UAV-based 3D-Space Mapping System

via a 3D camera and a mmWave radar

Formal Design Presentation

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10/15/2020

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Access Needs and Problem Statement

- **Access Needs:**
  - Needs access to high-risk areas for explorations or rescues.
  - Needs managements of large-scale facilities.
  - Needs non-intrusive monitoring for public health and safety

- **Problem Statement:**
  - For missions above:
    - unsafe to access an unknown environment
    - needs plenty of resource (time or labor)
    - difficult to non-intrusively monitor large public areas
  - UAV(drones) with cameras and radar sensors can 3D-image and track objects with ease, low cost, high efficiency and flexibility.

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Requirements

1. Capability to outline shapes of objects in a 3D space
2. Accurately estimates positions of objects
3. Portable (small and lightweight)
4. Mounted on a drone (connector)
5. Low-cost
6. Easy to use

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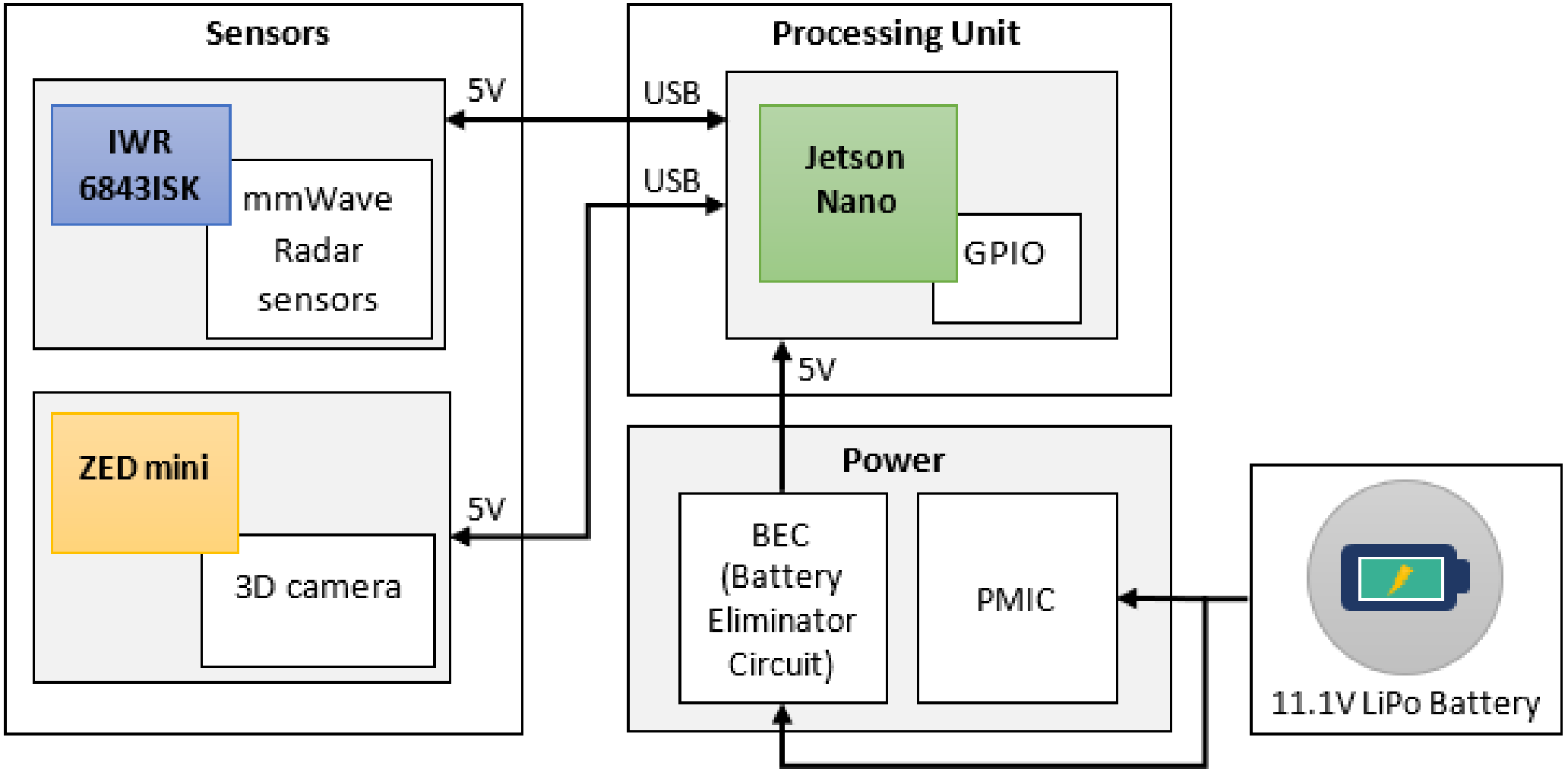
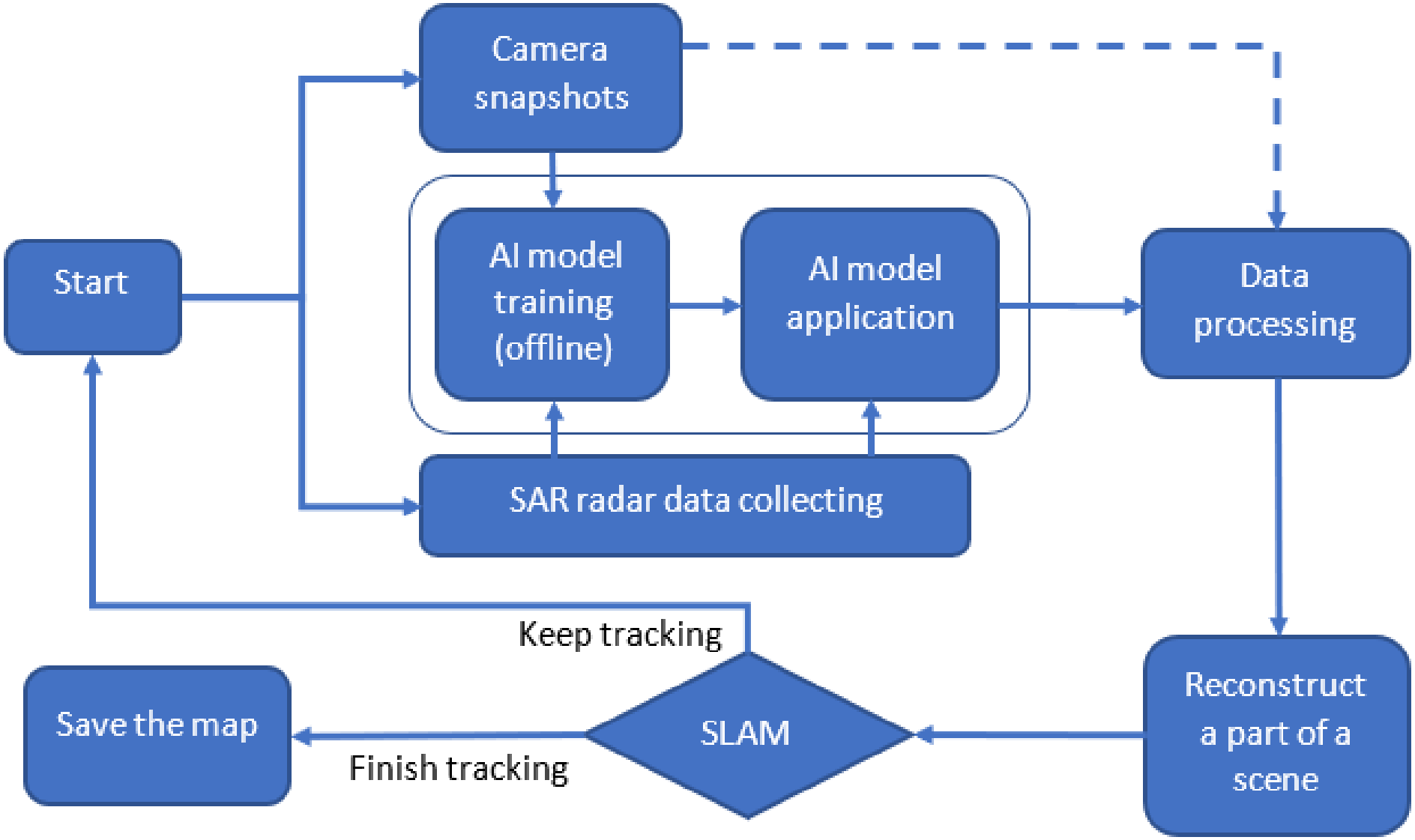
Proposed Solution: Hardware Block Diagram



The computing platform Jetson Nano and the power supply system are not included in our mapping system

Proposed Solution: System Architecture



Subsystem: 3D Camera

- **ZED mini** from StereoLABS
- Depth sensing and motion tracking
- Visual-inertial stereo SLAM
- Size: 124.5 x 30.5 x 26.5 mm (≈100.63cm^3)
- Weight: 62.9g
- Satisfies requirements 1, 3, 5, 6
  - **(3D-Mapping; Portable; Low-cost; Easy-to-use)**

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Subsystem: mmWave Radar Sensor

- **IWR6843ISK** from Texas Instruments
- Long-range antennas, 4RX, 3TX
- Operating frequency 60GHz (5mm wavelength)
- FMCW technology
- Ability to detect movements that are as small as a fraction of a millimeter
- Size: 69 x 55 x 7mm (≈27cm^3)
- Weight: 18g
- Satisfies requirements 2, 3, 5, 6
  - **(Accurate; Portable; Low-cost; Easy-to-use)**

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Subsystem: Device Connector

- 3D-printed
- Simple frame to hold camera and radar sensor
- Extendable to other platforms (e.g. drone, ceiling, wall)
- Satisfies requirements 3, 5, 6
  - **(Portable; Low-cost; Easy-to-use)**
- Helps satisfying requirement 4
  - **(Mount to a drone)**

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Subsystem: Embedded Software

- For Jetson Nano to process sensor data
- Enables different configurations
- Developed from SDKs provided by StereoLABS and TI

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Preliminary Budget

No.	Item	Qty	Unit Price (USD)	Price (USD)	Note
1	ZED mini	1	399	399	3D camera
2	IWR6843ISK	1	135	135	mmWave radar sensor
3	3D-printed connector	1	N/A	10	Holding radar and camera, extend to a drone
	Total			544	

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Design Alternatives - The Kinect

- 3D cameras for depth sensing and motion tracking
- Products by Microsoft
- Kinect V2
  - **249 x 67 x 66 mm (≈1101cm^3)**
  - **1400g**
  - **$289**
- Azure Kinect DK
  - **103 x 39 x 126 mm (≈506cm^3)**
  - **440g**
  - **$399**
- Captured data can be used as ground truth for reference
- Partly satisfy requirements 3 (portable, requires a bigger drone)

- ZED mini: 124.5 x 30.5 x 26.5 mm (≈100.63cm^3), 62.9g

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Design Alternatives - Lidar

- 3D laser scanning for imaging, detection, ranging, mapping
- High resolution and accuracy
- Cannot deal with smoke and fog
- Velodyne Lidar Puck
- VLP-16
  - **103ø x 72mm (≈600cm^3)**
  - **830g**
  - **$8000**
- Partly satisfy requirement 3 (portable, requires a bigger drone)
- Does NOT satisfy requirement 5 (Low-cost)
- Some Lidar products are less expensive

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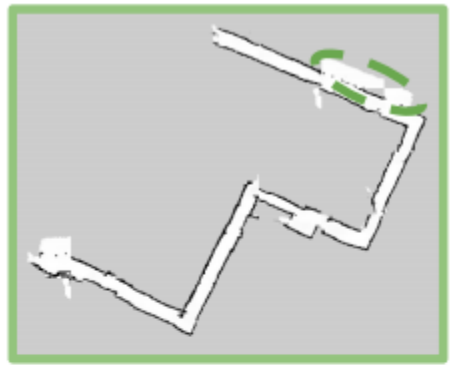
Design Alternatives - The milliMap

- Low-cost indoor 2D-mapping system
- Available on Github
- Uses mmWave inputs
- Accuracy comparable to lidar
- Relies on radar point cloud data
  - **Sparse**
  - **not information-rich**
- Does NOT satisfy requirements 1, 6 (2D-mapping only, needs to be upgraded to 3D)



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Design Alternatives - Slider for SAR

- Uses small, lightweight, precise slider to perform SAR on drone
- Off-the-shelf sliders are large and heavy
  - Needs to be customized
  - Hard to guarantee precision
- Needs redesigning the connector
- Increases size, weight, power consumption
- Limited space for installation

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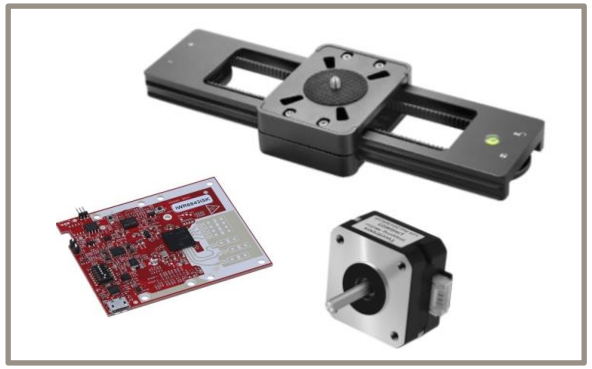

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Metrics for Performance Measurement

Requirement	Measurement
• Capability to outline shapes of objects in a scene	Operate the system with and without the drone and observe that objects in a scene are successfully outlined.
• Accurately estimates positions of objects	Compare our result to ground truth given by Kinect or OptiTrack system
• Portable (small and lightweight)	Measure physical dimension and weight (**≈ 100g**)
• Mounted on a drone (connector)	Confirm that a connector is given, and all hardware components can be secured on a drone through this connector.
• Low-cost	Calculate the overall budget (**≤ $1000)**
• Easy to use	Count the steps for configuration and operation (**≤ 10**)

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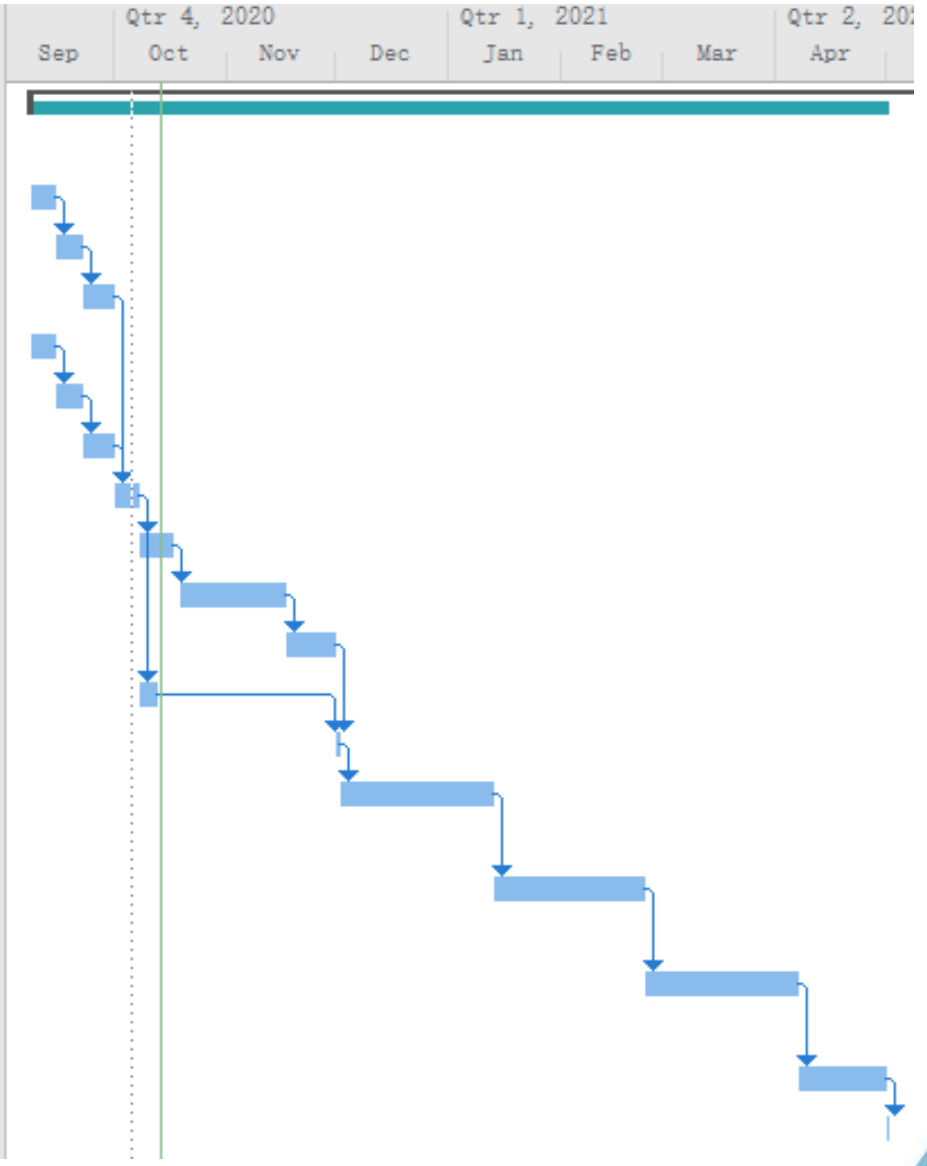
Project Management (GANTT Chart)

	Tas Moc	Task Name	Durati	Start	Finish
1		**Protable 3D Mapping System Design**	**193 days?**	**Tue 9/8/20**	**Mon 5/31/21**
2		Reasech mmWave radars	5 days	Tue 9/8/20	Mon 9/14/20
3		Configure radar	5 days	Tue 9/15/20	Mon 9/21/20
4		Test radar data collecting	7 days	Tue 9/22/20	Wed 9/30/20
5		Reasech 3D camera	5 days	Tue 9/8/20	Mon 9/14/20
6		Configure camera	5 days	Tue 9/15/20	Mon 9/21/20
7		Test camera data collecting	7 days	Tue 9/22/20	Wed 9/30/20
8		SAR experiments	7 days	Thu 10/1/20	Wed 10/7/20
9		Integrate sensor data	7 days	Thu 10/8/20	Fri 10/16/20
10		Analyze and process data	21 days	Mon 10/19/20	Mon 11/16/20
11		Firmware modification	10 days	Tue 11/17/20	Mon 11/30/20
12		3D printing a connector	3 days	Thu 10/8/20	Mon 10/12/20
13		Prototype ready	1 day	Tue 12/1/20	Tue 12/1/20
14		System building on UAV and tests	30 days	Wed 12/2/20	Tue 1/12/21
15		System test & data processing-1	30 days	Wed 1/13/21	Tue 2/23/21
16		System test & data processing-2	30 days	Wed 2/24/21	Tue 4/6/21
17		Optimize the product	18 days	Wed 4/7/21	Fri 4/30/21
18		Final product ready	1 day	Sat 5/1/21	Sat 5/1/21



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Deliverables

- A fully functioning 3D-space mapping system
  - **With ZED mini and TI IWR6843ISK**
  - **Accurate**
  - **Low-cost**
- Modified radar firmware
- Embedded software for Jetson Nano to process sensor data
- A holder for connecting the camera and radar, and mounting the system on the drone

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Anticipated problems/Risk Management

- Safety issue during flight tests
  - **Wear eye protectors, gloves**
  - **Use mats on floor, nets on surrounding for protection**
  - **Make sure everything is alright before the launch**
- Privacy issue and low-visibility conditions (smoke, fog)
  - **Pick another time or place**
  - **Turn off camera and use pre-trained models**
- Access to flight-test room on campus:
  - **Use the public facility with nets covering**
  - 

Members, Activities, and Communication Plan

- CM/TM: Dr. Honggang Zhang
- Basic members
  - **Zhuoming Huang**
    - Major data collecting, processing, validating.
  - **Alinson Sanquintin**
    - Junior observer
    - Assist with minor research, data processing, reviewing.
- External help:
  - **Lucas Lomba and Yue Sun**
    - For SAR data processing and model training issues
- Weekly meetings:
  - **CM/TM/Team meetings: 15:30 – 17:00 Monday**
  - **Zoom**
  - **File sharing on Google Drive**

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Question?