Team B- Space Jockey

Preliminary Design Review

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Outline

- Project Overview
- Functional and System Architectures
- Subsystem Breakdowns and Status
- Milestone and Test Overview
- Work schedule
- Revised parts list & budget
- Risk analysis

Motivation

- Spacecraft surfaces degrade in space
- The results can be catastrophic

- Repair by astronauts is dangerous, expensive, and time-consuming

Project Description

User Needs:

- Aid the inspection and maintenance the outer hull of a spacecraft
- Operate in a vacuum in microgravity
- Be cheaper and safer than Astronaut Extra-vehicular Activity (EVA)

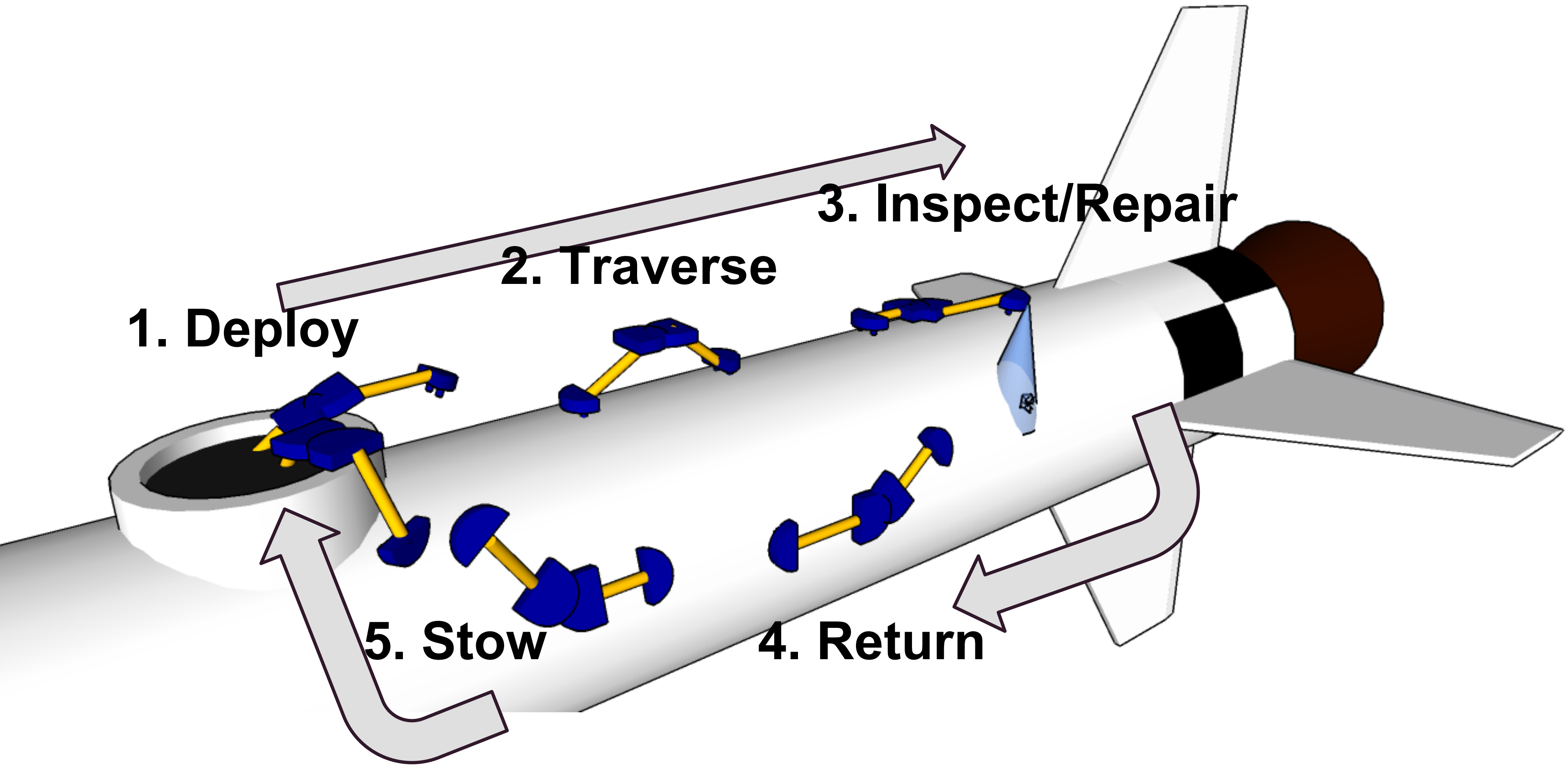
Project Description

Proposed System:

- Mobile robot that can be deployed onto the surface of a spacecraft
  - Able to traverse the hull with minimal tethers and infrastructure
  - Sensors detecting hull flaws or degradation
  - Adequate battery life for representative mission

- Command console program which can control the robot
  - Teleoperation with some elements of autonomy
  - Display sensor data in a meaningful and useful way
  - Computation-heavy tasks such as localization and path-planning

Graphical Representation



Mandatory System Requirements

Functional

#	Code	Description
1	ATTACH	Maintain attachment to the hull* TPM: Supports own weight on a 1G vertical surface
2	TRAV	Traverse the craft at a reasonable speed TPM: 10 meters per hour
3	PLANE	Plane Transitions TPM: 60-degree transitions
4	SENSE	Visual feedback from cameras, joint encoders, and foot sensors
5	*FOOT	Detect footholds with actionable accuracy

Non-Functional

#	Code	Description
1	BATT	Battery Powered
2	EARTH	System can be validated in terrestrial conditions
3	MASS	As light-weight as possible to reduce launch requirements TPM: <10kg
4	SIZE	Minimal volume for efficient storage TPM: 8 Cubesats (10cm cube)
5	COST	Total system cost must not Exceed $4000

Desirable System Requirements

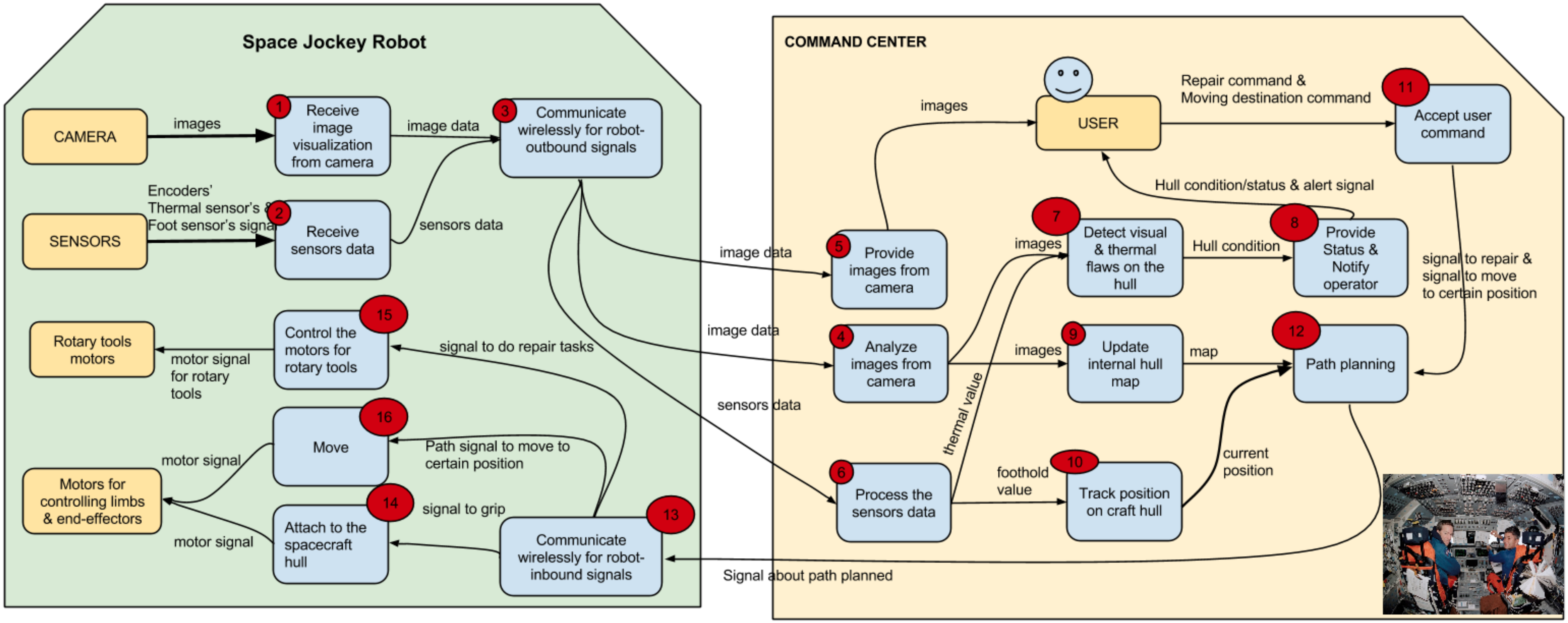
Functional

#	Code	Description
1	MANIP	Use a rotary tool to tighten a fastener or perform other maintenance function
2	TEMP	Thermal Imaging capability
3	SPACE	Develop plan to convert into a space-ready system
4	DETECT	Autonomous identification of surface flaws
5	PLANE2	Plane Transitions (90-degree)

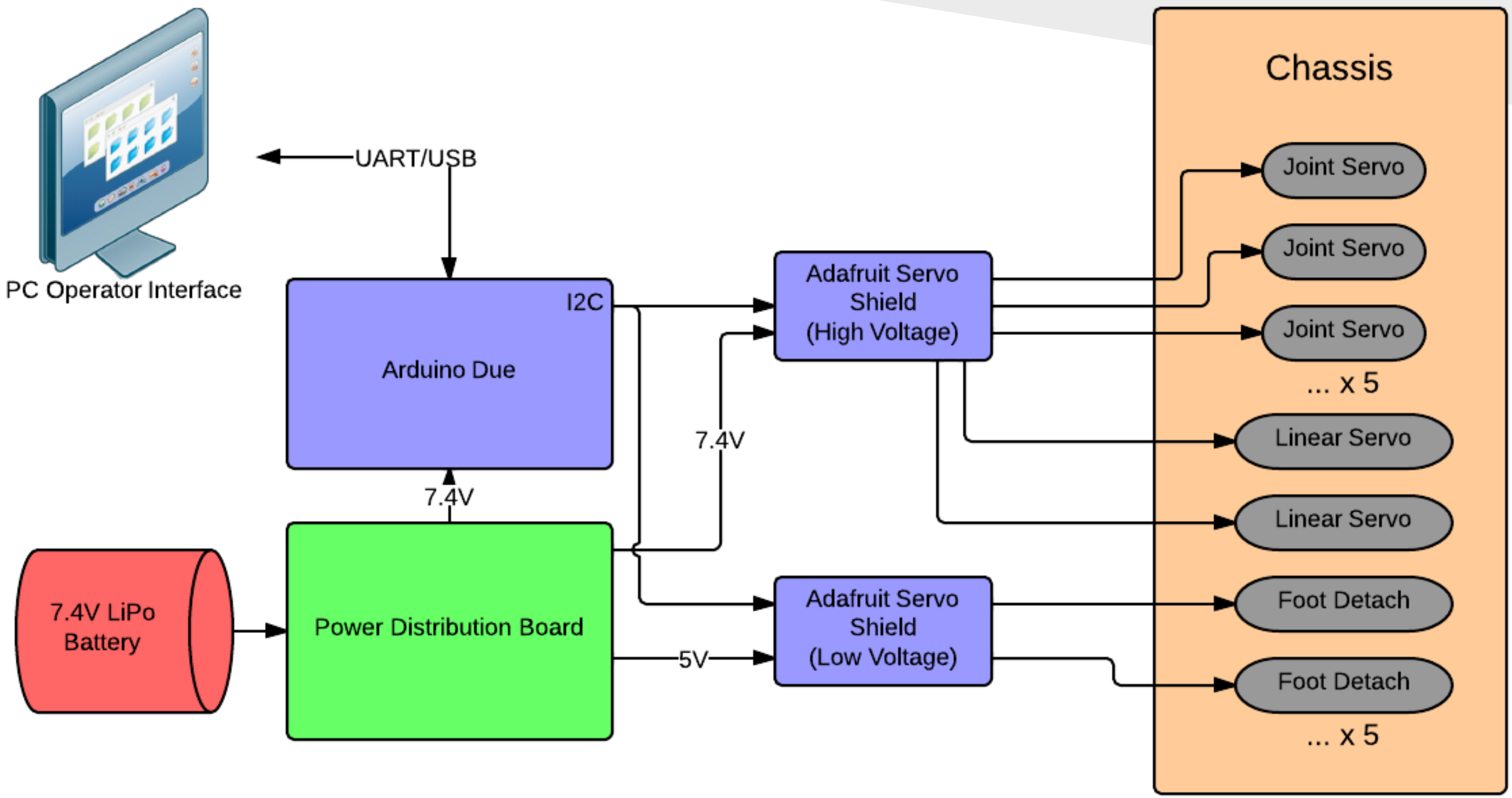
Non-Functional

#	Code	Description
1	WIFI	Completely wireless operation
2	INFRA	Minimal Spacecraft Support Infrastructure
3	ATTACH2	Maintain attachment to the hull* TPM: Supports own weight on a 1G **inverted** surface

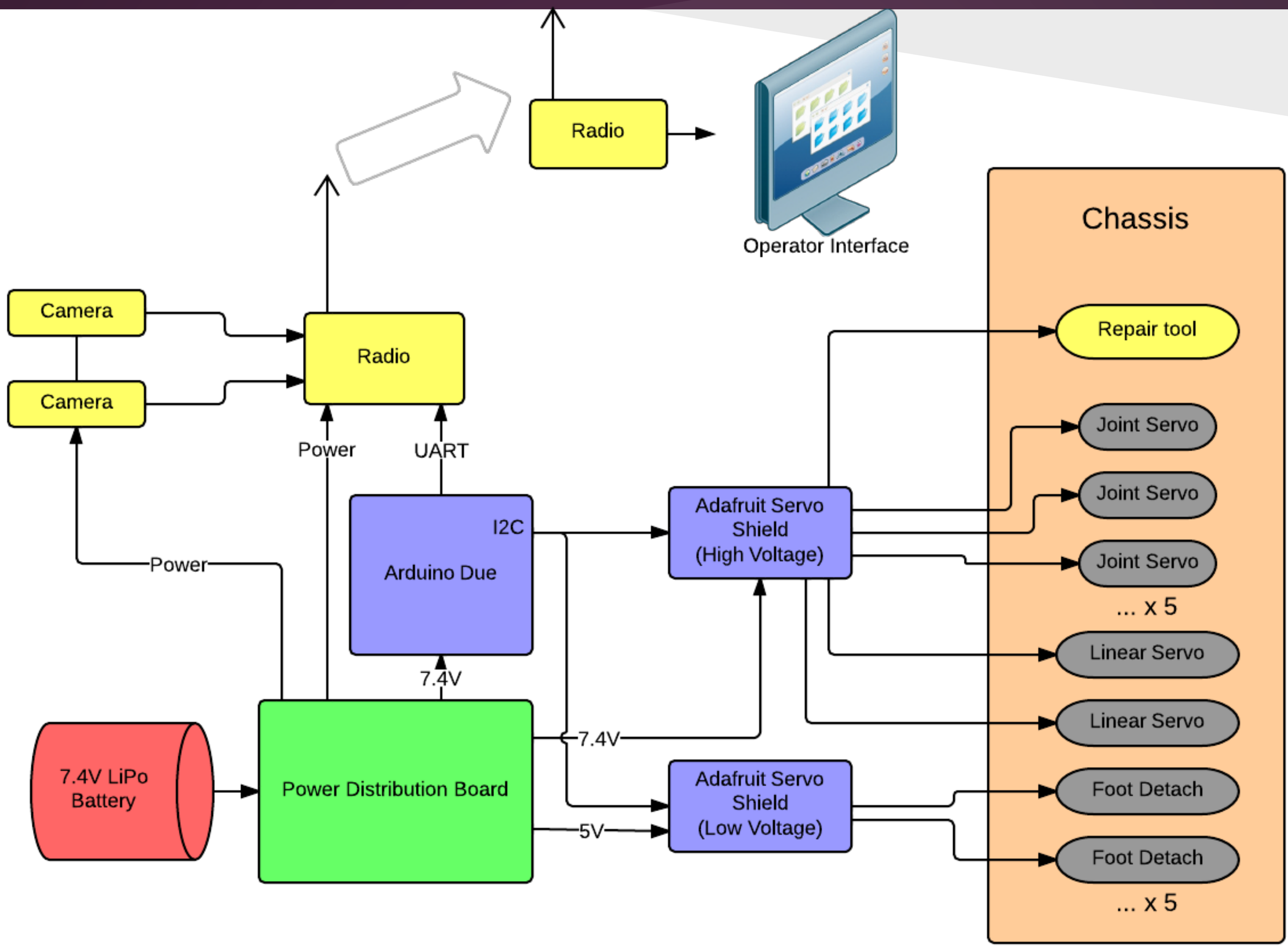
Functional Architecture



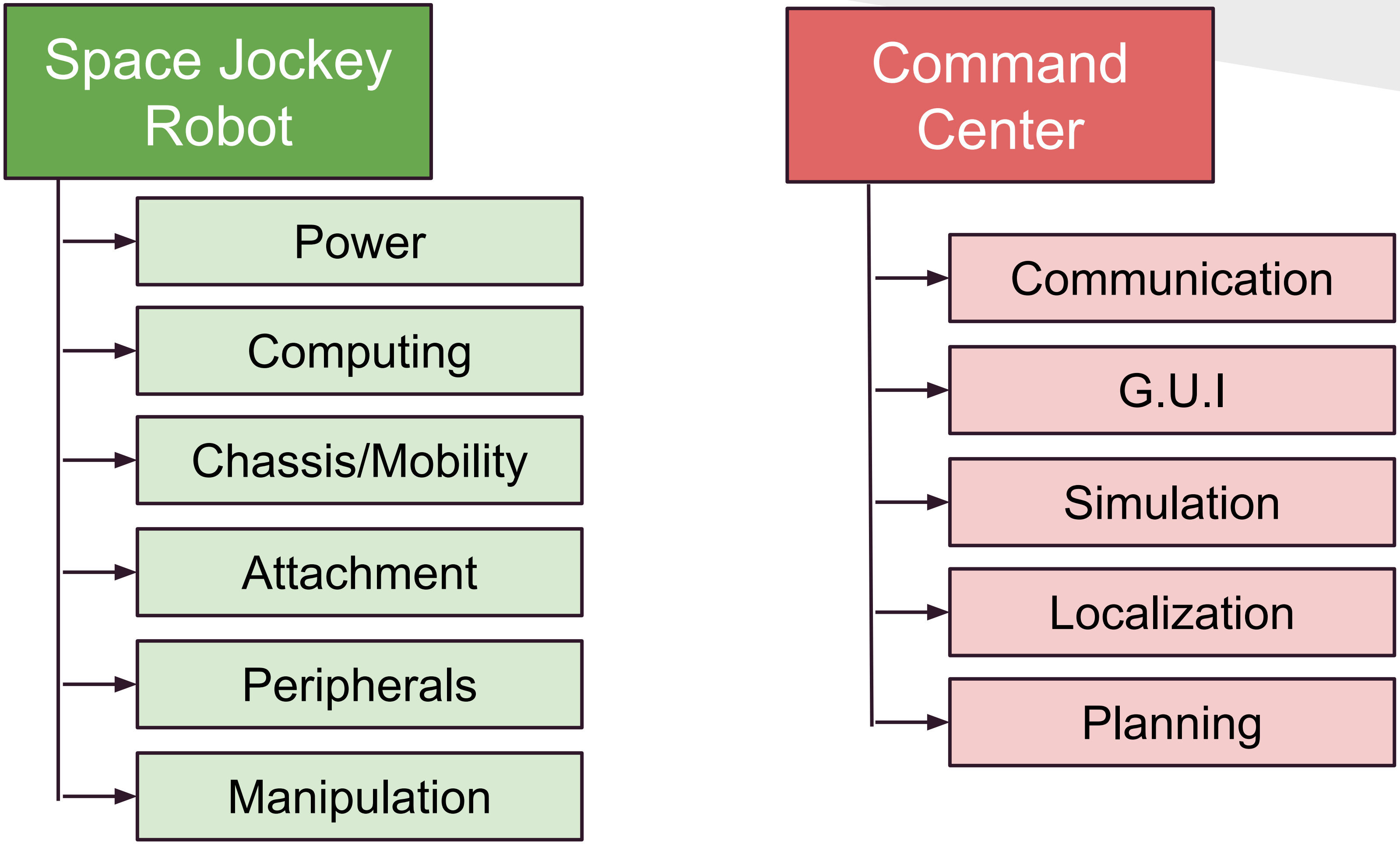
Physical Architecture - Fall



Physical Architecture - Spring



Subsystem Breakdown



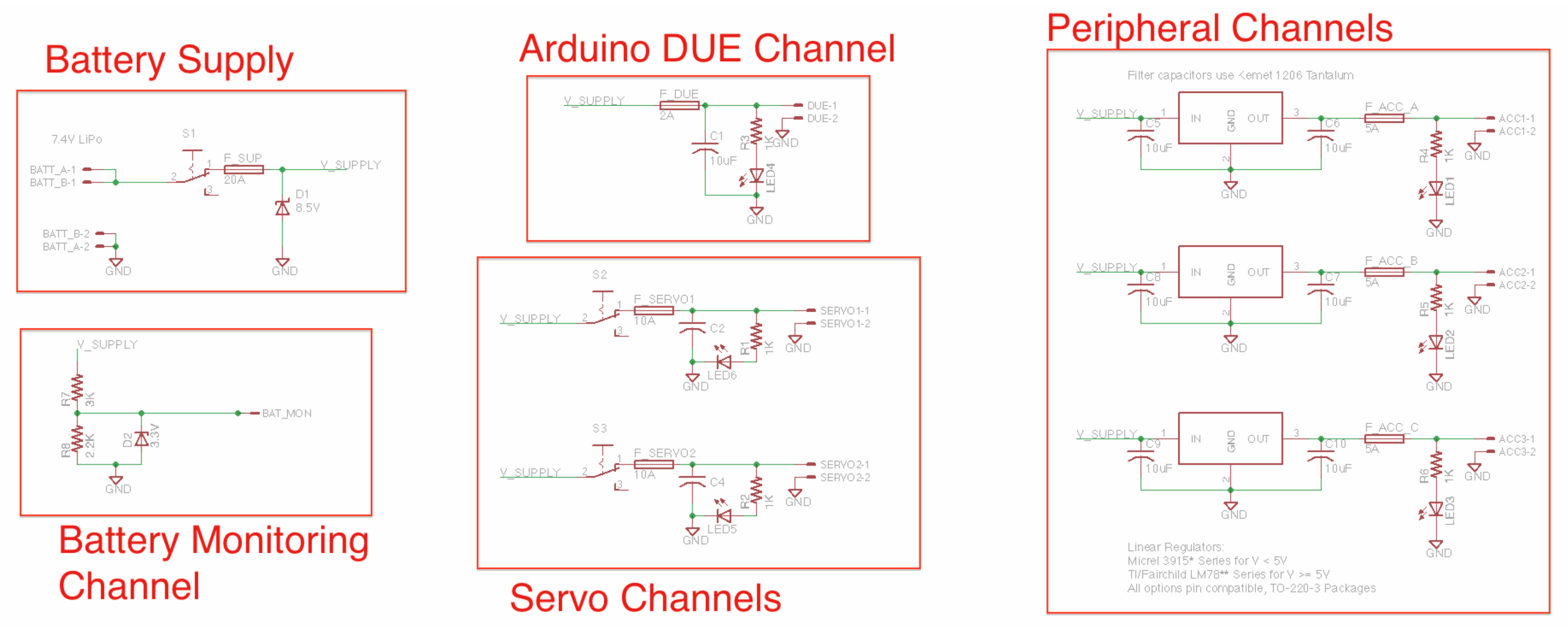
Subsystem Descriptions

Subsystem	Module	Description
Power	Robot	Batteries and power distribution system
Computing	Robot	Sensor/Motor Drivers, Communication
Chassis/Mobility	Robot	Mechanical structure & Actuators
Attachment	Robot	“Sticky” Feet or Hardpoint Grasping System
Peripherals	Robot	Sensors, Cameras
Manipulation	Robot	Tool Use (Desired)
Communication	Command Center	Serial Communication, later WIFI
G.U.I.	Command Center	GUI Control Panel, Sensor Displays
Simulation	Command Center	Simulation and Robot Representation
Localization	Command Center	Sensor Fusion, Mapping, Localization
Planning	Command Center	Joint Trajectory Generation, Path Planning

Status - Power Subsystem

Power Subsystem - Batteries and power distribution system

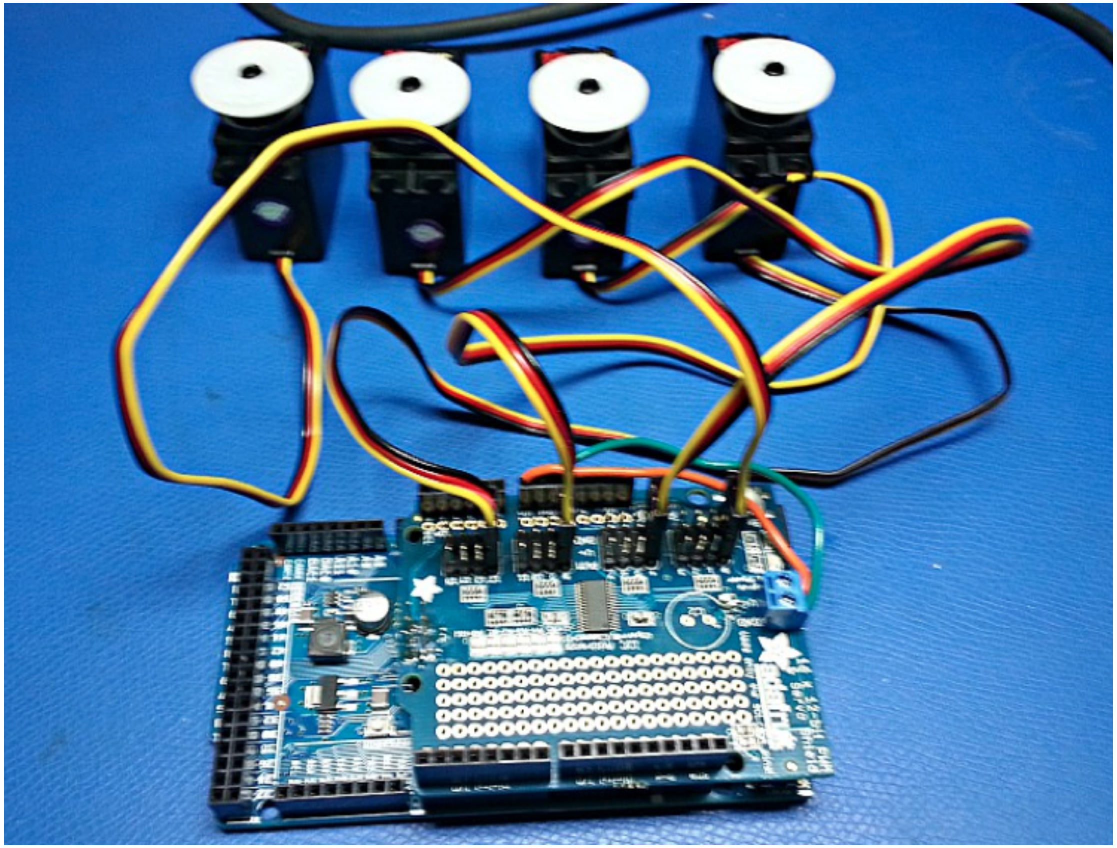
- Power distribution board under development
- Battery acquired



Status - Computing Subsystem

Computing Subsystem - Sensor/Motor Drivers, Communication

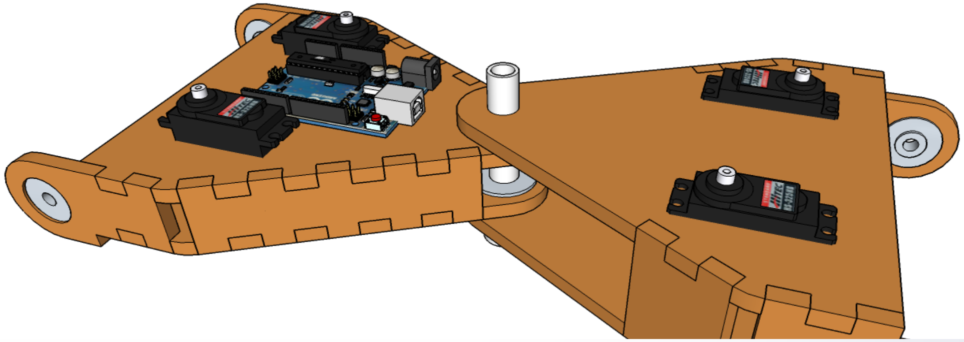
- Arduino DUE acquired
- Servo driver tested

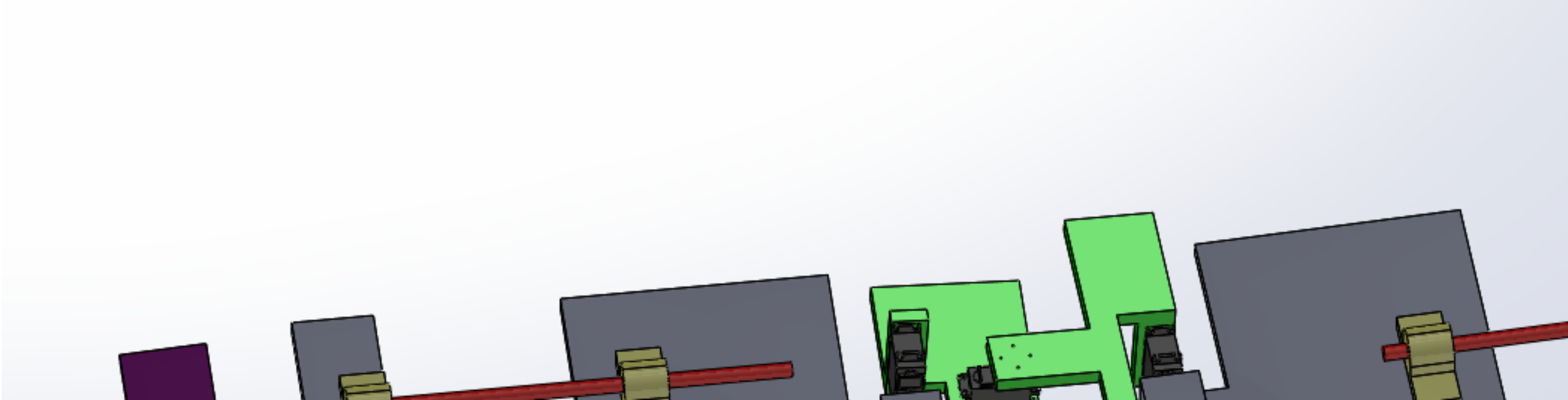


Status - Chassis/Mobility Subsystem

Computing Subsystem - Mechanical Structures & Actuation

- Servos acquired and tested
- CAD concept and partial design for the chassis

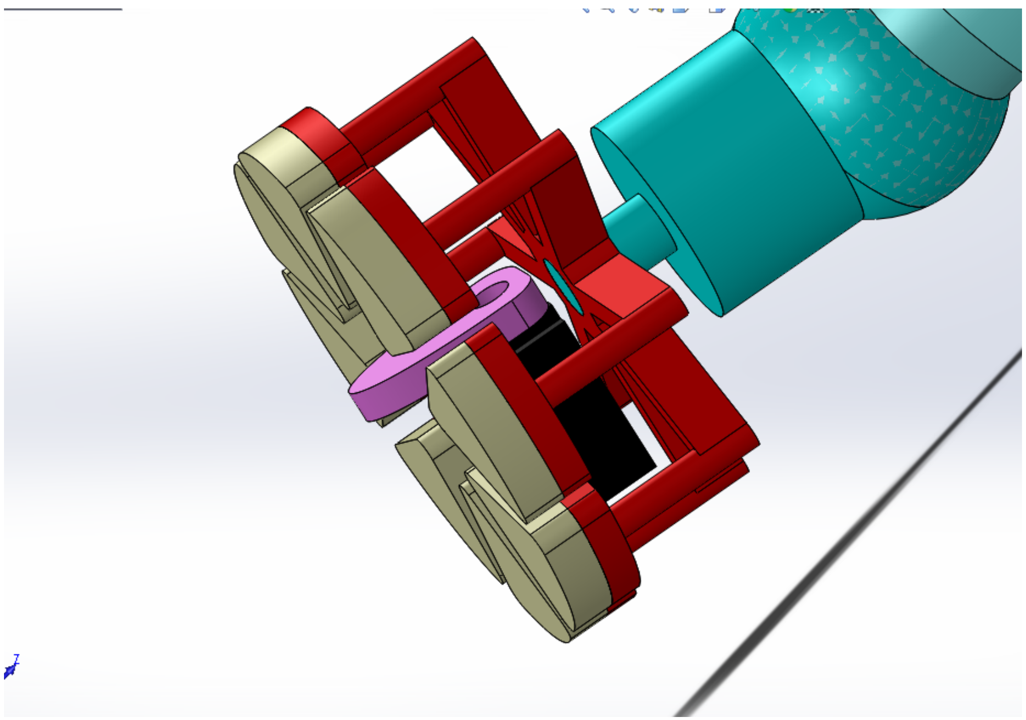


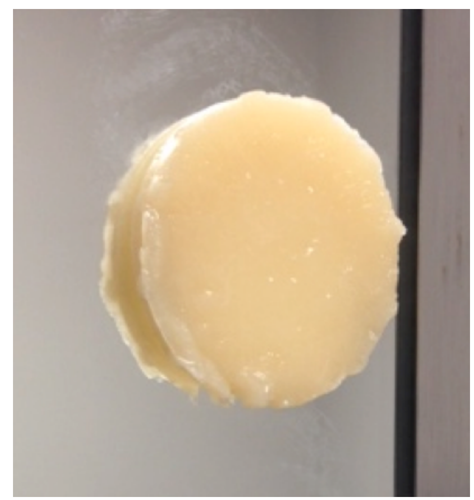


Status - Attachment Subsystem

Attachment Subsystem - “Sticky” Feet

- Foot Mechanism Design
- Vytaflex-10 Trial Moldings





Status - Peripheral & Manipulation

Peripheral Subsystem - Sensors, Cameras

- Servo encoders implicit in their operation
- Camera & IMU (Spring) options budgeted for

Manipulation

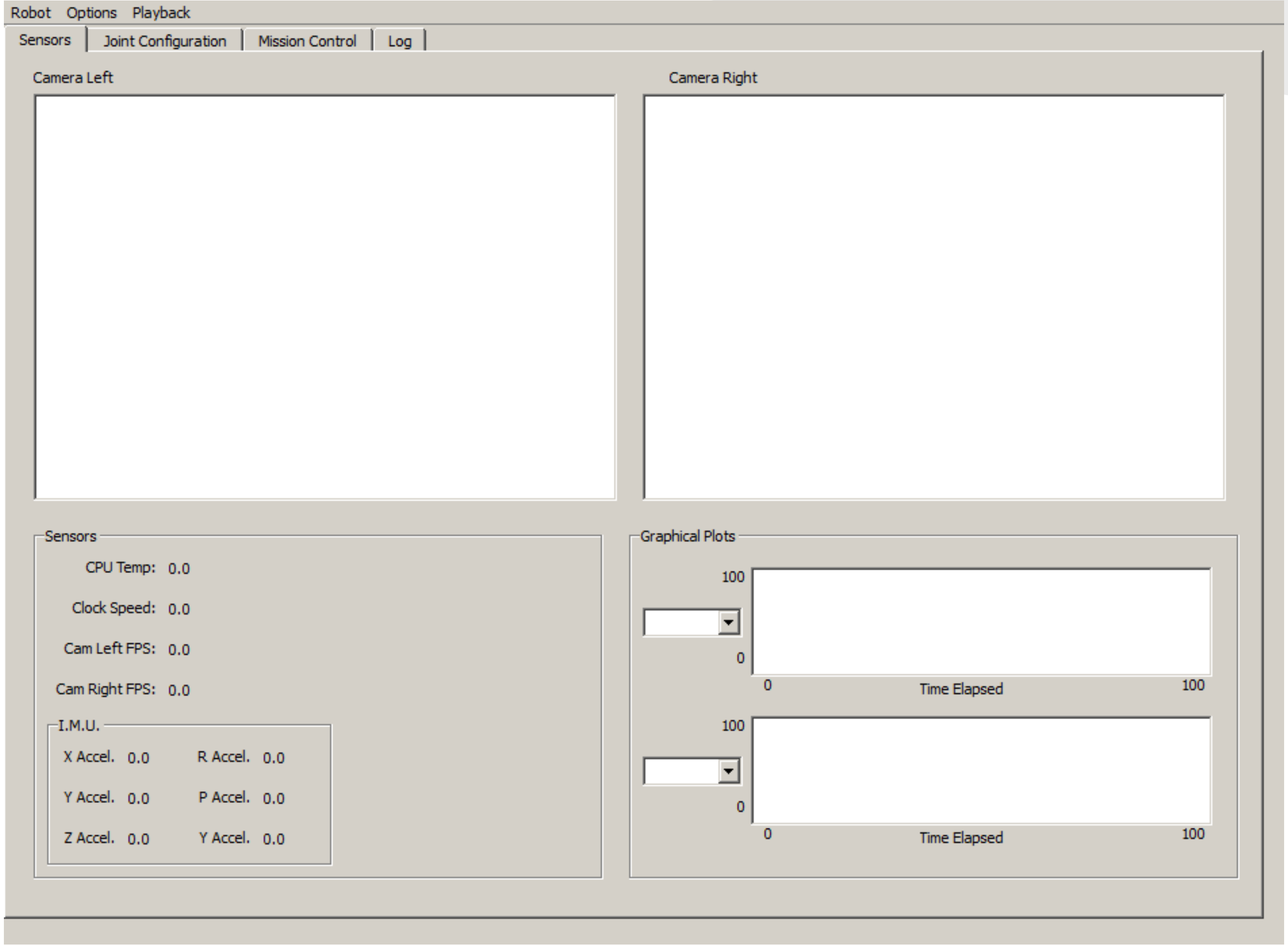
- Spring semester desirable
- Mounted to one or more end segments

Status - Command Center Subsystems

Software Progress

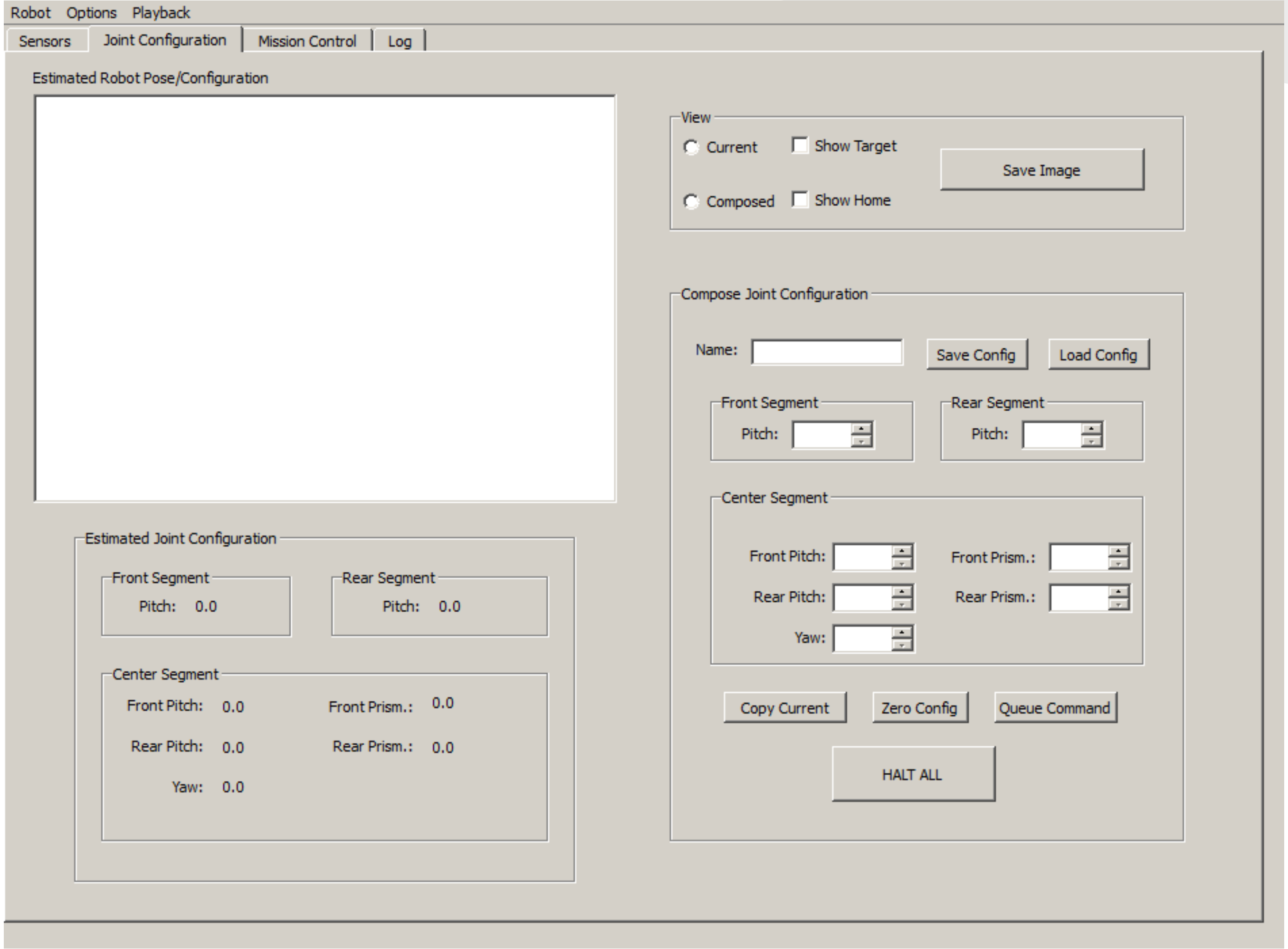
- GUI fleshed out
  - Doubles as software functions wishlist
  - Interface to all other Command Center subsystems
- ROS familiarization and partial package list
- Basic servo control
- Ready for GUI/ROS/driver integration

Status - GUI Subsystem



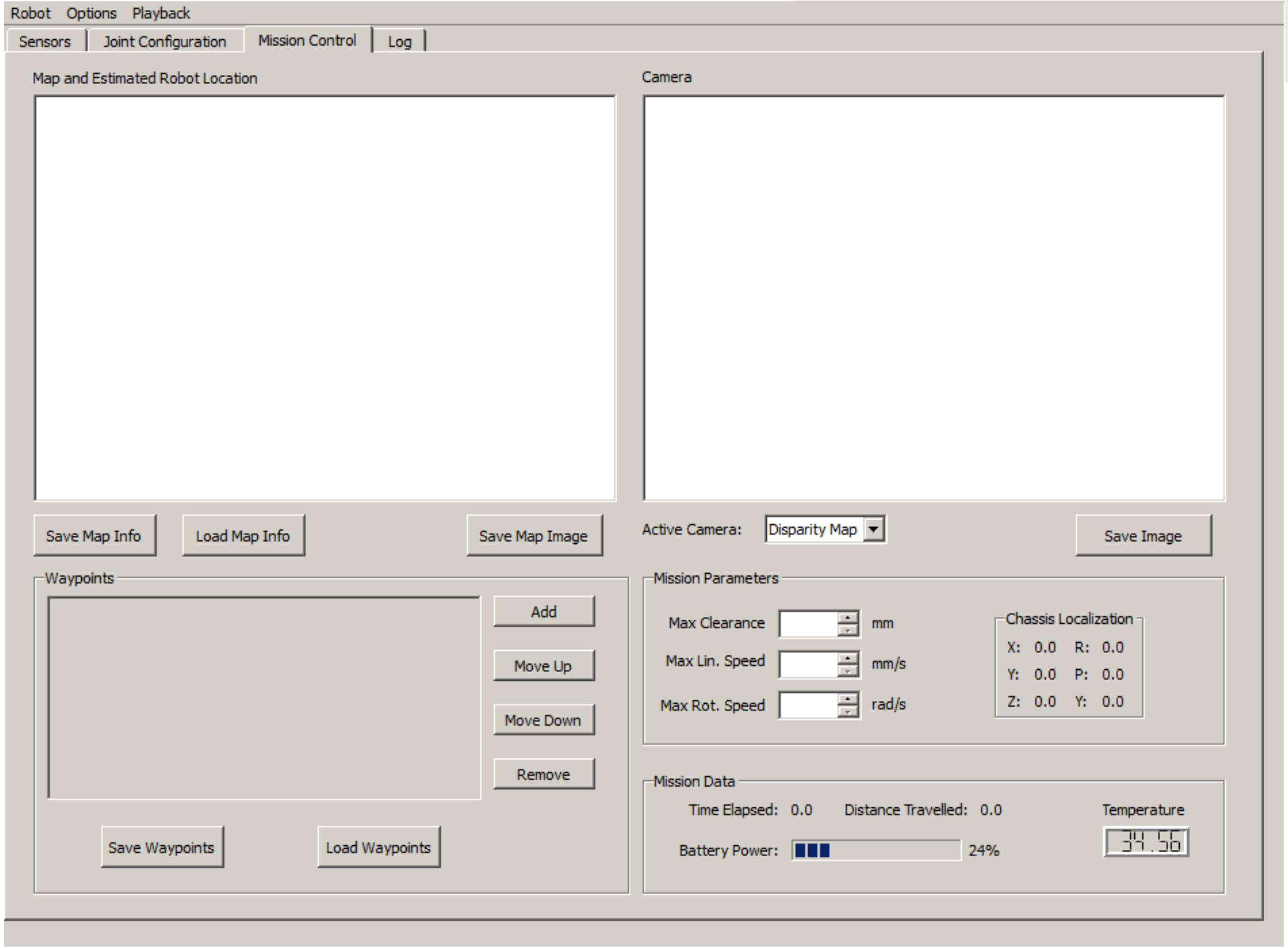
Sensor Management Pane - Assists Comm. Subsyst. Verification

Status - GUI Subsystem (2)



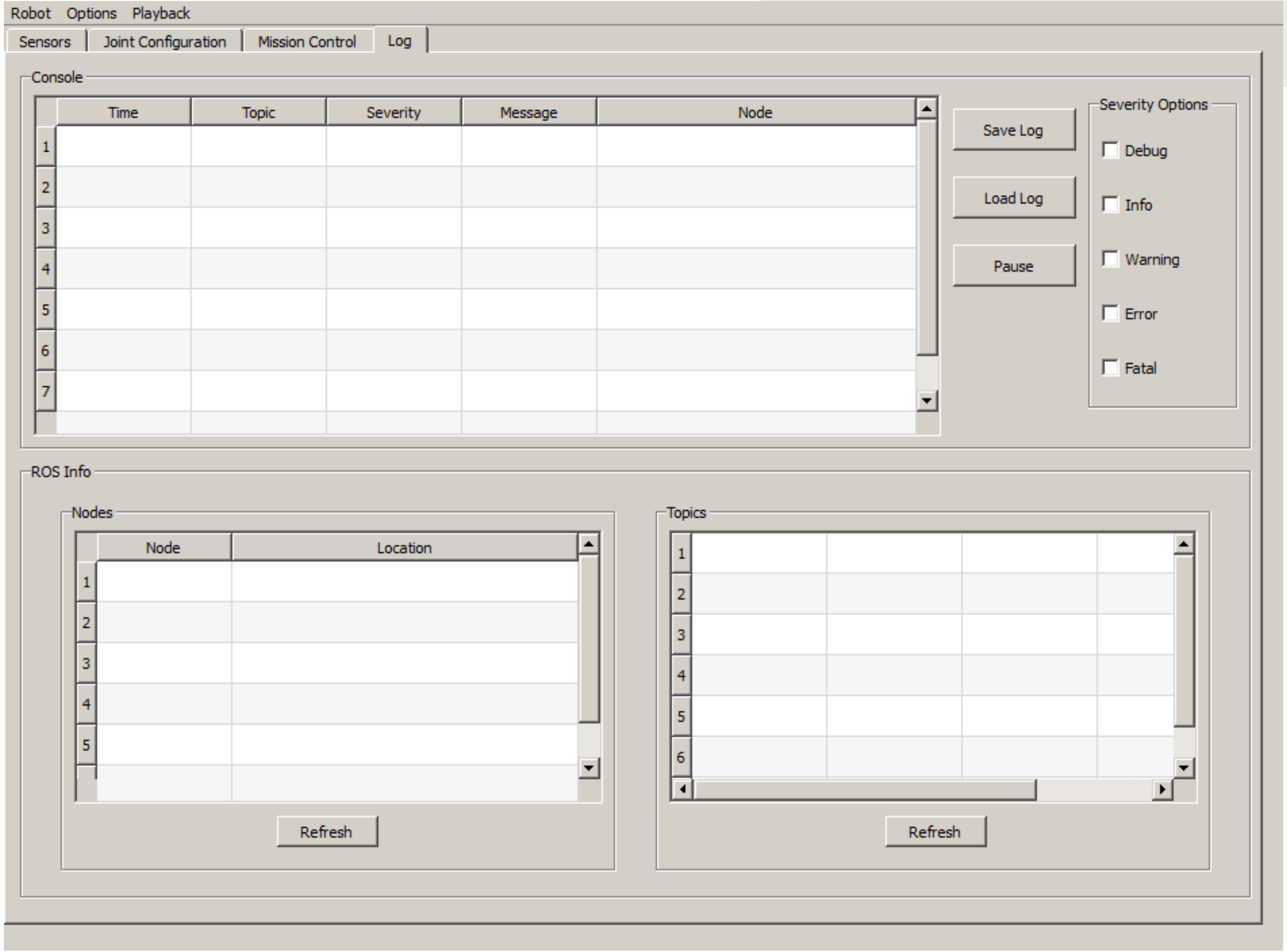
Configuration Management Pane - Assists Simulation Subsystem

Status - GUI Subsystem (3)



Mission Control Pane - Assists Localization & Planning Subsysts.

Status - GUI Subsystem (4)



Log Management Pane - Assists Comm. Subsyst. General Integration

Fall Capability Milestones

	Date	Summary	Test Description
PR 3	11/6	Prototype Precursors	ROS Integration, Simulation Started 1st Prototype Designed Power Distro Board complete Foot Material Cast
PR 4	11/20	1st Prototype	Fully fabricated, assembled chassis with power distribution board Stance commands and basic gait Foot prototyped & tested
PR 5	11/25	Fall Validation Experiment	*See Next Slide*

Fall Validation Test - Setting

Demo Setup

- Location: NSH Level B
- Equipment:
  - Robot
  - Command Center
  - Table or whiteboard as a surface
  - Safety Tether
- Estimated operating area: 6’x6’

Fall Validation Test - Procedure

1. Robot shall be powered on and GUI started
2. GUI will display sensor data from the robot
3. Robot commanded to assume pre-configured stances that collectively demonstrate actuation of all motors
4. Robot will maintain or recover its stance in response to external disturbances
5. Robot commanded to move forward and backward and demonstrate such motions with reasonable smoothness of motion [TPM: 1 meter in 6 minutes]
6. Robot commanded to execute a 45 degree turn while moving forward, and will demonstrate such motion [TPM: Turn within 5 degrees]

Spring Capability Milestones

Month	Summary	Test Description
Jan.	Spring Preparation	Simulation is complete Mechanical redesign priorities list Electrical miniaturization plan
Feb.	1st Prototype Endgame	Camera and IMU integrated Final prototype mostly designed Electrical system redesign finished
March	Final Prototype Completion	Final prototype assembled Mapping and localization operational Radio communication Test environment constructed
April	Demo Preparation	Software demonstrates all mandatory capabilities, Demo procedure rehearsed and finalized
May	Spring Demo	*See Next Slide...*

Spring Demo - Setting

Demo Setup

- Rehearsals in NSH Level B, Demo in Atrium
- Equipment:
  - Robot
  - Command Center
  - Spacecraft Analogue Structure with plane changes
  - Scaffolding
  - Safety Tether
- Spacecraft analogue suspended from floor 4 if possible
- Estimated operating area: 12’x12’

Spring Demo - Procedure

Demo Procedure

1. Robot is powered on and GUI indicates communication
2. Robot is commanded to move by teleoperation and begins inspection
3. Waypoints are set using GUI
4. Path planning generates a motion plan
5. Robot will autonomously travel between the waypoints while updating sensor map [TPM: 10m/hr]
6. At least one waypoint shall require a plane transition [TPM: 60 degrees]

Desirable Extras

1. During teleoperation, the robot will be moved to and tighten a fastener using a rotary tool [TPM: Done in <10 min]
2. In the course of mapping, the command console will identify and alert the user to a flaw in the hull [TPM: 80% Success]

Name	Begin date	End date
1 Software	10/14/13	5/2/14
1.1 User Interface	10/14/13	11/29/13
1.1.1 Spec & Build GUI	10/14/13	10/25/13
1.1.2 ROS Setup	10/28/13	11/1/13
1.1.3 Wire GUI to ROS	11/4/13	11/8/13
1.1.3 Stance Commands	11/11/13	11/22/13
1.1.4 Waypoint Functionality	11/25/13	11/29/13
1.2 Control	10/14/13	11/22/13
1.2.1 Servo Drivers	10/14/13	10/25/13
1.2.2 Kinematic Solver	10/28/13	11/8/13
1.2.3 Gait Generation	11/11/13	11/22/13
1.3 Perception	10/28/13	2/28/14
1.3.1 Sensor Interpretation	10/28/13	11/8/13
1.3.2 Stereo Vision	1/20/14	2/7/14
1.3.3 Localization	2/10/14	2/28/14
1.4 Planning	11/11/13	3/21/14
1.4.1 Buld Simulation	11/11/13	1/31/14
1.4.2 Mapping Representation	2/10/14	2/28/14
1.4.3 Waypoint Execution	12/2/13	12/20/13
1.4.4 Path Planning	3/3/14	3/21/14
1.5 Demo Preparation	3/3/14	5/2/14
Basic Motion Automation	3/3/14	3/21/14
Planar Waypoint Following	3/24/14	4/4/14
Plane Transitions	4/7/14	4/18/14
Rehearsal and Tweaking	4/21/14	5/2/14
2 Mechanical Design	10/14/13	3/28/14
2.1 CAD Modelling	10/14/13	2/14/14
2.1.1 Center Segment	10/14/13	10/25/13
2.1.2 End Segment	10/28/13	11/8/13
2.1.3 Camera Mount	1/20/14	1/24/14
2.1.4 Final Prototype	12/30/13	2/14/14
2.2 Fabrication	10/28/13	2/28/14
2.2.1 Center Segment	10/28/13	11/8/13
2.2.2 End Segment	11/11/13	11/22/13
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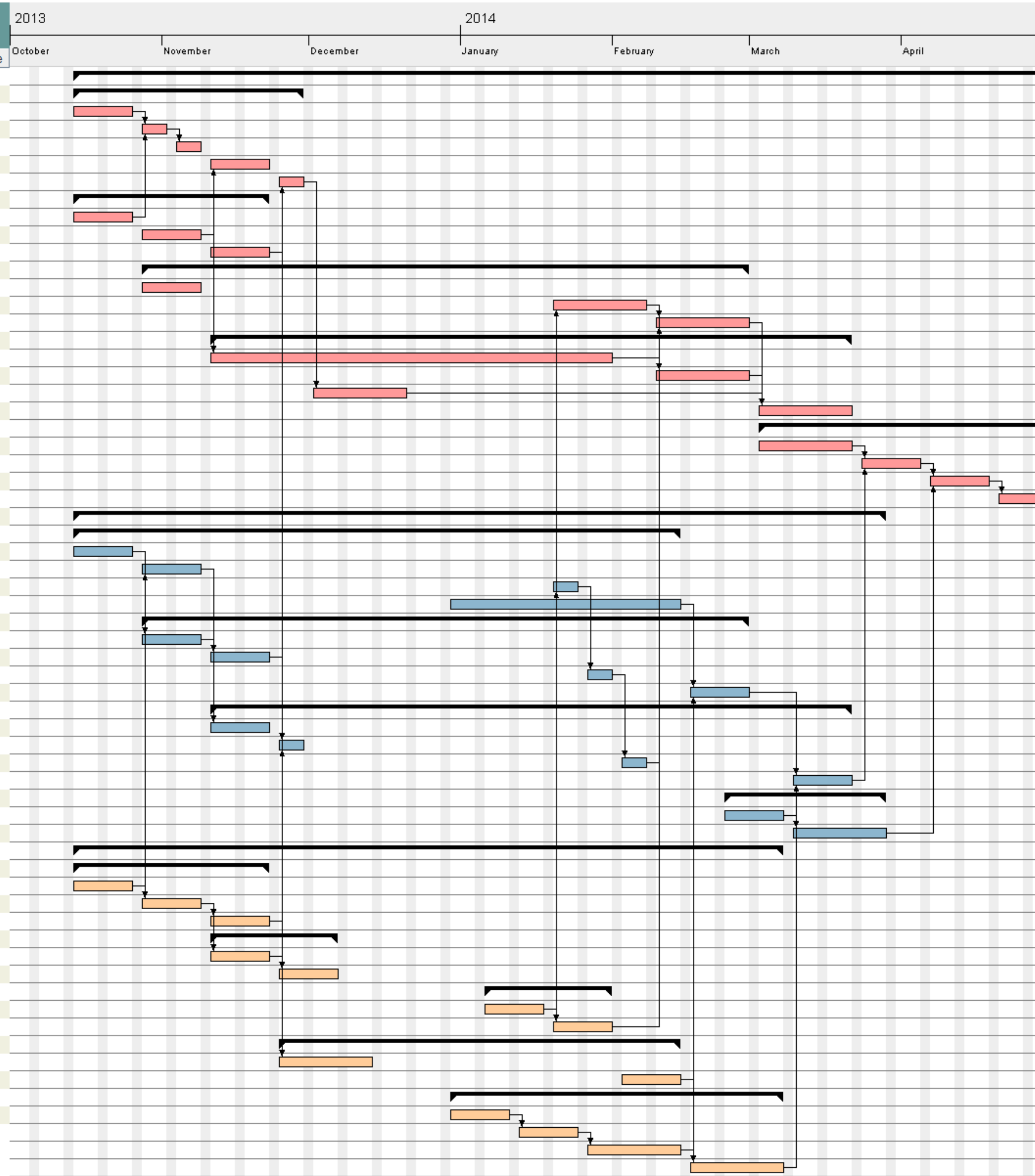
2.4 Demo Preparation	2/24/14	3/28/14
2.4.1 Environment Design	2/24/14	3/7/14
2.4.2 Environment Construction	3/10/14	3/28/14
3 Electrical Design	10/14/13	3/7/14
3.1 Power Distribution System	10/14/13	11/22/13
3.1.1 Needs Analysis & Design	10/14/13	10/25/13
3.1.2 Fabricate PCB	10/28/13	11/8/13
3.1.3 Acquire/Assemble Parts	11/11/13	11/22/13
3.2 Control System	11/11/13	12/6/13
3.2.1 Acquire uC and Servo Driver	11/11/13	11/22/13
3.2.2 Implement Position Feedb...	11/25/13	12/6/13
3.3 Sensor Integration	1/6/14	1/31/14
3.3.1 Acquire Cameras & IMU	1/6/14	1/17/14
3.3.2 Integrate with uC/Comms	1/20/14	1/31/14
3.4 Communications	11/25/13	2/14/14
3.4.1 Serial Tether	11/25/13	12/13/13
3.4.2 Radio Comms	2/3/14	2/14/14
3.5 Final Prototype	12/30/13	3/7/14
3.5.1 Prototype Analysis	12/30/13	1/10/14
3.5.2 Miniaturization Study	1/13/14	1/24/14
3.5.3 Redesign/Tweaking	1/27/14	2/14/14
3.5.4 Assembly	2/17/14	3/7/14



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Schedule - Mechanical

2 Mechanical Design	10/14/13	3/28/14
2.1 CAD Modelling	10/14/13	2/14/14
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Schedule - Electrical Design

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3.5.4 Assembly	2/17/14	3/7/14

Risk Management - Sources

Risk	Associated Requirements	Description	Type	Cause	Likelihood	Consequences
Team Member Illness	Timely Project Completion	A team member is severely ill for a significant period	Schedule	Largely Chance	Somewhat Likely	Lost Man-Hours and Expertise
Insufficient Servo Torque	Mobility, Traversal	Unable to lift segments with given motors	Technical	Unexpectedly High Mass	Rather Likely	Reduced or No Mobility
Overweight Linear Actuators	Mobility, Traversal	COTS linear actuators too heavy	Technical	Servo Torque constraints	Extremely Likely	Reduced or No Mobility
Insufficient “Stick”	Attachment	Adhesive foot material provides Insufficient “Stick” to support robot	Technical	Robot Weight, Foot material properties	Somewhat Likely	Poor attachment on vertical or inverted surfaces
Actuator cost over-budget	Cost	Actuators and associated component cost exceed expectations	Cost	Budget constraints	Somewhat likely	Total project over-budget
ROS Package Incompatibility	Technical	A ROS package we need is not compatible with our ROS version	Technical (Software)	ROS Developers	Likely	Limited software capability

Risk Management - Mitigation

Risks	Reduction Plan	Actions Planned	Expected Outcome	Comments
Team Member Illness	Redundant system knowledge between team members. Healthy living / Flu shots.	Primary and secondary assignees for all project tasks.	Minimal loss of expertise.	Nothing can be done about lost man-hours
Insufficient Servo Torque	Designed with Mid-range servos in mind, larger torques available if needed.	Weight budgeting and motor trade studies. Support additional gear/linkage reduction in design.	All torque needs met. Some time lost in redesign/shipping.	
Overweight linear actuators	Find workarounds for specialized actuators.	Retrofit and modify hobby servos to suit linear applications	Time lost, but lower weight actuators.	
Insufficient “Stick”	Hardpoint-attachment	Test feet with generous weight Develop hardpoint attachment backup plan	Smooth transition to hardpoint plan if necessary	Peg-in-hole attachment method
Actuator cost over-budget	Total project budget significantly less than class limit.	Cut into managerial overhead	Total budget does not exceed $4000	
ROS Package Incompatibility	Spec packages early	Attempt upgrade or write package ourselves	Lost Dev. Time	

Parts List - To Date

Description	Part #	Vendor	Qty.	Cost	Total
Adafruit 16-Channel 12-bit PWM/Servo Shield	1411	Adafruit	2	$17.50+5.35	$35.35
3x4 Right Angle Male Header	816	Adafruit	2	$2.95	$5.90
Shield Stacking Headers	85	Adafruit	2	$1.95	$3.90
Arduino Due Board	1050-1049-ND	Digikey	2	$51.91	$103.83
Std. Size 7.4V Hitec Servo	HS-5496MH	Servo City	4	$34.99+6.99	$146.95
Vytaflex 10 - Trial Size	Vytaflex-10	Smooth-On	1	$25.96+8.13	$34.09
XT60 Bullet Connectors x10	XT60	Amazon	1	$6.82+4.4	$11.22
3’ USB A to Micro B Cable x2	N/A	Amazon	2	$8.99	$17.98
MDF Project Panel ‘2x’4x’1/4	1508104	Home Depot	3	$6.67	$20.01
Total					$379.23

Parts Budget Projection - Fall

Description	Qty.	Cost	Total
Costs to date	*N/A*	*$379.25*	*$379.25*
Additional rotary joint servos + linkages	5	$60	$300
Linear Actuator Assemblies	2	$160	$320
7.4V LiPo Battery Packs (MRSD Stock)	2	$50	$100
Micro Servos (Foot Peeling Mechanism)	6	$25	$150
Prototyping Supplies and Misc. Hardware.	N/A	$500	$500
Fall test environment construction	N/A	$200	$200
Fall Total			$1950

Parts Budget Projection - Spring

Description	Qty.	Cost	Total
Cameras (Wifi or UHF)	2	$150	$300
IMU	1	$150	$150
Radios (XBee Pro) + Breakout	2	$75	$150
Misc. Hardware	N/A	$500	$500
Spring demo environment construction	N/A	$100	$100
Spring Total			$1200

Total Project Budget

Fall Expenditures	$1950
Spring Expenditures	$1200
Managerial Overhead	$500
Total	**$3650**

Q&A

Thank You!

Acknowledgements:

- Dimi Apostolopoulos
- Metin Sitti
- MRSD Project Course Advisors (John, Neil, Ben)