Team E: Preliminary Design Review

Dock-in-Piece

"FLYING IS SIMPLE! NOT HITTING THE ~~GROUND~~ DOCK IS HARD"

-Fortune Cookie

Rushat Gupta Chadha **Keerthana Manivannan** **Bishwamoy Sinha Roy**
Aishanou Osha Rait **Paul M. Calhoun**

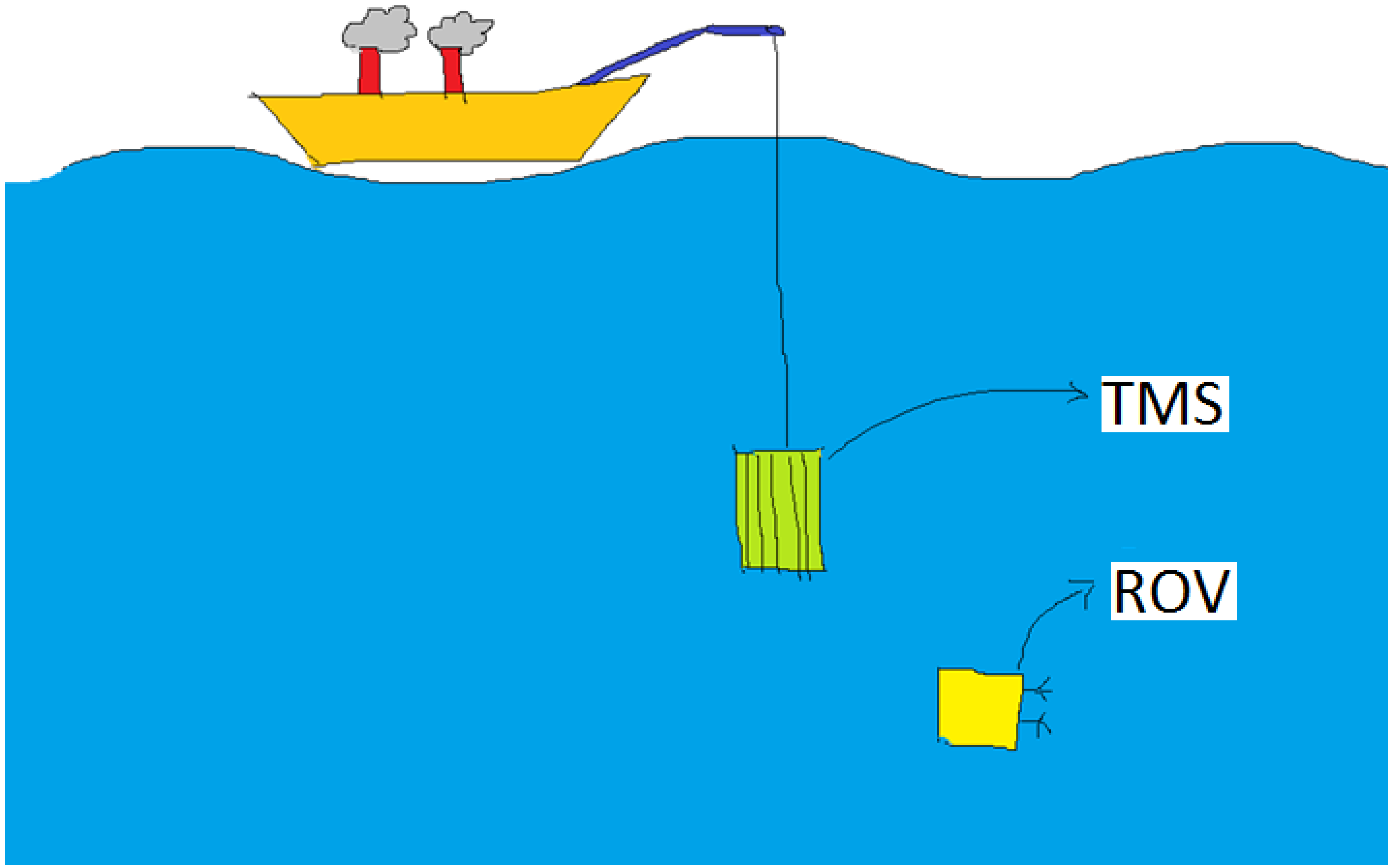
Overview

• Project Description	Rushat
• Use Case	Paul
• System-level Requirements	Keerthana
• Functional Architecture	Keerthana
• Cyber-physical Architecture	Roy
• Subsystem Description	Roy
• Current System Status	Rushat
• Schedule & Test Plans	Aishanou
• Project Management Details	Paul

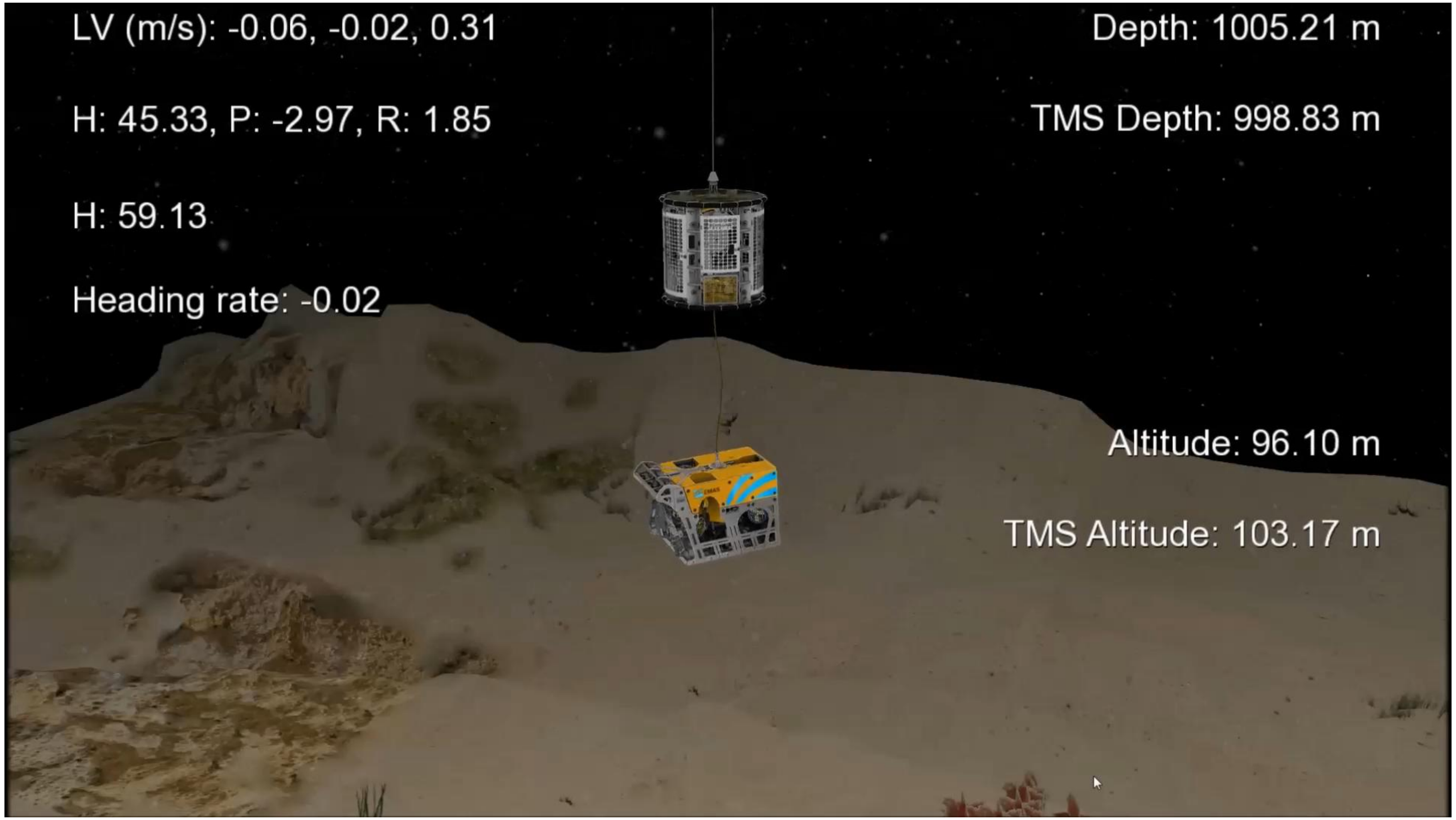
Project Description

- A terrestrial solution to a real world subsea problem at Schilling Robotics
- What does Schilling Robotics do?
  - Manufactures world-class remotely operated vehicles (**ROVs**) and manipulator arms
  - Core philosophy - Continuous improvement both in **reliability** and **cost efficiency**

Project Description



Project Description - Video

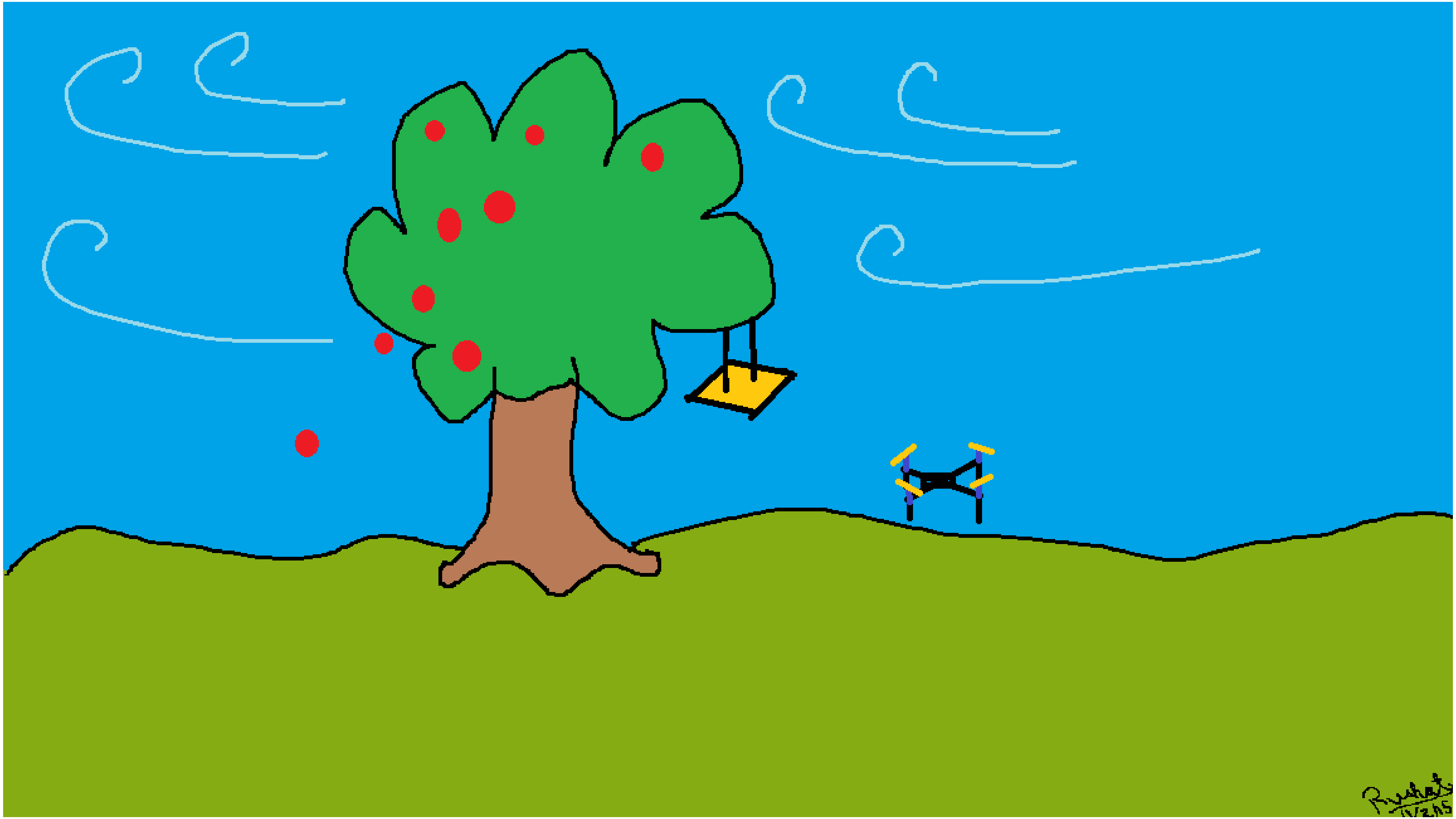


Use Case

Presented by: Paul

RETROFIT KIT


Customer Survey
Excellent
Very Good
Meet Expectation
Below Expectation
Poor Performance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SYMA

INVOICE

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[Company Slogan]

[Stress Address]
[City, ST ZIP]
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Fax: [000-000-0000]

DATE:	11/1/2011
INVOICE #	[123456]
Customer ID	[123]

BILL TO:
[Name]
[Company Name]
[Stress Address]
[City, ST ZIP]
[Phone]

SHIP TO (if different):
[Name]
[Company Name]
[Stress Address]
[City, ST ZIP]
[Phone]

SALESPERSON	P.O. #	SHIP DATE	SHIP VIA	F.O.B.	TERMS

ITEM #	DESCRIPTION	QTY	UNIT PRICE	TOTAL
[2345678]	Product XYZ	15	150.00	2,250.00
[2342342]	Product ABC	1	75.00	75.00
				-
				-
				-
				-
				-
				-
				-

SUBTOTAL	$	2,325.00
TAX RATE		6.875%
TAX	$	159.84
S & H	$	-
OTHER	$	-
TOTAL	**$**	**2,484.84**

Other Comments or Special Instructions
1. Total payment due in 30 days
2. Please include the invoice number on your check

If you have any questions about this invoice, please contact
[Name, Phone #, E-mail]

Make all checks payable to
[Your Company Name]

Thank You For Your Business!

Please detach the portion below and return it with your payment.

REMITTANCE

[Company Name]

[Stress Address]
[City, ST ZIP]
Phone: [000-000-0000]
Fax: [000-000-0000]

DATE	11/1/2011
INVOICE #	[123456]
Customer ID	[123]

AMOUNT ENCLOSED

PROGRAM EXECUTIVE OFFICE

PEO IWS

INTEGRATED WARFARE SYSTEMS

System Level Requirements

Presented by: Keerthana

Mandatory Functional Requirements

- The system shall –
  - F1. Have two major components: quadcopter and a moving docking platform
  - F2. Detect and communicate when **docking is not possible**
- The docking platform shall –
  - F1.1 Be moving till the quadcopter has been docked
  - F1.2 **Withstand the weight** of the quadcopter once it has been docked
- The quadcopter shall –
  - F2.1 **Localize** itself w.r.t. the docking platform
  - F2.2 **Plan** a path to the docking platform
  - F2.3 **Navigate** to the platform
  - F2.4 **Dock** to the platform without any collision

Mandatory Non Functional Requirements

- The system shall:
  - NF1. Function in a GPS degraded environment
  - NF2. Provide a user interface with DOCK option and current status
- The quadcopter shall:
  - NF2.1 Have a payload capacity of > 500g

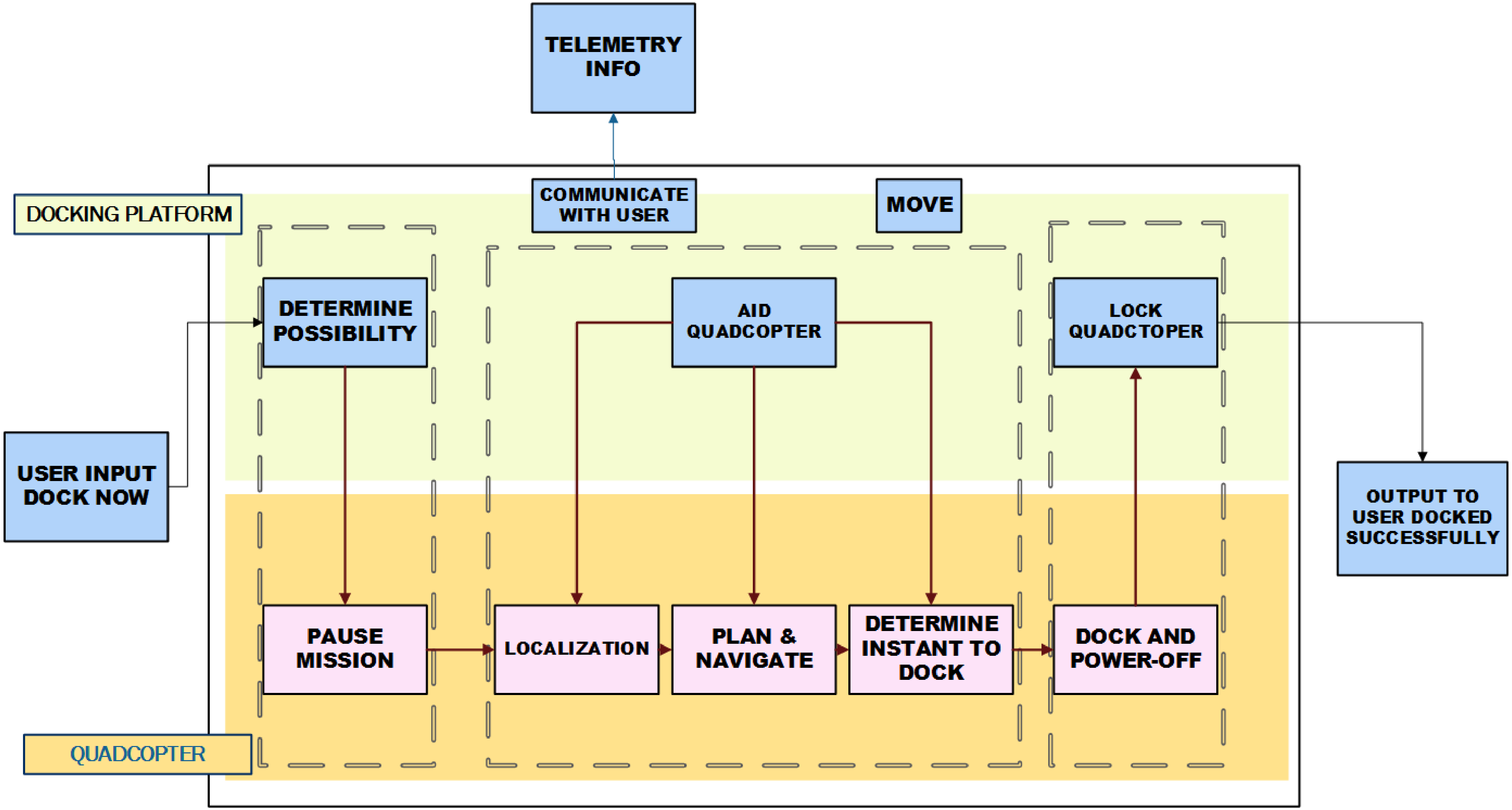
Desirable Requirements

- The docking platform shall –
  - DP1.1. Have 3 degrees of freedom along X, Y and Z-direction
  - DP1.2. Have random movements in 3D space
- The quadcopter shall –
  - DP2.1. Localize w.r.t. platform within 50 mm accuracy
  - DP2.2. Navigate to the platform within 5 minutes

Functional Architecture

Presented by: Keerthana

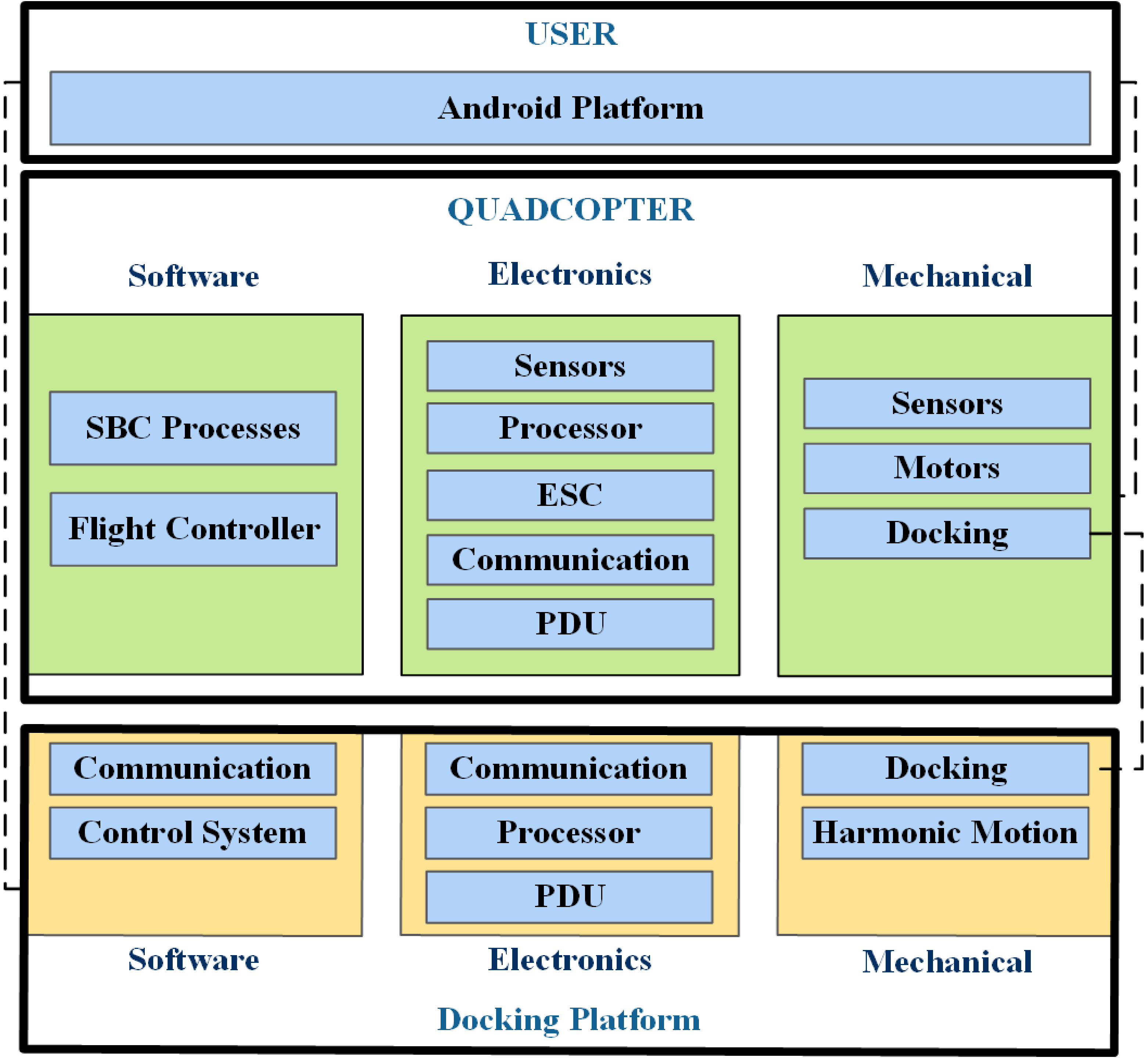
Functional Architecture - Docking



Cyber-physical architecture

Presented by: Roy

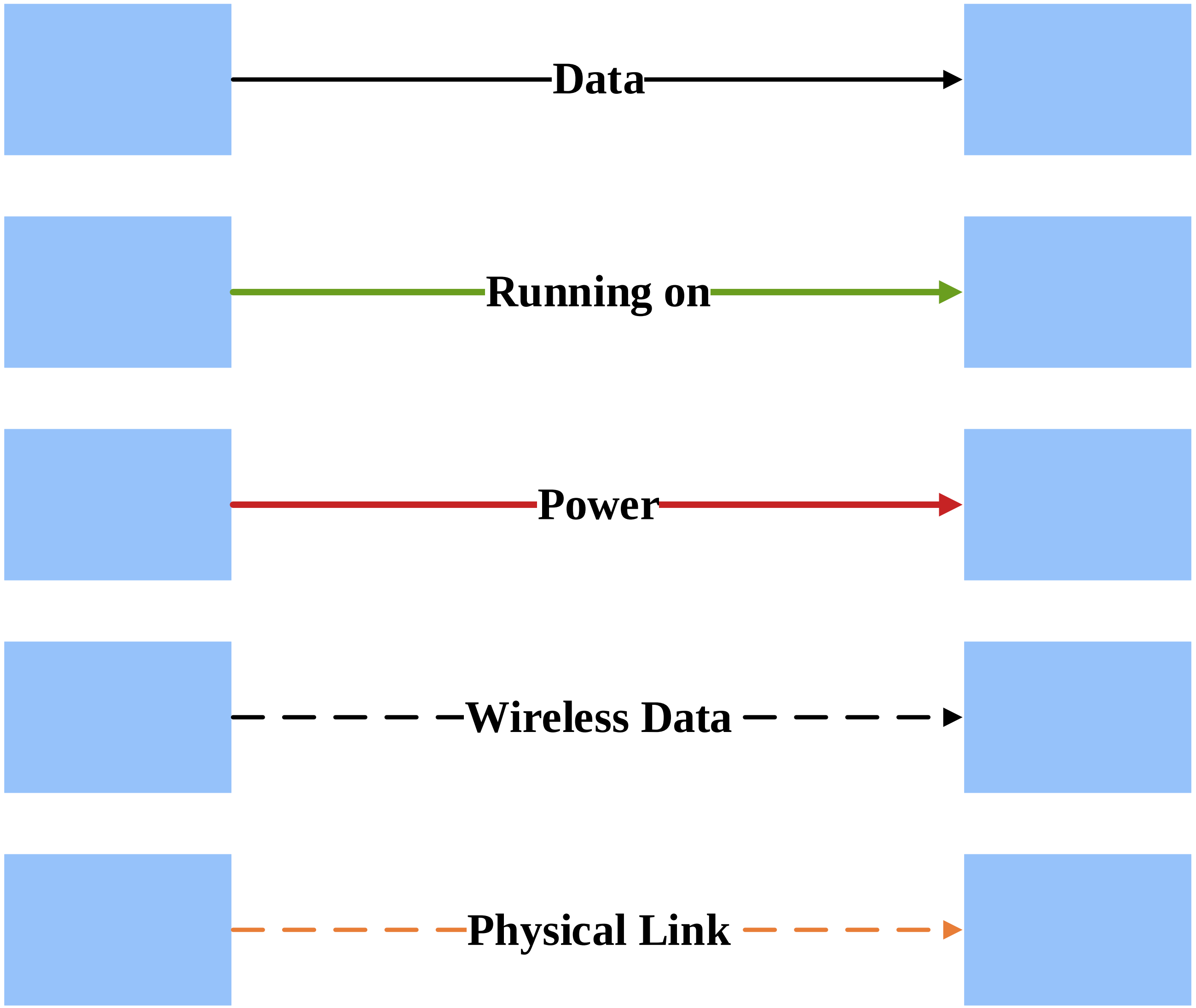
Overview


USER
Android Platform
QUADCOPTER
Software
Electronics
Mechanical
SBC Processes
Flight Controller
Sensors
Processor
ESC
Communication
PDU
Sensors
Motors
Docking
Communication
Control System
Communication
Processor
PDU
Docking
Harmonic Motion
Software
Electronics
Mechanical
Docking Platform

Subsystem Description

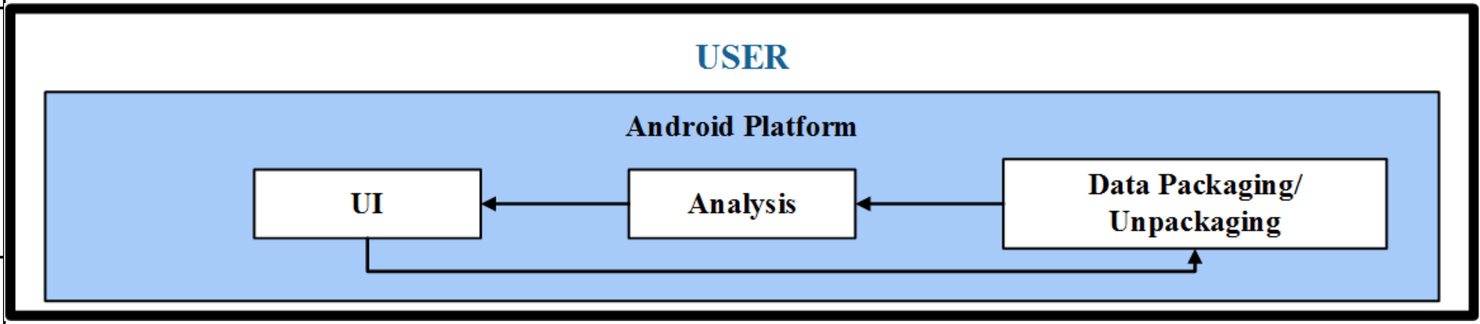
Presented by: Roy

Legend



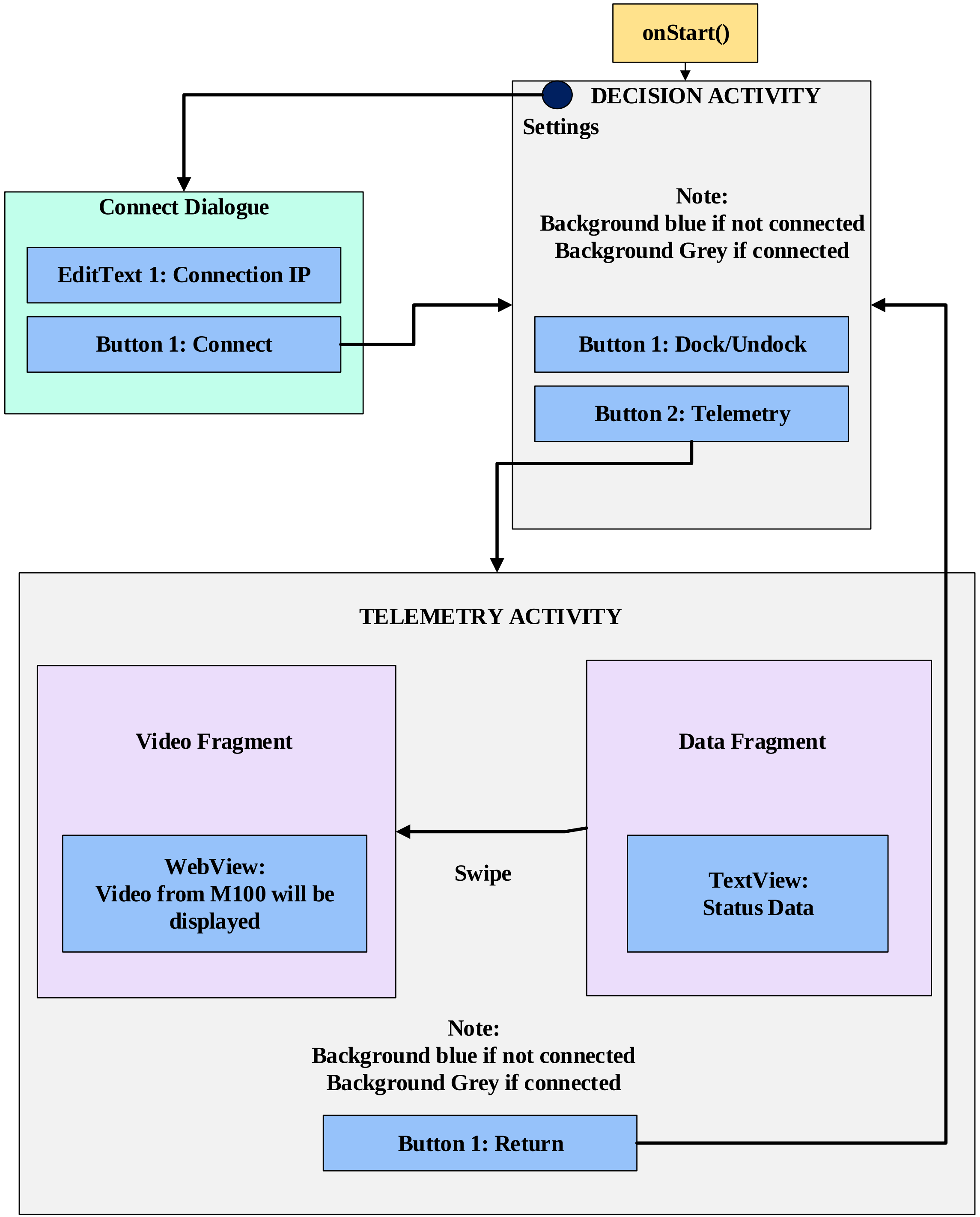
Subsystem - User

INPUT	• Quadcopter status information • Dock status information • User Input
ANALYSIS	Un-packaging and Packaging of data
OUTPUT	Dock Command
PLATFORM	Android Application



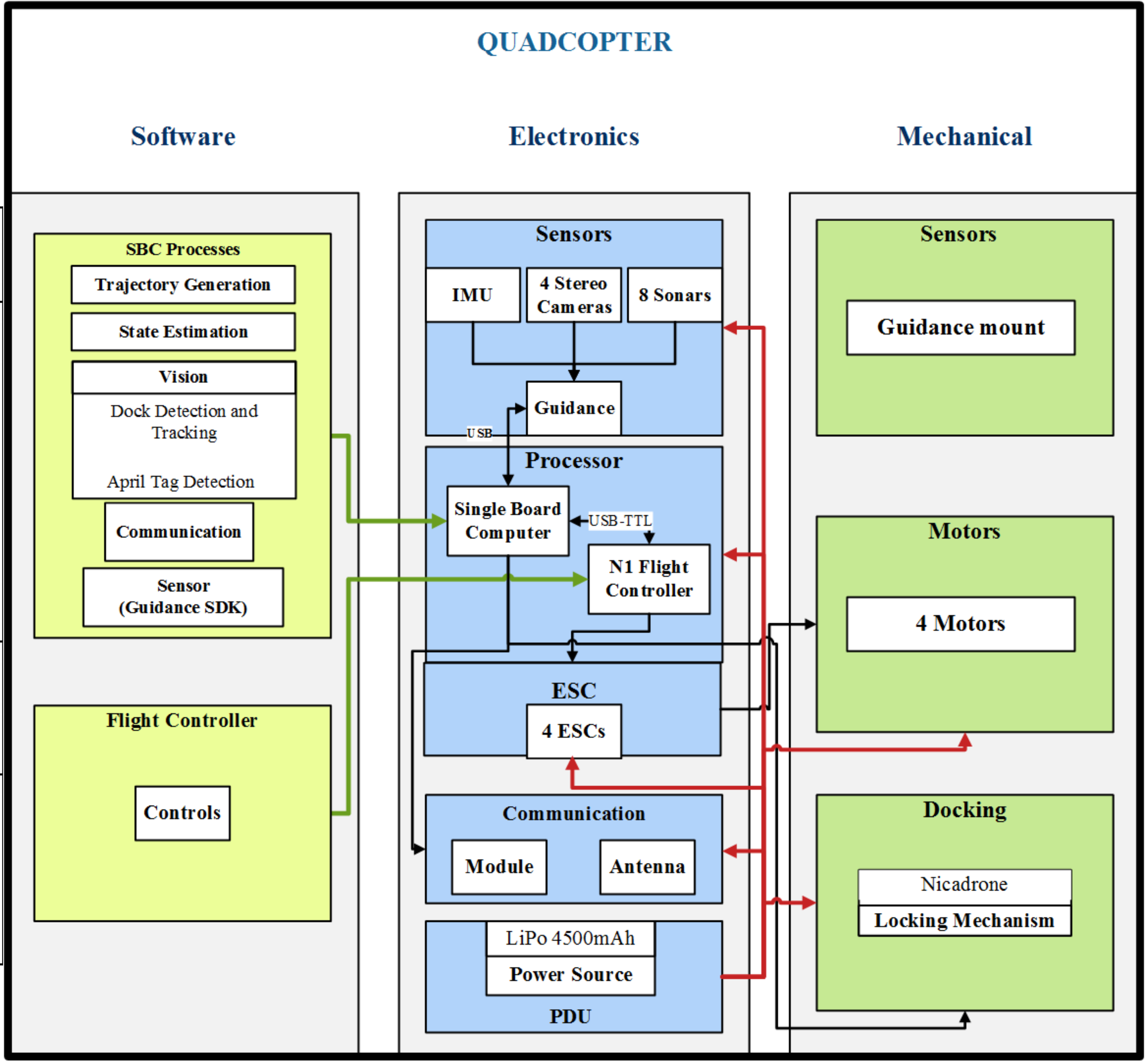
Subsystem - User

- App Wireframe – shows the interaction between different activities

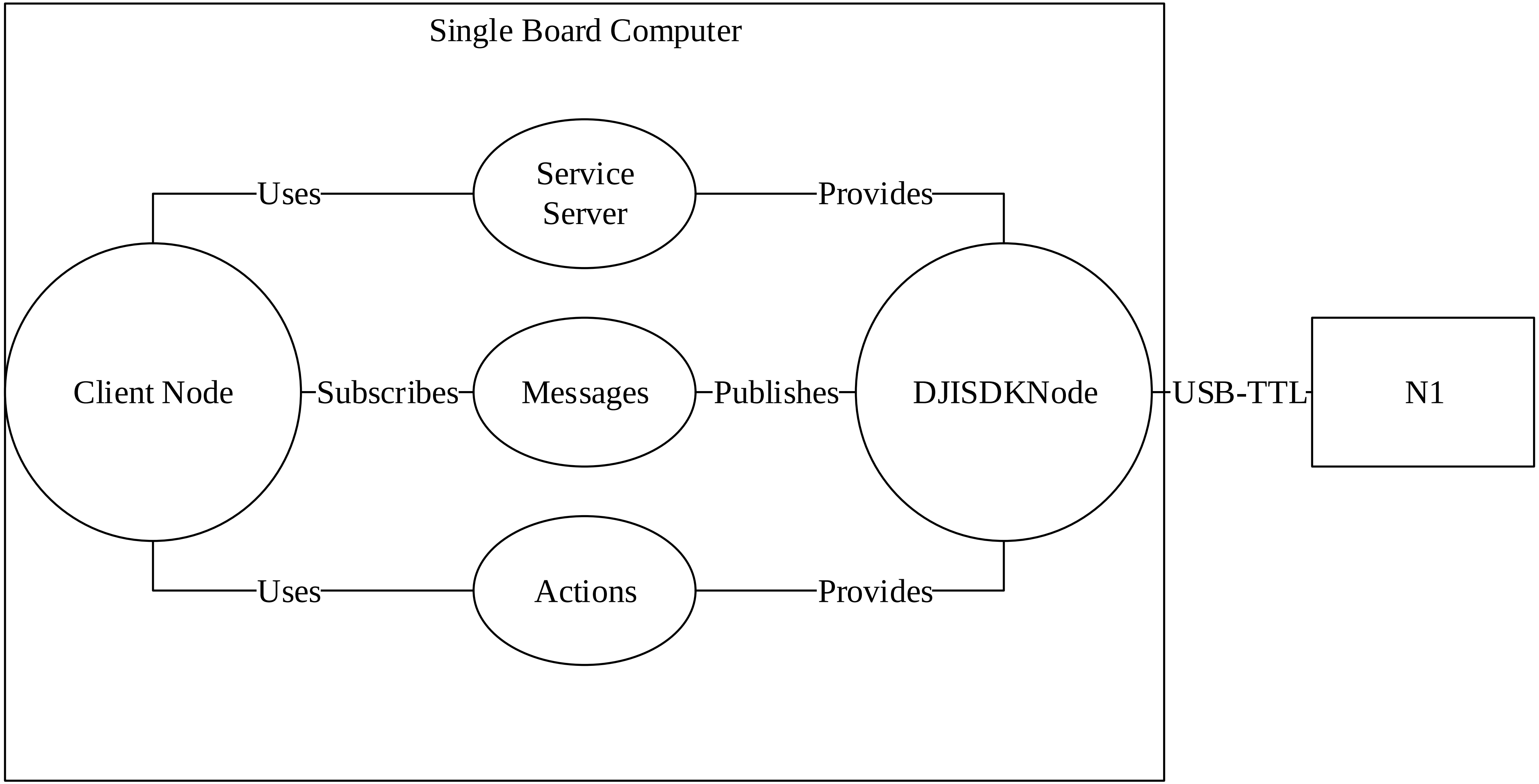


Subsystem -Quadcopter

INPUT	Dock Commands
ANALYSIS	Trajectory Generation State Estimation Vision/Sensors Data Packaging and Un-Packaging
OUTPUT	Video/State Data Docked Status
PLATFORM	DJI M100 with Guidance Backup - Searching



Single Board Computer – N1 Overview of provided example



Onboard SDK Publishes Topics from N1 Data

Topics	Description
dji_sdk/acceleration	Acceleration of the quadcopter Internal IMU
dji_sdk/flight_status	Mode (return to home, control etc.)
dji_sdk/local_position	Position with original GPS cooardinate
dji_sdk/power_status	Battery status
dji_sdk/velocity	Velocities from IMU
dji_sdk/odometry	ROS nav_msgs pose pose

Onboard SDK Provides Following Services

Service	Description
dji_sdk/attitude_control	Angular rates control (open loop)
dji_sdk/drone_task_control	Return to Home Takeoff Land
dji_sdk/local_position_control	x,y,z position control (open loop)
dji_sdk/velocity_control	Velocity control (open loop)

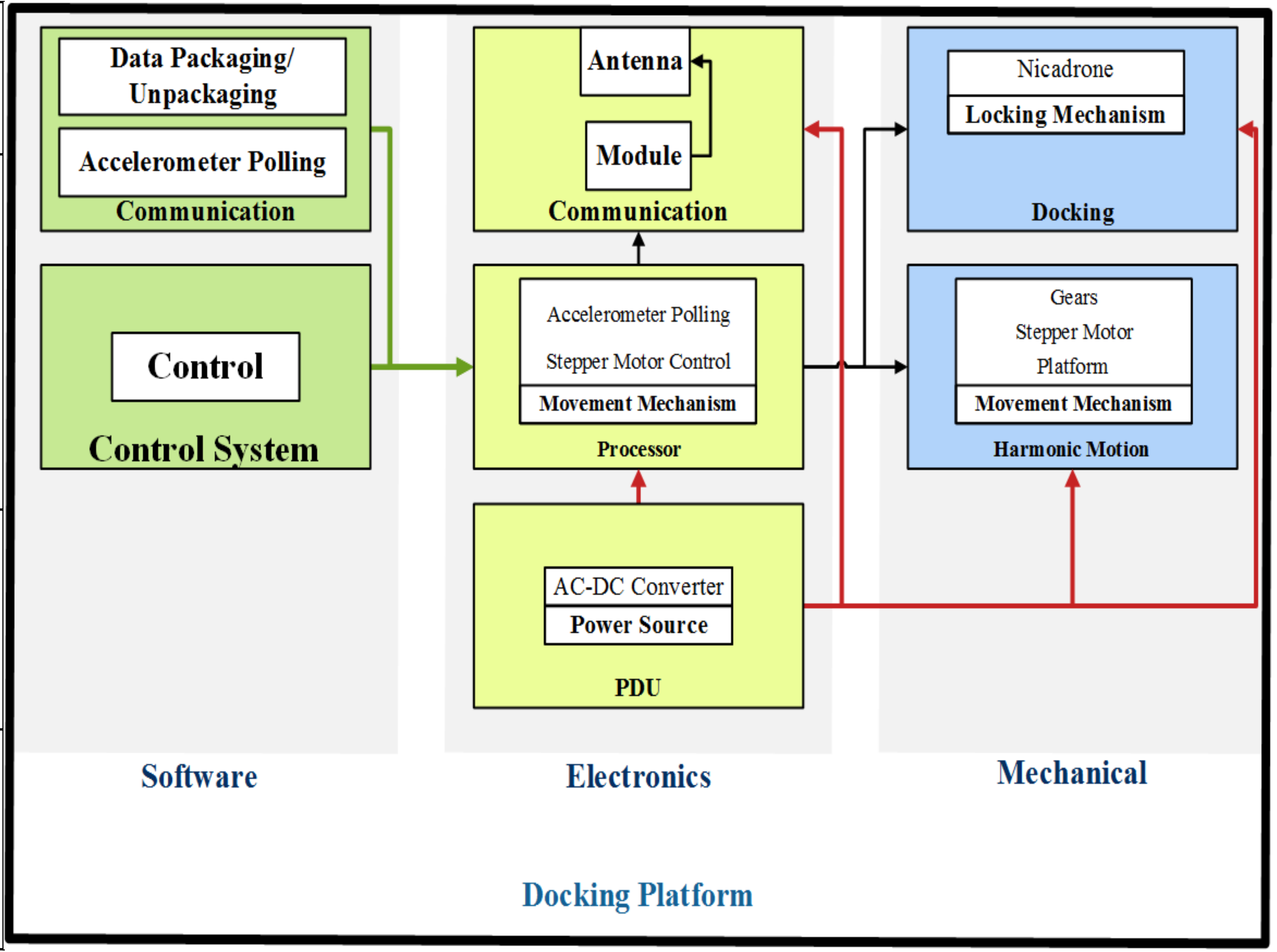
Onboard SDK Provides Following Actions

- Can write actions to use N1 data and control position of M100

Service	Description
dji_sdk/drone_task_action	Closed loop by providing feedback to client node
dji_sdk/local_position_navigation_action	

Subsystem - Dock

INPUT	Frequency and Amplitude Commands
ANALYSIS	Control System Accelerometer Polling Data Packaging and Un-Packaging
OUTPUT	Harmonic Motion
PLATFORM	Crank-Slider Mechanism



Current System Status

Presented by: Rushat

1. Quadcopter

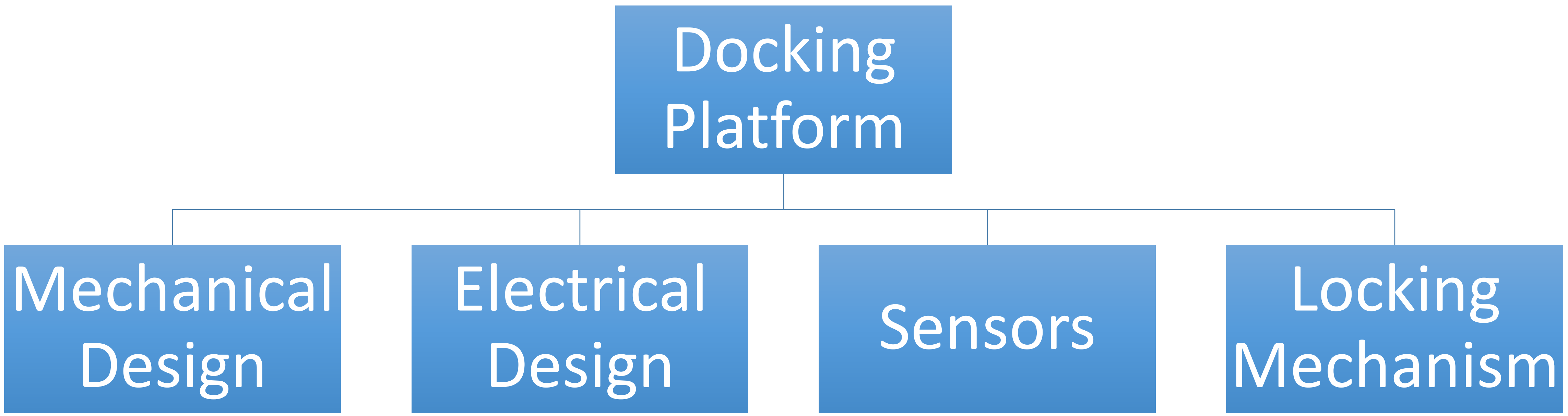
DJI Matrice M100

DJI Guidance System

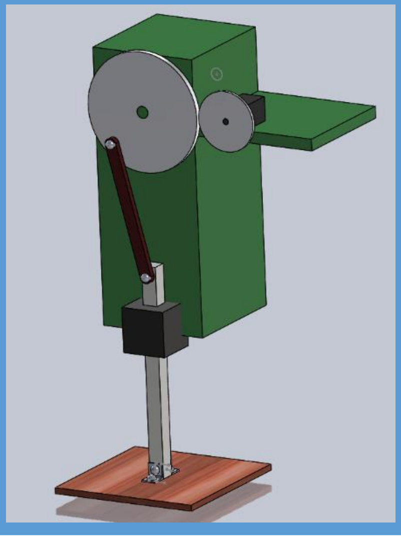
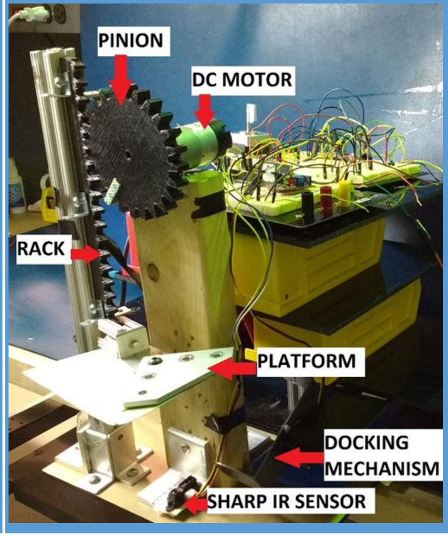
1. Quadcopter Trade Studies

Category	Weights (100%)	DJI Matrice 100	TurboAce Matrix	3DR solo	3DR X8+
Payload Capacity	20	8	9	4	7
Customizability of processor	15	8	1	7	7
Availability of an SDK	20	9	0	8	8
Documentation of SDK	20	9	0	8	8
Position of on Board Camera	10	8	9	4	4
Battery Life	5	8	8	6	4
Spares / availability	5	8	8	8	8
Cost	5	3	6	7	8
Total	10	8.35	4.35	6.9	7.45

2. Docking Platform

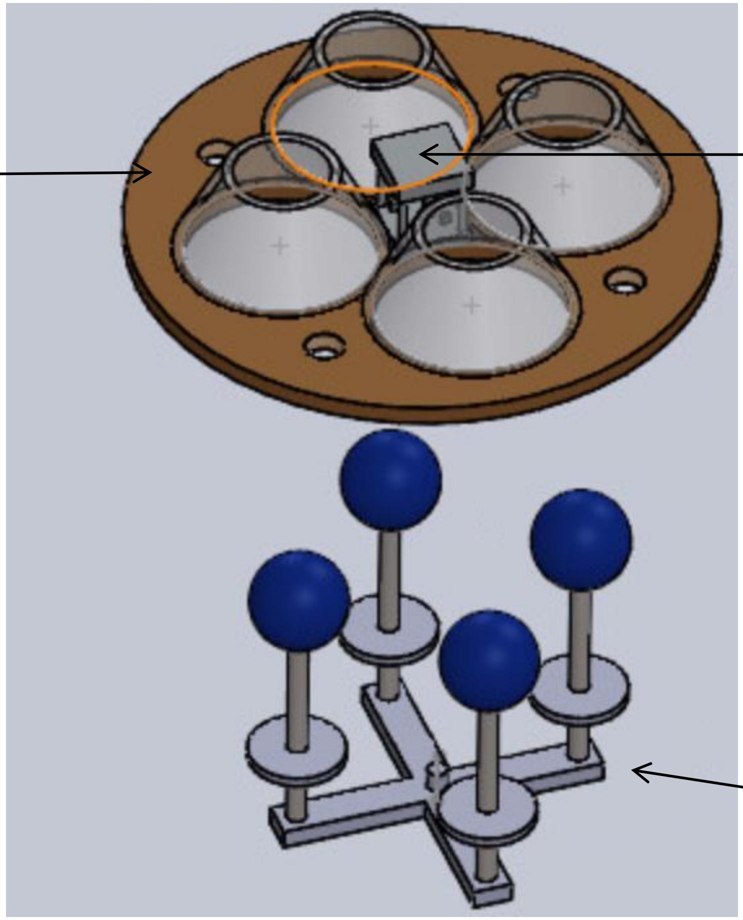


2.1 Mechanical Design

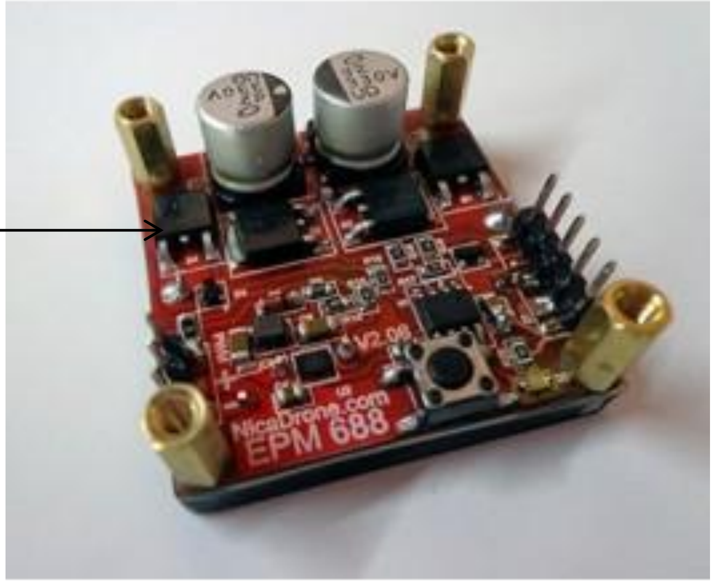
Criteria	Weights (100%)	Geared Crank-Slider 	Rack-Pinion 	Ballscrew 
Power Requirements	30	9	7	2
Ease of Operation	15	9	4	4
Ease of Manufacturability	20	4	4	8
Accuracy	15	9	6	8
Reliability of mechanism	20	7	4	9
TOTAL	100	7.6	5.2	5.8

2.2 Locking Mechanism

Docking Platform

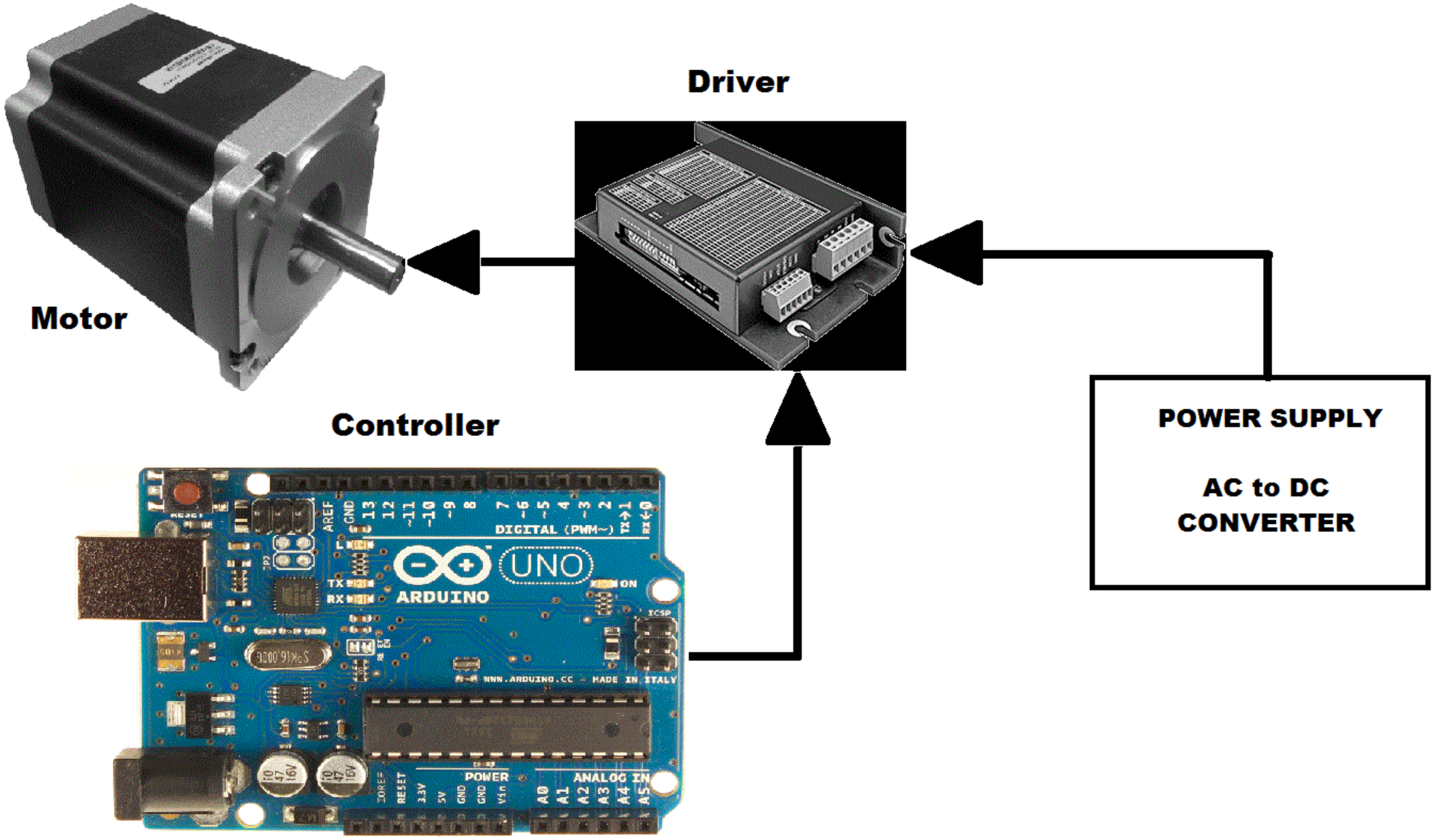


Nicadrone

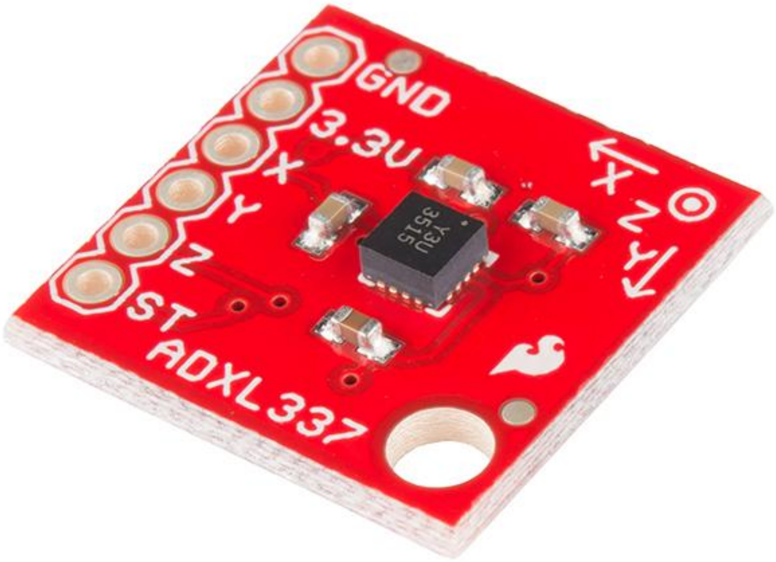


Quadcopter appendage

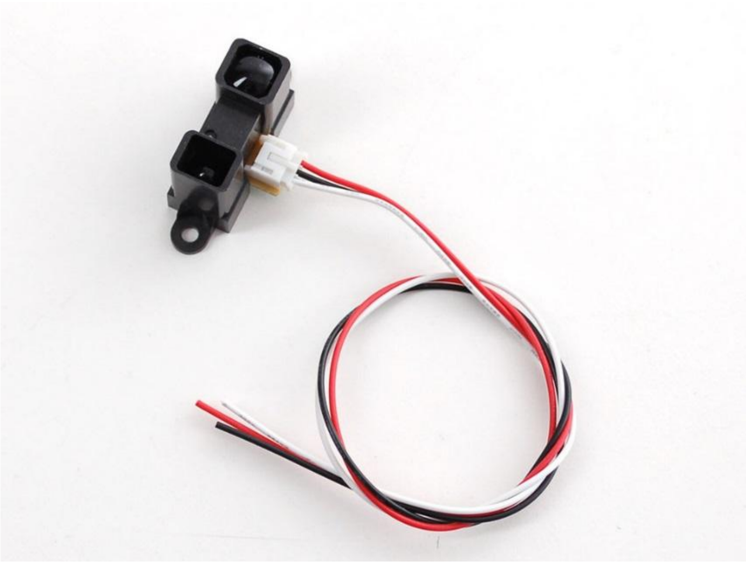
2.3 Electrical Design



2.4 Sensors



Accelerometer



IR Distance Sensor

Schedule

Presented by: Aishanou

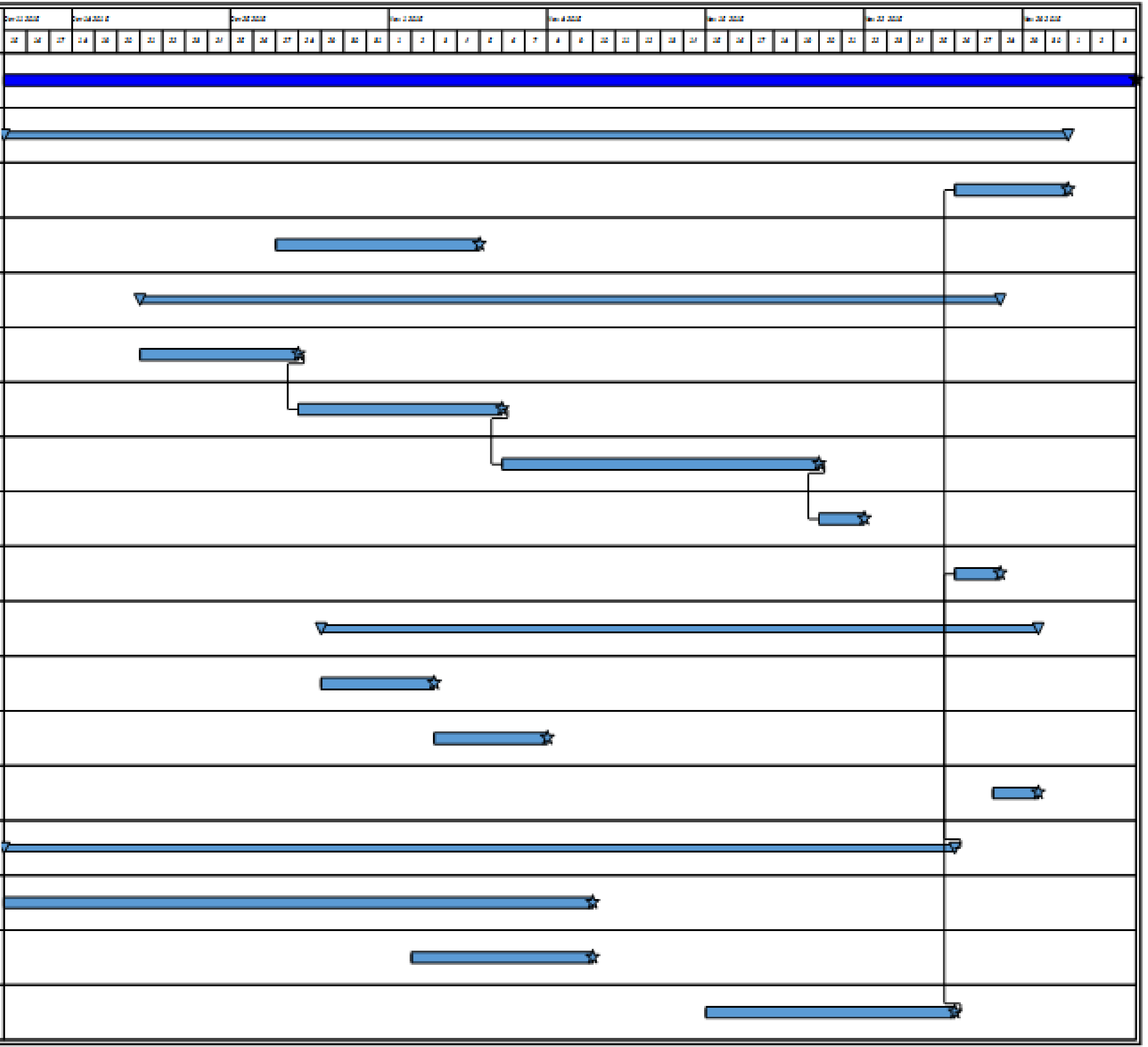
Platform Design Schedule

Presented by: Aishanou

Major Goals Fall

- Harmonic Motion
- Sensor package to analyze platform motion
- Wireless Communication

ID	Task Name	Resource Names	Start	Finish	Duration
1	Semester 1 Demo		10/15/2015	12/3/2015	50d
2	**Functional Dock**		**10/15/2015**	**11/30/2015**	**47d**
3	Integrate	All	11/26/2015	11/30/2015	5d
4	PCB Design	Paul	10/27/2015	11/4/2015	9d
5	**Motor**	**Rushat, Paul, and Aishanou**	**10/21/2015**	**11/27/2015**	**38d**
6	Motor Design		10/21/2015	10/27/2015	7d
7	Order Motor		10/28/2015	11/5/2015	9d
8	Receive Motor		11/6/2015	11/19/2015	14d
9	No-Load Control		11/20/2015	11/21/2015	2d
10	Full-Load Control		11/26/2015	11/27/2015	2d
11	**Sensors**	**Keerthana**	**10/29/2015**	**11/9/2015**	**12d**
12	Receive Accelerometer		10/29/2015	11/2/2015	5d
13	IR vs Accelerometer test		11/3/2015	11/7/2015	5d
14	Frequency Analysis		11/8/2015	11/9/2015	2d
15	**Physical Fabrication**	**Keerthana, Rushat, and Paul**	**10/15/2015**	**11/25/2015**	**42d**
16	CAD Design		10/15/2015	11/9/2015	26d
17	Order Parts		11/2/2015	11/9/2015	8d
18	Fabrication		11/15/2015	11/25/2015	11d



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12	Receive Accelerometer		10/29/2015	11/2/2015	5d
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14	Frequency Analysis		11/8/2015	11/9/2015	2d
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16	CAD Design		10/15/2015	11/9/2015	26d
17	Order Parts		11/2/2015	11/9/2015	8d
18	Fabrication		11/15/2015	11/25/2015	11d

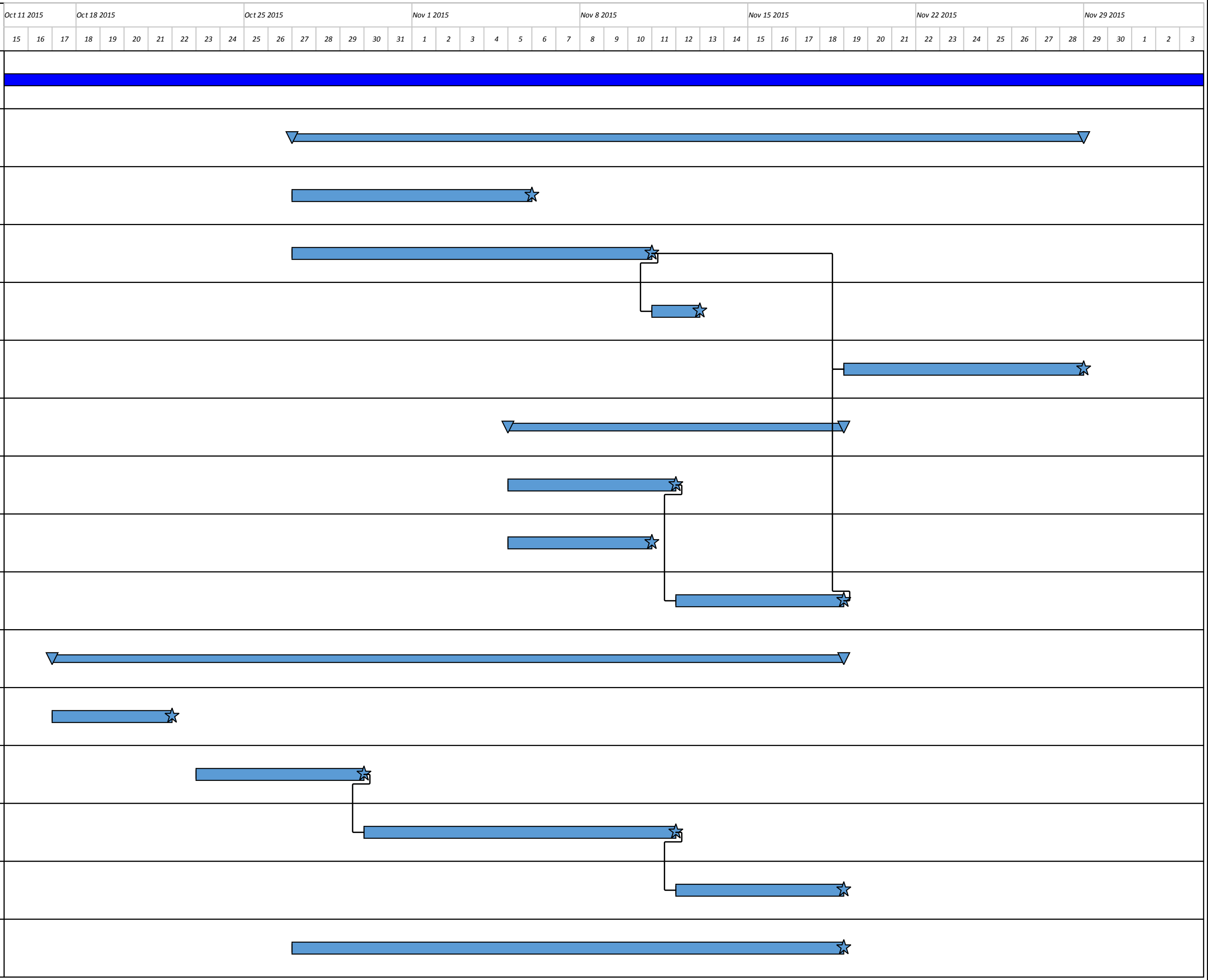
Quadcopter

Presented by: Aishanou

Major Goals Fall

- Computer Vision – Get Pose Estimate within visual range of the fiducial
- State Estimation – Get a pose estimate from onboard sensor of quadcopter
- Navigation – Use State Estimation to go from point A to point B
- Communication – Between the dock, quadcopter, and laptop

ID	*Task Name*	*Resource Names*	*Start*	*Finish*	*Duration*
1	Semester 1 Demo		10/15/2015	12/10/2015	57d
2	**Quadcopter Navigation**	**Roy and Aishanou**	**10/27/2015**	**11/28/2015**	**33d**
3	Acquiring Quadcopter		10/27/2015	11/5/2015	10d
4	Learning the Code Base		10/27/2015	11/10/2015	15d
5	Hover and Manual Control		11/11/2015	11/12/2015	2d
6	Path Vector (Point A to B)		11/19/2015	11/28/2015	10d
7	**State Estimation**	**Keerthana, Rushat, & Paul**	**11/5/2015**	**11/18/2015**	**14d**
8	Literature Review		11/5/2015	11/11/2015	7d
9	Quad Review		11/5/2015	11/10/2015	6d
10	Ros Topic Publication		11/12/2015	11/18/2015	7d
11	**Computer Vision Aligning with Platform**	**Aishanou & Roy**	**10/17/2015**	**11/18/2015**	**33d**
12	Pipeline		10/17/2015	10/21/2015	5d
13	Tag Detection (Laptop)		10/23/2015	10/29/2015	7d
14	Pose Estimation (Laptop)		10/30/2015	11/11/2015	13d
15	ROS Topic Publication		11/12/2015	11/18/2015	7d
16	**Communication**	**Roy & Keerthana**	**10/27/2015**	**11/18/2015**	**23d**



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12	Pipeline		10/17/2015	10/21/2015	5d
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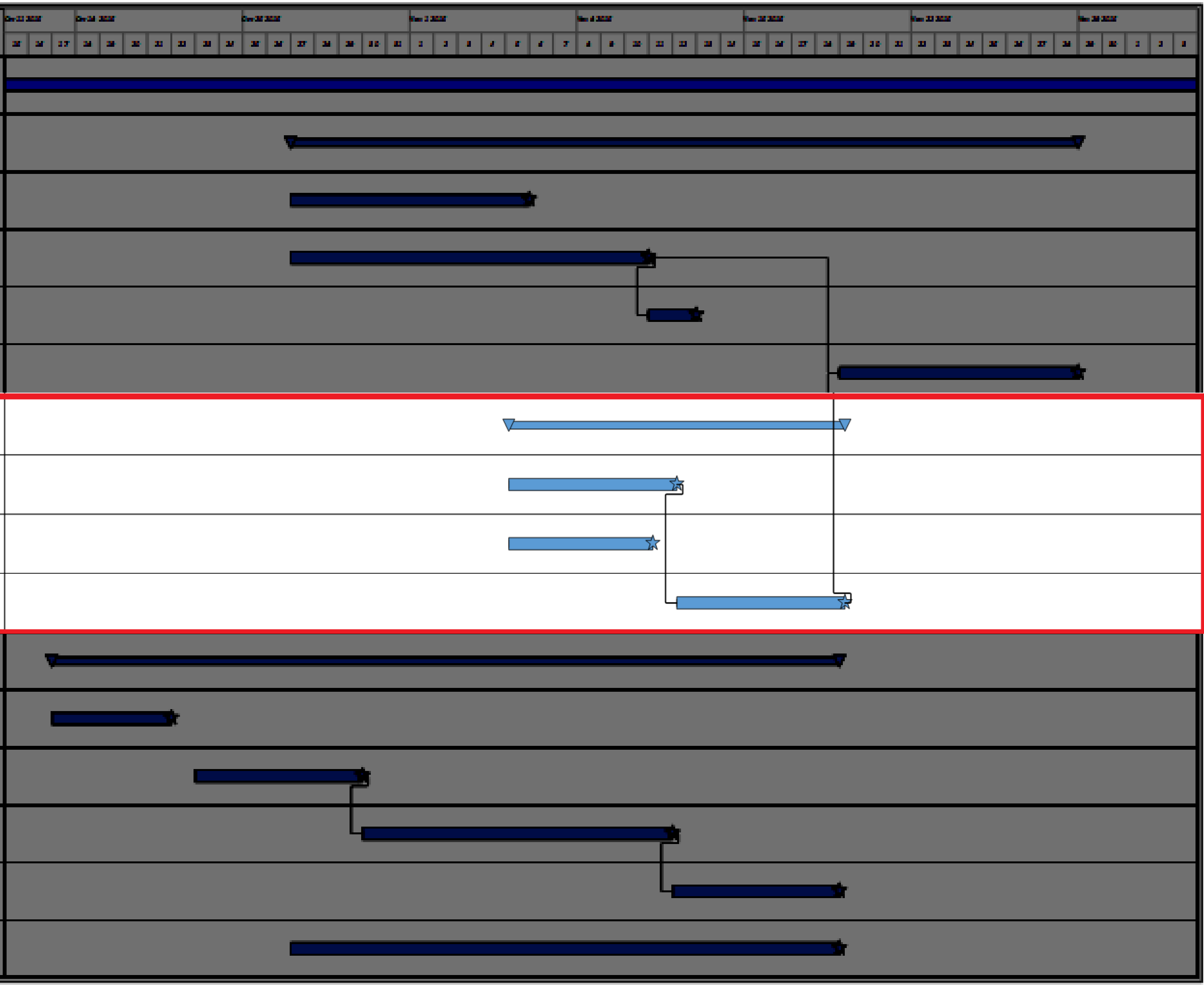
14	Pose Estimation (Laptop)		10/30/2015	11/11/2015	13d
15	ROS Topic Publication		11/12/2015	11/18/2015	7d
16	**Communication**	**Roy & Keerthana**	**10/27/2015**	**11/18/2015**	**23d**



Performance Requirements

Platform	Quadcopter
Have 1 degree of freedom along Z-direction	Localize w.r.t. platform within 100mm accuracy
Oscillate at in harmonic motion with dominant frequency < 0.3 Hz	Navigate to the platform within 10 minutes
Have oscillations' amplitude <= ±200mm	Dock to the platform autonomously and safely within 10 minutes
Have a locking mechanism which supports weight of at least 5 kg	Get pose w.r.t. the platform within 3 m

LEGEND
Red: Fall
Black: Spring

Fall Test Plans

Progress Review	Summary	Test Description
#3 (Nov 12)	CV algorithm and quadcopter motion	• Pose estimation implemented using external camera • Quadcopter manually controlled using laptop
#4 (Nov 24)	• State Estimation • CV-ROS integration	• Reading pose of the quadcopter using ROS • Running pose estimation node as a ROS topic
#5 (Dec 03)	Fall Validation Experiment	• Platform motion along Z-direction at user defined frequency • Motion of platform detected using sensors • Waypoint navigation of quadcopter (Point A to B)
#6 (Dec 10)	Fall Validation Experiment Encore	Same as above

Spring Test Plans

Month	Summary	Test Description
January	Platform motion prediction	Position and velocity of platform predicted using CV and sensors
February	• Docking without collision • User-Interface ready	• Quadcopter docks to the platform and locks • User interface designed and communicates with the quad and the platform
March	System Integration	• Achieve docking and provide status as requested by the user
April	Spring Validation Experiment	Same as above

Fall Validation Experiment

Where?	NSH B Level
Equipment used	Quadcopter, Camera, Designed Platform
What will we show?	• Platform moves in harmonic motion along Z-direction with varying frequency • The quadcopter will navigate between user defined waypoints

Procedures :

Platform	Quadcopter
• Turn on the power – Platform will move up and down harmonically at 0.2 Hz frequency • Change frequency from user interface (Range 0.15 to 0.3 Hz) • The frequency of platform motion changes as desired • Motion detected by sensors and graph plotted showing desired waveform	• Place the quadcopter at any arbitrary position and turn on the power • Select target position (within 10 m of starting position) using the UI • The quadcopter will move to the target location with an accuracy of 0.5 m • Repeat above steps 10 times with different starting positions

Spring Validation Experiment

Where?	NSH B Level
Equipment used	DJI Matrice 100, Guidance, Designed Platform, Smartphone
What will we show?	• The right instant to dock is decided based on the motion of the platform • Quadcopter docks to platform without collision

Procedures:

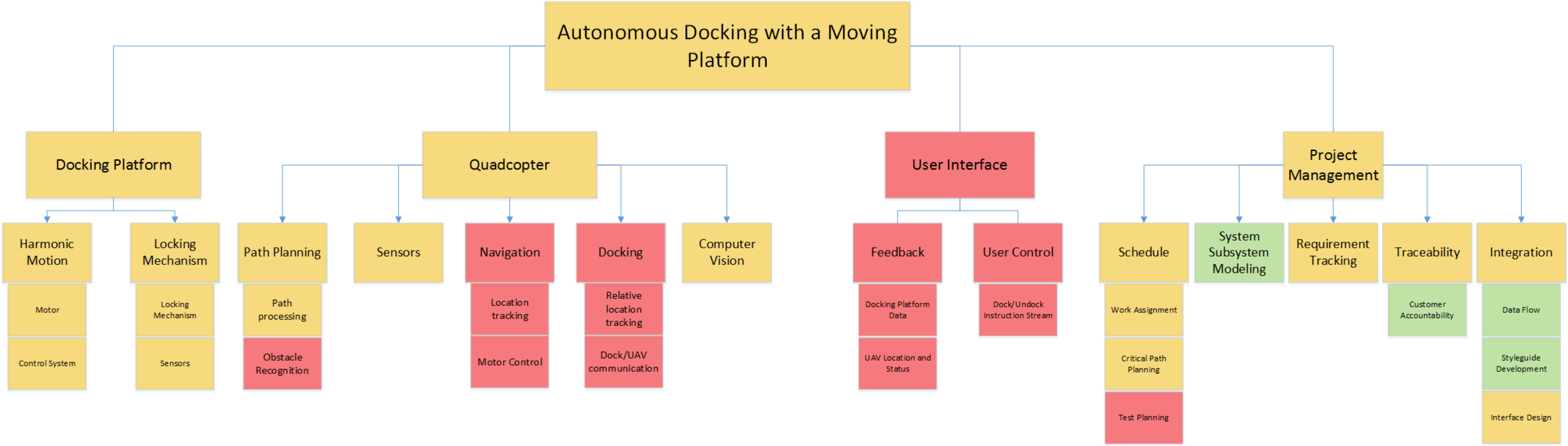
Platform
• Turn on the power – Platform will move up and down harmonically at 0.2 Hz frequency • Change frequency from user interface (Range 0.15 to 0.3 Hz) • The frequency of platform motion changes as desired • Motion detected by sensors and graph plotted showing desired waveform

Spring Validation Experiment

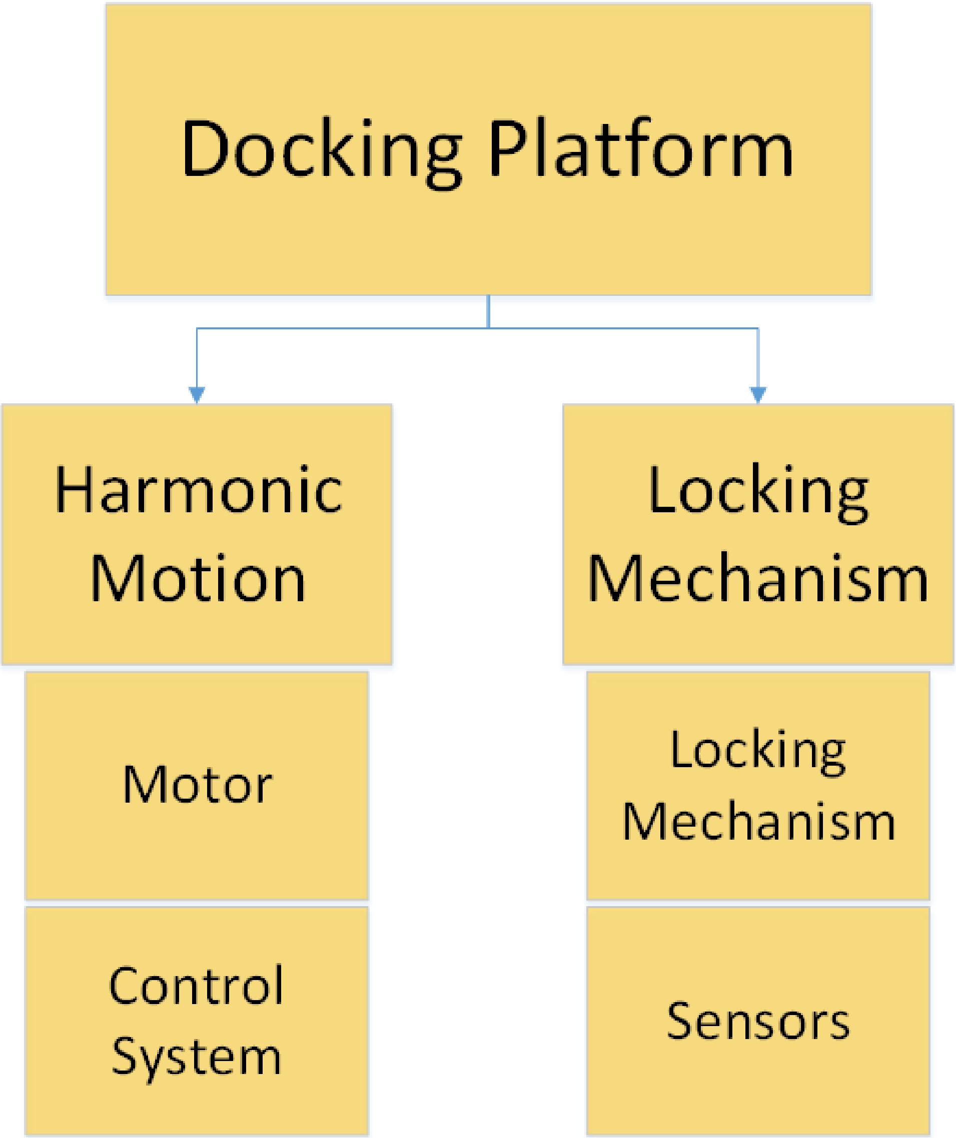
Procedures :

Quadcopter
• Place the quadcopter at any arbitrary position on the ground (within 5 m from the platform) and turn on the power • Initiate docking operation from the user interface • The quadcopter will take off and search for the platform • The quadcopter will travel horizontally to below the platform • The quadcopter will hover 1m below the platform (within 0.5 m accuracy) to determine safe instant to dock • The quadcopter will dock to the platform without collision • Platform motion would stop and UI will display “DOCK SUCCESSFUL” • Repeat above steps 10 times with different starting positions and different frequencies of platform

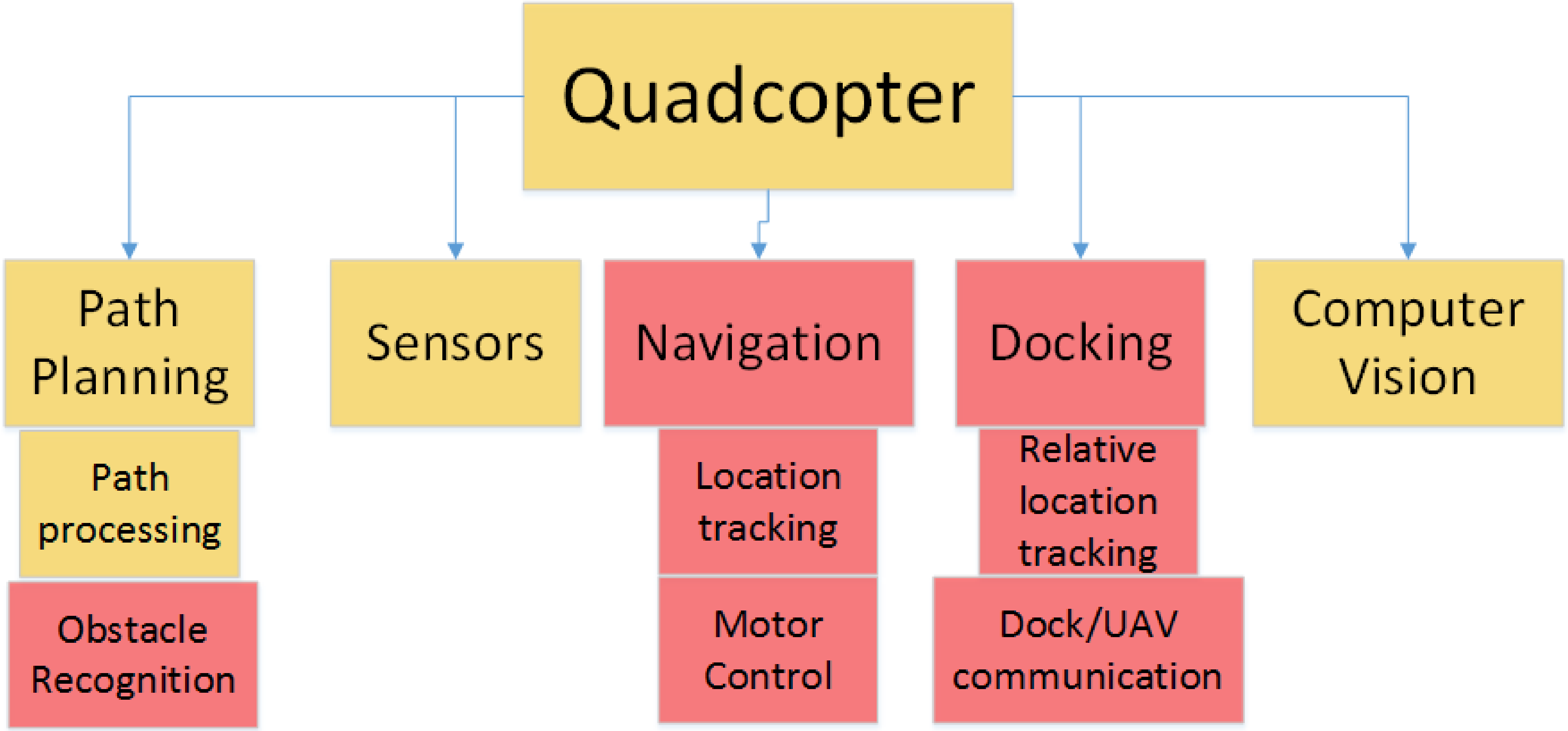
WBS - Overview



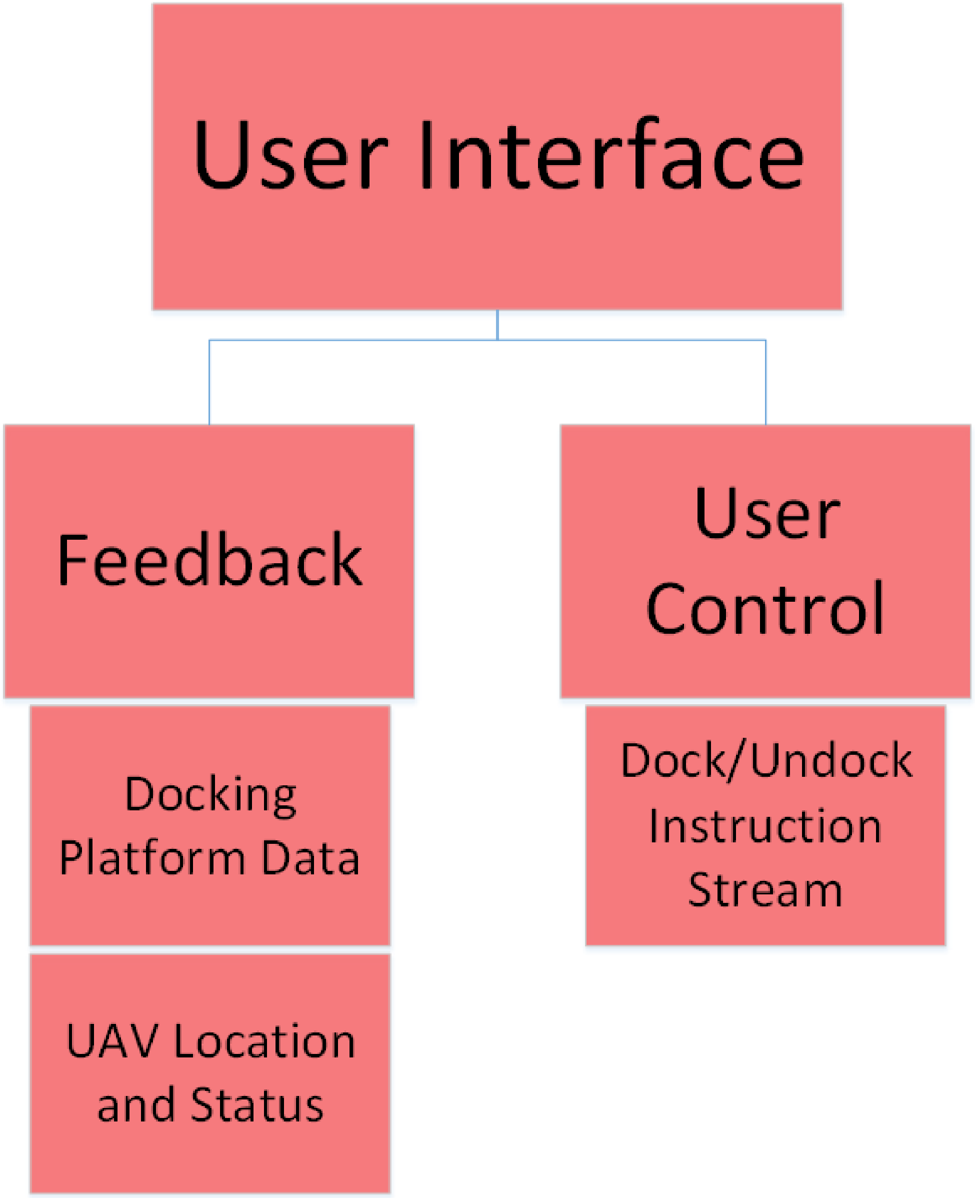
WBS - Platform



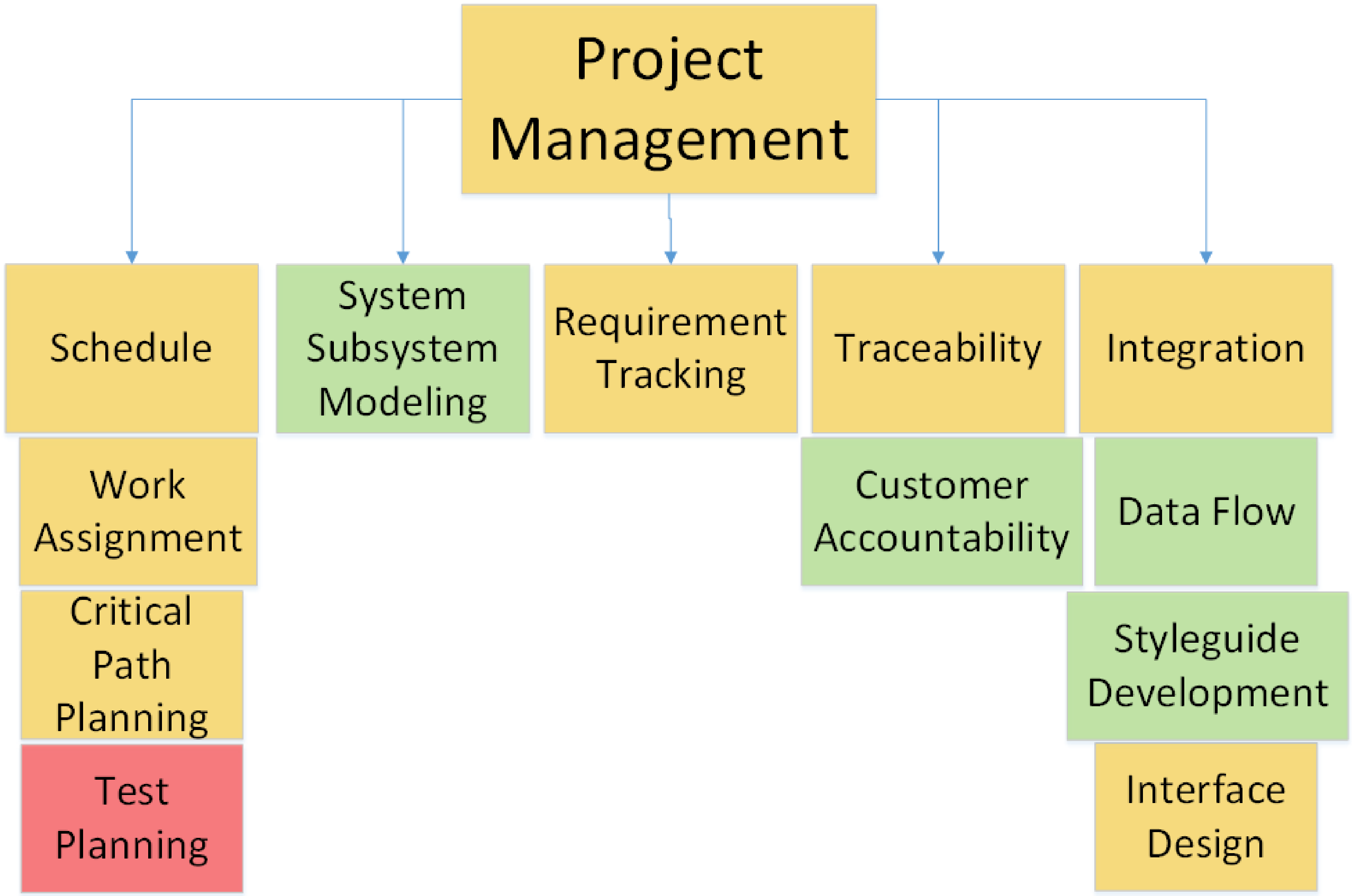
WBS - Quadcopter



WBS - UI

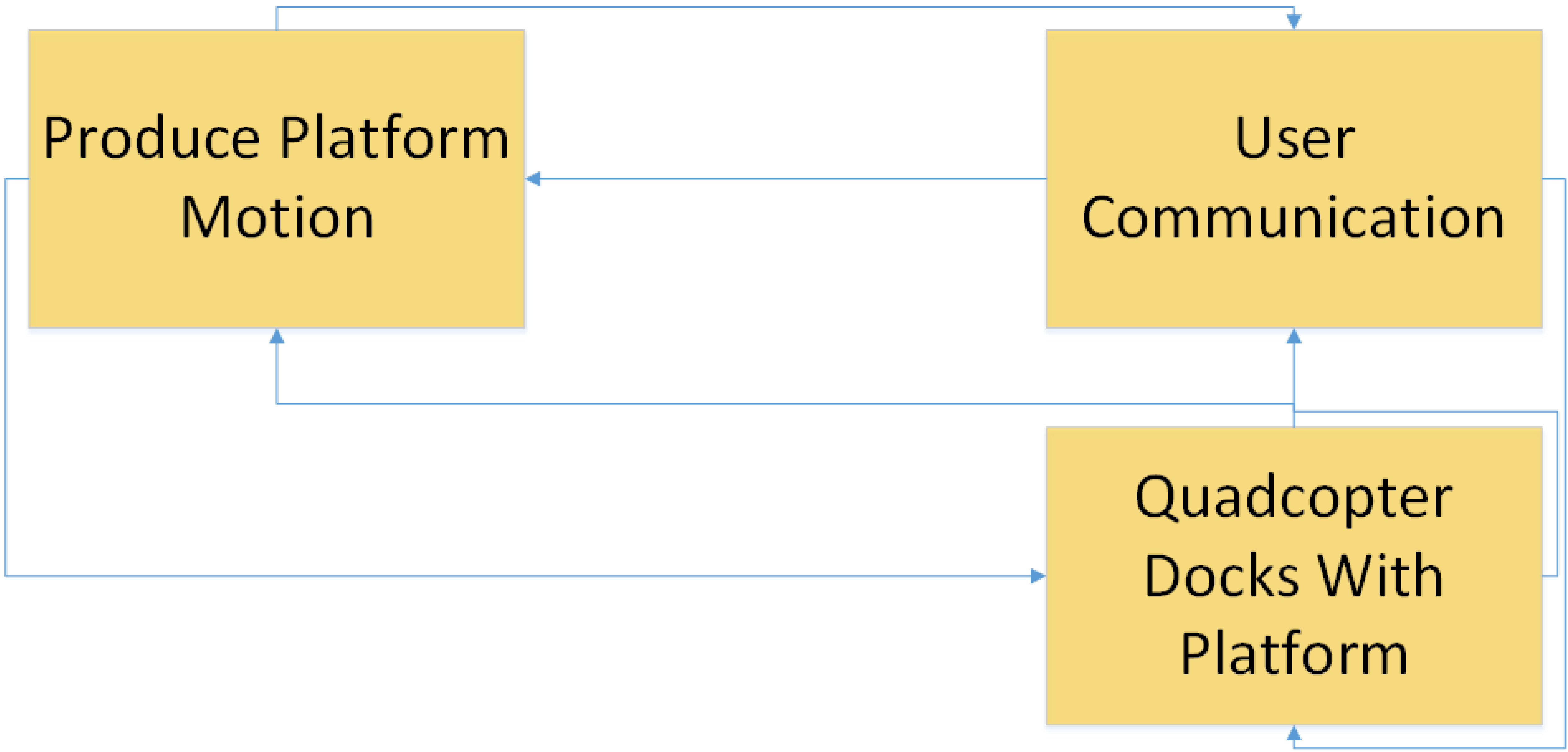

User Interface
Feedback
User Control
Docking Platform Data
UAV Location and Status
Dock/Undock Instruction Stream

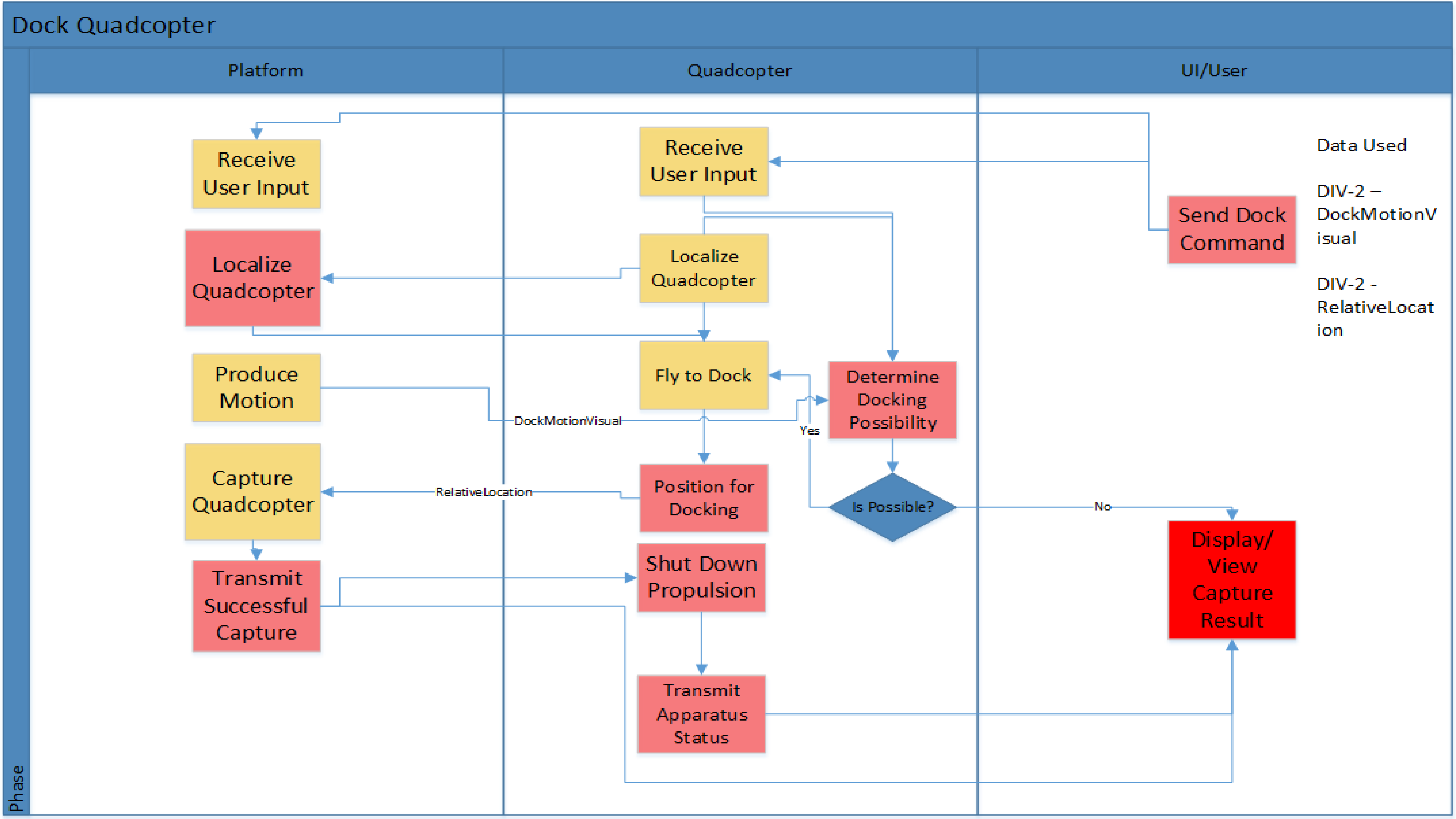
WBS – Project Management

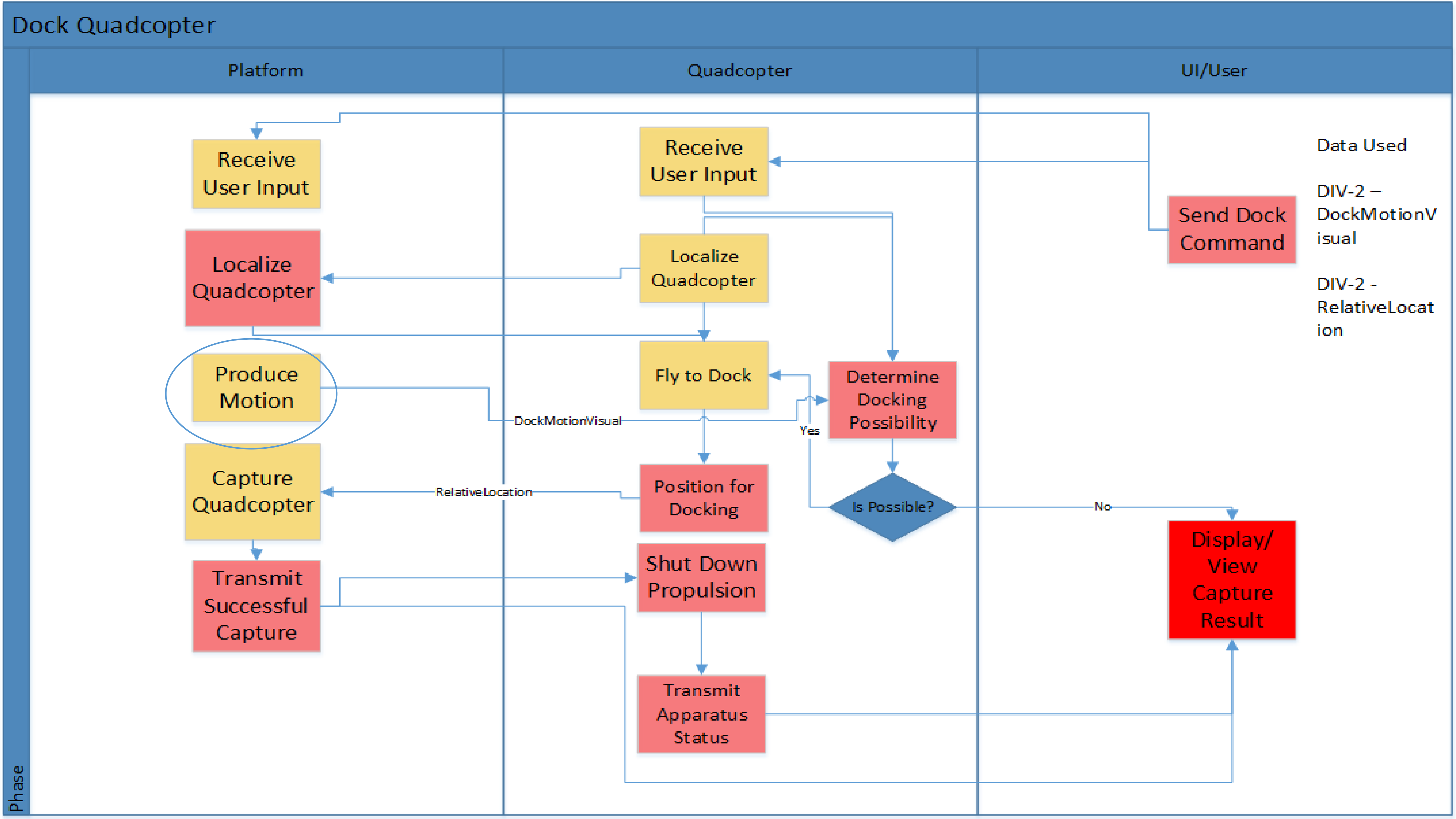


IDD/SSDD

- OV-1 – Capability/Activity Overview
- OV-2 – Required capability breakout by activity
- OV-2a – Main supporting activity
- OV-2b – Secondary supporting activity


Produce Platform Motion
User Communication
Quadcopter Docks With Platform


Dock Quadcopter
Platform
Quadcopter
UI/User
Phase
Receive User Input
Localize Quadcopter
Produce Motion
Capture Quadcopter
Transmit Successful Capture
Receive User Input
Localize Quadcopter
Fly to Dock
Position for Docking
Shut Down Propulsion
Transmit Apparatus Status
Determine Docking Possibility
Is Possible?
Yes
No
DockMotionVisual
RelativeLocation
Send Dock Command
Display/ View Capture Result
Data Used
DIV-2 – DockMotionVisual
DIV-2 - RelativeLocation



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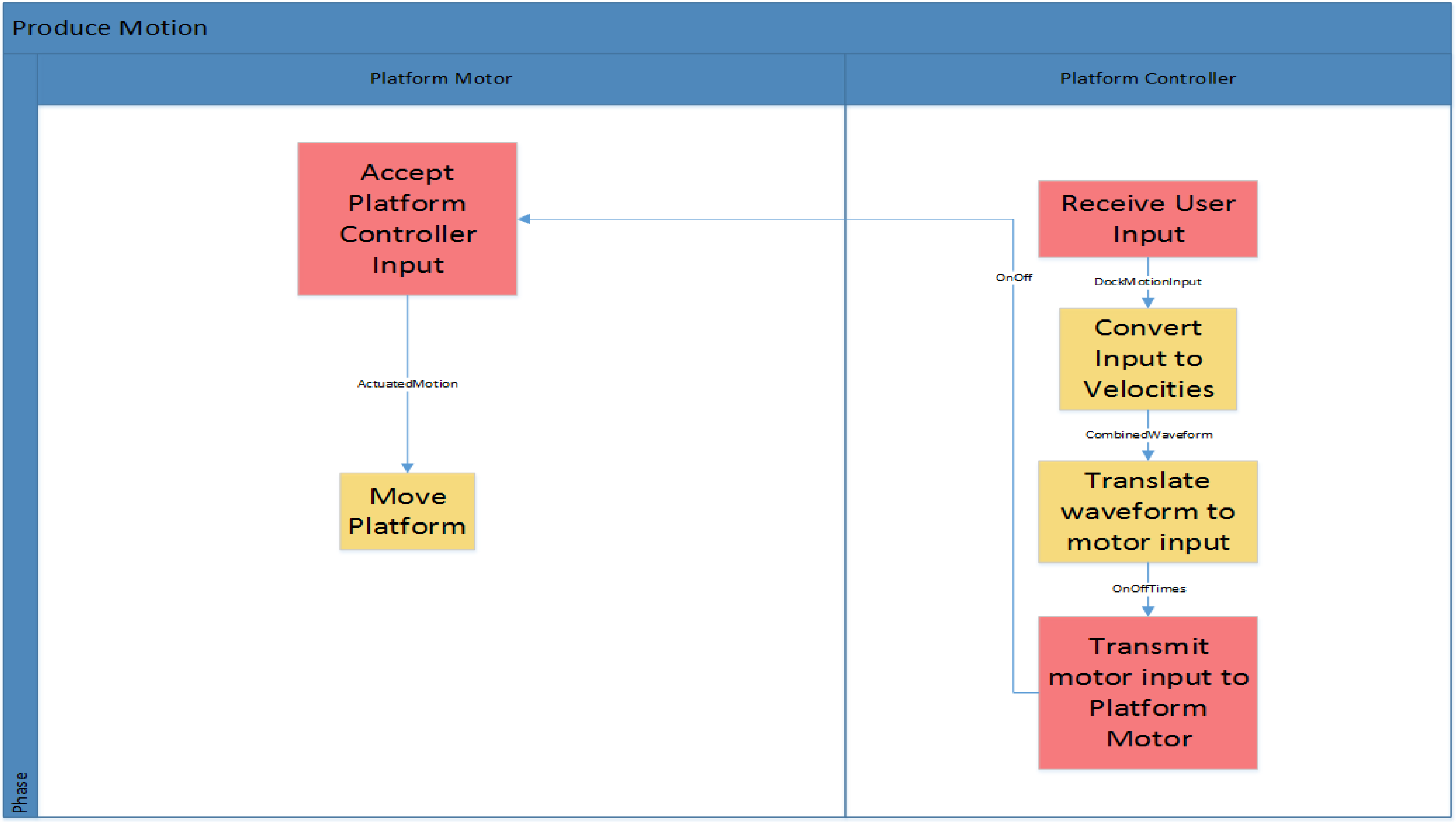
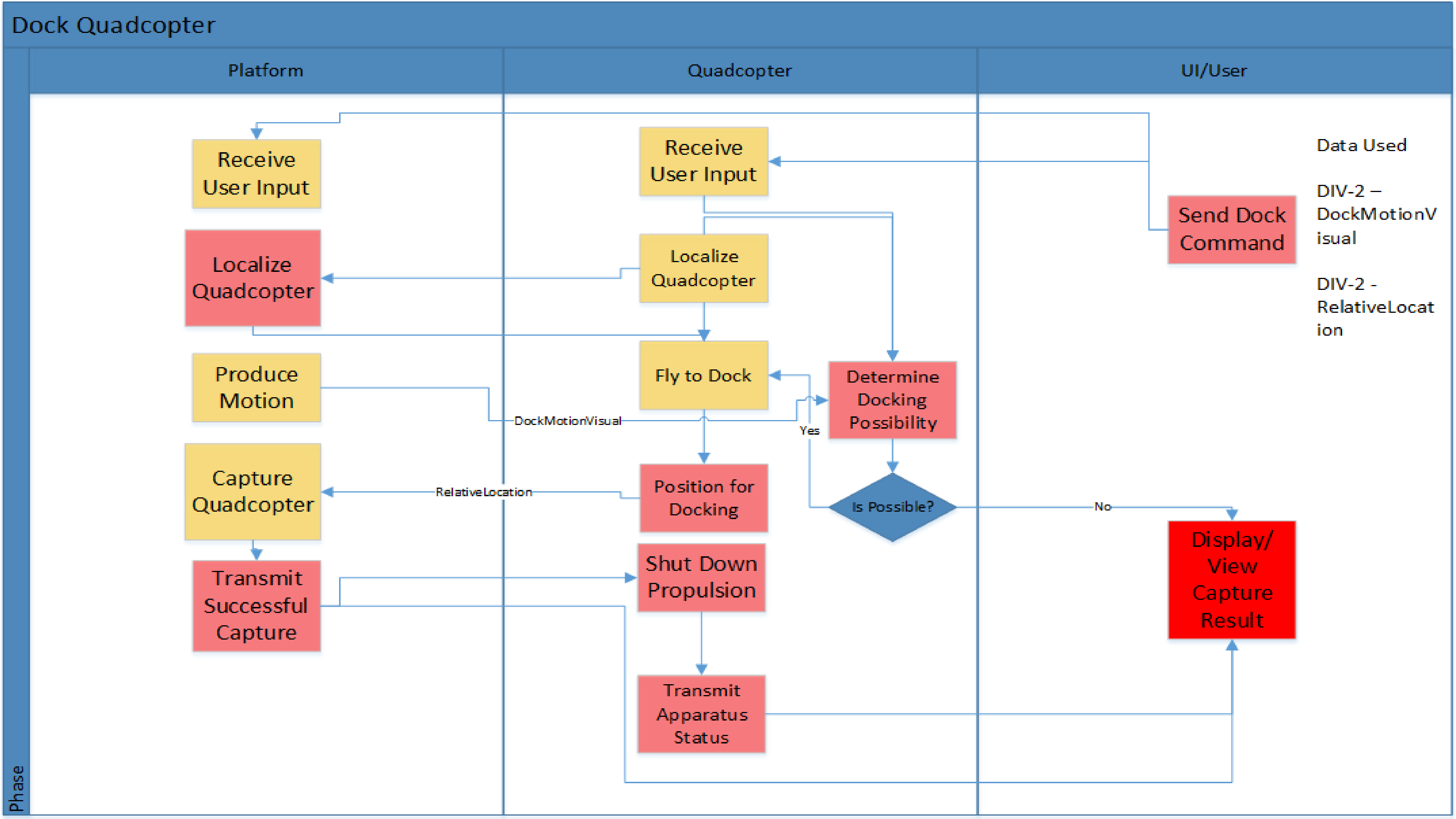


Produce Motion
Platform Motor
Platform Controller
Phase
Accept Platform Controller Input
ActuatedMotion
Move Platform
Receive User Input
DockMotionInput
Convert Input to Velocities
CombinedWaveform
Translate waveform to motor input
OnOffTimes
Transmit motor input to Platform Motor
OnOff



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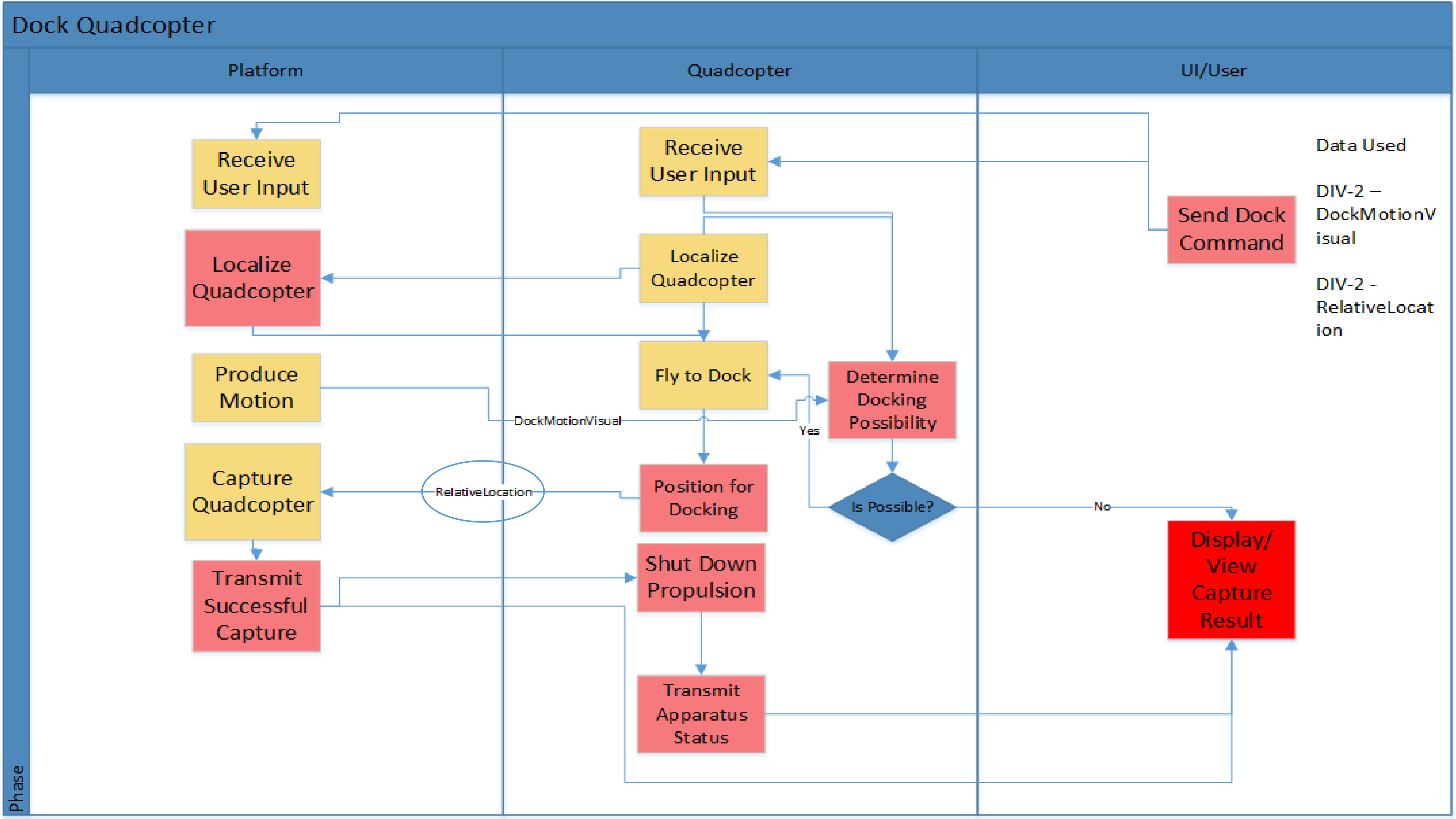

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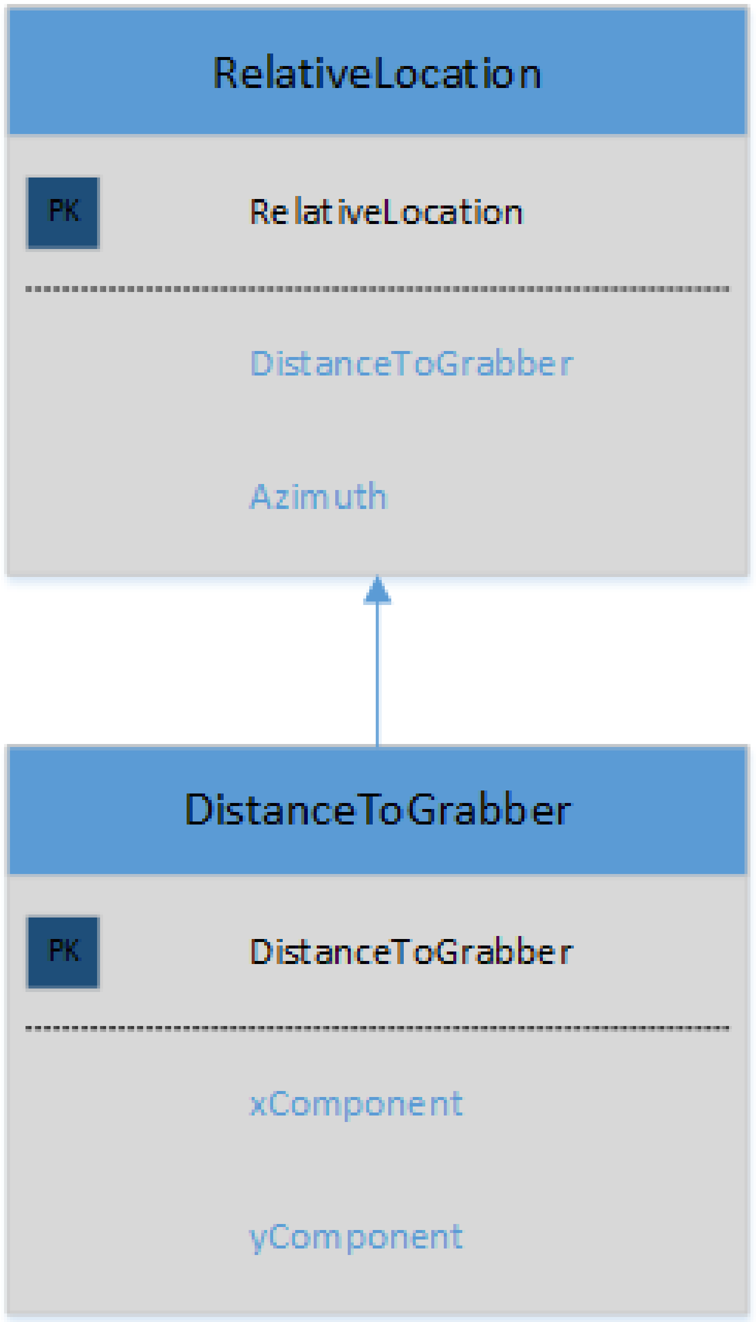
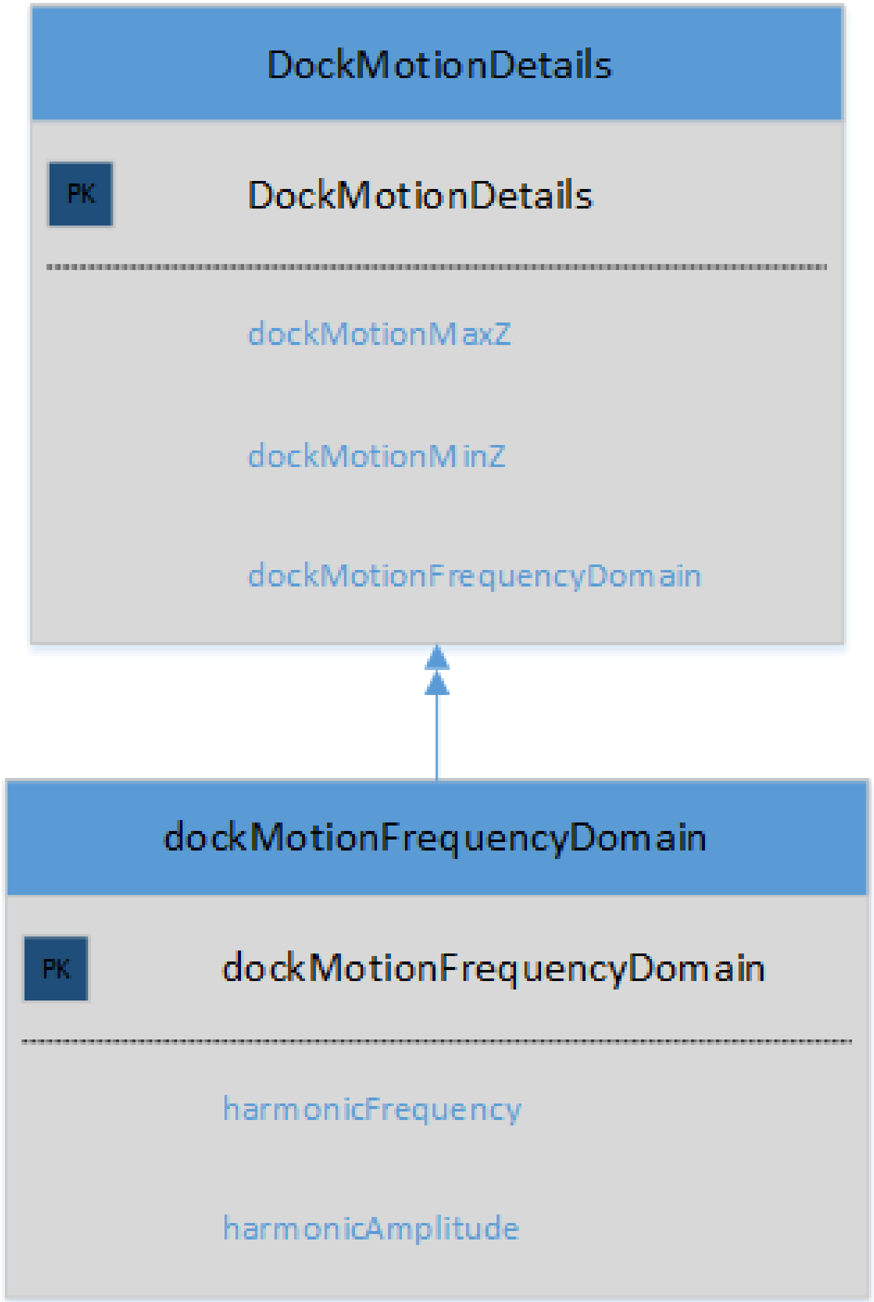

RelativeLocation
PK
RelativeLocation
DistanceToGrabber
Azimuth
DistanceToGrabber
PK
DistanceToGrabber
xComponent
yComponent


DockMotionDetails
PK
DockMotionDetails
dockMotionMaxZ
dockMotionMinZ
dockMotionFrequencyDomain
dockMotionFrequencyDomain
PK
dockMotionFrequencyDomain
harmonicFrequency
harmonicAmplitude

Budget

Item	Cost	Type	Status	Funding Source	Comment
DJI Matrice 100	$3,299.00	Capital	Executed	Sponsor	Developer Quadcopter
DJI Guidance	$999.00	Capital	Executed	Sponsor	Sensor suite and collision avoidance for quadcopter
Guidance Connector Kit	$79.00	Consumable	Executed	Sponsor	Connectors to attach Guidance to M100
TB48D Battery	$199.00	Capital	Executed	Sponsor	M100 extra battery
Dock Motor	$215.00	Capital	Planned	CMU	High torque motor for dock
Dock Motor Driver	$488.00	Consumable	Planned	CMU	Integrated with dock
Accelerometer	$20.00	Consumable	Executed	CMU	Integrated with dock
Nicadrone x2	$90.00	Consumable / Spare	Obligated	CMU	Docking Mechanism
Spare Propellors x2	$20.00	Consumable Spare	Planned	CMU	Spares for M100

Total Executed from CMU	$20.00
Total Executed from sponsor	$4,576.00
CMU total budget	$4,000.00
Sponsor total budget	$5,000.00
CMU budget remaining	$3,980.00
Sponsor budget remaining	$424.00

Risk - Overview

Probability		Severity: A Negligible	B Low	C Moderate	D Severe	E Catastrophic
5	Nearly Certain	0	0	1	0	0
4	Likely	0	1	0	1	0
3	Possible	0	0	2	0	1
2	Unlikely	0	0	2	1	1
1	Rare	0	1	1	4	1

Immediate Action
Urgent Action
Action
Monitor
No Action

Risks - Specifics

1. Risk: Quadcopter Fails to Arrive In Time For FVE
   - Risk Type: Programmatic Risk, Schedule Risk
   - Adjudicated: 5 C (Urgent Action)
   - Mitigation: Use Quadcopters in Inventory,
   - Status of Mitigated Risk: 3 B (Action)
2. Risk : Indoor flight impossible
   - Risk Type: Schedule risk
   - Adjudicated: 3 E (Urgent Action)
   - Mitigation: Redo the sensors for the N1
   - Status of Mitigated Risk: 2 C (Monitor)
3. Risk: SDK Legal Issues Continue for significant time
   - Risk Type: Schedule risk
   - Adjudicated: 3 E (Action)
   - Mitigation: Get a Personal License (DONE)
   - Status of Mitigated Risk: 0 (Mitigated)

Docking...

Questions?