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Autonomous Robotic Microgrids

Microgrids for Resilience

Ft Collins Microgrid Symposium

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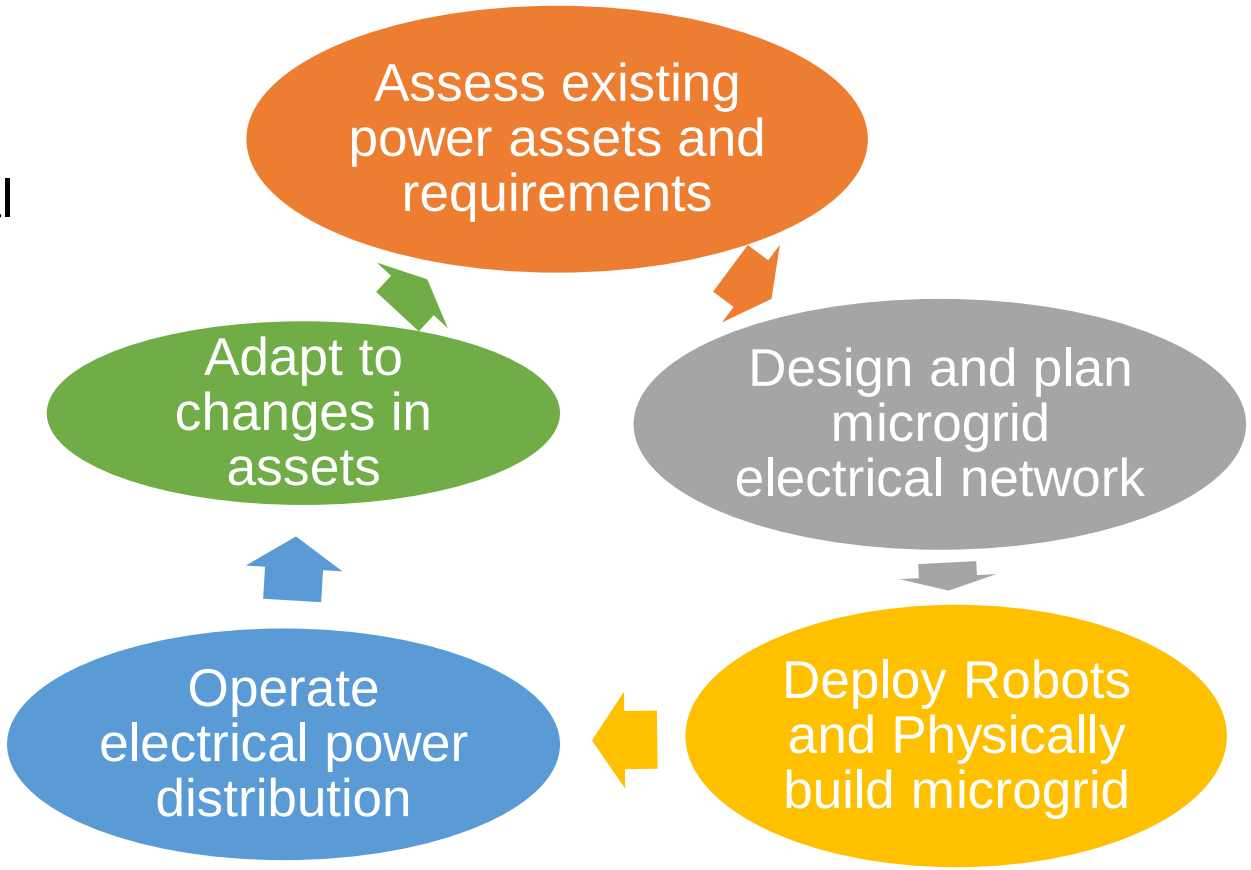
AIM

Short Term Needs/Solutions

- Most immediate need during/after natural or man-made disasters:
  - *Human life*
  - Communication/power network for first responders
- Maximize life saving manpower
- Short Term Micro(Nano?)grids offer efficient reliable temporary power for recovery efforts
- Use technology and automation to establish temporary disaster recovery power.
- Remove burden on setting up temporary networks = more hands for search/rescue.

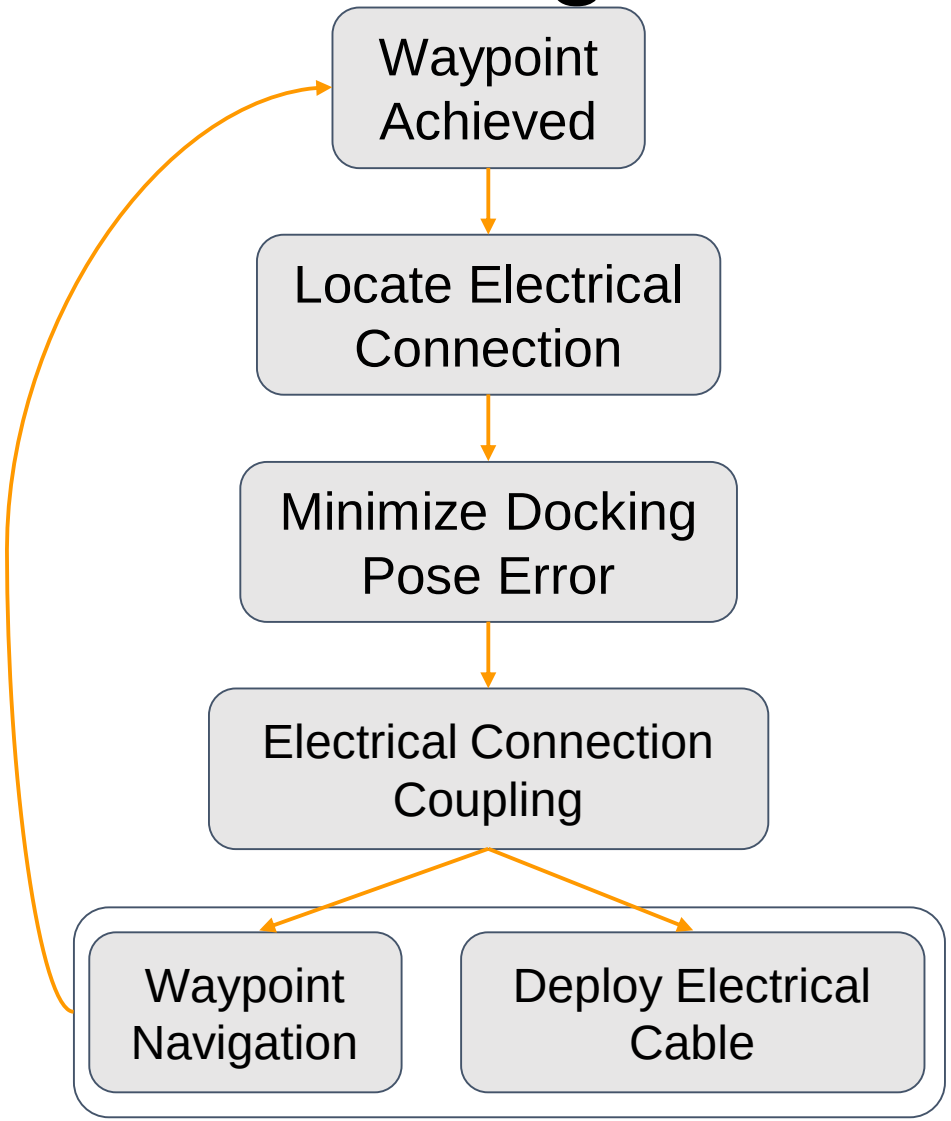
Autonomous Microgrid Deployment & Operation

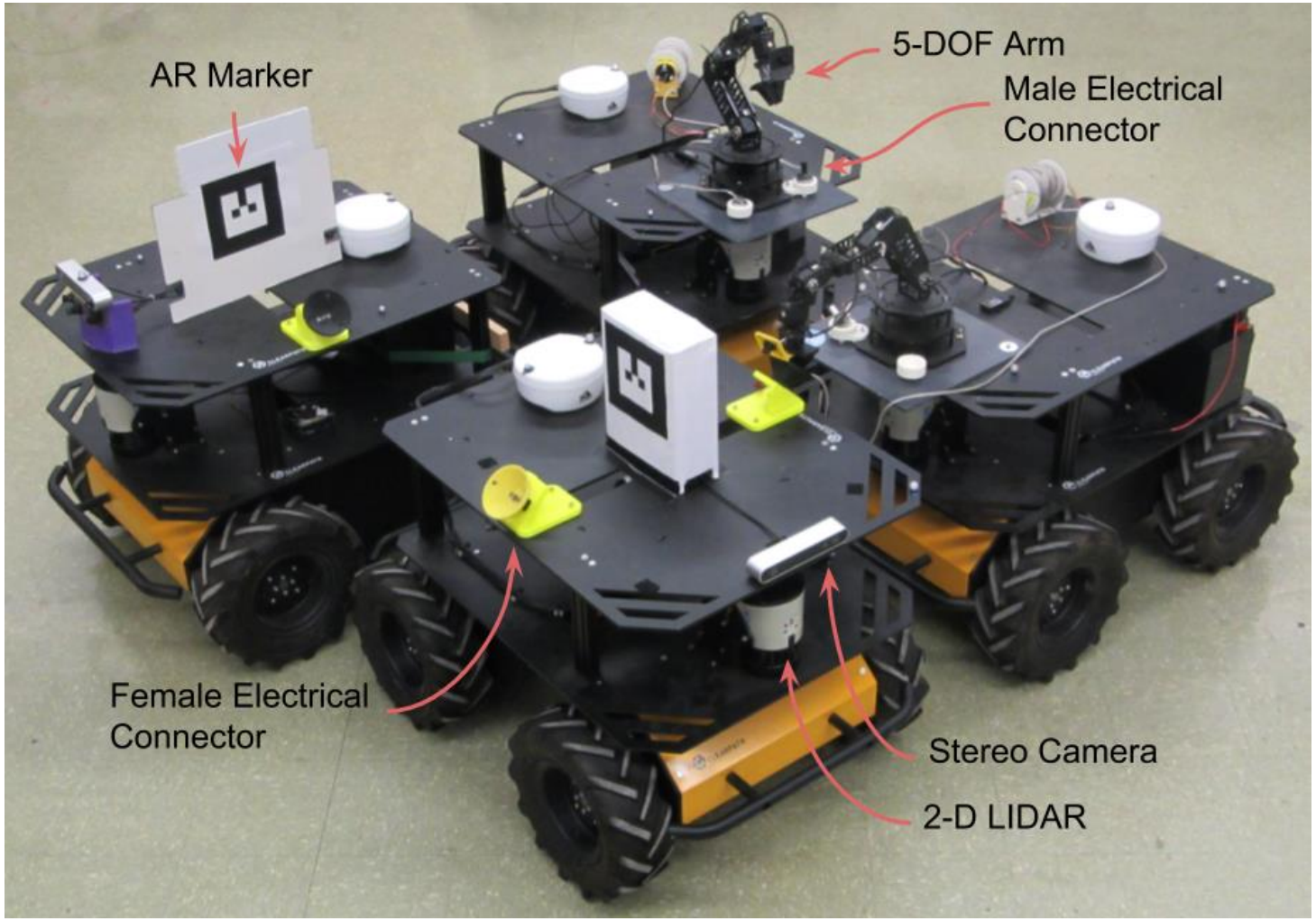
- Situations exist that require the ability to preposition a basic level of energy infrastructure.
  - Deploying forward operating bases
  - Providing power to areas damaged by natural or man-made disasters
  - Exploring and developing the arctic's oil potential
  - Manned and Unmanned space missions.
- Electric power prepositioning system using small autonomous swarm robots
- Each robot can contain
  - A power electronic conversion
  - Cabling
  - Energy generation/storage



- Moridian B., Mahmoudian N., Weaver W., and Robinett R., "Post-Disaster Electric Power Recovery Using Autonomous Vehicles", *IEEE Transactions on Automation Science and Engineering,* vol. 14, no. 1, pp. 62-72, 2017
- S. DaraniR, R Robinett, WW Weaver, O. Oabdelk, C. Majhor, "Optimal Positioning of Energy Assets in Autonomous Robotic Microgrids for Power Restoration". *IEEE Transactions on Industrial Informatics*, vol 15 , no 7, pp 4370-4380, 2019

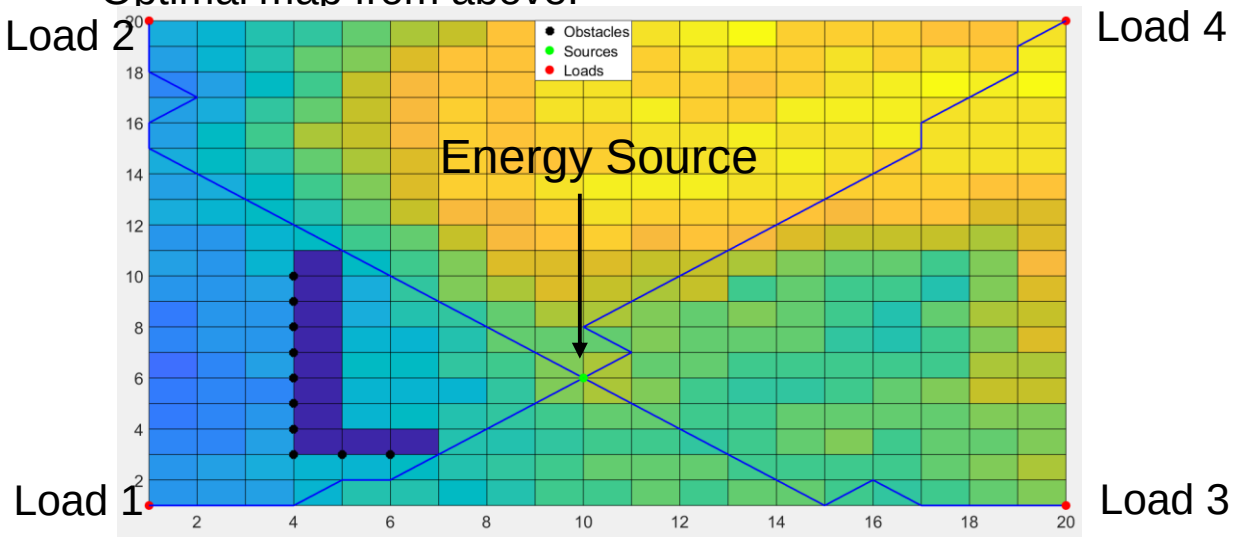
Robotic Algorithm Requirements



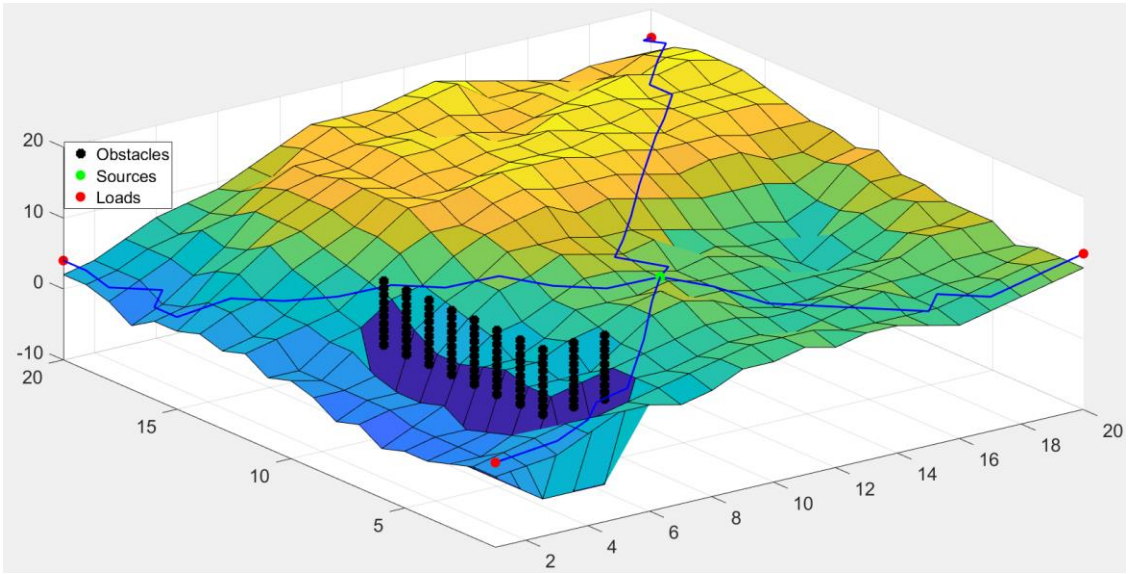


Microgrid Network Deployment Planning

Optimal map from above:



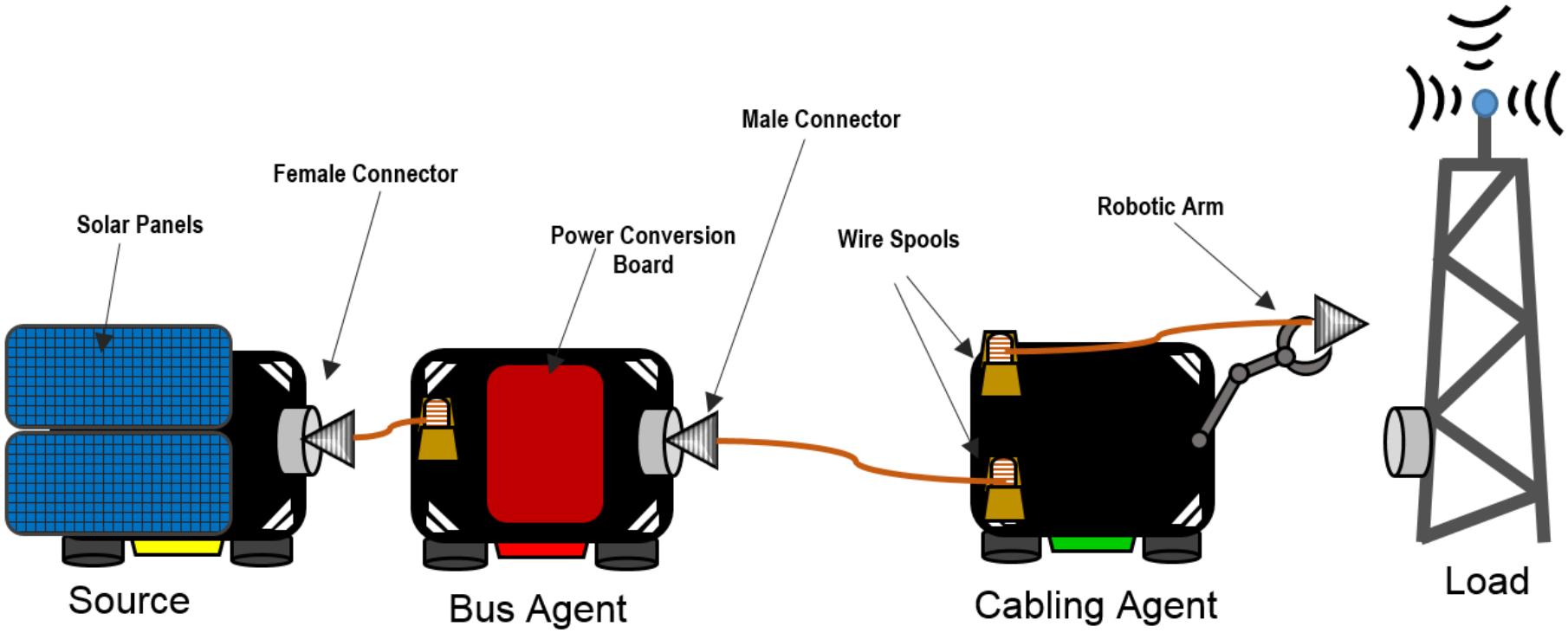
Optimal map with 3D perspective:



- Optimized source location
- Ensure all prioritized loads are serviced
- Minimize cable lengths
- Minimizing traversing path cost over the terrain and avoiding obstacles
- Maximize runtime given fuel, battery and renewable resources.
- Pre-Plan for resource redistribution when assets are depleted.

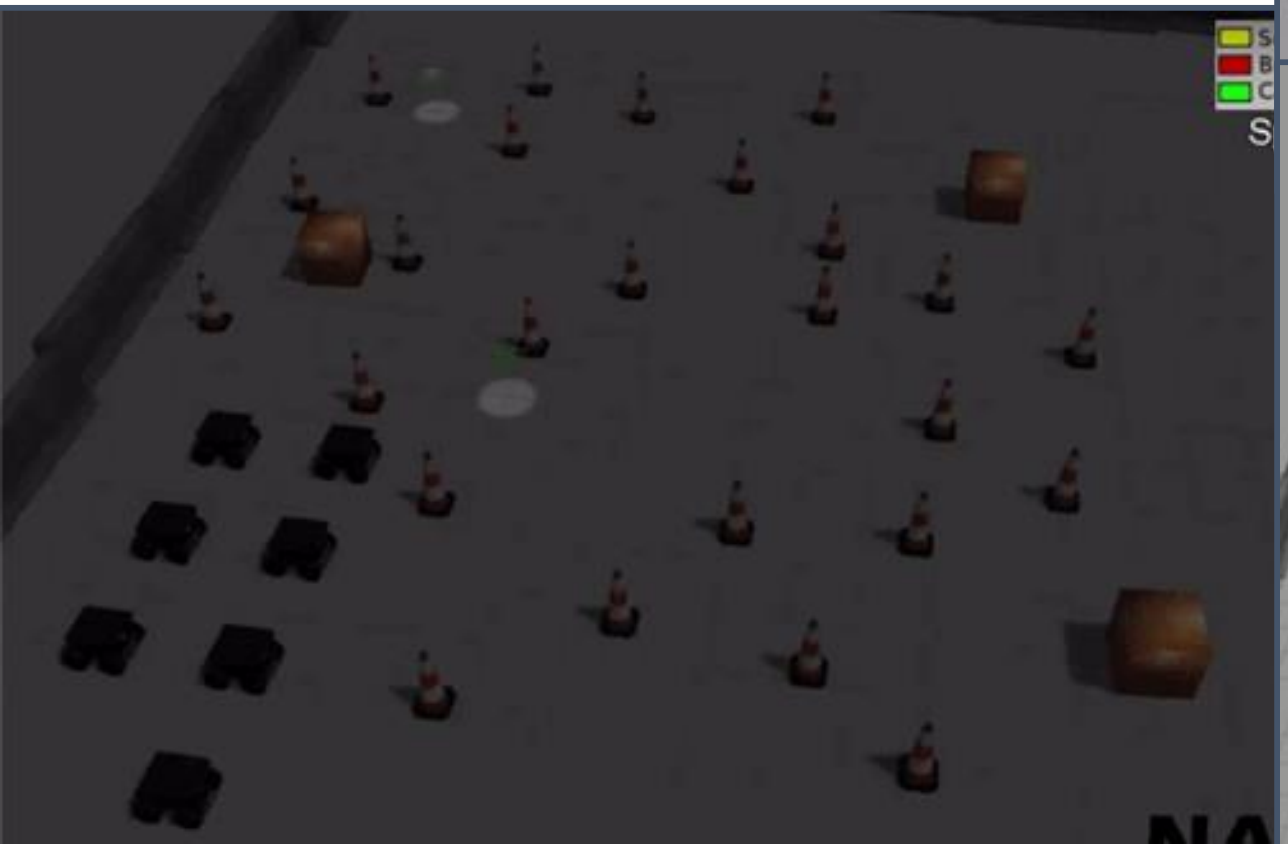
Robotic Agents in the Microgrid

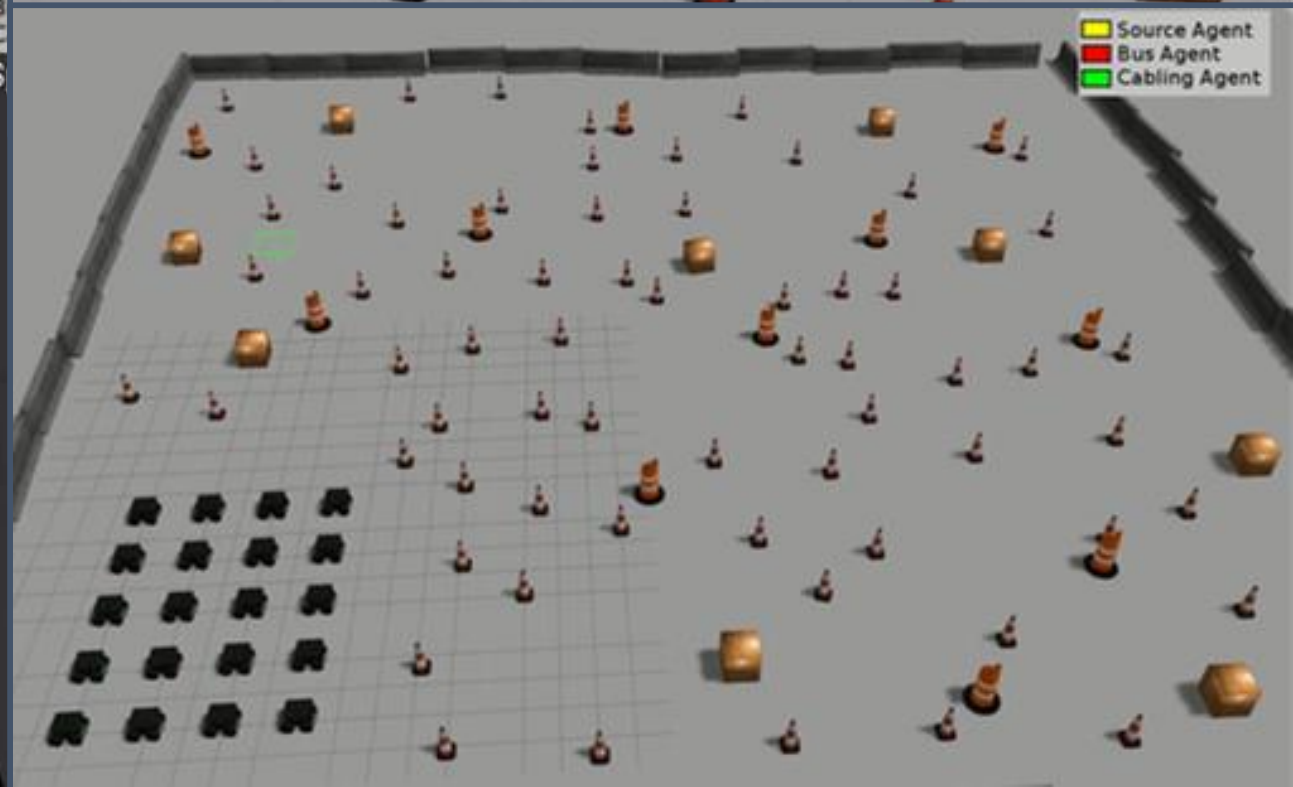
- Each robot is responsible for a



Microgrid Simulation

Validate scalability of microgrid navigation.





Outdoor Microgrid Test in Winter

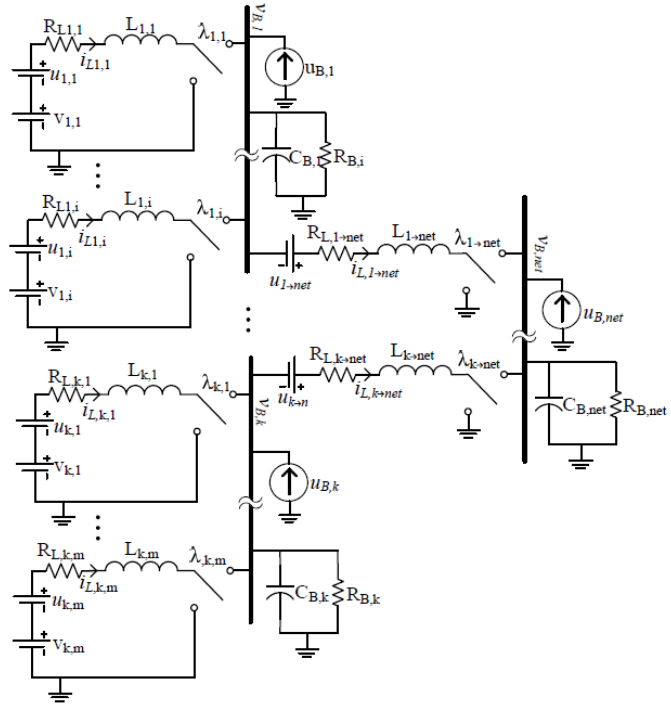
Microgrid navigation in more challenging environments.

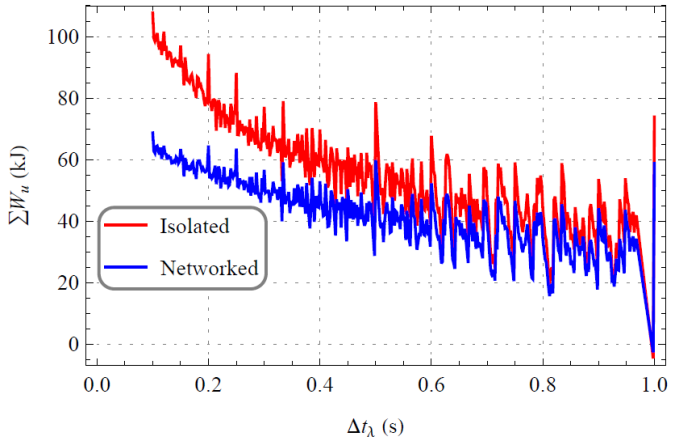
Micorgrid Electrical Operation

- Once physical connections are made, electrical control actuates system.
- Hamiltonian surface shaping methods optimize power and energy flows while ensuring stability and robustness.

$$\mathbf{M}\dot{\mathbf{x}} = \mathbf{R}\mathbf{x} + \mathbf{u} + \mathbf{v} = \left[\overline{\mathbf{R}} + \tilde{\mathbf{R}}\right]\mathbf{x} + \mathbf{u} + \mathbf{v}$$

$$\mathbf{H} = \frac{1}{2}\tilde{\mathbf{x}}^T\mathbf{M}\tilde{\mathbf{x}} + \frac{1}{2}\left(\int_0^t \tilde{\mathbf{x}}^T d\tau\right)\mathbf{K_I}\left(\int_0^t \tilde{\mathbf{x}} d\tau\right)$$





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Autonomous Microgrids

- This work aims to establish the theoretical foundations of a flexible, stable and efficient ad-hoc microgrids assembled and controlled autonomously.
- Potential for rapid deployment of emergency resources autonomously.
- Establish electrical power autonomously in event of a disaster, freeing up human resources for life saving operations.
- Also applicable to
  - Deploying forward operating bases
  - Exploring and developing the arctic's oil potential
  - Manned and Unmanned space missions.