Mobile-Controlled Drone Autonomous Delivery System

Harvard-HKUST International Design Experience 2015

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What?

Why?

Who?

How?

Does it work?

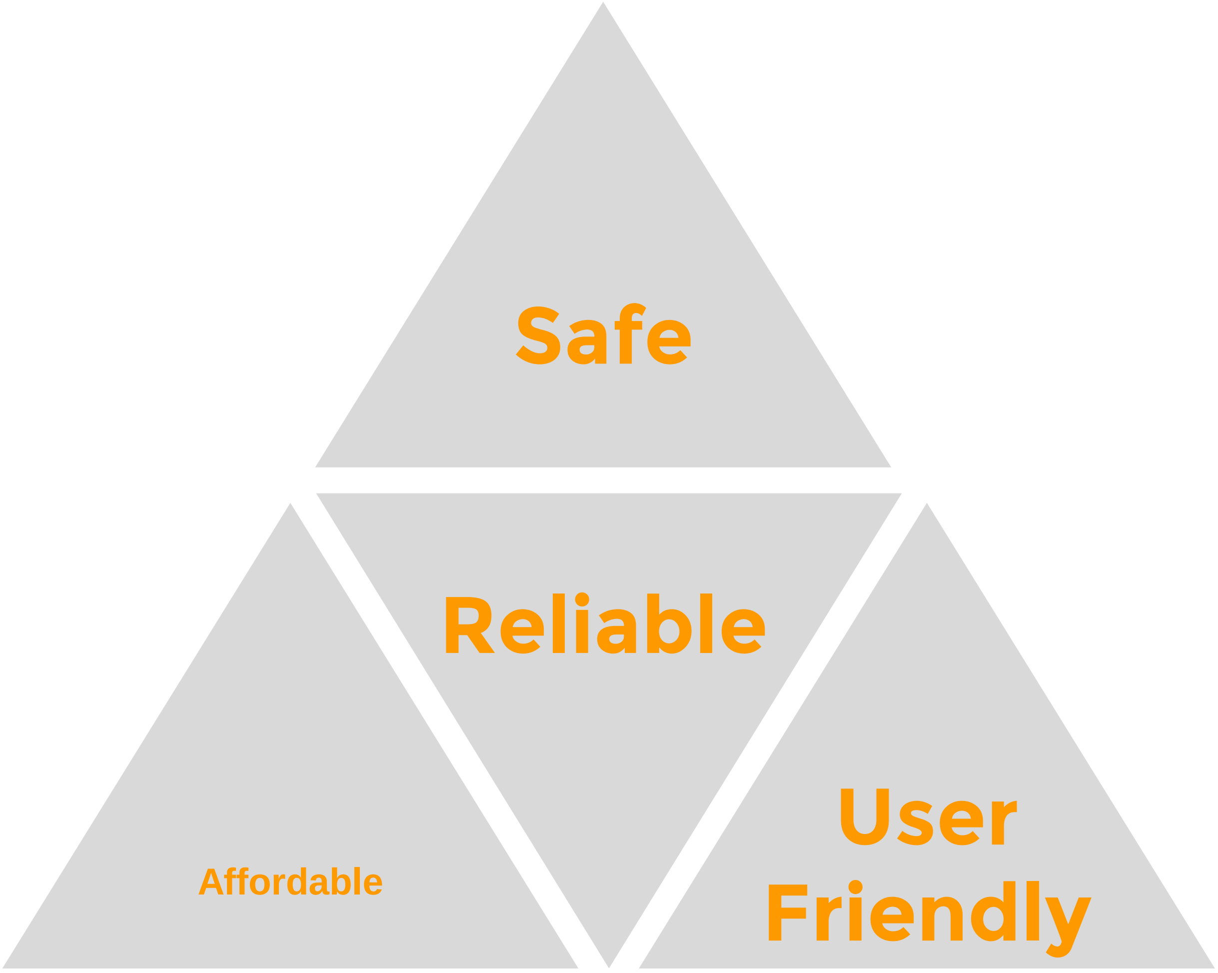
What is next?

Starting Point

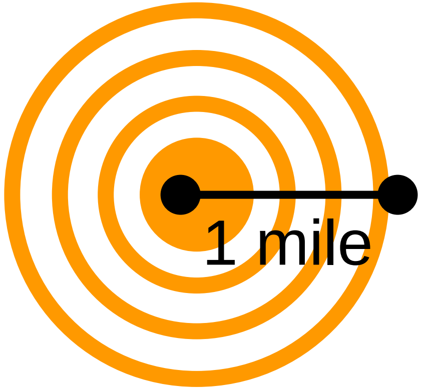
DJI Flamewheel 450

Pixhawk Autopilot

Functional Requirements



Technical Specifications



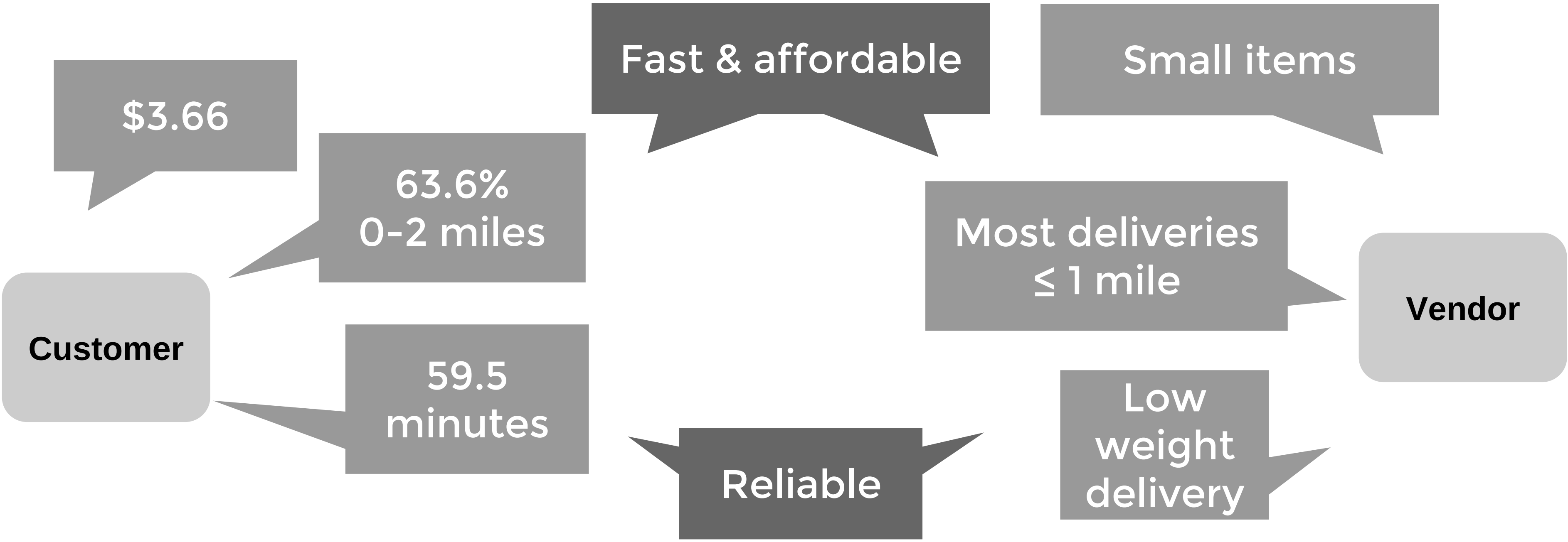
Technical Specifications

20 min
Battery Life

1 mile
Communication

0.2%
loss rate

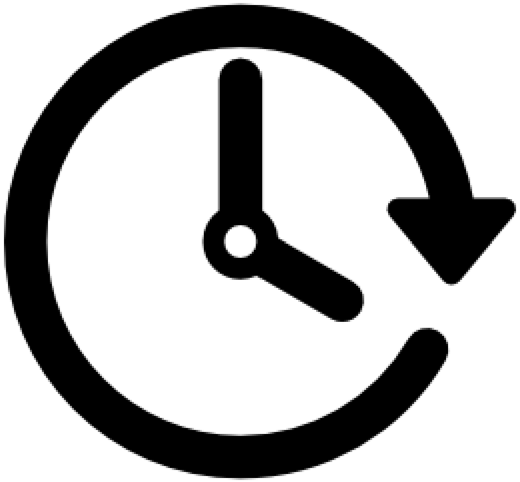
Customer & Vendor Surveys



*Taken from survey of 33 users and 10 businesses.

Customer & Vendor Surveys

Long Wait for Delivery



Unpredictable Delivery Time

What
?

Why?

Who?

How?

Does
it
work?

What
is
next?

image courtesy of Amazon

Flirtey drone

DJI Phantom 3

Mobile-Controlled Drone Autonomous Delivery System


Avoidance

What?

Why?

Who?

How?

Does it work?

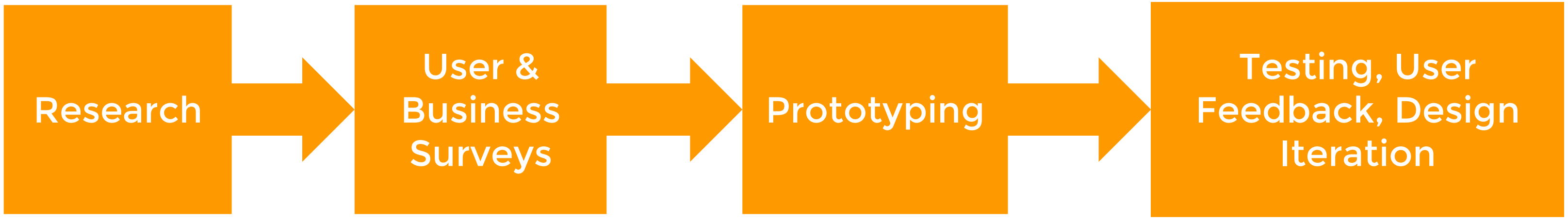
What is next?

Our Users

Young Professionals

Local Business Owners

Design Process



What ?

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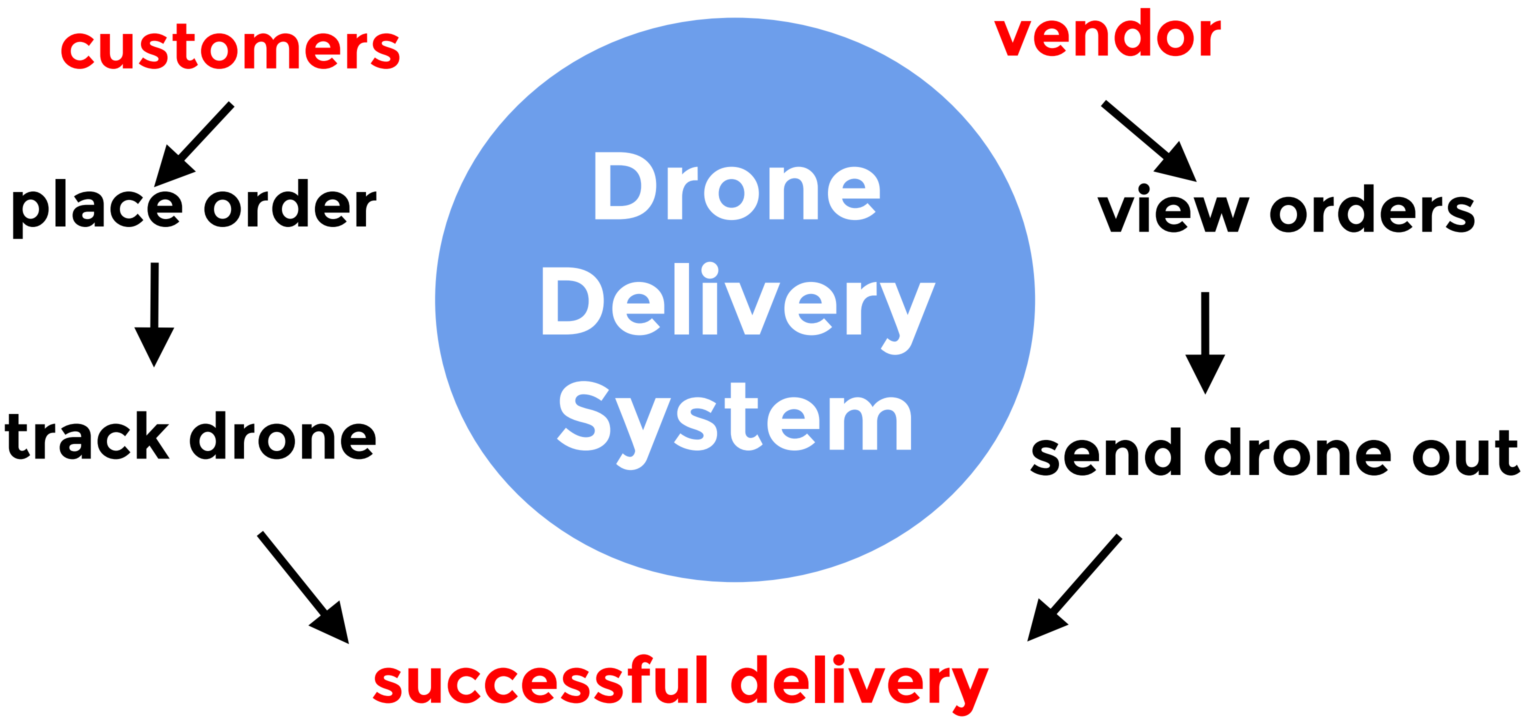
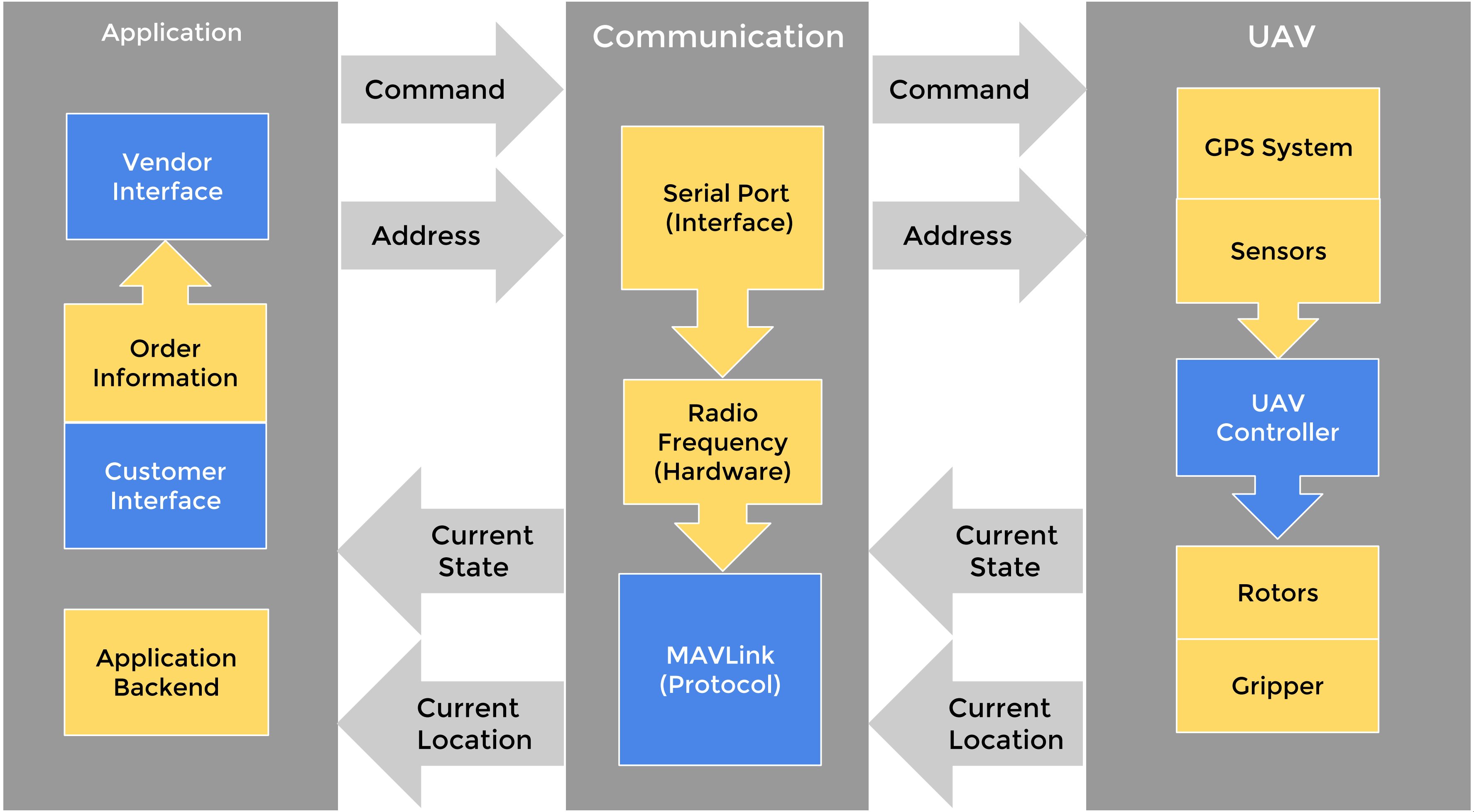
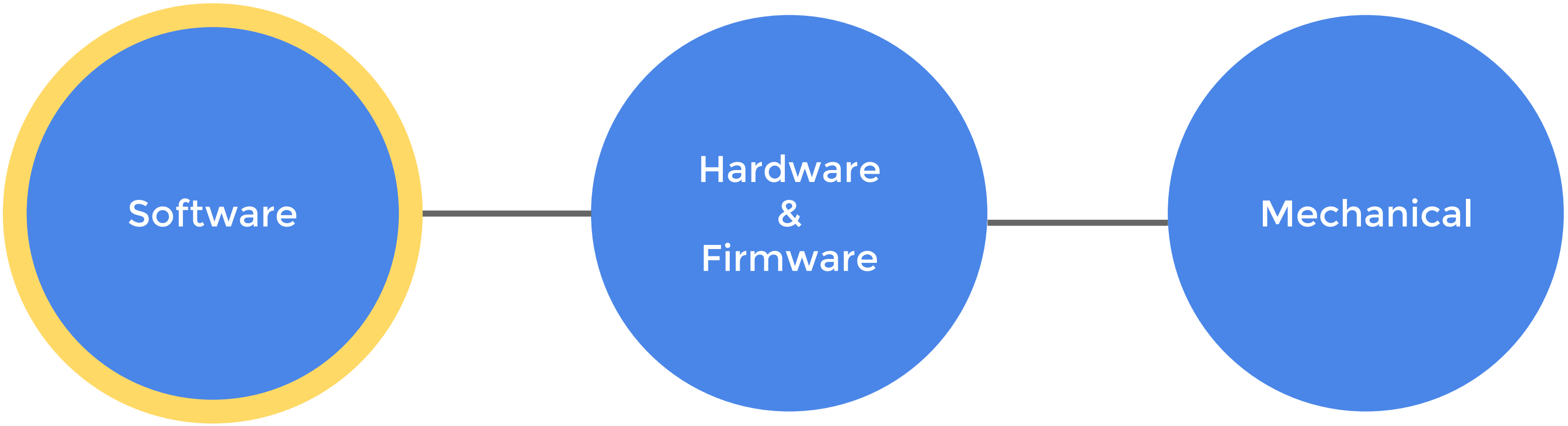
Operations Flow Chart



Key Technical Points


Application
Vendor Interface
Order Information
Customer Interface
Application Backend
Command
Address
Current State
Current Location
Communication
Serial Port (Interface)
Radio Frequency (Hardware)
MAVLink (Protocol)
Command
Address
Current State
Current Location
UAV
GPS System
Sensors
UAV Controller
Rotors
Gripper

Key Technical Points



MAVLink - Micro Air Vehicle Communication Protocol

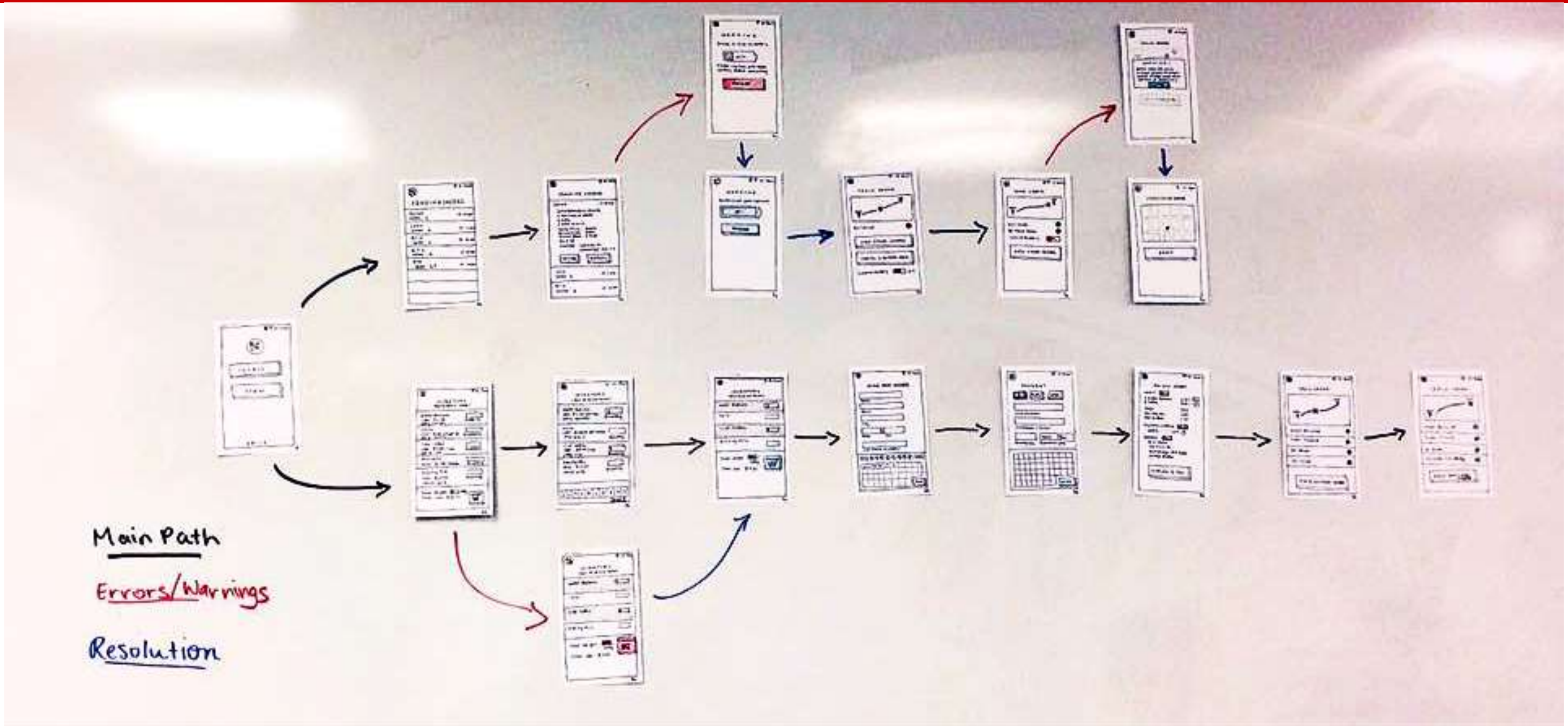
Qt Creator - Powerful cross-platform GUI design tool

Deployable to Android devices and potentially to iOS

Application Structure

User Interface	QML	QtLocation & QtPositioning APIs	Responsive Design
Functions & Logic	C/C++	Page Handlers	Functions
Communication	MAVLink	Serial Port (radio)	WiFi

User Interface: Paper Prototyping




TRACK ORDER
Current Status:
Delivered
Returned
Manual control
View other orders
Cancel Order and Return

Predicted vs. Actual Flight Path

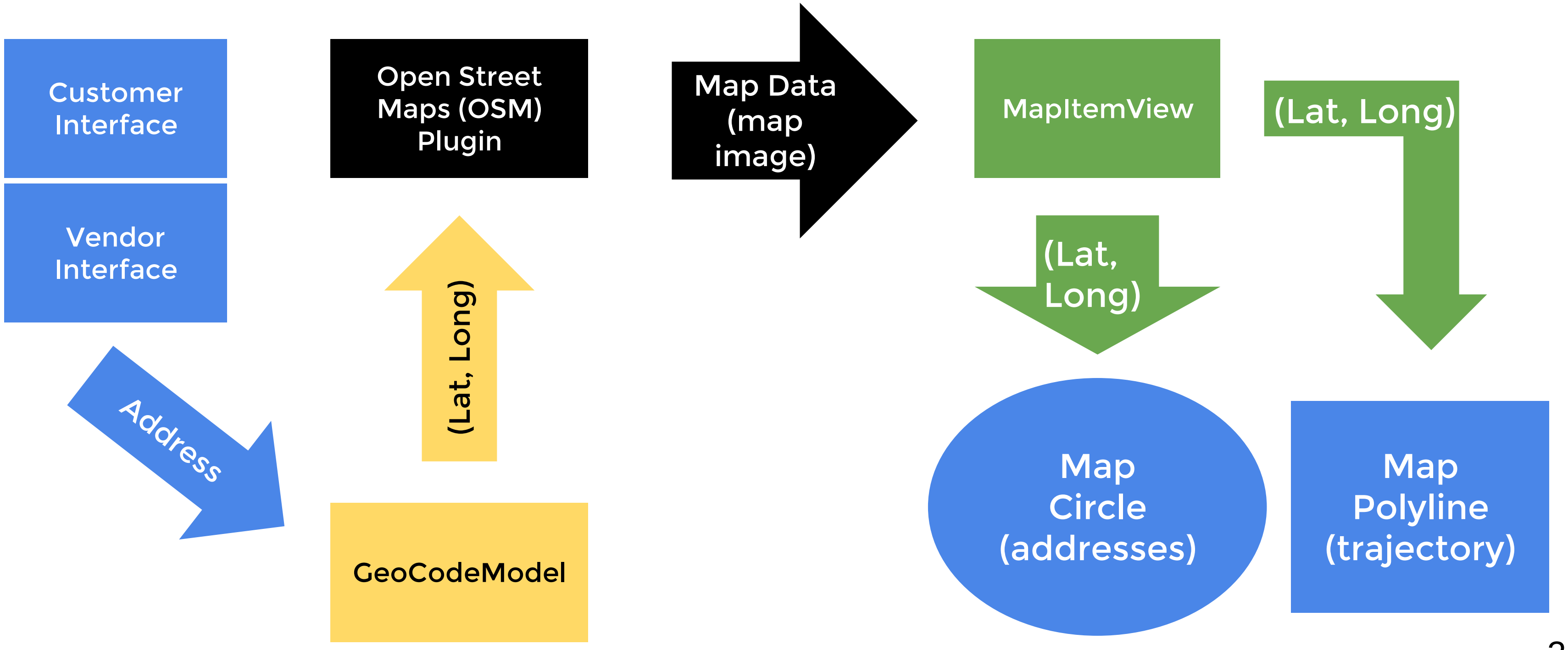
Predicted

Actual Path

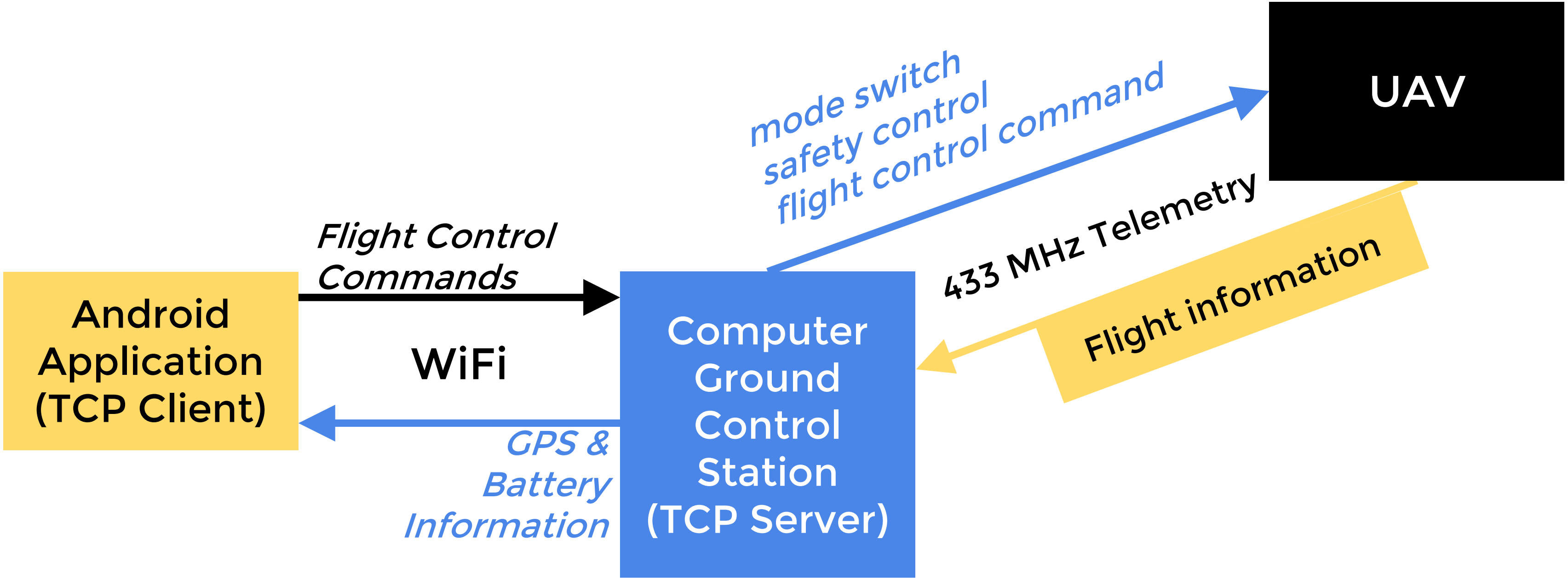
Start

End

QtPositioning & QtLocation APIs



Communication Network



MAVLink

To reduce latency, we tried to limit the transmission datastream by making smart choices of messages. We picked 9 out of more than 200 MAVLink messages:

#1	**heartbeat: time information**
#2	**system status: battery voltage and percentage**
#30	**attitude: row, pitch, yaw and attitude rates**
#32	**local position: x, y, z, 3-axis velocity and 3-axis acceleration**
#33	**global position: latitude, longitude, relative altitude**
#105	**high resolution IMU**
#253	**status text: drone flight log**
#69	**manual_control: direct flight commands and mode switch**
#76	**long command: arm and disarm**

Features

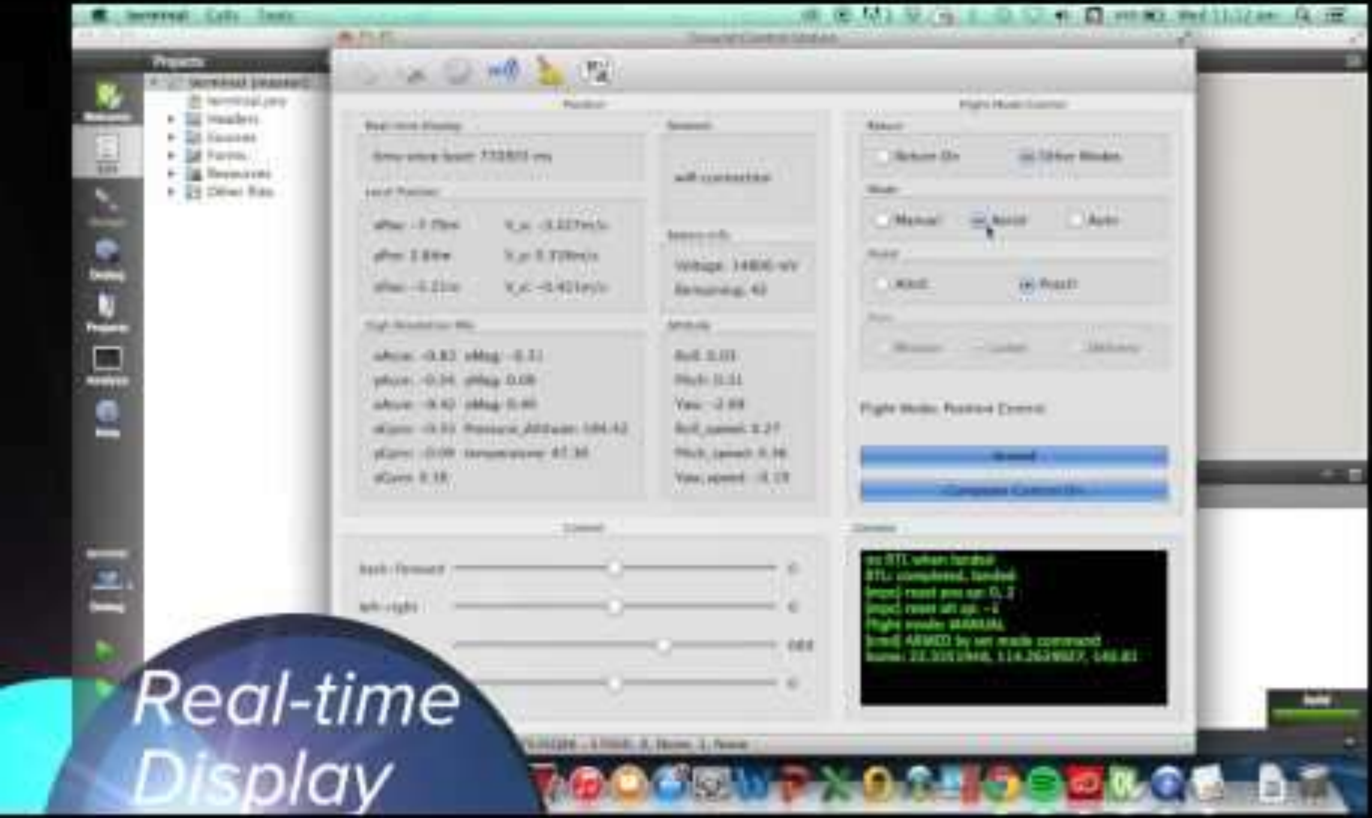
Computer Ground Control Station (GCS) has

- **a serial port for radio telemetry to communicate with UAV**
- **a TCP server to connect the Android app and UAV together**
- **a flexible mode switch panel**
- **a display of real-time flight data**
- **a console to display flight log**
- **four sliders for manual control of row, pitch, yaw, throttle and fast key**

Android Application has:

- **a TCP client to connect to the server via IP address and port number**
- **functional manual control in the local area network (LAN)**

Ground Control Station



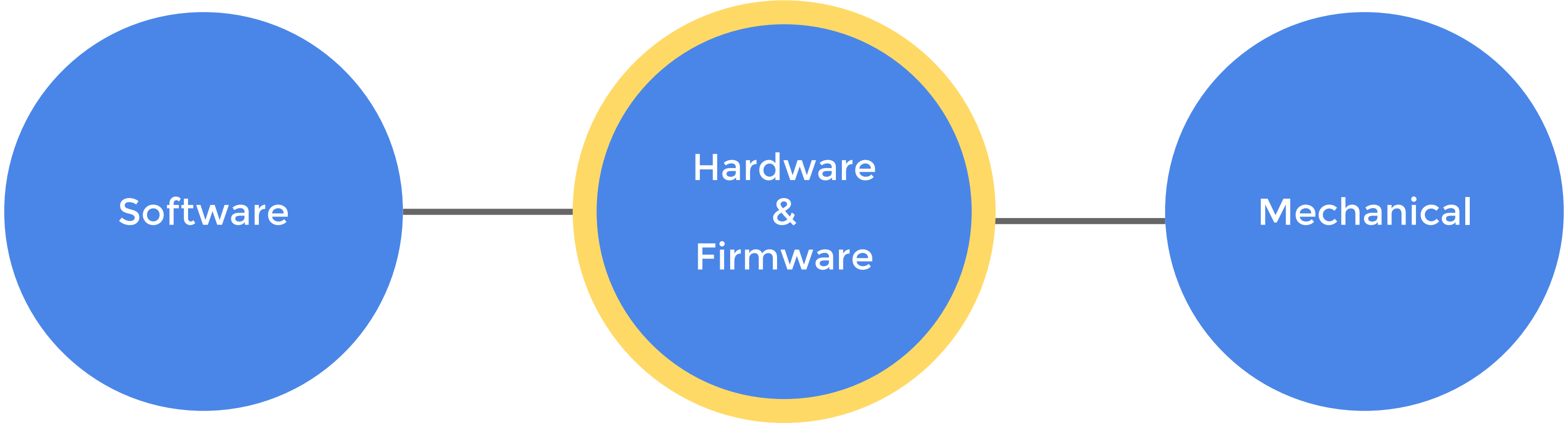
App


Delivering to:
Erin Walk
HKUST Lee Shau Kee Business Building
Hong Kong, Hong Kong 999077
Current Distance:
Order Recieved

User Experience Survey (Application)

Summary of the User Experience Survey Results, *Survey Size N=12*		
	Average Score (out of 10)	Standard Deviation
Ease of ordering (Customer)	8.8	1.1
Usefulness of the Map (Customer)	7.8	2.3
Ease of delivering (Vendor)	9.2	0.7
Ease of checking pending orders (Vendor)	9.7	0.6
Ease of checking battery status (Vendor)	8.6	1.4
Overall	**8.8**	**/**

Key Technical Points



Delivery

Object Avoidance

Gripper

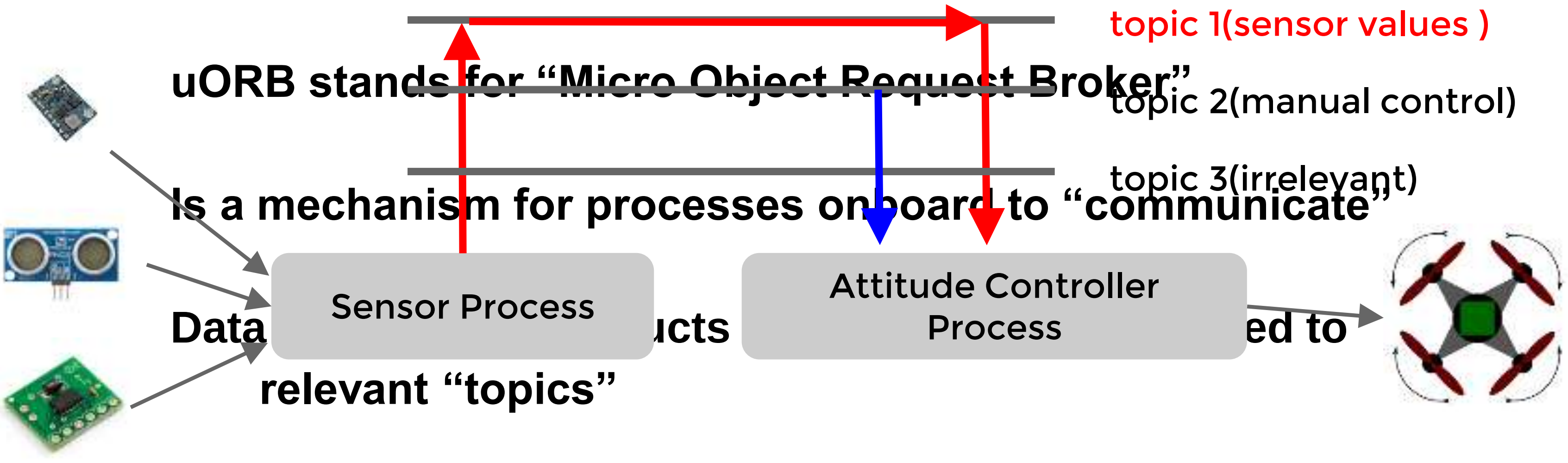
Inter-Process Communication ——uORB

- Firmware onboard is consisted of multiple processes

uORB stands for "Micro Object Request Broker"

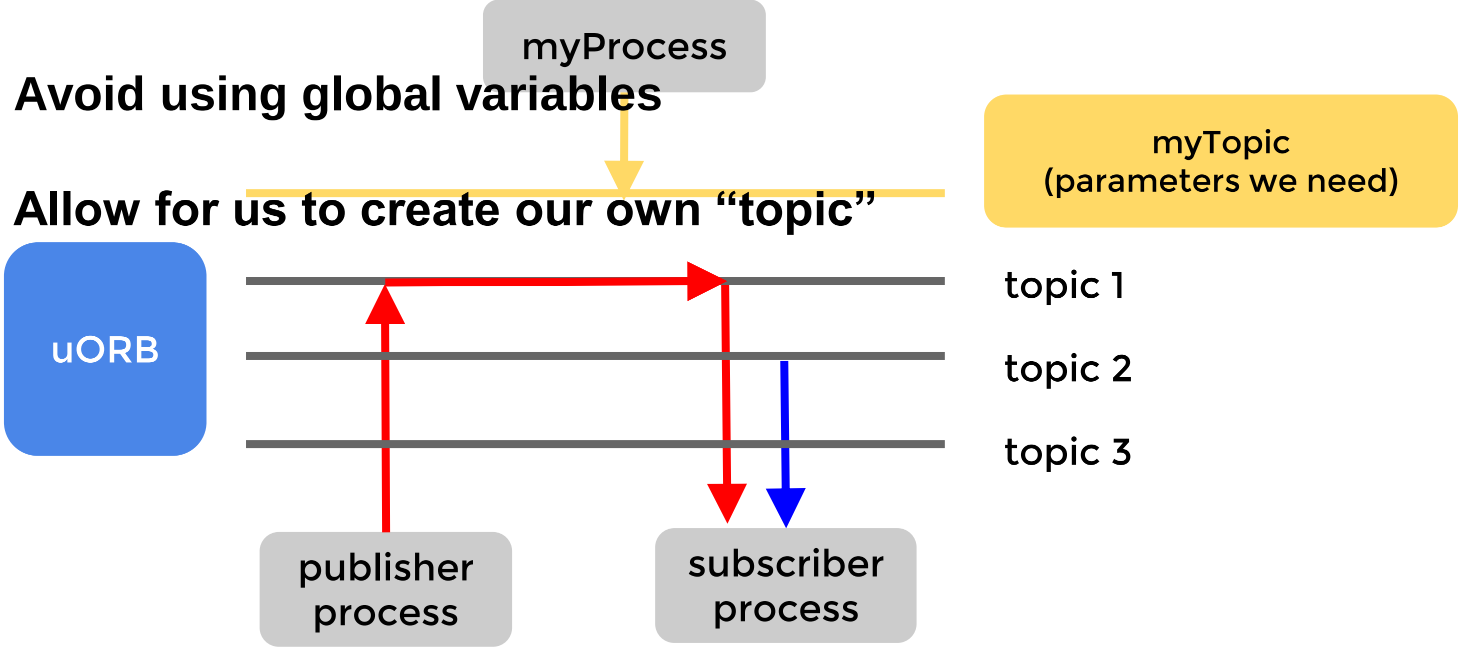
Is a mechanism for processes onboard to "communicate"

Data ... ucts ... ed to relevant "topics"



Inter-Process Communication ——Advantage

- **Avoid using global variables**
- **Allow for us to create our own "topic"**



How the Radio Controller works

Radio signal is decoded into several values including: Roll, Pitch, Yaw and Throttle

Then published to the MANUAL_CONTROL_SETPOINT topic

Subscribed by the Position Controller Process

Position Controller Process maneuvers the drone

Transmit →

Decode →

Roll
Pitch
Yaw
Throttle

Publish →

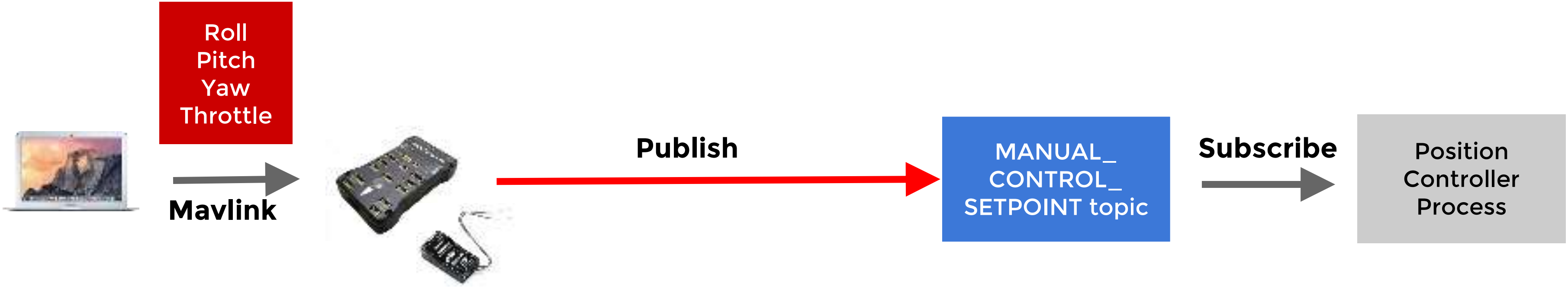
MANUAL_
CONTROL_
SETPOINT topic

Subscribe →

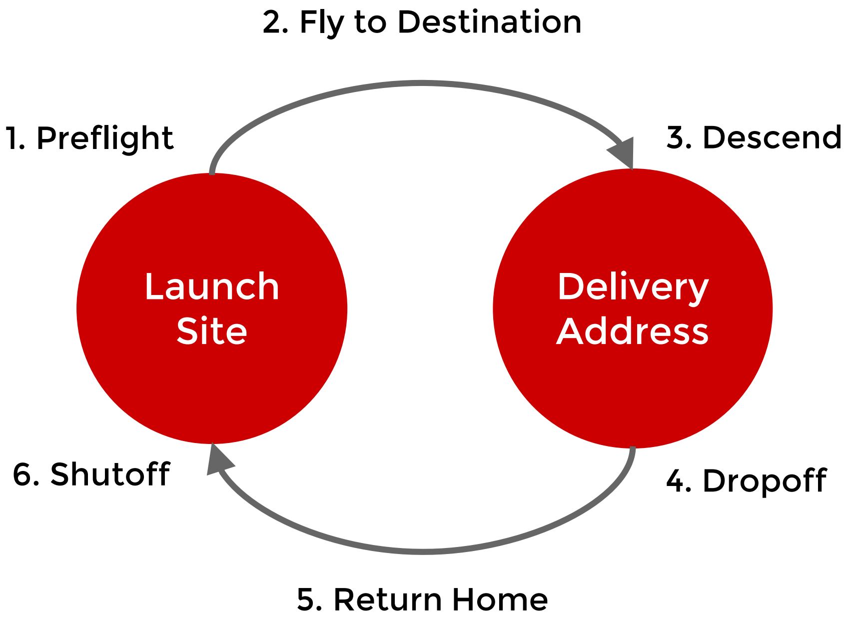
Position
Controller
Process

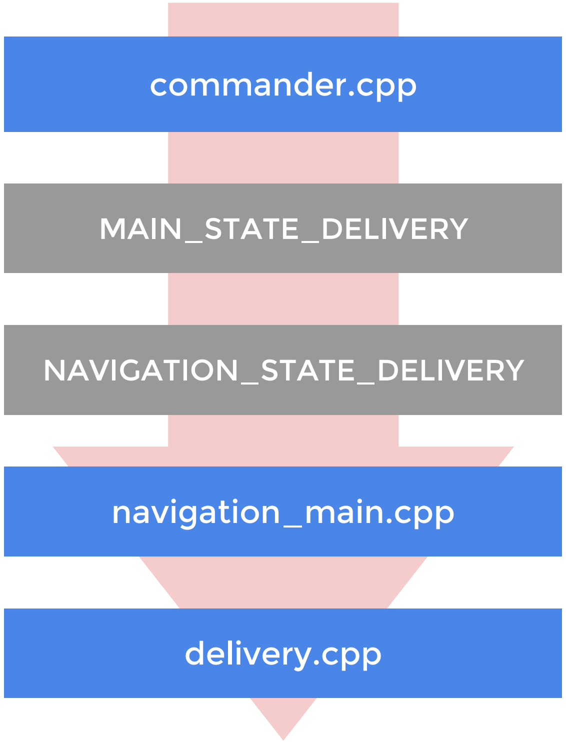
Controlling by Mobile/PC Terminal

How our <u>PC/Mobile</u> Control works:
Instead of going through the decoding procedure, we send desired Roll, Pitch, Yaw, and Throttle information <u>directly to the mainboard using MAVlink Protocol</u>



Delivery Route





Barrier Avoidance Feature

Using the MB-1240 ultrasonic proximity sensor to detect barrier

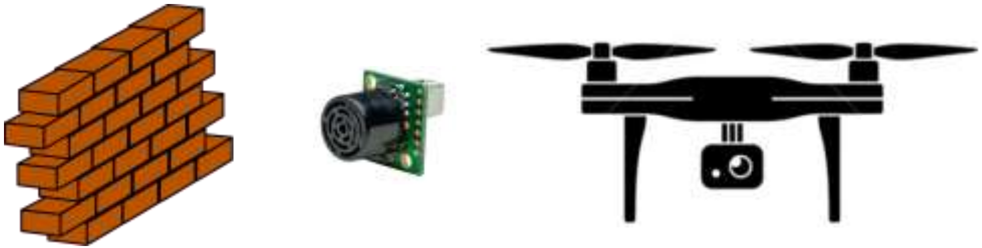
Accurate sensing range from 20cm to 600cm

Sensor gives out analog output ranging from 0-3.3V

ADC sampling function runs in System Ticks

Sample rate of 100Hz

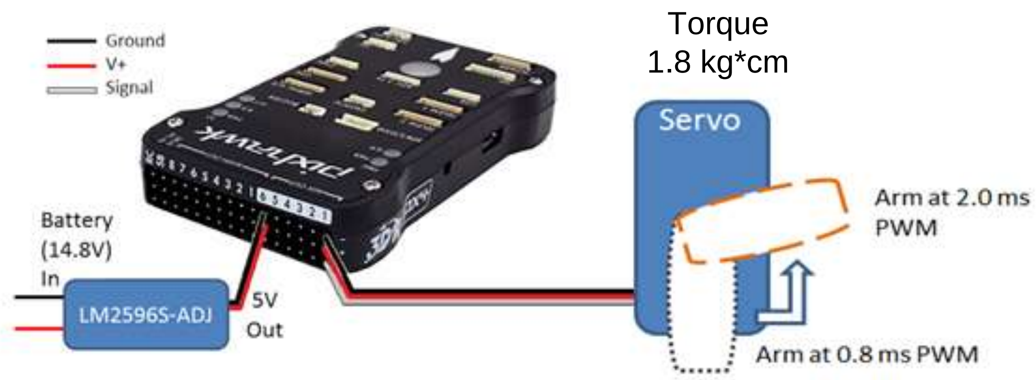
Barrier Avoidance Feature

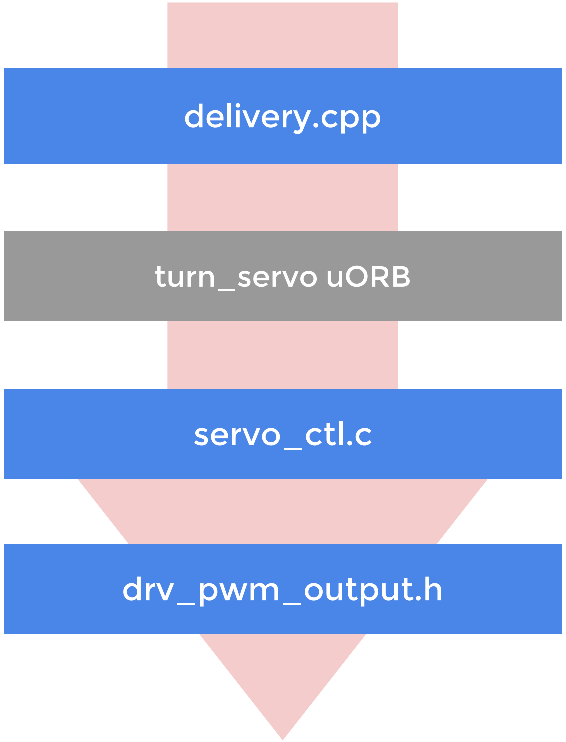


Barrier Detected → Stop → Ascend till barrier avoided

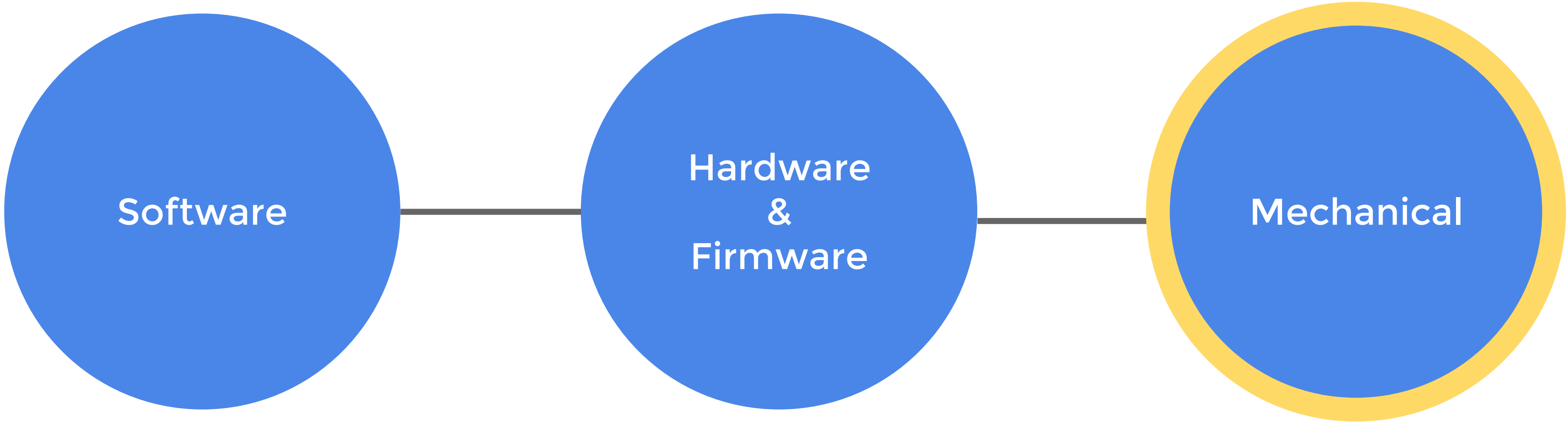
- adc.cpp
- ADC_PROX uORB
- commander.cpp
- MAIN_STATE_POSCTL
- Publish a thrust information
- mc_pos_control.cpp

Gripper Control





Key Technical Points



Gripper

Landing Gear

Shell

Gripper Design

Retractable-wire pulley

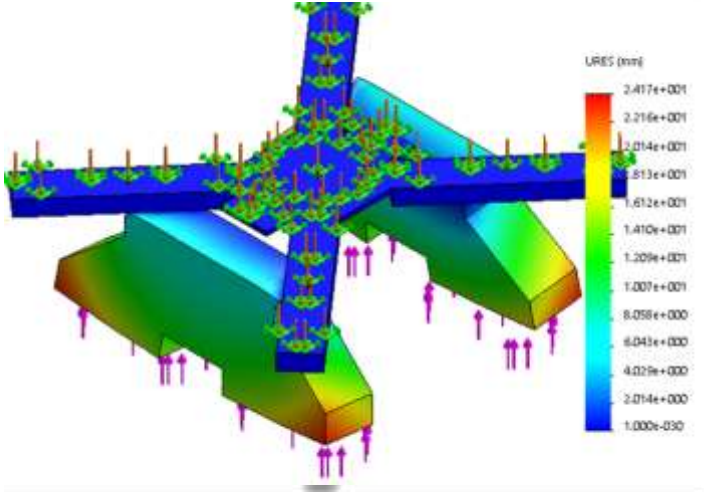
Efficient delivery
Less power consumed

Fragile

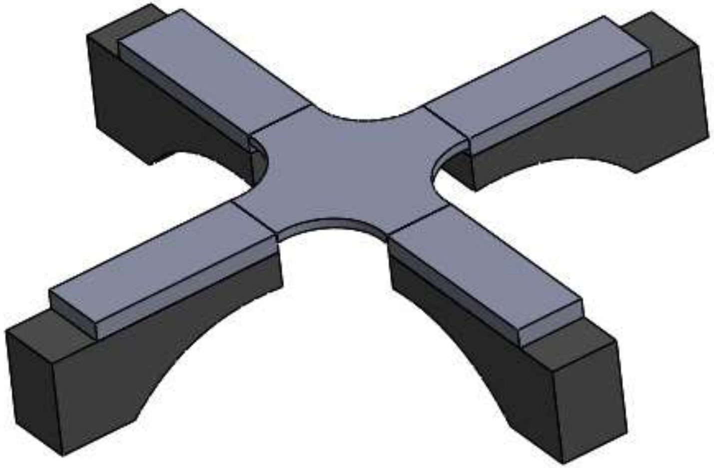
Servo controlled Jaw

Simple
Robust

Landing Gear: Design Analysis



More bending at all 4 corners
Cause UAV to topple
Redundant central part



Styrofoam supports at the four ends
Extended out for better balance
Easy attachment

UAV Shell: Design Evolution

Beautiful and robust
heavy: 600g
complex: hard to 3d print and manufacture

Simpler, less complex,
still heavy: 250g
easy to manufacture but fragile

Simpler, robust,
light (weight: 70g)
easy to manufacture,
And beautiful!

What ?

Why?

Who?

How?

Does it work?

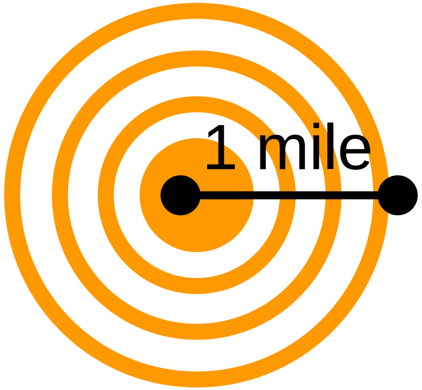
What is next?

Performance Testing

Flight Speeds on a 57 m Trajectory		
Trial	Time in Flight (s)	Mean Speed (m/s)
1	8.5	6.7
2	8.3	6.8
3	7.8	7.3
Average	**8.2**	**6.9**

Battery Life Testing		
Trial	3300mAh (320g)	5000mAh (541g)
1 (Min:Sec)	15:20	20:43
2 (Min:Sec)	15:21	20:09
Average	**15:21**	**20:26**

Technical Specifications



> 5m/s

450g

1.25 miles

7 m/s

Technical Specifications

20 min
Battery Life

1 mile
Communication

0.2%
loss rate

20:26

1.25 miles

0%

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Future Work

Increasing payload to 1 kg (~ the weight of 15” pizza)
Optimizing battery usage for 30 minutes
Increasing delivery mileage to 3 km
- Improving the communication system range

Improving accuracy of drone tracking for door deliveries
Developing more comprehensive object avoidance
- More than just ascending

Acknowledgements

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Q&A

DEMO

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Design Team 2015

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Mayank Kumar
Yixing Liu (Eva)
Vinh Nguyen
KamFai Tsang (Elvis)
Erin Walk
Billie Wei
Ruilin Wen (Gary)

Fin

Appendix I – Flight Safety Concern

Flight Certification

Preflight
Checklist

Appendix II

http://www.gizmag.com/flirtey-drones-deliver-medicine-in-us-first/38102/

- The citizens of Wise County, Virginia lack access to proper healthcare
- Previously, medical supplies were delivered each year to the area by truck
- CEO Sweeney says, "they said that if there was a way they could receive the medication quicker that would help"
- Sweeney hopes this proof of concept whereby the benefits of drone delivery are realized, albeit on a small scale, will act as a catalyst for the delivery of everyday items.

Appendix III

http://www.forbes.com/sites/gregorymcneal/2015/02/15/the-drones-are-coming-heres-what-president-obama-thinks-about-privacy/

Drones are expected to create 70,000 jobs with an economic impact of more than $13.6 billion in the first three years after their integration into U.S. skies.

Feedback:

Evelyn:
-Move functional requirements to the beginning
-explain what we wanted to create at the very beginning
-use more words
-lead up to the video, don’t use it in the first slide
-tell audience what the hard parts of the project were
-introduce very basics of project at the start
-make it sound difficult
-slide 22 is a good slide, but needs more time to explain it
-audience needs a little

Chris
-switching speakers too frequently
-group the slides so that one person can talk for a longer period of time
-loud background music took away from narration
-explain what is impressive in the videos
-talk to someone who has not been involved with the project
-slides at the end should explain what we accomplished relative to the technical specs we listed at the beginning

Avi
-good groupings, but missing out on explaining context
-start with the why
-do not talk about technical specifications until slide 50
-how did we work in existing firmware and glob of code?

questions
-why does
only go up
reaches a
Could this
in areas lik
-why does
gear not g
height to a
payload?
-what is m
some text
written def