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Autonomous Radiation Mapping Using UGV

Anthony Abrahao

Florida International University

Interregional Workshop on Optimization of Technology Selection
for Decommissioning of Large and Small Nuclear Installations

September, 2019





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Applied Robotics Laboratory

“Helping the efforts to overcome the challenges of an aging workforce actively and aggressively targeting college students across the US to enter DOE’s workforce.”

Principle Investigator:

Leonel Lagos, PhD

Project Manager:

Dwayne McDaniel, PhD, PE

Research Scientist:

Anthony Abrahao, MS
Aparna Aravelli, PhD

Researcher:

Shailendra Chivate

Postdoctoral Assistant:

Sebastian Zanlogo, PhD
Shervin Tashakori, PhD

DOE Fellow:

Christopher Excellent
Daniel Martin
Jason Soto
Jeff Natividad
Michael Thompson
Patrick Uriarte

Work supported by:

DOE-EM, DOE-NETL, DOE-NEUP, DOE-MSIPP and NSF



Research Assistant:

Abdulmueen Alrashide
Daniel Martinez
Joel Adams
Julie Villamil
Mackenson Telusma, MS



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Autonomous Radiation Mapping and Quantification

Using an Unmanned Ground Vehicle

Radiation quantification is crucial in nuclear facility Deactivation and Decommissioning (D&D).

Accurate quantification of the radionuclides and the associated actinide activity ensures the D&D personnel work within the safe exposure limits.

Conventional methods of taking radiation measurements by hand within or around the containment areas, and analyzing the collected data to obtain the result are:

- **ineffective** and
- **puts the scientists to the risk** of radiation exposure.





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Autonomous Radiation Mapping and Quantification

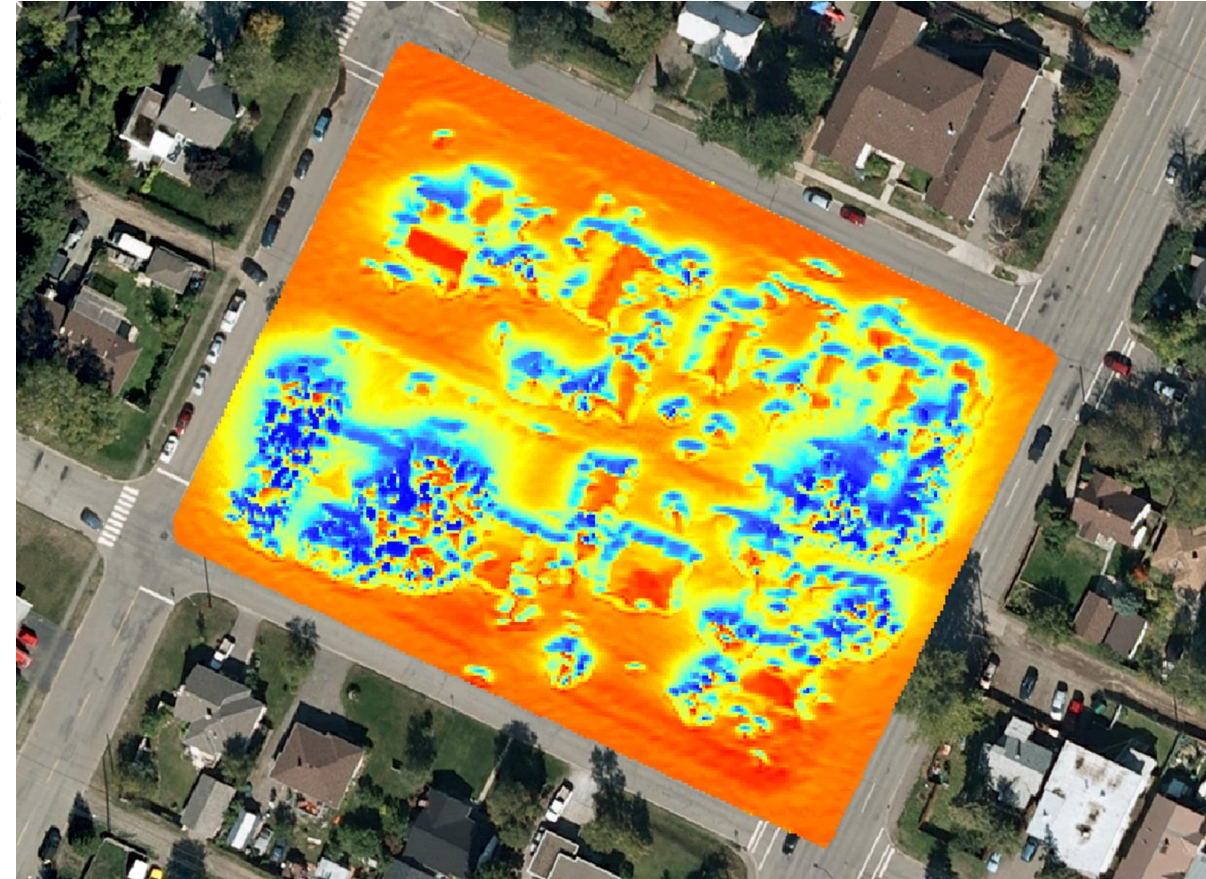
Using an Unmanned Ground Vehicle

This research project goal is to design a mobile robotic system to support Deactivation and Decommissioning (D&D) activities by developing:

- **continuous stochastic models using Gaussian Processes**

to predict the overall radiation field by simultaneously fusing data from:

- **non-destructive gamma measurements,**
- **surrounding images, and**
- **three-dimensional LiDAR mapping.**



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Non-autonomous

SAE level 0 – No automation

Human driver manages all driving tasks

SAE level 1 – Driver assistance

Automated system can assist the human driver during some driving tasks

SAE level 2 – Partial automation

Automated system can conduct some steering and acceleration/deceleration while the human driver monitors the driving environment and handles the rest of the driving task

Autonomous driving

SAE level 3 – Conditional automation

Automated systems can conduct driving tasks and monitor the driving environment, but the human driver must be ready to retake control when the automated system requests

SAE level 4 – High automation

Autonomous systems can drive the vehicle and monitor road conditions; the human driver does not need to take control, but the system can only operate in specific conditions and environments

SAE level 5 – Full automation

The fully autonomous vehicle can perform all driving and road-monitoring tasks in all driving conditions



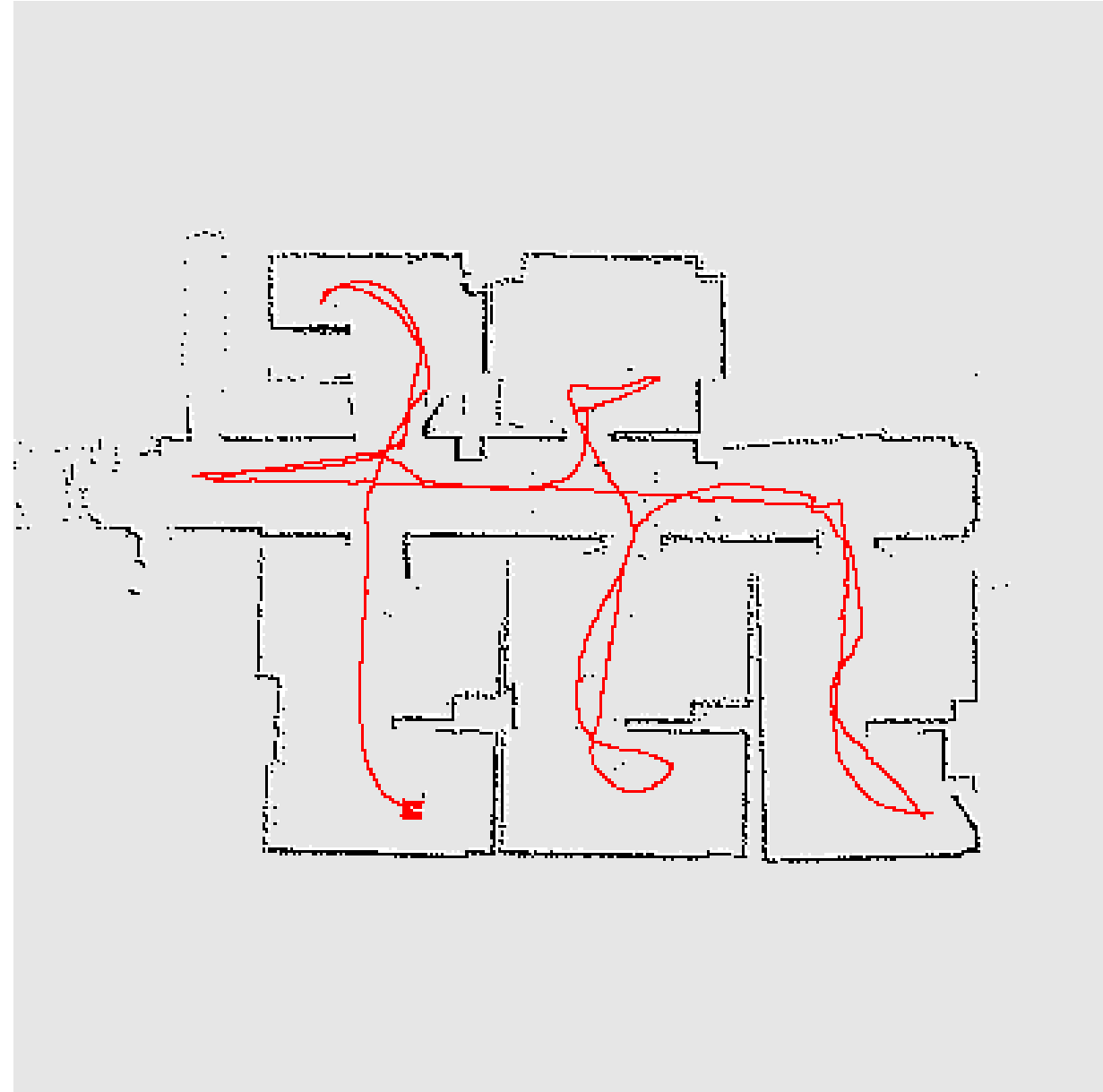
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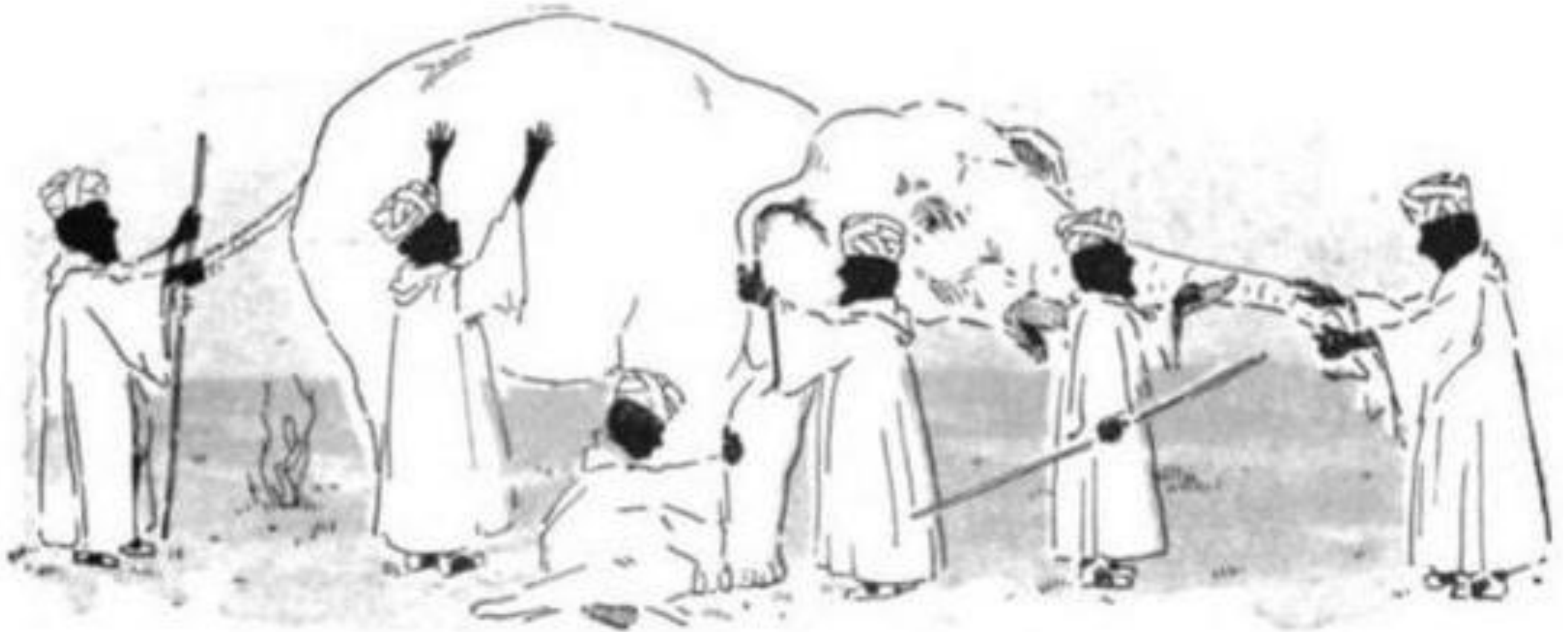


Autonomous Systems Design

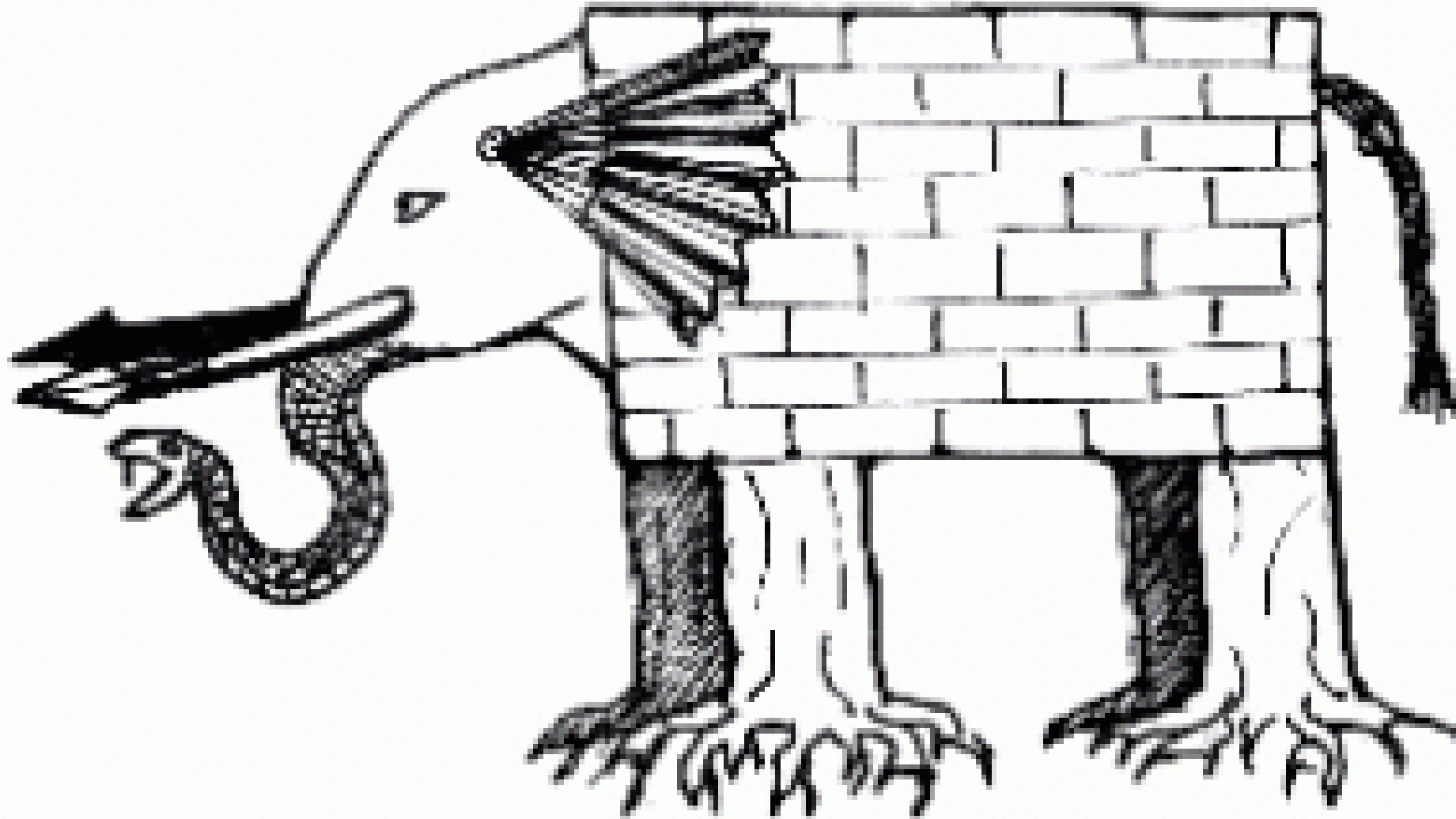
Mission Planning

- ~~Teleoperated~~
- Reactive driving
- Semi-autonomous planned mission
- **Adaptive informative sampling** ←





The Blind men and the elephant!



Sensor Fusion & Uncertainty Reduction!



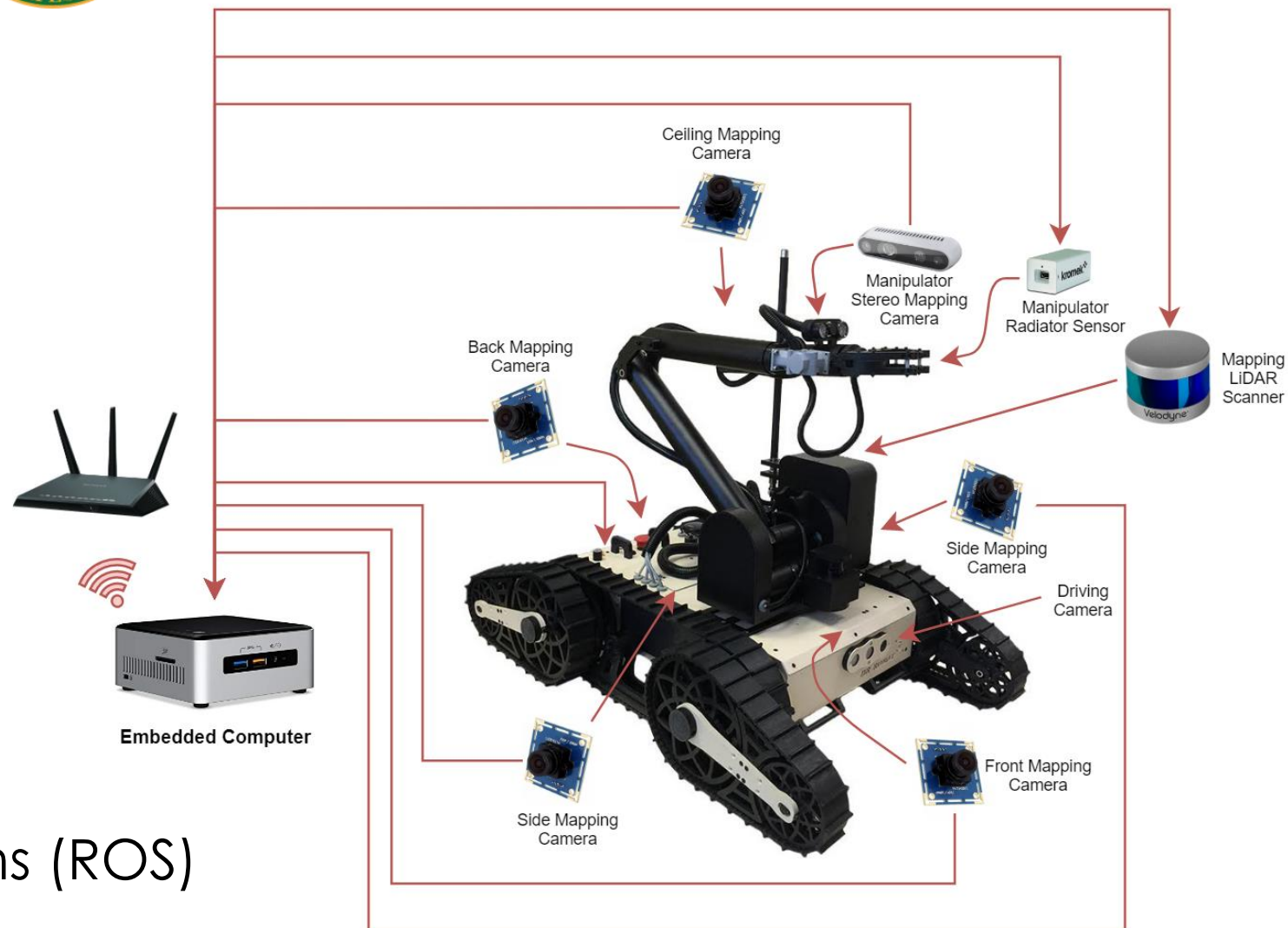
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Autonomous Radiation Mapping and Quantification

Using an Unmanned Ground Vehicle

- Unmanned Ground Vehicle
- Radiation Sensor
- Several Surrounding Cameras
- Multi-channel LiDAR
- The Robotic Operating Systems (ROS)

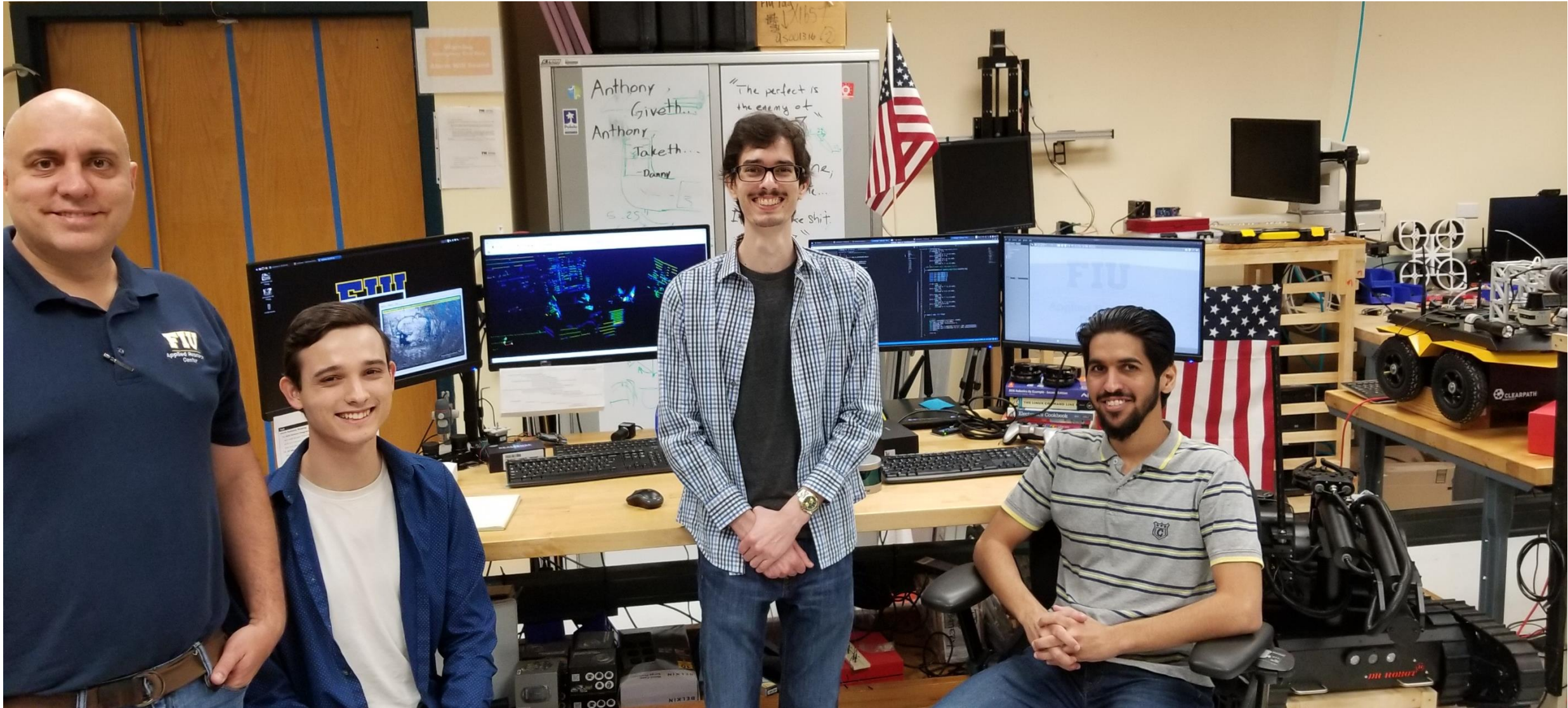




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The Team



Anthony Abrahao, M.S.
Principal Investigator
Research Scientist

Joel Adams
Undergraduate Research Assistant
Mechanical Engineering

Sebastian Zanlongo, Ph.D.
Postdoctoral Associate
Computer Science

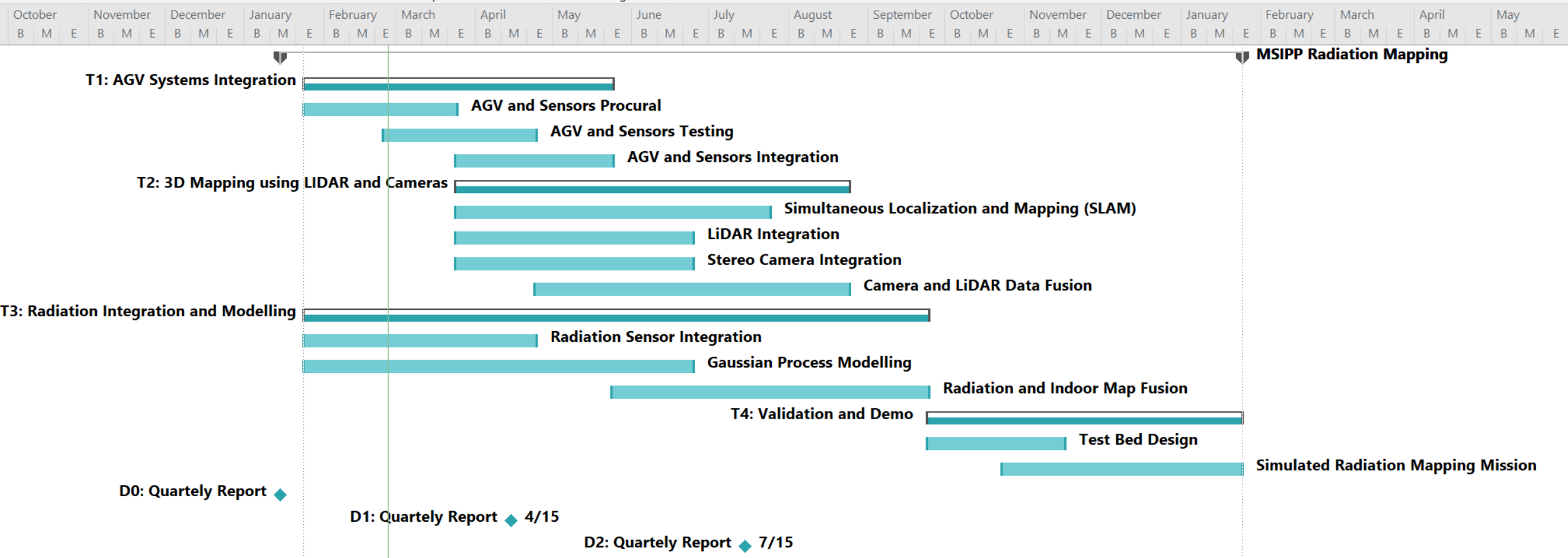
Abdulmueen Alrashide
Graduate Research Assistant
Electrical Engineering

Jaguar V6
Unmanned Ground Vehicle



Autonomous Radiation Mapping and Quantification

Using an Unmanned Ground Vehicle

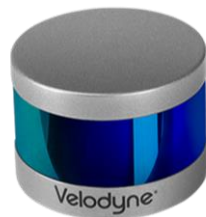


Team	PI	Start
Anthony Abrahao	Task 1 & 2	1/24/2019
Abdulmueen Alrashide	Task 1	2/1/2019
Joel Adams	Task 2	2/24/2019
Sebastian Zanlongo	Task 3	2/1/2019



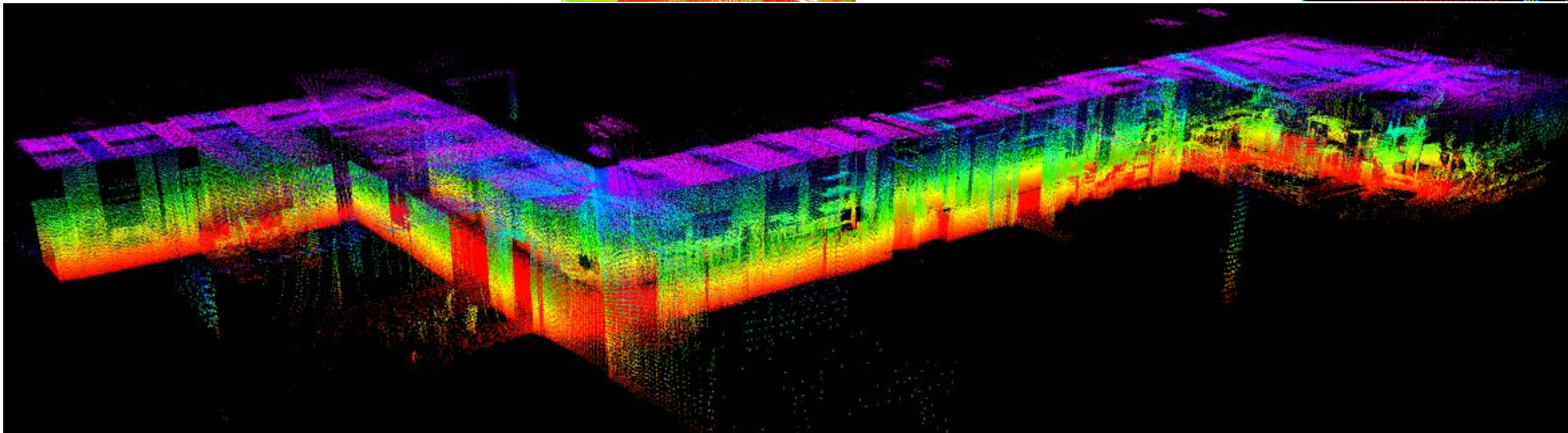
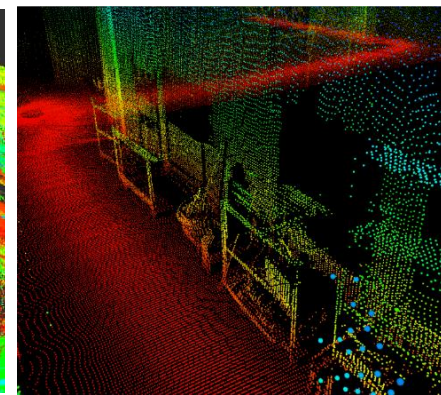
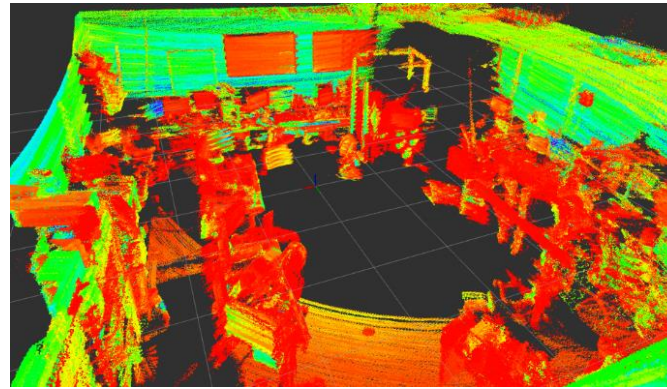
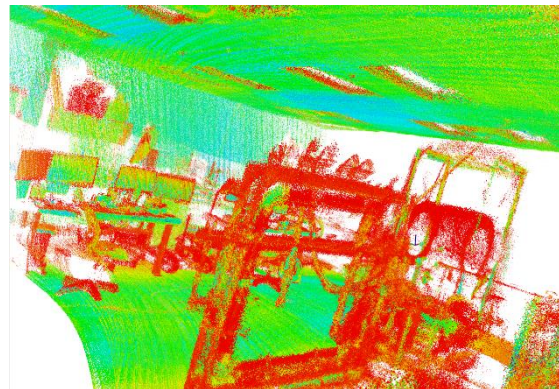


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Environment Mapping

LiDAR Data



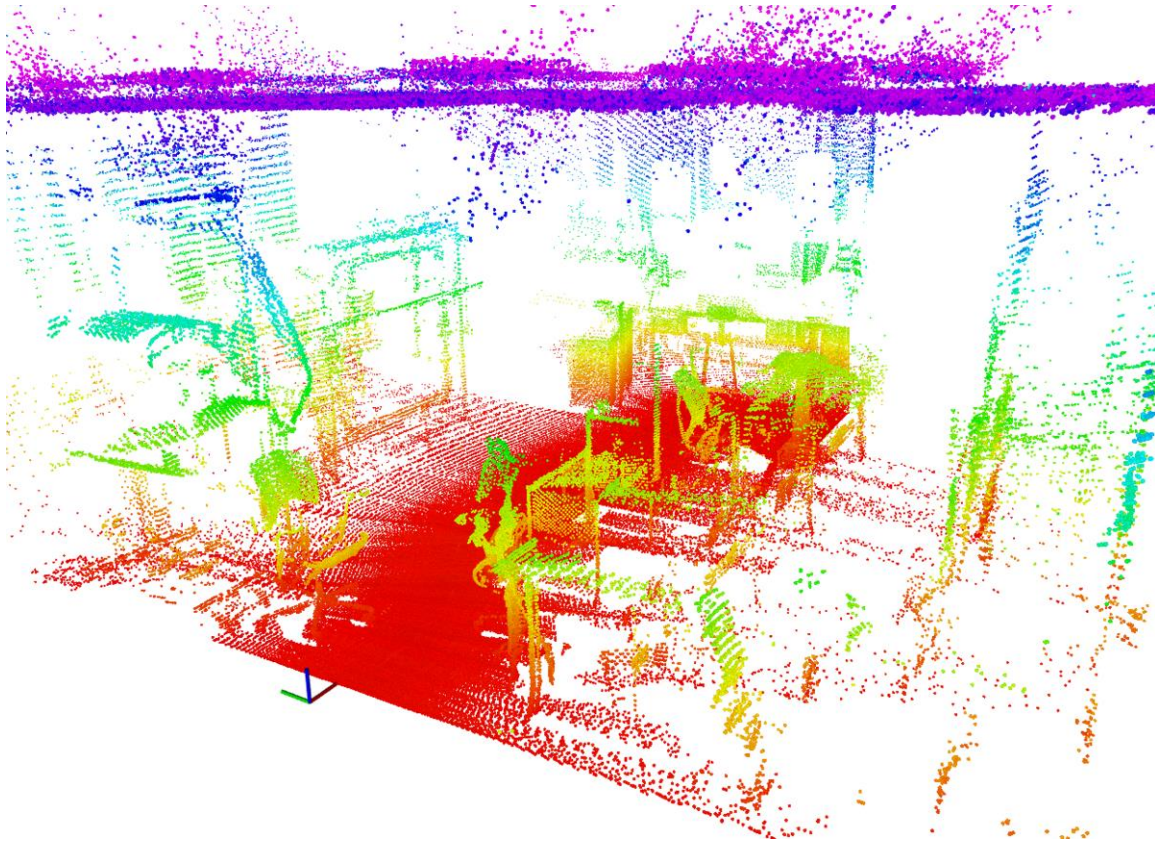


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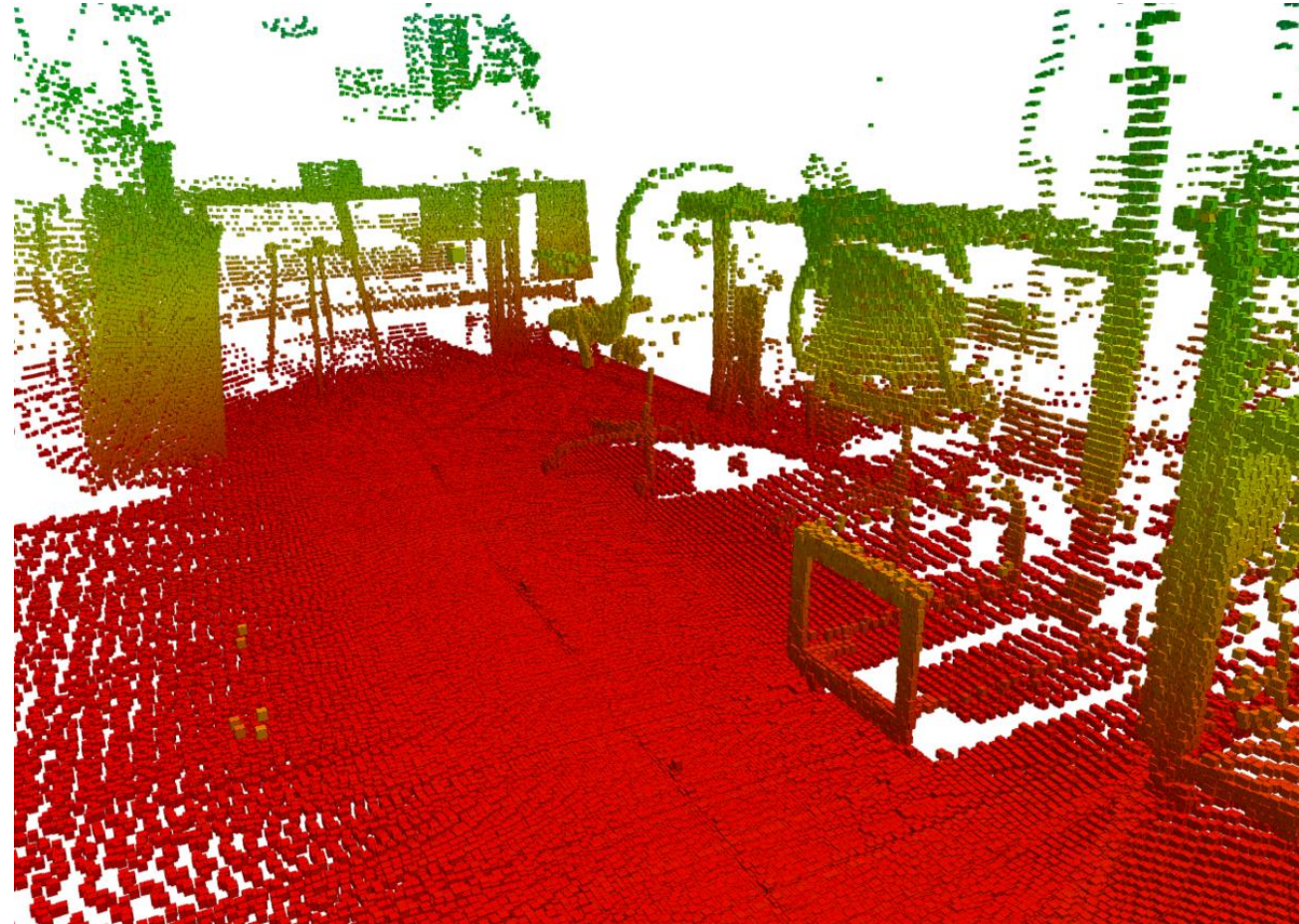


Environment Mapping

3D Mapping Framework



Unstructured point cloud



Structured occupancy grid mapping

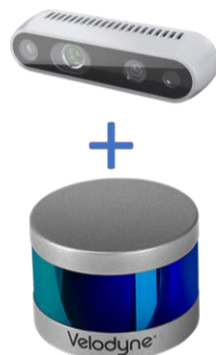
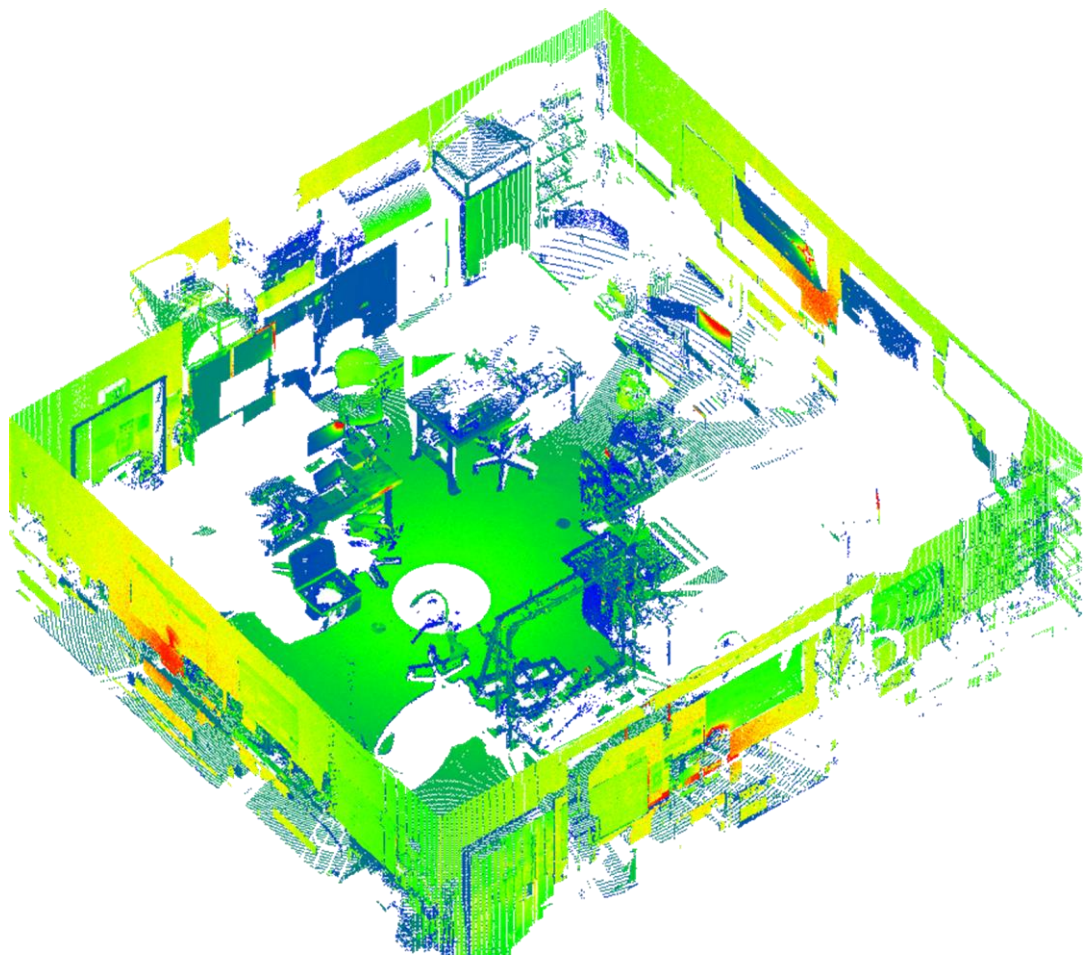


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Environment Mapping

Point cloud and Video Image Fusion



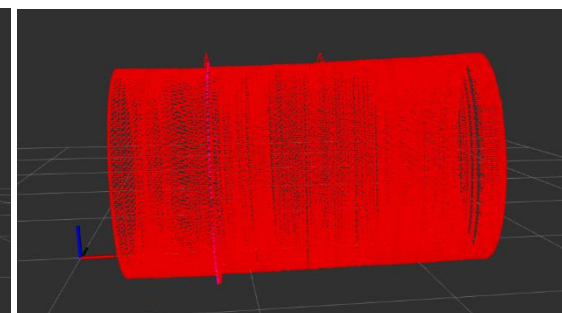
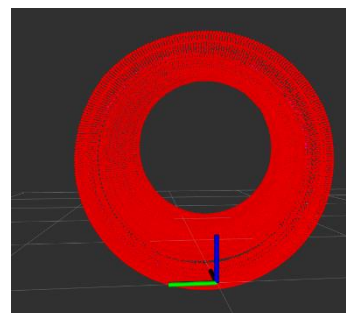
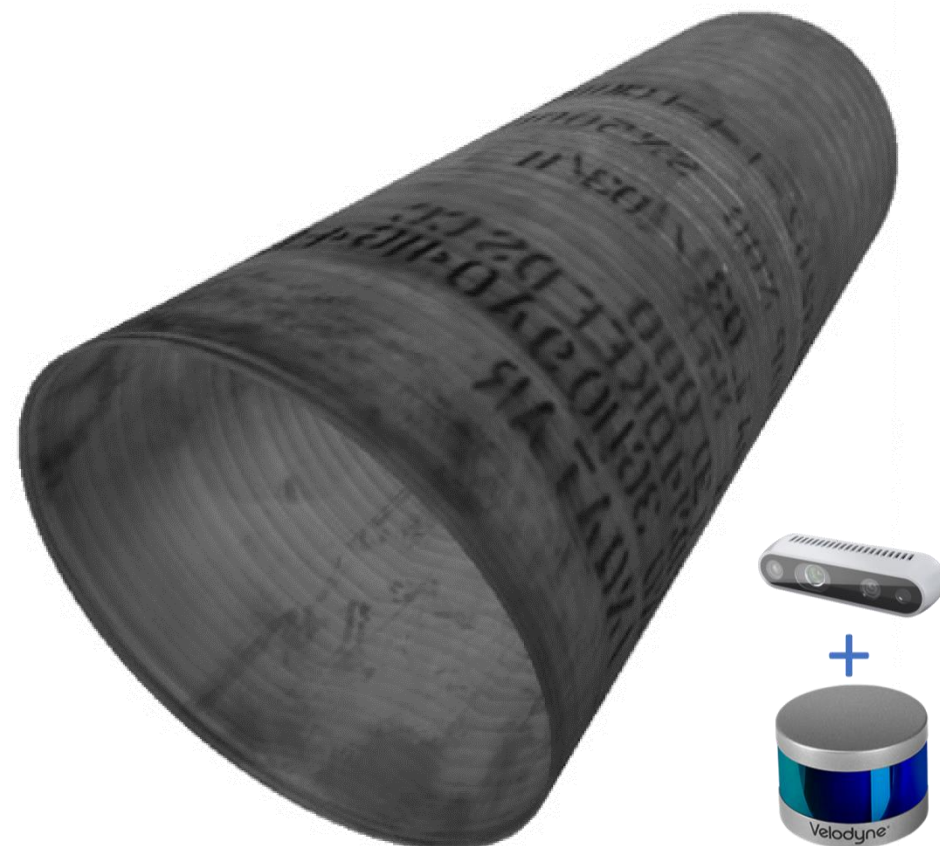


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Environment Mapping

Feature Extraction





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Environment Characterization

Hyperspectral Imaging Camera



+



+



Human eye



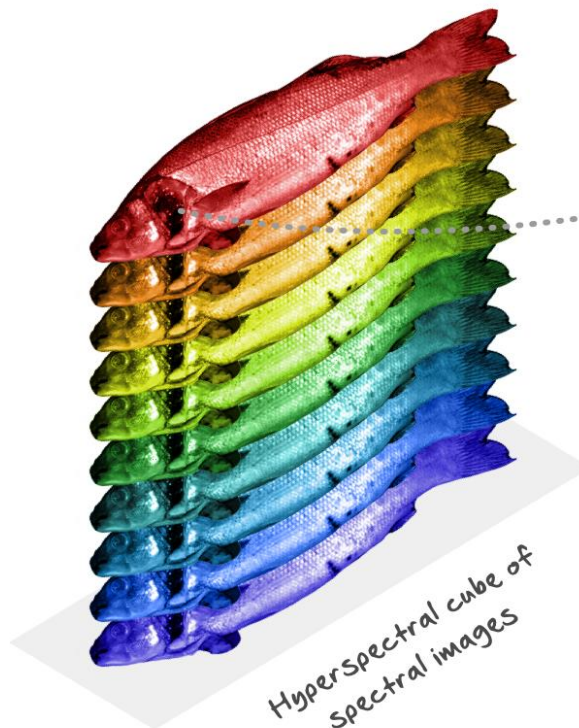
Hyperspectral camera



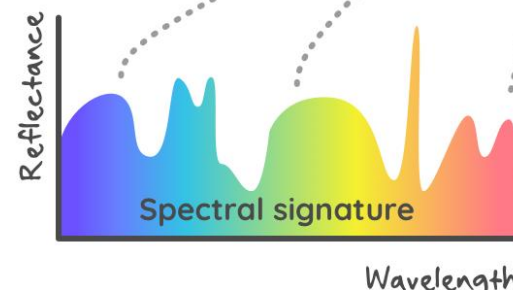
Hyperspectral image



Natural color image



Hyperspectral cube of spectral images



Fused with radiation modeling?



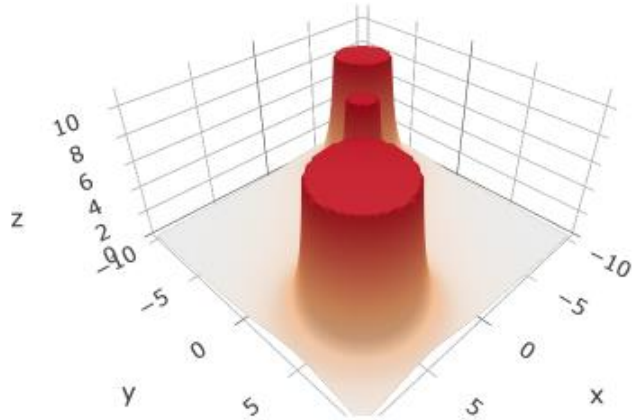
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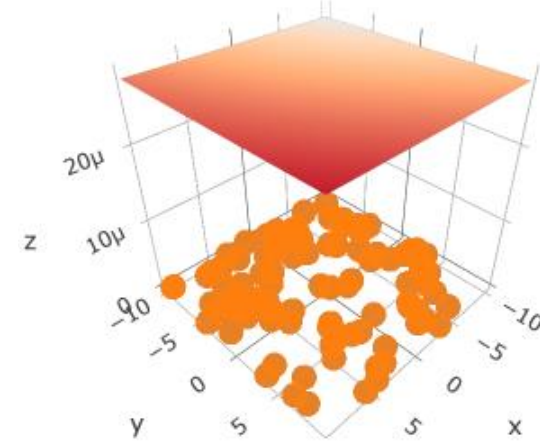
Radiation Modeling

Adaptative Sampling

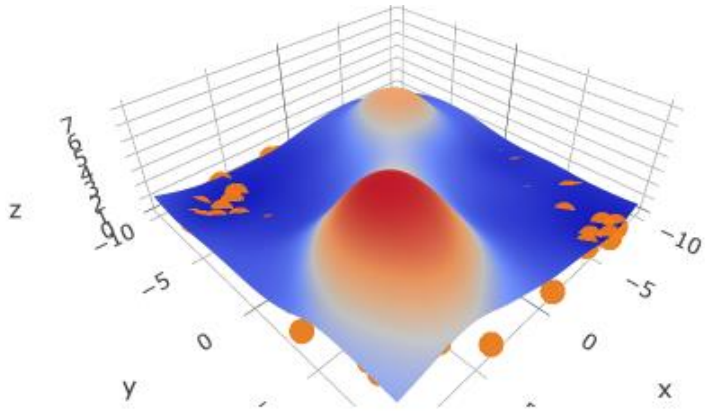
Radiation Sensor Dwell Time



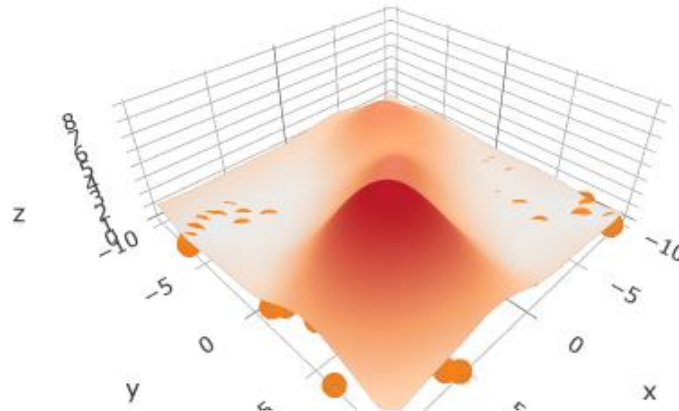
Ground Truth



Regression, Dwell Time 1

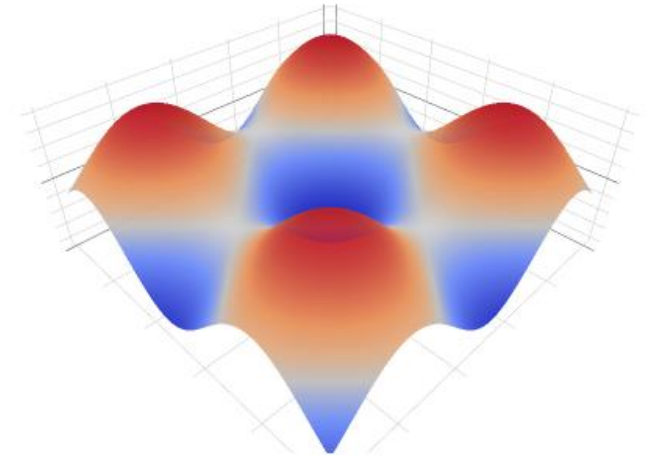


Regression, Dwell Time 10

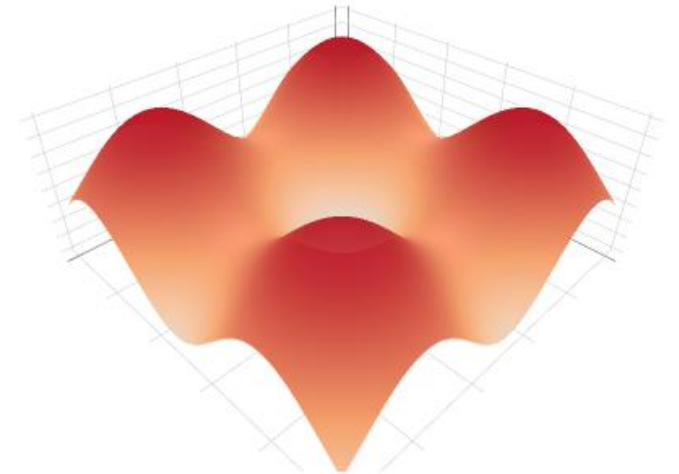


Regression, Dwell Time 100

Interpolation Across Time



Time = 0



Time = 10

Gaussian Process Regression + Bayesian Optimization



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Project
Outcome

Deliver an advanced field deployable characterization system designed to be customized and to autonomously support real-time missions involving

a) radiation mapping, quantification and rapid radiological source localization, and

b) enhanced physical, radiological and possible chemical characterization.

A byproduct of the project will be a robust, upgradable, tested, open-source software framework for perception, localization, mapping, data fusion, gamma-image reconstruction, adaptative sampling, and autonomous driving.

Another byproduct is to **produce future roboticists** engaged in D&D applications



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Project
Path Forward

❖ Robust autonomy driving

- Exploring and mapping of unknown environments consistently
- Obstacle avoidance
- Safety assistance

❖ Object identification

- AI and Tensor Flow
- Computer Vision and OpenCV

❖ Autonomous Surveillance

- Continuous monitoring of infrastructure and D&D facilities
- Inventory tracking





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Laboratory Future?

- i. Deployment oriented design
- ii. Develop advanced autonomous tools
- iii. Target challenging D&D applications
- iv. Train future roboticists
- v. Enhance collaboration
- vi. Provide disposable Robots

