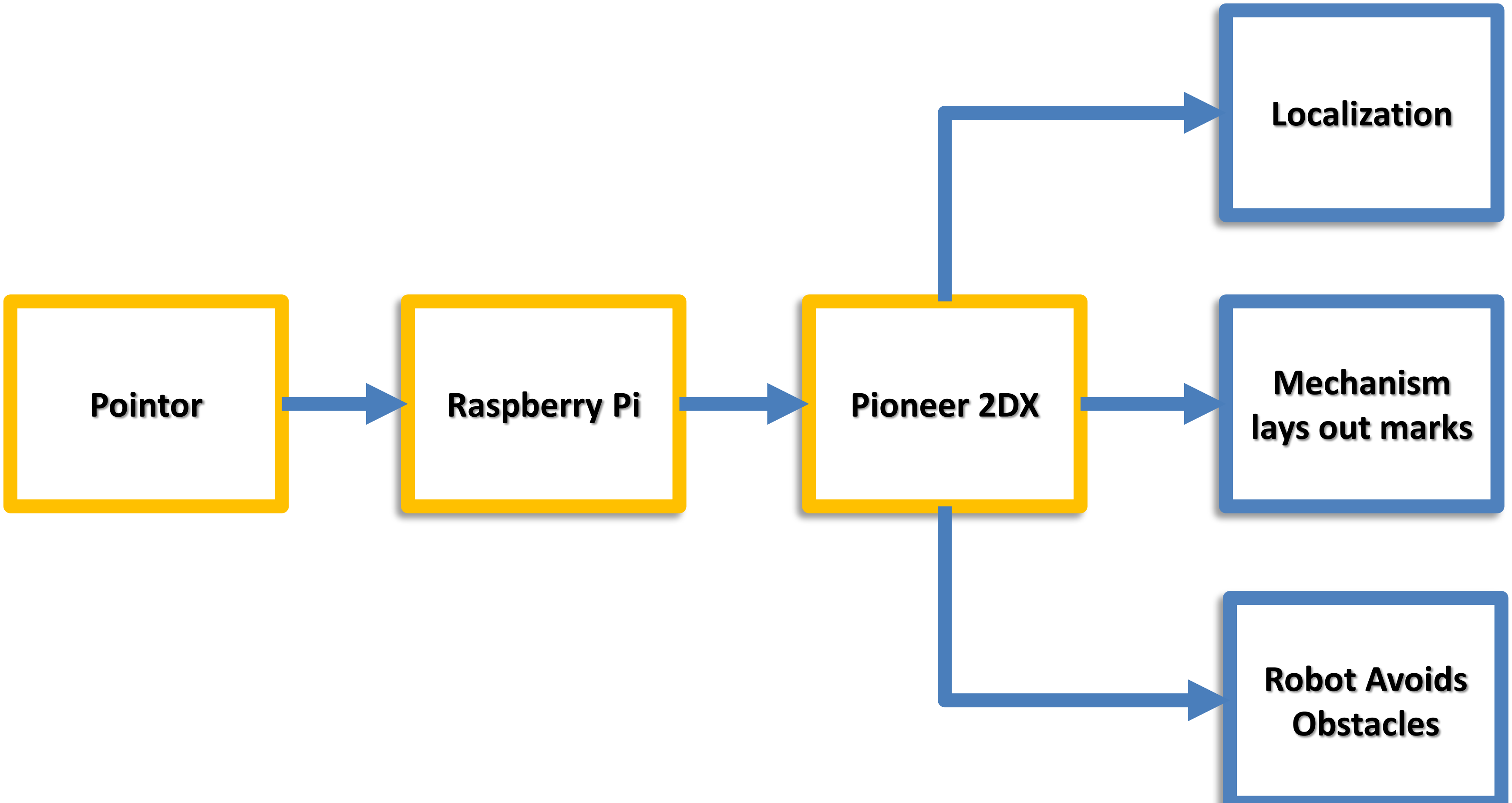
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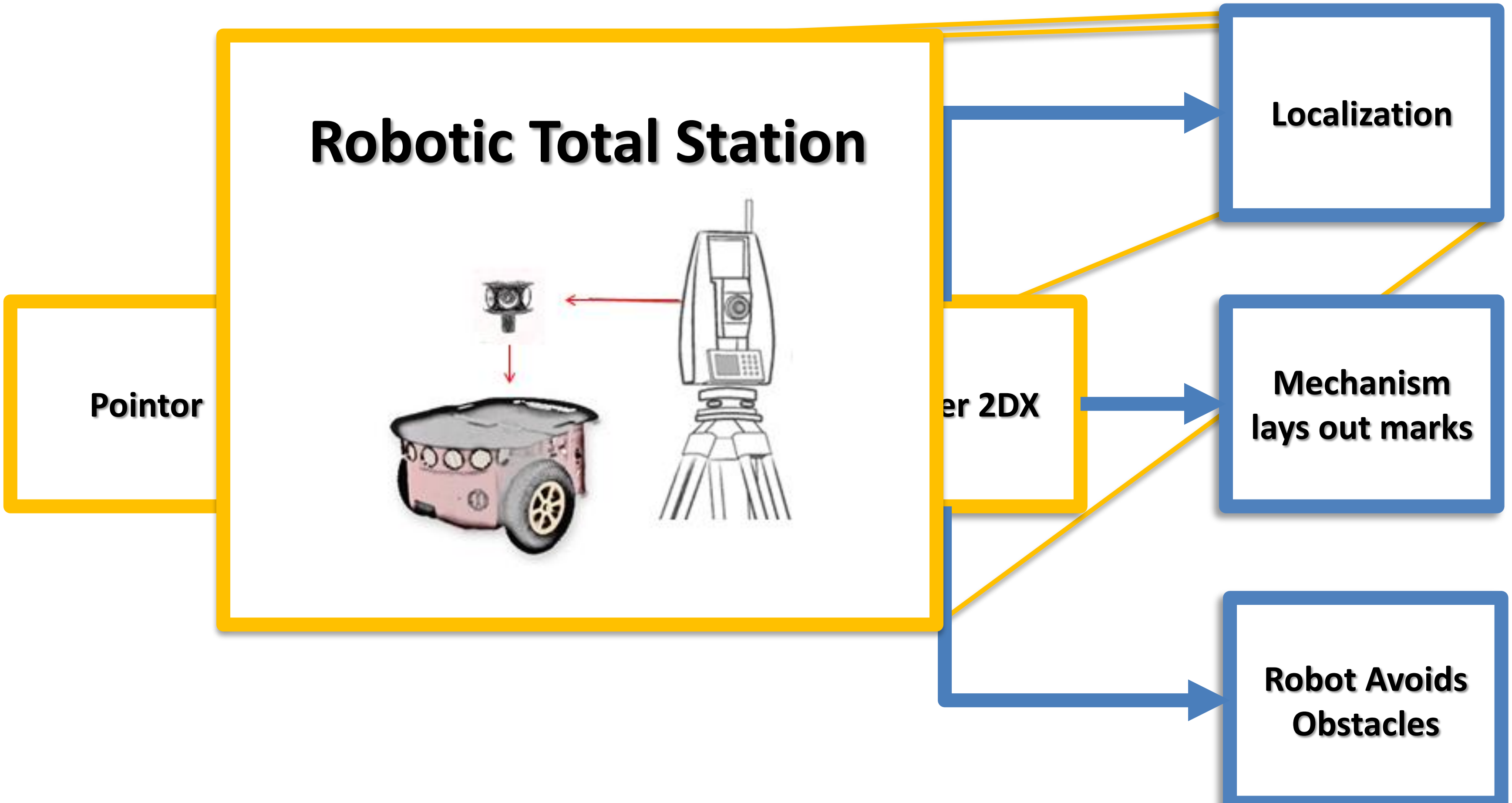
Robotic Total Station
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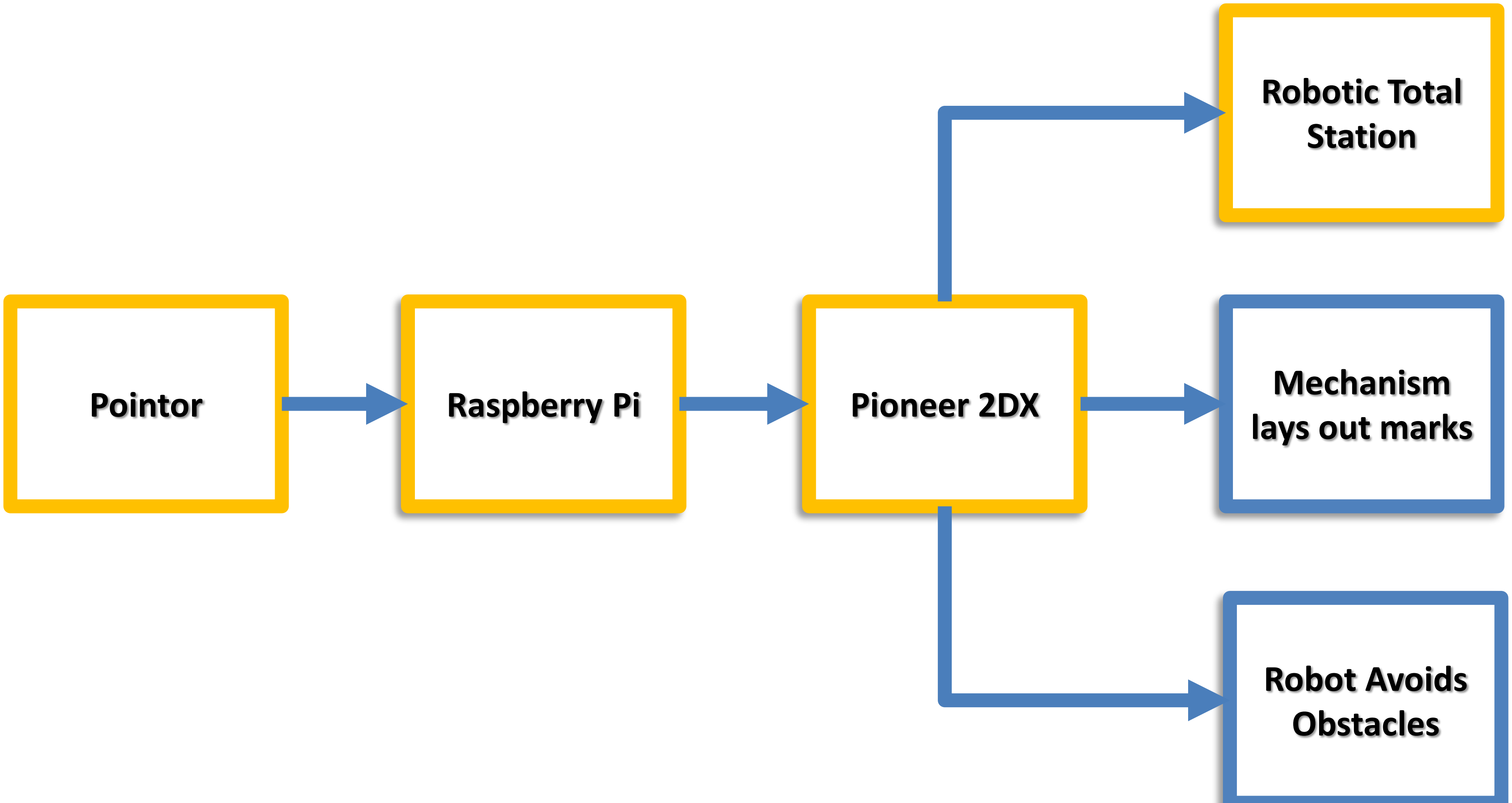
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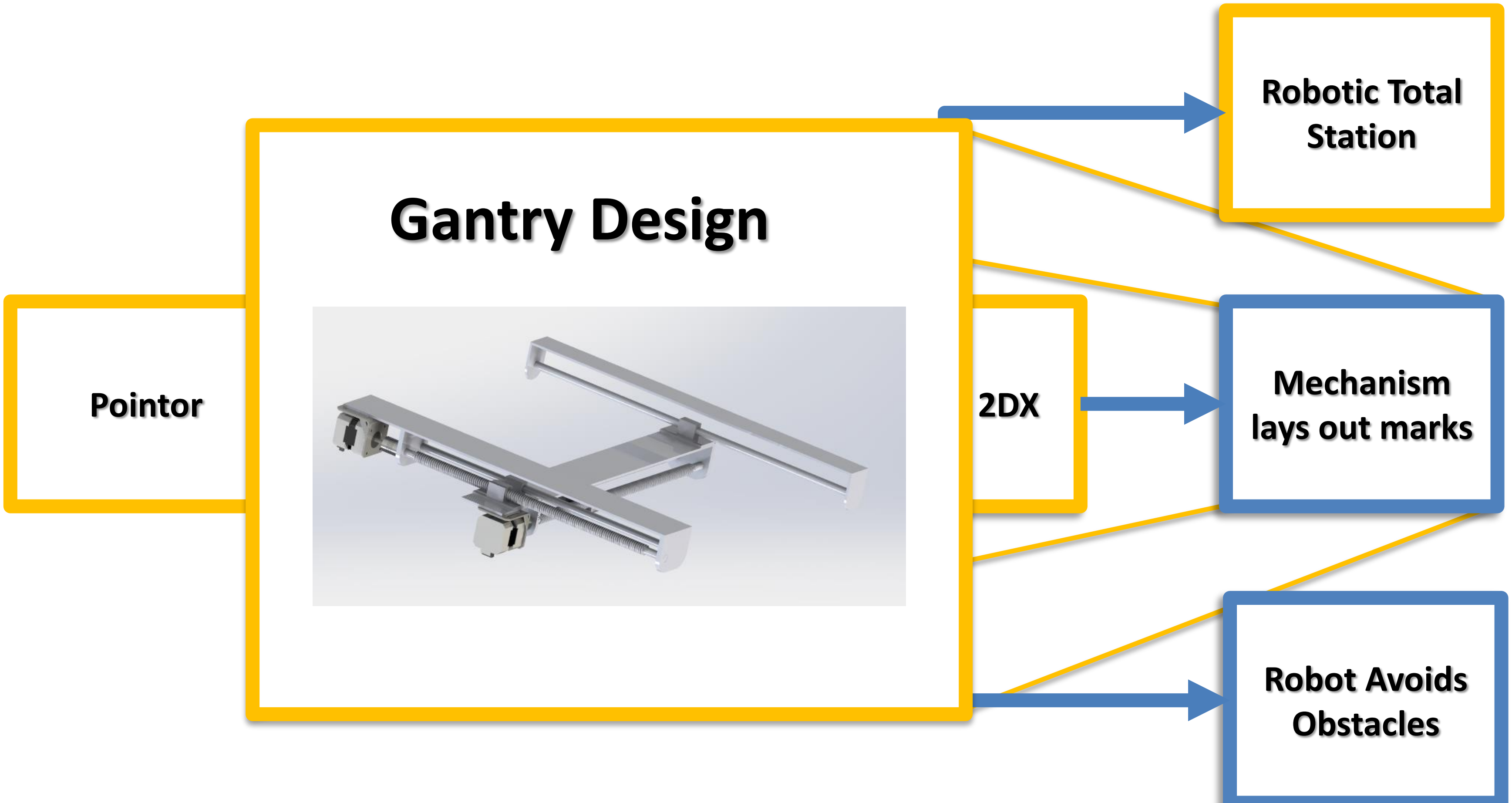
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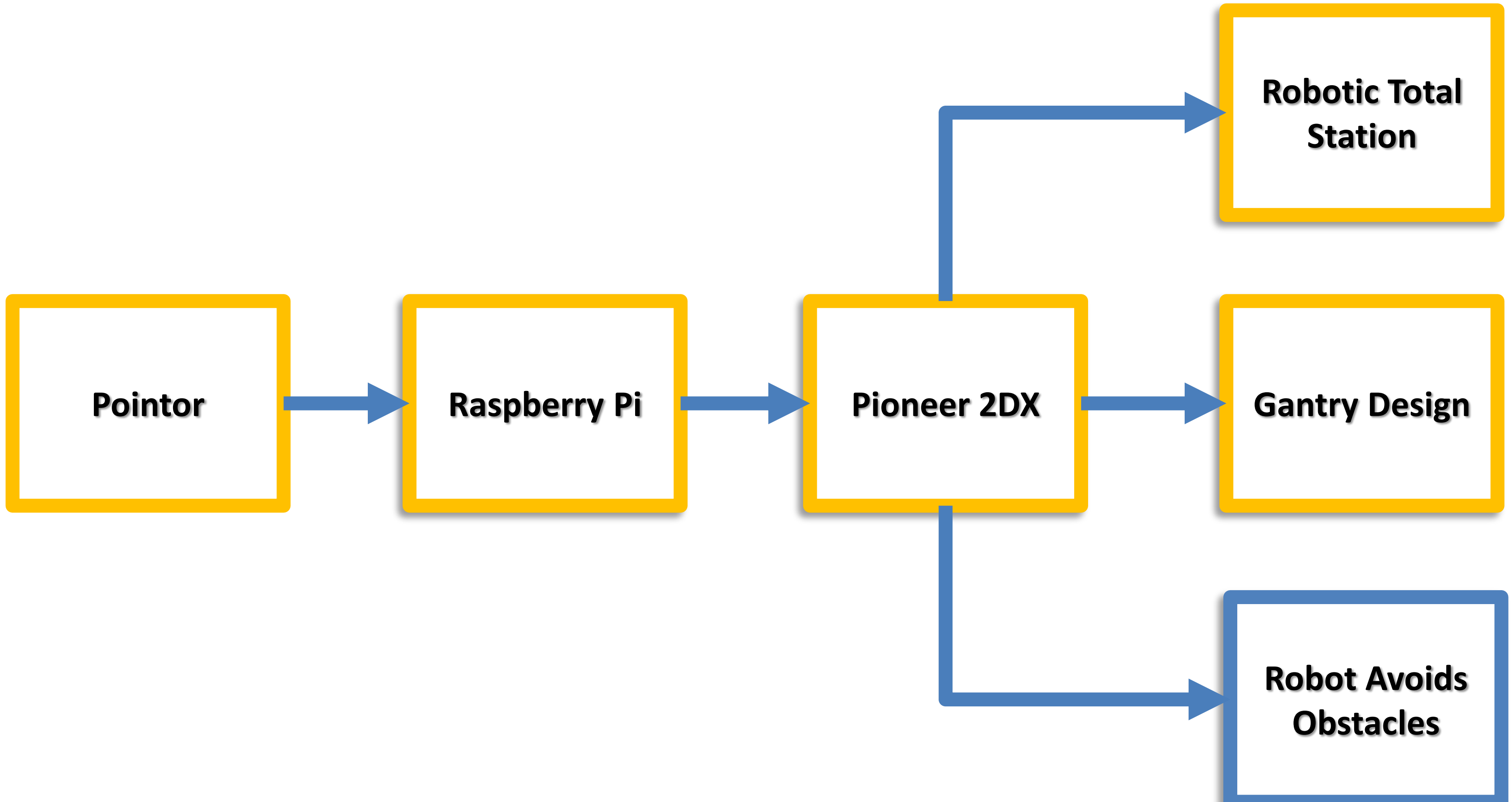

Robotic Total Station
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Summary

Robotic Total Station

Sick LMS 200

Pointor

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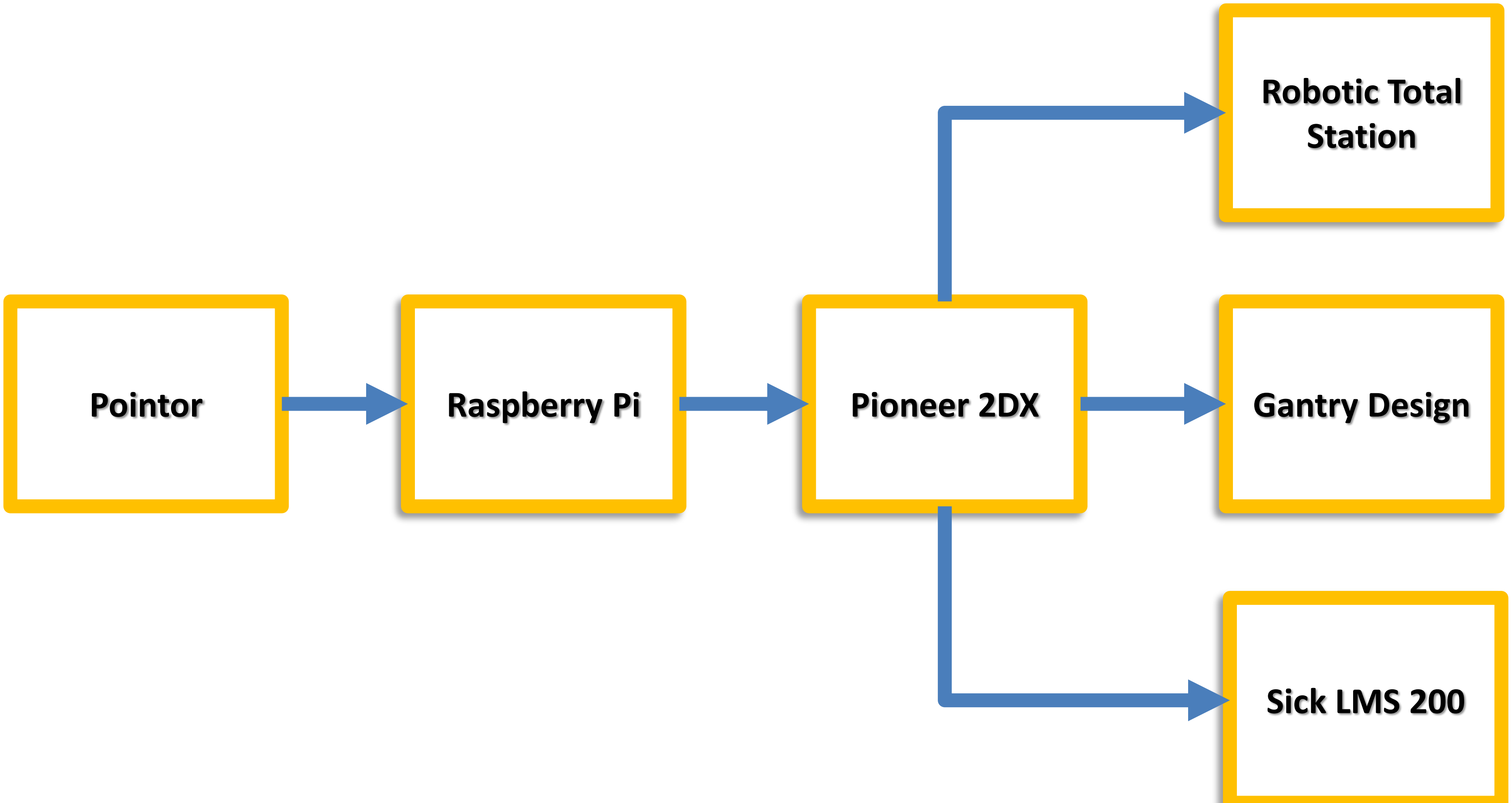

Robotic Total Station
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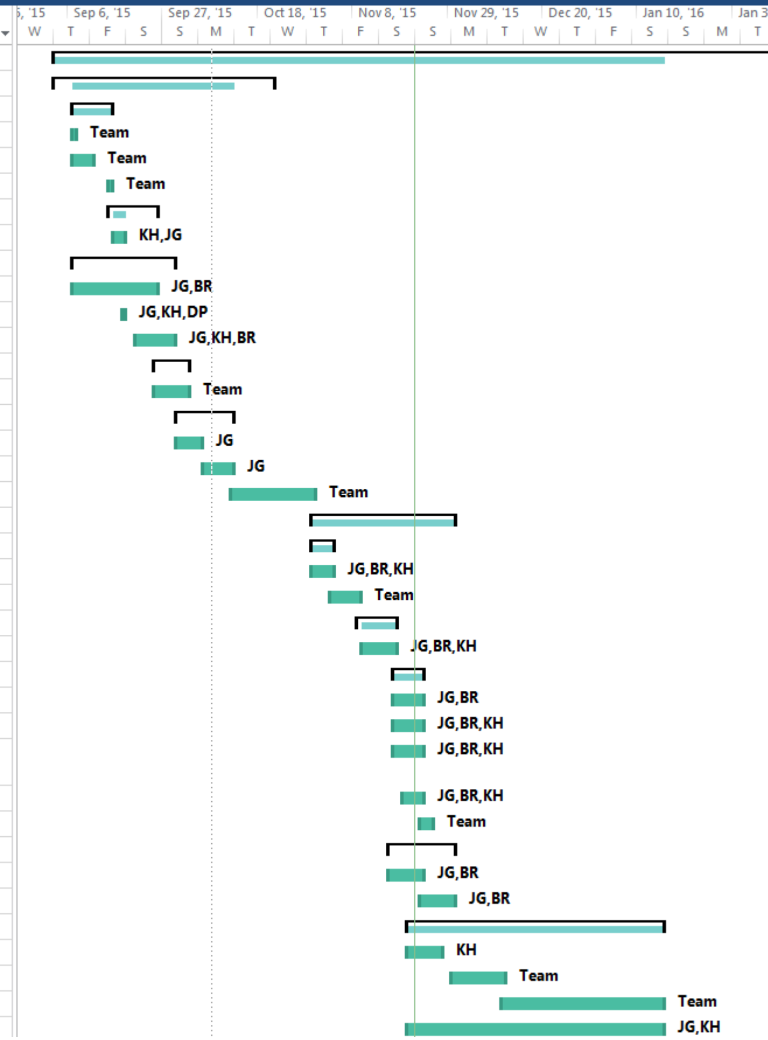
Sick LMS 200

Planning for the Future

Gantt Chart – Marking Mechanism

Task Name	Duration	Start	Finish
Marking Mechanism	**8.7 mons**	**Thu 9/3/15**	**Sun 5/1/16**
Conceptual Design	**35 days**	**Thu 9/3/15**	**Wed 10/21/15**
Define Problem	**7 days**	**Mon 9/7/15**	**Tue 9/15/15**
Initial Meeting	1 day	Mon 9/7/15	Mon 9/7/15
Review Project Proposal	5 days	Mon 9/7/15	Fri 9/11/15
Meeting with Sponsor	1 day	Tue 9/15/15	Tue 9/15/15
Customer Needs	**9 days**	**Tue 9/15/15**	**Fri 9/25/15**
Sponsor Survey	3 days	Wed 9/16/15	Fri 9/18/15
Gather Information	**17 days**	**Mon 9/7/15**	**Tue 9/29/15**
Research of Similar Robots	15 days	Mon 9/7/15	Fri 9/25/15
Trip to Construction Site	1 day	Fri 9/18/15	Fri 9/18/15
House of Quality	7 days	Mon 9/21/15	Tue 9/29/15
Concept Generation	**6 days**	**Fri 9/25/15**	**Fri 10/2/15**
Individual Brainstorming	6 days	Fri 9/25/15	Fri 10/2/15
Concept Selection	**9 days**	**Wed 9/30/15**	**Mon 10/12/15**
Morphological Chart	4 days	Wed 9/30/15	Mon 10/5/15
Pugh Matrix	5 days	Tue 10/6/15	Mon 10/12/15
Iteration of Conceptual Design	15 days	Mon 10/12/15	Fri 10/30/15
Product Architecture	**23 days**	**Fri 10/30/15**	**Mon 11/30/15**
Determine Final Concept	**4 days**	**Fri 10/30/15**	**Tue 11/3/15**
Determine Movement Methods	4 days	Fri 10/30/15	Tue 11/3/15
Finalize Design	5 days	Tue 11/3/15	Mon 11/9/15
Make CAD Drawings	**7 days**	**Mon 11/9/15**	**Tue 11/17/15**
Find Exact Dimensions	6 days	Tue 11/10/15	Tue 11/17/15
Calculate Physical Needs	**5 days**	**Tue 11/17/15**	**Mon 11/23/15**
Motor Power	5 days	Tue 11/17/15	Mon 11/23/15
Material Strengths	5 days	Tue 11/17/15	Mon 11/23/15
Guide Rail, Lead Screw Options/Sizes	5 days	Tue 11/17/15	Mon 11/23/15
Select Components	3 days	Thu 11/19/15	Mon 11/23/15
Create Bill of Materials	3 days	Mon 11/23/15	Wed 11/25/15
LiDar	**11 days**	**Mon 11/16/15**	**Mon 11/30/15**
Initial Design for Moving	6 days	Mon 11/16/15	Mon 11/23/15
Finalized LiDar Moving Design	6 days	Mon 11/23/15	Mon 11/30/15
Verification and Testing	**41 days**	**Fri 11/20/15**	**Fri 1/15/16**
Order Parts	6 days	Fri 11/20/15	Fri 11/27/15
Build Mechanism	10 days	Mon 11/30/15	Fri 12/11/15
Testing (On and Off Site)	26 days	Fri 12/11/15	Fri 1/15/16
Documentation of Activities	41 days	Fri 11/20/15	Fri 1/15/16



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Construction Marking Robot

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Motor Power	5 days	Tue 11/17/15	Mon 11/23/15
Material Strengths	5 days	Tue 11/17/15	Mon 11/23/15
Guide Rail, Lead Screw Options/Sizes	5 days	Tue 11/17/15	Mon 11/23/15
Select Components	3 days	Thu 11/19/15	Mon 11/23/15
Create Bill of Materials	3 days	Mon 11/23/15	Wed 11/25/15
LiDar	**11 days**	**Mon 11/16/15**	**Mon 11/30/15**
Initial Design for Moving	6 days	Mon 11/16/15	Mon 11/23/15
Finalized LiDar Moving Design	6 days	Mon 11/23/15	Mon 11/30/15

Gantt Chart – Marking Mechanism

Product Architecture	**23 days**	**Fri 10/30/15**	**Mon 11/30/15**
Determine Final Concept	**4 days**	**Fri 10/30/15**	**Tue 11/3/15**
Determine Movement Methods	4 days	Fri 10/30/15	Tue 11/3/15
Finalize Design	5 days	Tue 11/3/15	Mon 11/9/15
Make CAD Drawings	**7 days**	**Mon 11/9/15**	**Tue 11/17/15**
Find Exact Dimensions	6 days	Tue 11/10/15	Tue 11/17/15
Calculate Physical Needs	**5 days**	**Tue 11/17/15**	**Mon 11/23/15**
Motor Power	5 days	Tue 11/17/15	Mon 11/23/15
Material Strengths	5 days	Tue 11/17/15	Mon 11/23/15
Guide Rail, Lead Screw Options/Sizes	5 days	Tue 11/17/15	Mon 11/23/15
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Gantt Chart – Marking Mechanism

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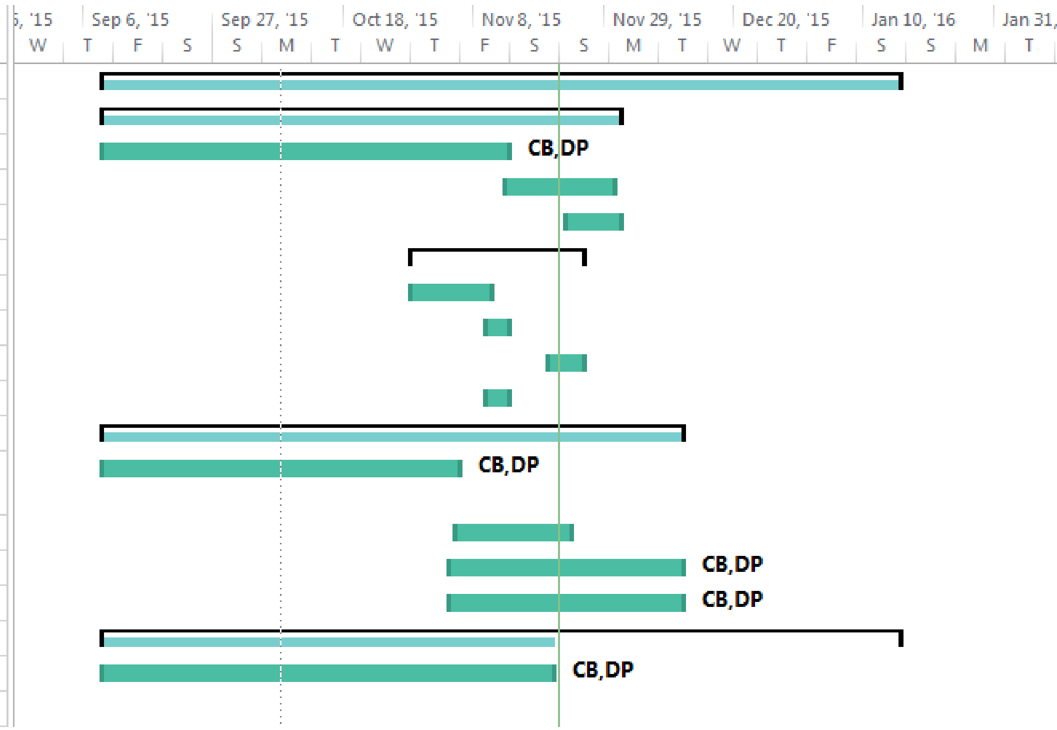
Finalized LiDar Moving Design	6 days	Mon 11/23/15	Mon 11/30/15

Gantt Chart – Programming

Task Name	Duration	Start	Finish
Programming	**94 days**	**Wed 9/9/15**	**Fri 1/15/16**
Locomotion	**61 days**	**Wed 9/9/15**	**Tue 12/1/15**
QnX Code Research	49 days	Wed 9/9/15	Fri 11/13/15
Turn on LED to represent marking	12 days	Fri 11/13/15	Mon 11/30/15
Make Robot Move	7 days	Mon 11/23/15	Tue 12/1/15
Microprocessor	**21 days**	**Thu 10/29/15**	**Wed 11/25/15**
Research Options	10 days	Thu 10/29/15	Tue 11/10/15
Raspbery Pi Work	4 days	Tue 11/10/15	Fri 11/13/15
Communication with Pioneer	4 days	Fri 11/20/15	Wed 11/25/15
Sourcing for Parts	4 days	Tue 11/10/15	Fri 11/13/15
Extraction of CAD Data	**69 days**	**Wed 9/9/15**	**Fri 12/11/15**
Find Software changing CAD to coordinates	43 days	Wed 9/9/15	Thu 11/5/15
MATLAB program for txt file	13 days	Thu 11/5/15	Mon 11/23/15
Task Assignments	28 days	Wed 11/4/15	Fri 12/11/15
Path Planning	28 days	Wed 11/4/15	Fri 12/11/15
Integration with Robotic Total Station	**94 days**	**Wed 9/9/15**	**Fri 1/15/16**
Research	54 days	Wed 9/9/15	Fri 11/20/15
Gather API			



PSBI
Construction Marking Robot

Schedule

- Marking Device
  - Select components
  - Create a bill of materials and order parts
  - Begin construction of marking device
- Programming
  - Continue with movement capabilities
    - Connect Raspberry Pi to Pioneer
    - Complete code with functions for Pioneer
  - Begin work with LiDar

Questions?