Heterogeneous Multi-Robot Sampling

Team G: SAMP

Outline:

1. Recap: Team Requirements & Architecture
2. Major subsystems description
3. Project work breakdown
4. Project schedule for Spring 2019
5. Spring Validation Experiments
6. Risk Analysis

Team SAMP:

Team Member:

- Yunfei Shi - Electrical Engineer
- Ning Wang - Computer Scientist
- Yang Zhang - Computer Engineer
- Jianmin(Paul) Zheng - Automation Engineer

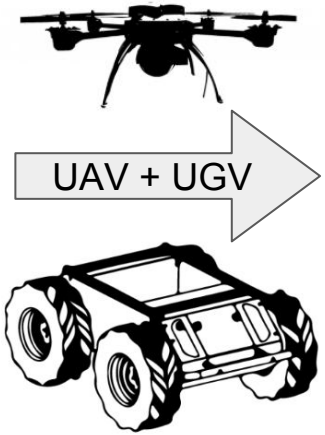
Stakeholders:

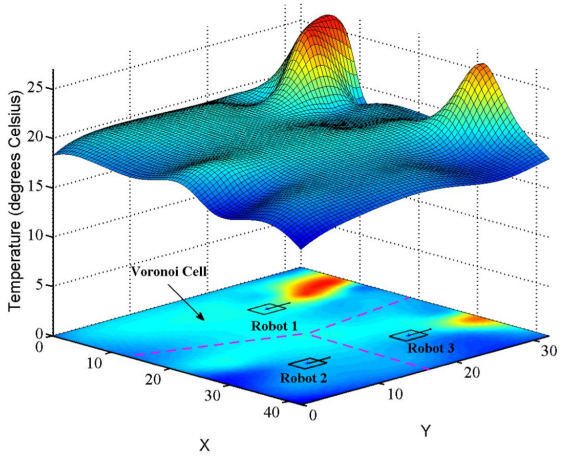
- Sponsor: Katia Sycara
- Mentors: Wenhao Luo, Sha Yi
- MRSD advisors: Dimi Apostolopoulos, John M. Dolan

Project Goal:

We aim to deliver a UAV-UGV team that performs online environmental sampling and modeling collaboratively given an outdoor area with different terrains.

https://secondnexus.com/environment/yellowstone-caldera-nasa-supervolcano/





Wenhao and Katia, ICRA, 2018

Functional Requirements:

F.R.1 Generate an environmental phenomenon distribution model for the area of interest.

F.R.2 Self-Identify informative locations to take samples from.

F.R.3 Collect accurate samples at discrete locations across the area.

F.R.4 Correct and update the model during sampling.

F.R.5 Navigate autonomously in the given terrain.

F.R.6 Plan obstacle-free paths autonomously.

Performance Requirements:

M.P.1 Generate an temperature distribution model for an area of interest within the dimension 20m x 20m x 5m.

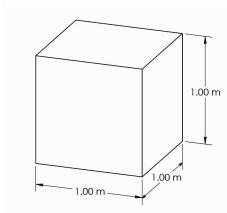
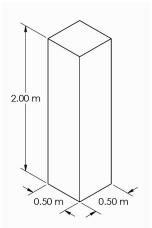
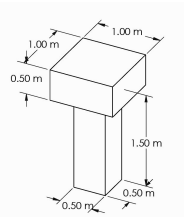
M.P.2 The temperature distribution model accuracy greater than 80%.

M.P.3 Self-select informative point which reduces local variance by at least 3% at each time.

M.P.4 Collect temperature sample with error within +/- 2 °C.

M.P.5 Update the model after receiving each sample.

Performance Requirements:

Obstacle	Quantity
	2
	2
	4

M.P.6 Navigate autonomously in the area with success rate greater than 80%.

M.P.7 Achieve sample localization accuracy better than +/- 2 m.

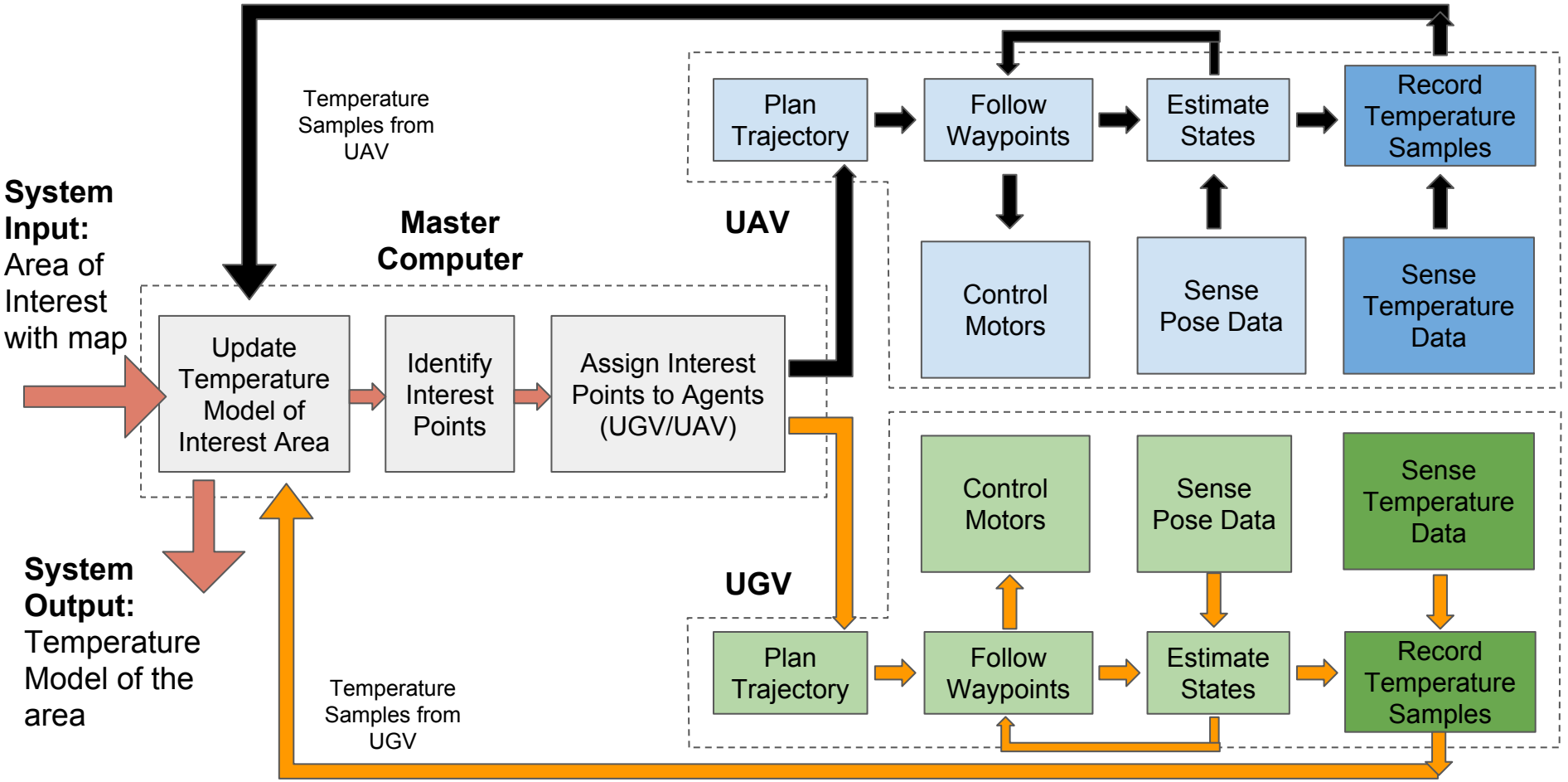
M.P.8 Plan obstacle-free path through randomly deployed obstacles.

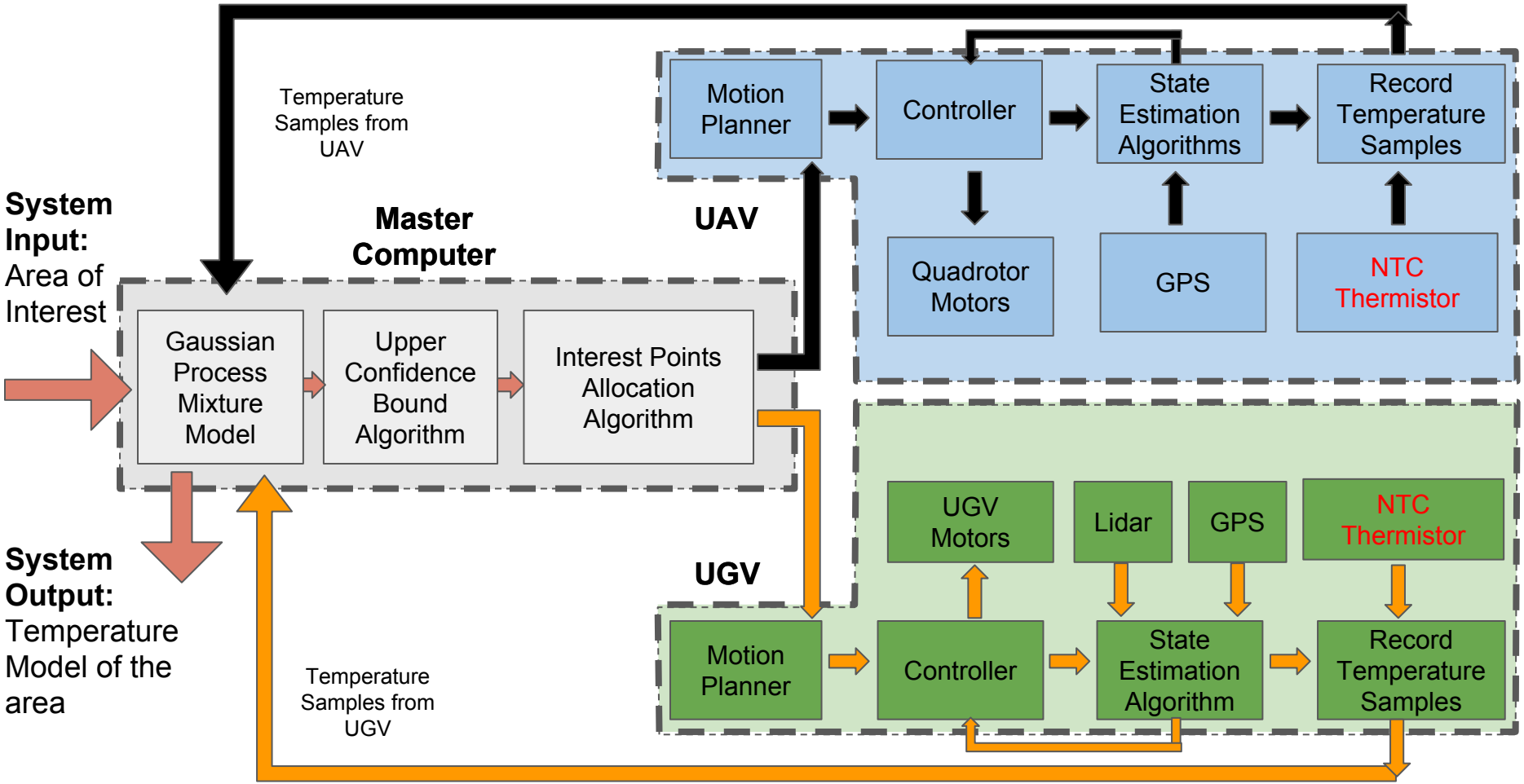
M.P.9 Last at least 15 minutes for one deployment.

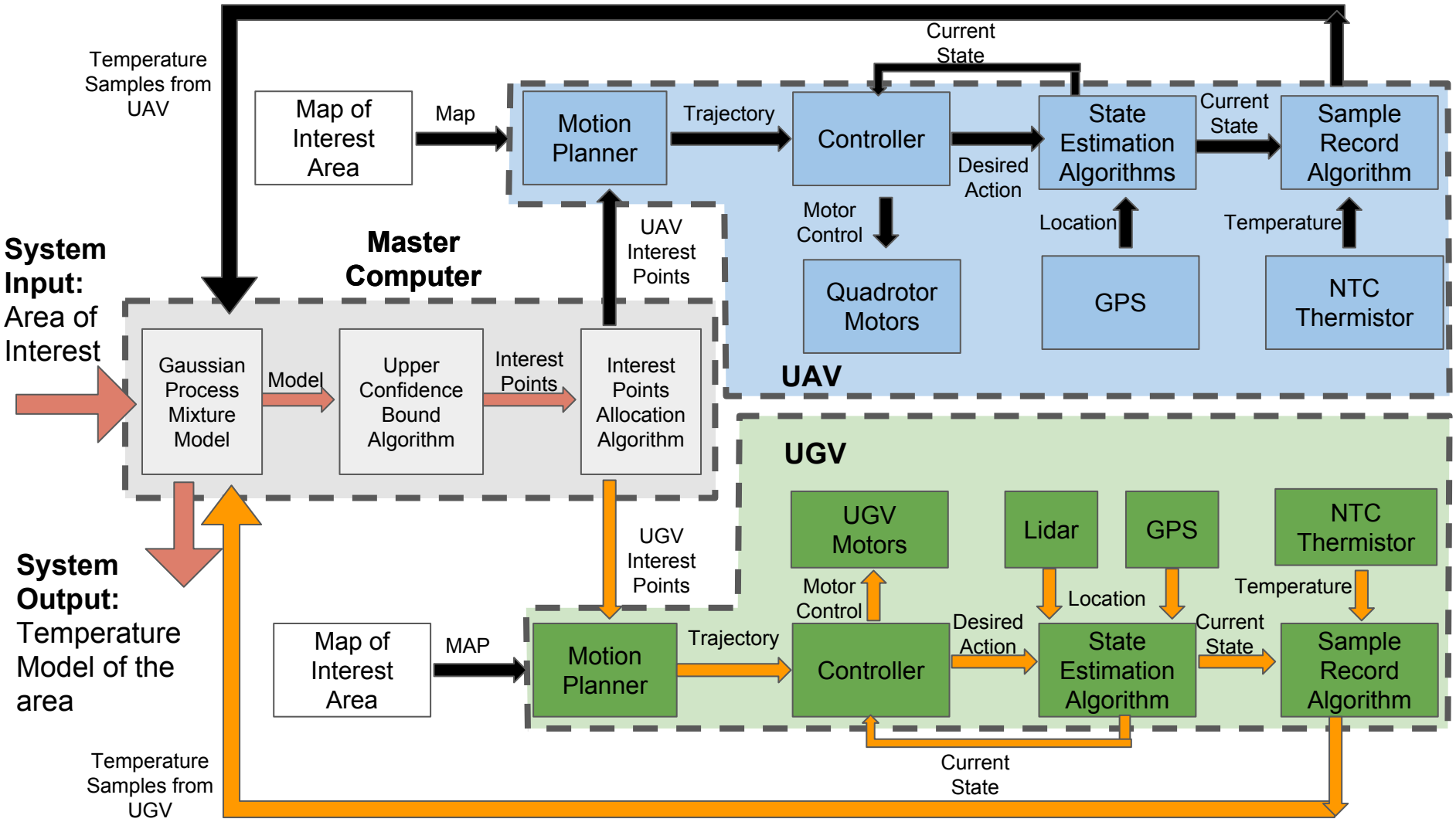
Nonfunctional Requirements

The system will:

1. Have safety features:
    a. UAV and UGV have no sharp edges.
    b. UAV has drone blade guards
    c. Emergency Stop
2. Environmental friendly:
    a. Maintain a low noise level
    b. Not damage operating environment
3. High extensibility:
    a. Scale up to multiple heterogeneous robots


Temperature Samples from UAV
System Input: Area of Interest with map
Master Computer
Update Temperature Model of Interest Area
Identify Interest Points
Assign Interest Points to Agents (UGV/UAV)
UAV
Plan Trajectory
Follow Waypoints
Estimate States
Record Temperature Samples
Control Motors
Sense Pose Data
Sense Temperature Data
UGV
Control Motors
Sense Pose Data
Sense Temperature Data
Plan Trajectory
Follow Waypoints
Estimate States
Record Temperature Samples
System Output: Temperature Model of the area
Temperature Samples from UGV


Temperature Samples from UAV
System Input: Area of Interest
Master Computer
Gaussian Process Mixture Model
Upper Confidence Bound Algorithm
Interest Points Allocation Algorithm
UAV
Motion Planner
Controller
State Estimation Algorithms
Record Temperature Samples
Quadrotor Motors
GPS
NTC Thermistor
UGV
UGV Motors
Lidar
GPS
NTC Thermistor
Motion Planner
Controller
State Estimation Algorithm
Record Temperature Samples
System Output: Temperature Model of the area
Temperature Samples from UGV


Temperature Samples from UAV
Current State
Map of Interest Area
Map
Motion Planner
Trajectory
Controller
State Estimation Algorithms
Current State
Sample Record Algorithm
Desired Action
Motor Control
Location
Temperature
Quadrotor Motors
GPS
NTC Thermistor
UAV
System Input: Area of Interest
Master Computer
UAV Interest Points
Gaussian Process Mixture Model
Model
Upper Confidence Bound Algorithm
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UGV Interest Points
System Output: Temperature Model of the area
UGV Motors
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State Estimation Algorithm
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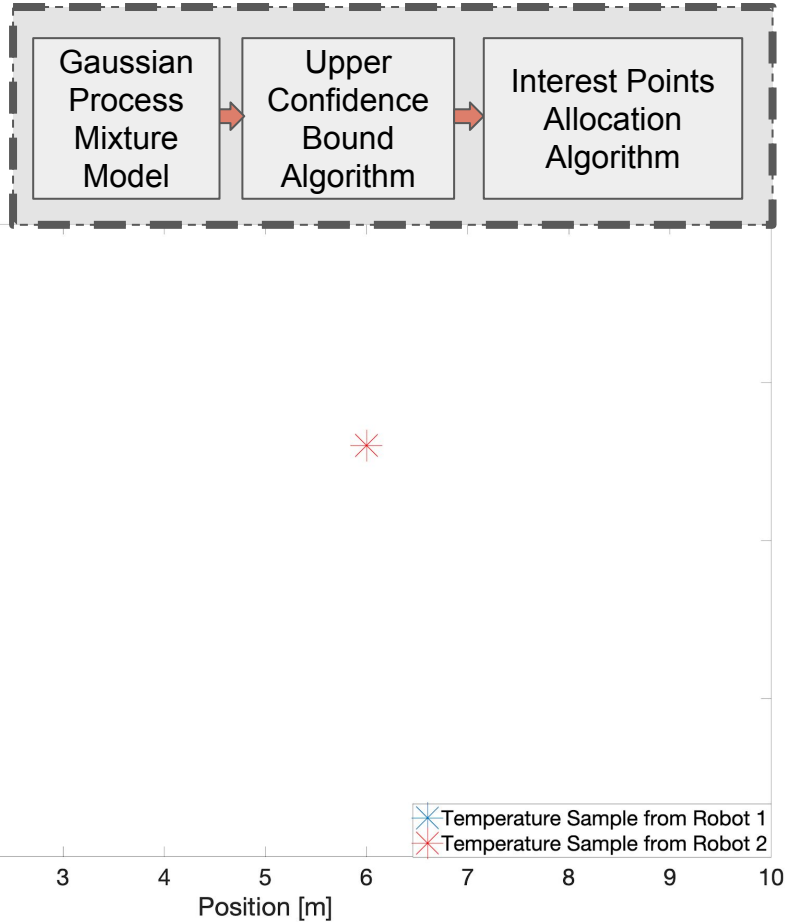
Sample Record Algorithm
Current State
Temperature Samples from UGV

Major subsystems overview

Master Computer

1. Read in temperature data

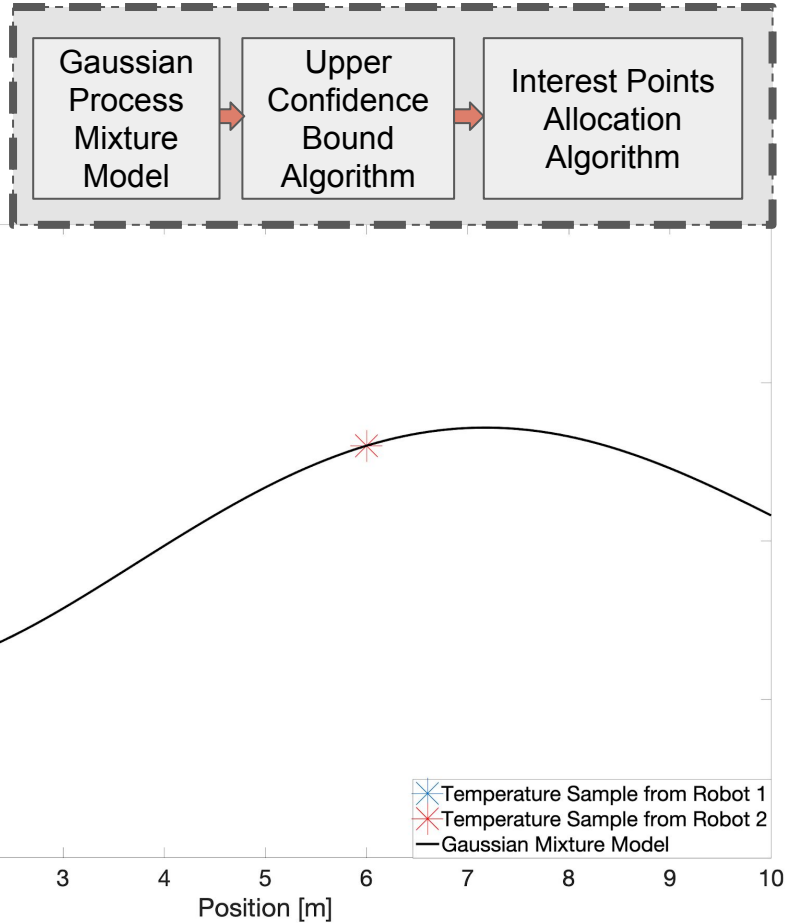


Major subsystems overview

Master Computer

1. Read in temperature data
2. Update Temperature Model

   (Gaussian Mixture Model)



Major subsystems overview

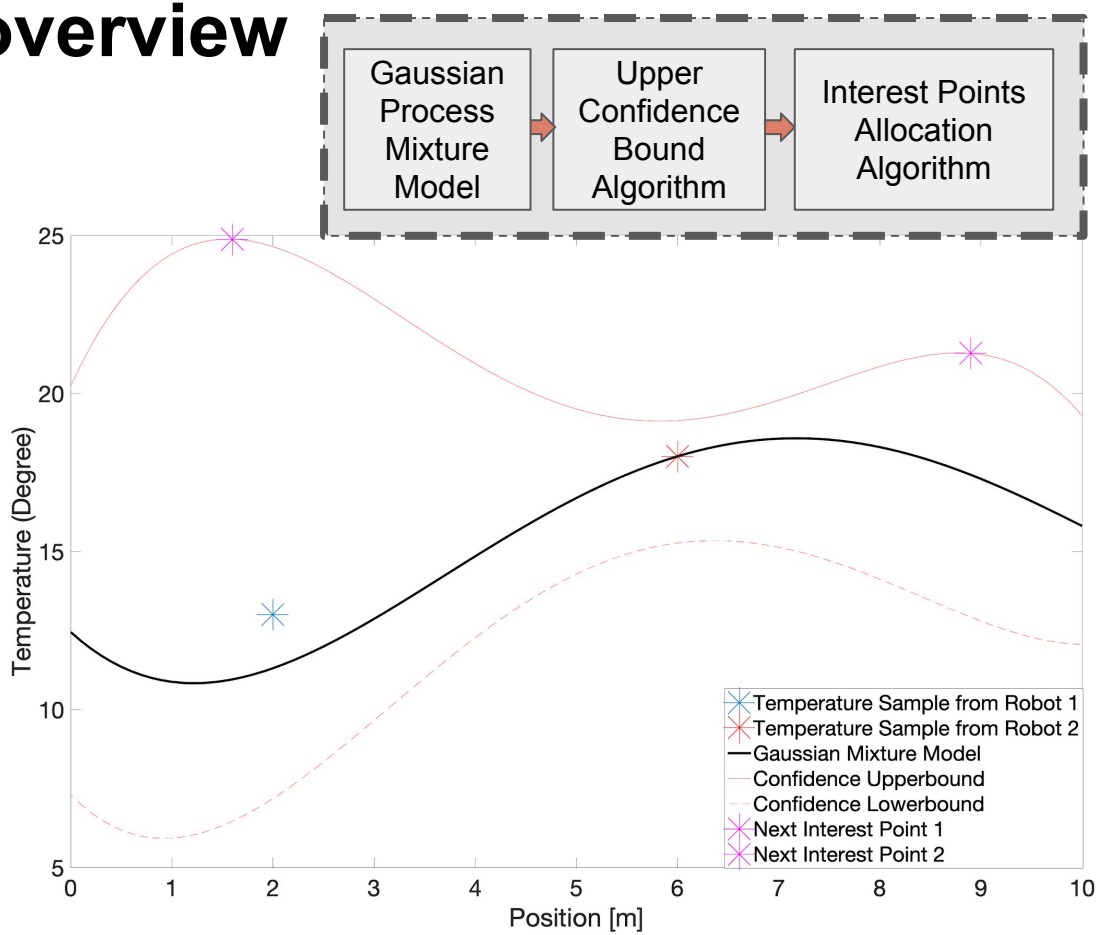
Master Computer

1. Read in temperature data
2. Update Temperature Model

   (Gaussian Mixture Model)

3. Identify Next Interest Point

   (Upper Confidence Bound)



Major subsystems overview

Master Computer

1. Read in temperature data
2. Update Temperature Model

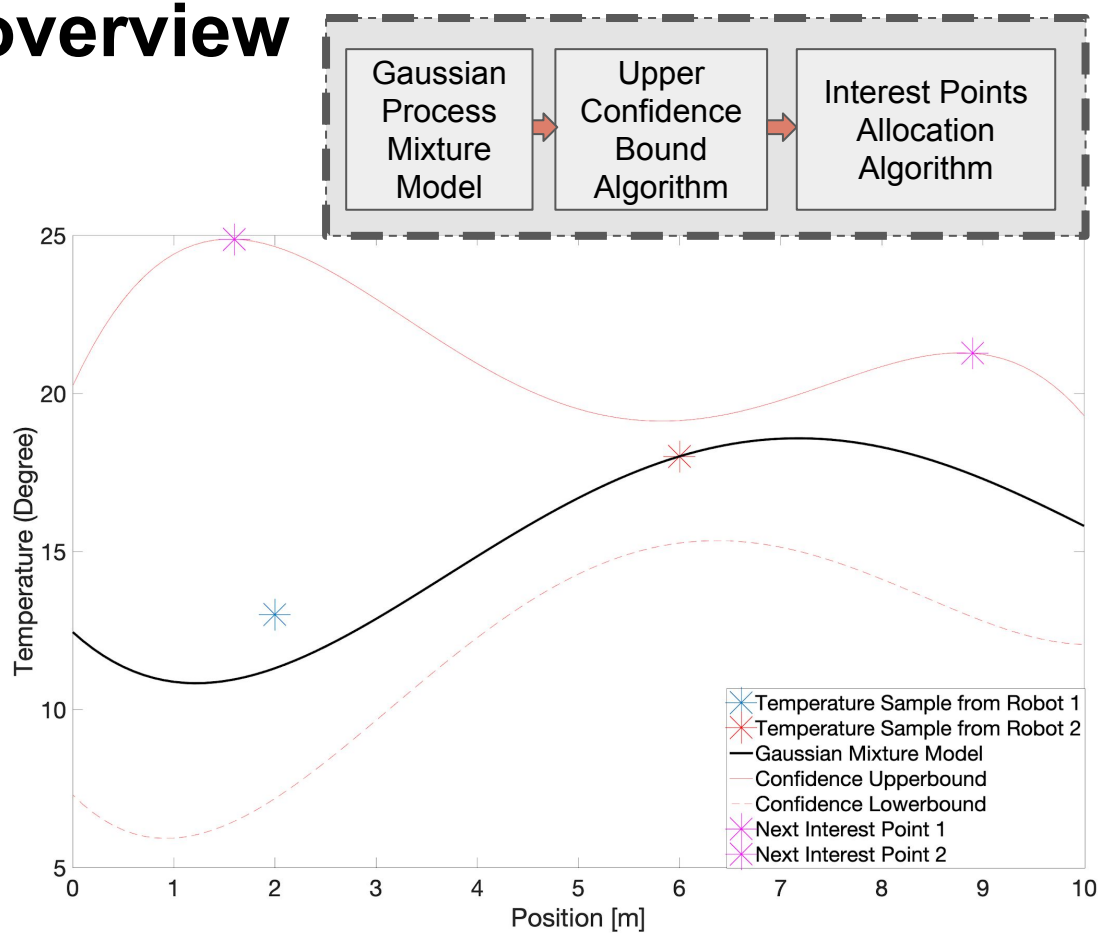
   (Gaussian Mixture Model)

3. Identify Next Interest Point

   (Upper Confidence Bound)

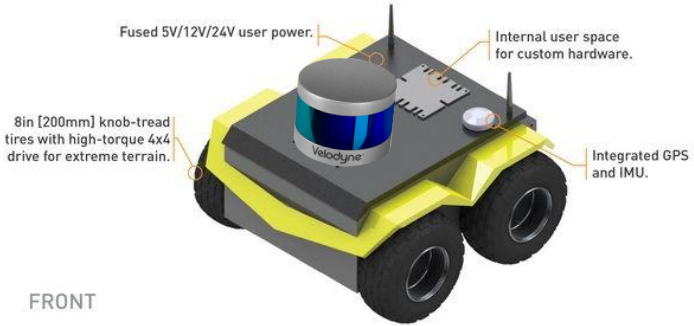
4. Allocate Interest Points to

   UGV/ UAV



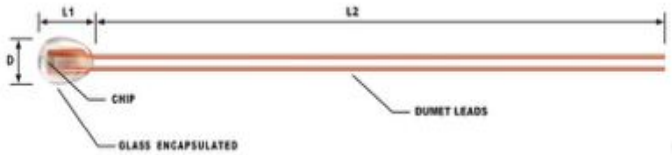
Major subsystems overview

UGV



Jackal UGV

- lightweight and waterproof
- flexible platform for integrating sensors and utilizing its ROS API
- Intel i5 onboard computer
- GPS
- wireless connectivity via both Bluetooth and wifi
- payload up to 20kg
- 4 hours duration with standard loads
- Velodyne VLP-16 LiDAR

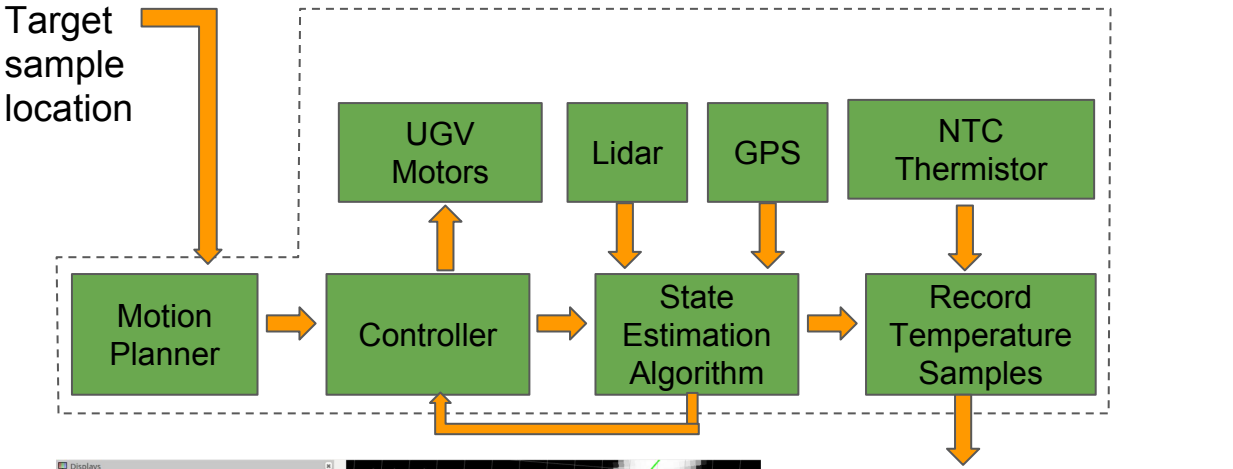


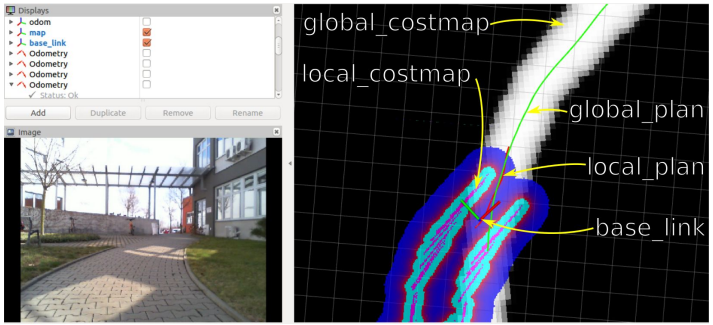
NTC Thermistor

- operating range: −55 °C to +200 °C
- temperature sensitivities: -3% to -6% per °C
- experience large change in resistance per Celsius

Major subsystems overview

UGV



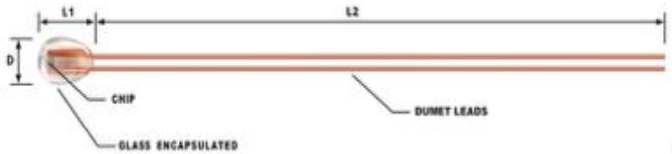


Major subsystems overview

UAV

AscTec Pelican UAV

- Intel® Core™ i7 on-board computer
- Lightweight and robust
- Hokuyo Laser Scanner (up to 30m range)
- GPS
- Wifi and XBee (wireless serial)
- AscTec Autopilot sensor board
- 16 minutes flight time
- 16 m/s maximum speed



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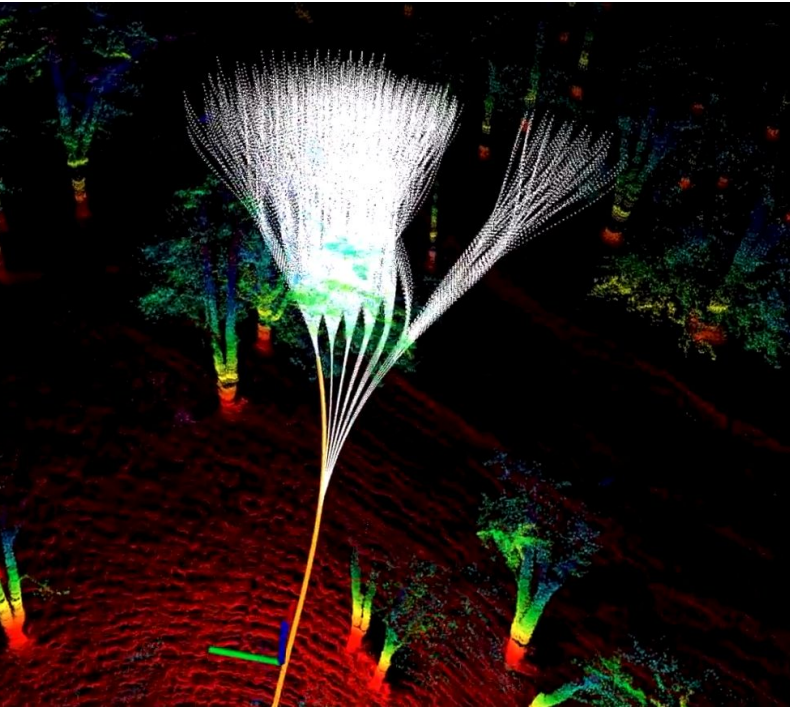
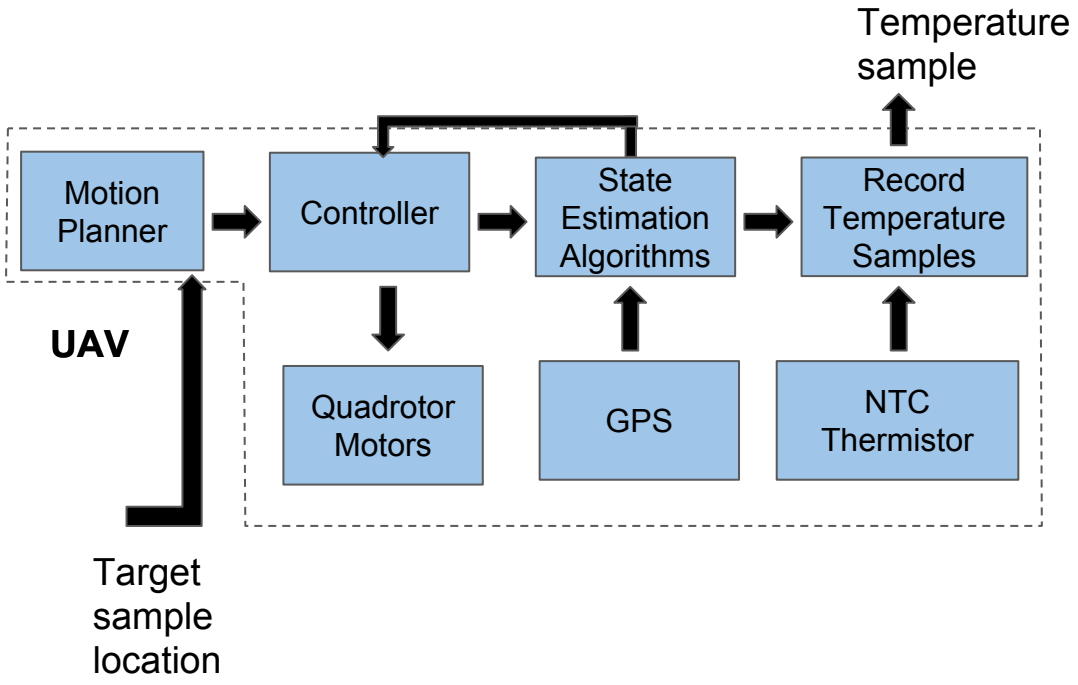
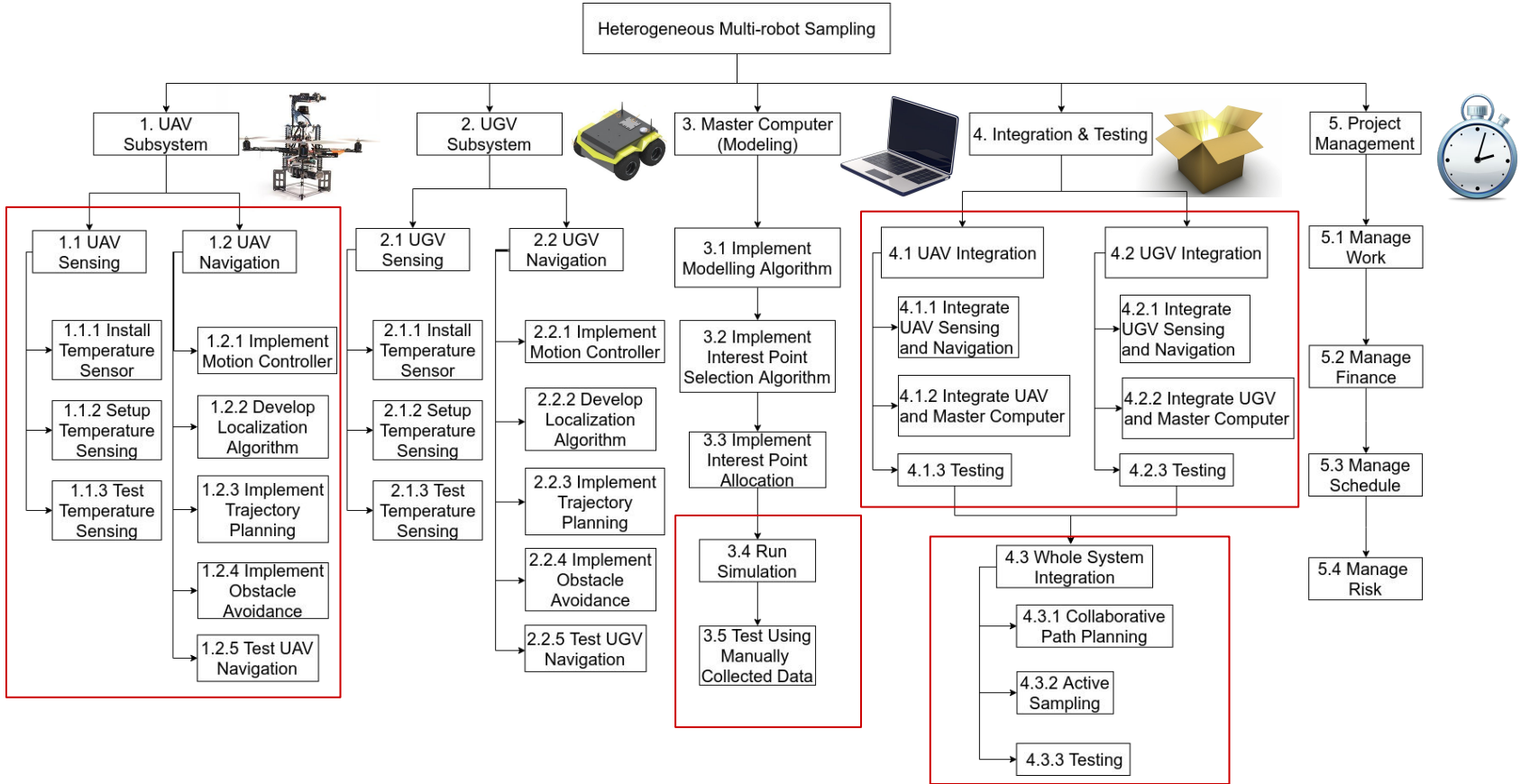
Major subsystems overview

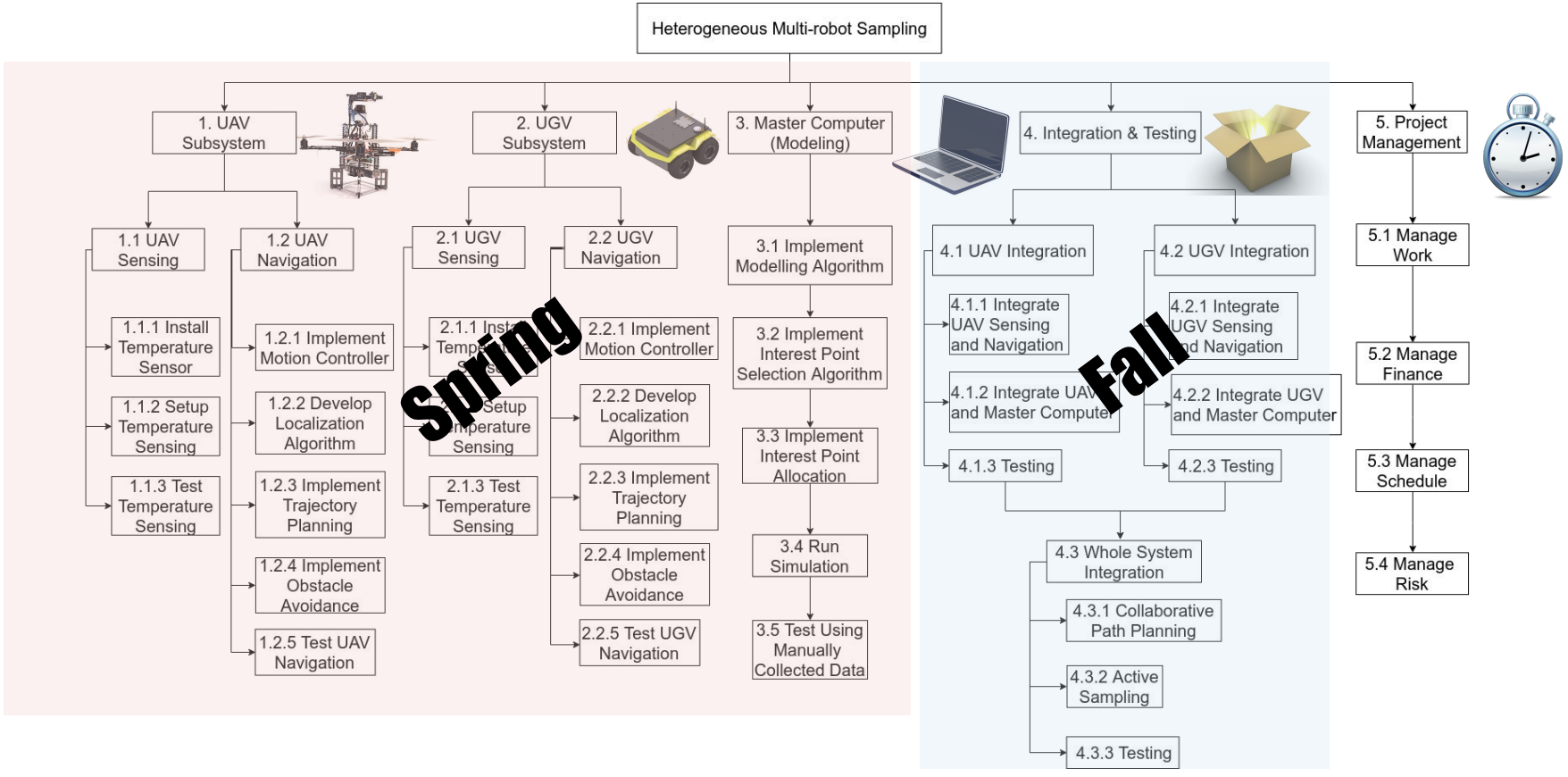




Project Work Breakdown



Project Schedule



Spring Project Schedule

Heterogeneous Multi-robot Sampling

Phase 1

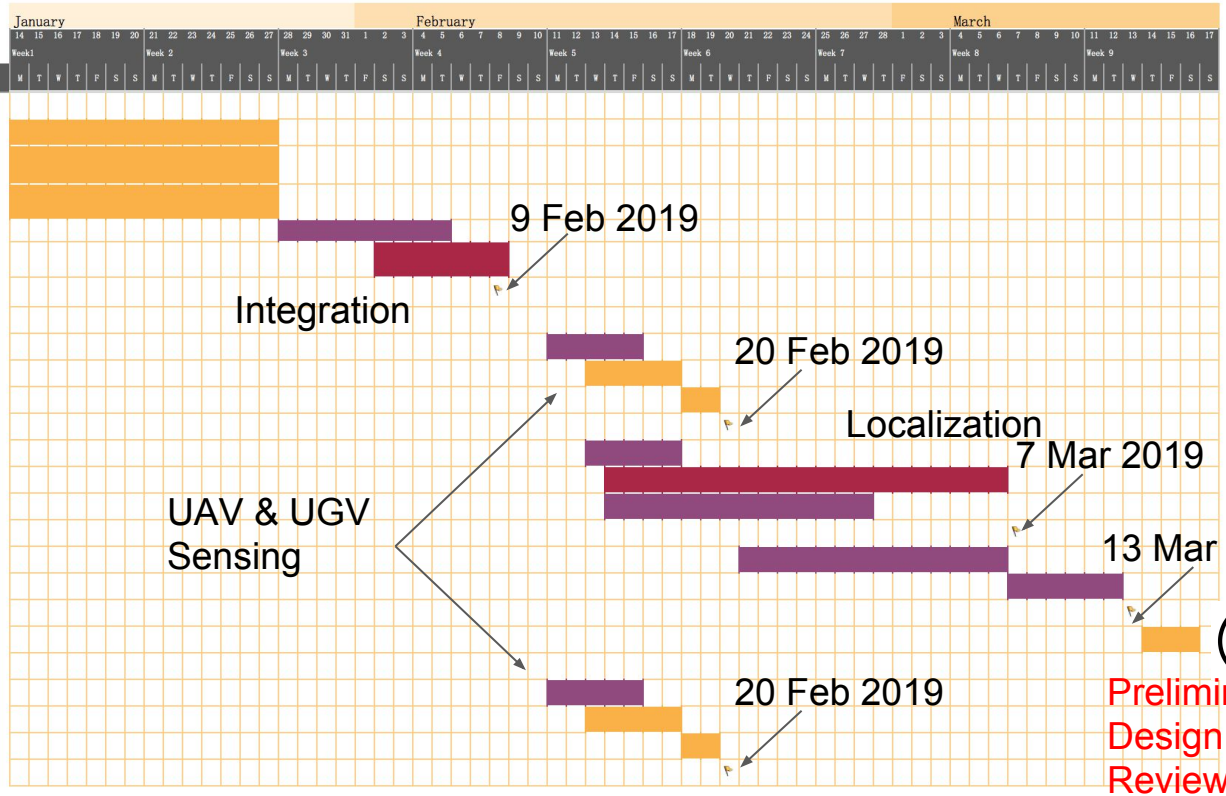
Jianmin, Yunfei, Yang, Ning

Project Start Date: 2019/1/14

Display Week: 1

Legend: On Track | Low Risk | Med Risk | High Risk | Unassigned

Milestone Description	Category	Assigned To	Progress	Start	No. Days
Master Computer					
3.1 Implement Modeling Algorithm	Low Risk	Ning	0%	2019/1/14	14
3.2 Implement Interest Point Selection Algorithm	Low Risk	Yang	0%	2019/1/14	14
3.3 Implement Interest Point Allocation	Low Risk	Jianmin, Yunfei	0%	2019/1/14	14
3.4 Run Simulation	Med Risk	Team	0%	2019/1/28	9
3.5 Test Using Manually Collected Data	High Risk	Team	0%	2019/2/2	7
Master Computer Validation	Milestone			2019/2/9	1
UGV Subsystem					
2.1.1 Install Temperature Sensor	Med Risk	Jianmin	0%	2019/2/11	5
2.1.2 Setup Temperature Sensing	Low Risk	Jianmin	0%	2019/2/13	5
2.1.3 Test Temperature Sensing	Low Risk	Ning	0%	2019/2/18	2
Hardware Test Check	Milestone			2019/2/20	1
2.2.1 Implement Motion Controller	Med Risk	Jianmin	0%	2019/2/13	5
2.2.2 Develop Localization Algorithm	High Risk	Ning, Yang	0%	2019/2/14	21
2.2.3 Implement Trajectory Planning	Med Risk	Yunfei	0%	2019/2/14	14
Localization Check	Milestone			2019/3/7	1
2.2.4 Implement Obstacle Avoidance	Med Risk	Yang, Yunfei	0%	2019/2/21	14
2.2.5 Test UGV Navigation	Med Risk	Team	0%	2019/3/7	6
UGV Validation	Milestone		0%	2019/3/13	1
Presentation & Demo Preparing	Low Risk	Team	0%	2019/3/14	3
UAV Subsystem					
1.1.1 Install Temperature Sensor	Med Risk	Jianmin	0%	2019/2/11	5
1.1.2 Setup Temperature Sensing	Low Risk	Jianmin	0%	2019/2/13	5
1.1.3 Test Temperature Sensing	Low Risk	Ning	0%	2019/2/18	2
Hardware Test Check	Milestone			2019/2/20	1



Spring Project Schedule

Heterogeneous Multi-robot Sampling

Phase 2

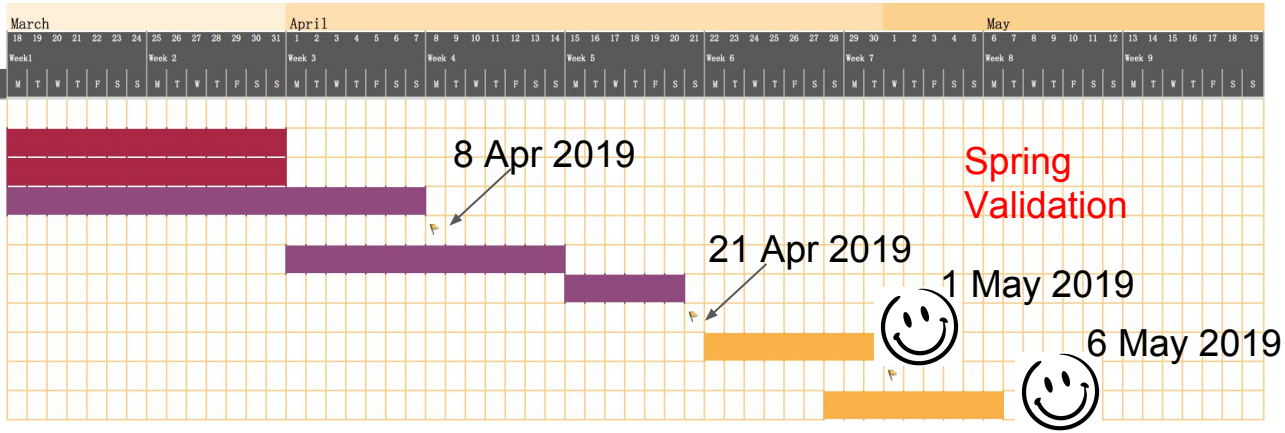
Jianmin, Yunfei, Yang, Ning

Project Start Date: 2019/3/18

Display Week: 1

Legend: On Track | Low Risk | Med Risk | High Risk | Unassigned

Milestone Description	Category	Assigned To	Progress	Start	No. Days
UAV Subsystem					
1.2.1 Implement Motion Controller	High Risk	Jianmin	0%	2019/3/18	14
1.2.2 Develop Localization Algorithm	High Risk	Ning, Yang	0%	2019/3/18	14
1.2.3 Implement Trajectory Planning	Med Risk	Yunfei	0%	2019/3/18	21
Localization Check	Milestone			2019/4/8	1
1.2.4 Implement Obstacle Avoidance	Med Risk	Yang, Yunfei	0%	2019/4/1	14
1.2.5 Test UAV Navigation	Med Risk	Team	0%	2019/4/15	6
UAV Validation	Milestone		0%	2019/4/21	1
Demo Preparing	Low Risk	Team	0%	2019/4/22	9
Spring Validation Experiment	Milestone		0%	2019/5/1	1
Report Writing	Low Risk		0%	2019/4/28	9



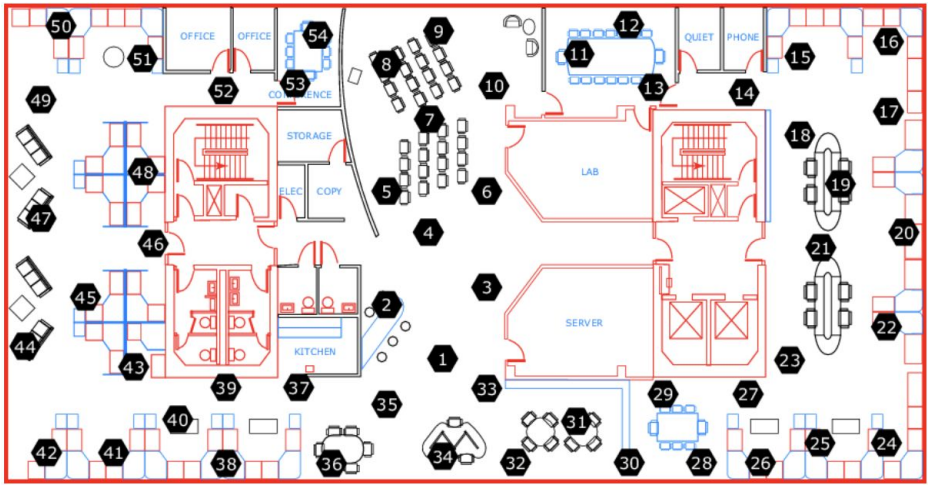
Spring Validation Experiment

Master Computer Validation Experiment

Equipment: Master Computer, Intel Lab Data

1. Master computer updates temperature model.
2. Master computer determines next interest points.
3. Master computer allocates points to UAV/UGV.
4. Return temperature data from dataset.
5. Loop through 1-4 until the model converges.
6. Compute root mean square error between the generated model and ground truth.

Pass Criteria: Error less than 1 °C.



http://db.csail.mit.edu/labdata/labdata.html

Spring Validation Experiment

UGV subsystem Validation Experiment

Location: Outdoor area within the dimension 20m x 20m x 5m

Criteria: Location error: less than 2m; Temperature error: less than 2 °C

Equipment: UGV, Tape measure, Stopwatch, Temperature Sensor

1. Power on UGV agent
2. Assign an interest point to UGV agent (and command it to stop once arrived)
3. After the UGV agent stops, measure the errors between the arrived location and desired location.
4. Export the recorded temperature sample from UGV and measure the error between the measured temperature and ground truth.

Spring Validation Experiment

UAV subsystem Validation Experiment

Location: Outdoor area within the dimension 20m x 20m x 5m

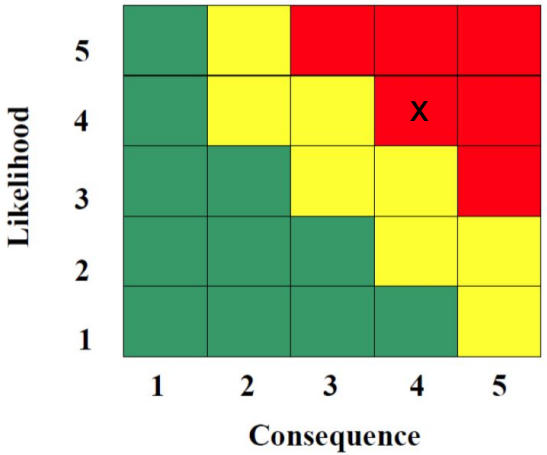
Criteria: Location error: less than 2m; Temperature error: less than 2 °C

Equipment: UAV, Tape measure, Stopwatch, Temperature Sensor

1. Power on UAV agent
2. Assign an interest point to UAV agent (and command it to collect temperature data and land once arrived)
3. After the UAV agent lands, measure the errors between the arrived location and desired location.
4. Export the recorded temperature sample from UAV and measure the error between the measured temperature and ground truth.

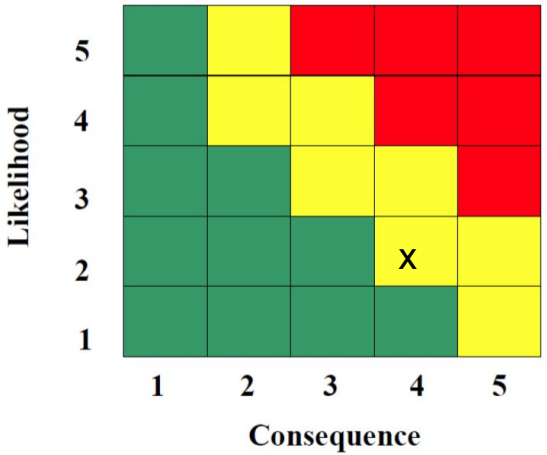
Top 5 risks and a priority mitigation action

Risk Title: Electric System Failure	Risk Owner: Jianmin Zheng
Description of the Risk: The battery and electric system may be damaged due to incorrect operation of the team members.	Risk Type: Technical
Risk Reduction Plan Summary: 1. Optimize the electrical design to protect the electric system. 2. Set up technical documents to regulate the operation of the team members.	



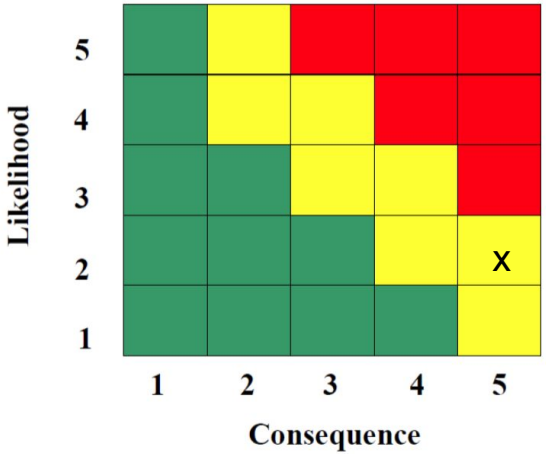
Top 5 risks and a priority mitigation action

Risk Title: Too small Temperature Variance	Risk Owner: Ning Wang
Description of the Risk: Temperature variance may be smaller than sensor noise	Risk Type: Technical
Risk Reduction Plan Summary: 1. Use sensors with higher sensitivities based on previous experiment results 2. Increase local temperature features when demo.	



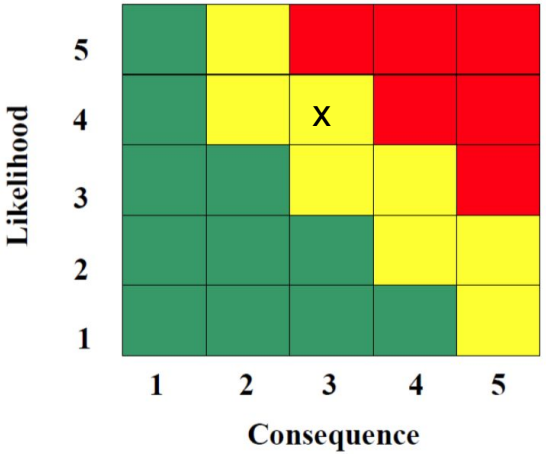
Top 5 risks and a priority mitigation action

Risk Title: Robot Mechanical Damage	Risk Owner: Yang Zhang
Description of the Risk: Robots mechanically break due to crash	Risk Type: Technical
Risk Reduction Plan Summary: 1. Add safety constraints. 2. Develop a safety checklist with teammates to ensure the operation is correctly performed during testing.	



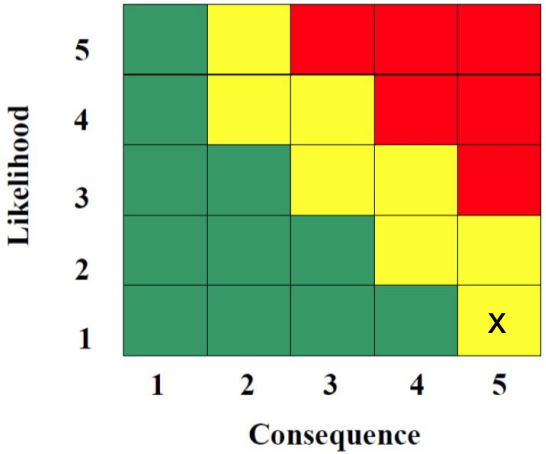
Top 5 risks and a priority mitigation action

Risk Title: Work Delay	Risk Owner: Yunfei Shi
Description of the Risk: Some part of work may be delayed due to personal fair and affect following work packages.	Risk Type: Schedule
Risk Reduction Plan Summary: 1. Append all the work to owners, make every team member be responsible for certain part of works. 2. Optimize the WBS, break down the workload into manageable pieces.	



Top 5 risks and a priority mitigation action

Risk Title: Run out of budget	Risk Owner: Yunfei Shi
Description of the Risk: Run out of funds purchasing parts and repairing robots	Risk Type: Financial
Risk Reduction Plan Summary: 1. Make robot safe using technical risk solutions 2. Make purchasing decision carefully after trade study.	



Q&A