# UCF Senior Design 1

*Robotic Solar Farm Grass Cutting System Design Challenge*
*Sponsored by: Duke Energy and Orlando Utility Commision*

*Department of Electrical Engineering and Computer Science*
*University of Central Florida*
*Dr. Samuel Richie*

*Initial Project Document and Group Identification*
*Divide and Conquer*

***Group 26***


| | | |
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**PROJECT NARRATIVE**

Solar panels “harvest” energy from the sun using photovoltaic panels by allowing photons, or particles of light, to detach electrons from atoms. This in turn generates a flow of electricity. These solar panels are usually installed and set into an array on a large grassy field in order to produce more energy, avoiding obstruction from large objects such as buildings, trees, etc. in order to have the highest yield of renewable energy. These arrays of solar panels are commonly referred to as a solar panel farm, where private companies, and even today the common house-owner, collect the sunlight to reduce carbon footprint emissions and produce energy through a cleaner, more environmentally friendly way. By converting the free energy of the sun into power, it seems that there is only profit to be gained. After an initial large fee to set up and install these panels, of course.

Although this source of energy becomes a “free” source of energy over time, there are still severely expensive upkeep costs. For example, most of these farms are built over grass, as the grass neither absorbs nor reflects heat as severely as a flat concrete pad. However, as all grass does in the world, it grows every day. The maintenance on such fields can be a major expense to the companies supplying the services and impacts the cost of energy users in the end. This requires constant lawn services to be contracted to keep the grass cut and low, in order to prevent any obstruction of view of the sunlight reaching the solar panels. Because of the way solar panels are built, this makes it very difficult for people and mowers to fit under and between the giant support beams and electronics that run these panels. Even worse, as we are all human, the potential for error exists when one is needed to cut near such expensive equipment. Accidents may occur and increase the risk of equipment damage and replacement.

Our solution is the “e-GOAT”: an AI-assisted autonomous solar powered rover-based robot that can cut the grass and reduce the cost of maintenance of the solar farm. The “e-GOAT” robot will be a high-functioning autonomous weed wacker that will move through terrain in order to cut the grass. The “e-GOAT” will be able to autonomously identify areas of grass that need attention, avoid obstacles, and provide motion and navigation to the land mower bot. The low-cost bot will also be friendlier to the environment than traditional lawn service equipment; the bot will be solar powered, like the panels it seeks to protect, which in turn will allow it to reduce the carbon footprint to almost, if not completely, to zero. As an added benefit, it will be able to operate at day or night, alleviating the need for extra lighting around the plant.

The project will be broken down into a series of task checkpoints in order to fully realize this idea come to life. We will be starting off with a research phase, where we will be looking more in depth into the types of terrain that the solar farms are built on. We will then begin research into the hardware that can aid in a potential success for this project design. This step will require more research and experimentation to see what does and what does not work. Finally, we will be in the construction phase, where a prototype will be designed through trial and error processes based off of the parts that we decide have made it to the final round.

**Customer Specifications**

Given the project specifications of our customer Duke Energy and Orlando Utility Commision (OUC), this is the product specifications they require:

1. Robotic rovers must use an off-the-shelf battery powered trimmer (no metal blade must be string-based) to cut grass.
2. The rover may consist of an off-the-shelf remote controlled system that is modified for the application but should still have an autonomous mode or capability.
3. The robotic grass cutting rovers must be equipped with a remote kill switch that can turn off the cutting system and locomotion at a distance of approximately 50 feet.
4. An off-the-shelf battery and charger must be utilized.
5. The rover must be capable of safely navigating in uneven terrain (~ 3 inch terrain differential over ~ 2 foot span in any direction) without capsizing while avoiding a series of obstacles.
6. No part of the system must be of a height no taller than 20 inches from the ground
7. The system must operate independently and have no attachments to existing solar farm array structures.
8. Total system materials and assembly cost target: $1500.
9. The ability to cut grass at an acceptable height (3 to 6 inches) is considered a plus. It is expected that teams will adapt and mount a commercially available string trimmer head to their devices.
10. The system must traverse the large areas and maneuver around PV support structures.
11. Avoid any damage to surrounding infrastructure, the environment and humans.
12. Provide a math model to estimate how much grass area the robot can cut per hour. Teams will be provided total size of a typical solar farm. Assume grass cutting of entire site on a monthly basis and provide analysis based on season/weather/location for purposes of this evaluation.
13. System to provide a secondary safety protocol to deal with rogue objects, in addition to the remote kill switch. Potential concepts might include; GPS with boundary kill and/or installed invisible fence with secondary kill protocol when crossed. System also to

include location beacon with independent power supply (the beacon should be able to operate for a defined period of time after the main battery is completely drained).

**Requirement Specifications**

Taking the customer specification stated above, this is what we will deliver:

| RS-ID | Description |
|---|---|
| RS-01 | The rover will be capable of navigating uneven terrain at an incline differential of 20° |
| RS-02 | The rover will consist of a remote kill switch that can be activated from 50ft |
| RS-03 | The rover will consist of an off the shelf battery and charger |
| RS-04 | The rover will use an off-the-shelf battery powered trimmer |
| RS-05 | The rover will travel at a speed of 2.5 mph. |
| RS-06 | The rover will not exceed a height of 20” from the ground. |
| RS-07 | The rover dimensions will be 2’ x 2’ x 1.5’ |
| RS-08 | The rover will weigh 20lbs |
| RS-09 | The rover will run at a safe temperature of 98° |
| RS-10 | The rover will run for 1 hour until the power is consumed. |
| RS-11 | The rover will stop one foot away from the solar poles |
| RS-12 | The rover will stop 0 feet away from the boundary |
| RS-13 | The rover will be able to navigate in a 50’ x 10’ field |
| RS-14 | The rover will contain a two layer printed circuit board with a footprint of 7”x9” |
| RS-15 | The rover will cut the grass to a maximum of 3” |
| RS-16 | The rover electric components will be shielded by a plastic casing |
| RS-17 | The rover will have a maximum voltage consumption of 12v |
| RS-18 | The rover will be able to detect foreign objects from 3’ |

Table 1- Requirement Specification Table

**Team and Product Constraints:**

1. Terrain - there are several ways to structure a Solar plant farm dependant upon the terrain given in the area. We are lucky that Florida is a predominantly flat state, however, other states, and countries, have a much more treacherous terrain to navigate. For the constraint of this project, we will be navigating a majorly flat surface area. We are able to design and plan around a more mountainous terrain, but this would most likely require a different design of wheels than the schematics for the wheels we have in mind.
2. Time - as with any project, there is a deadline for when everything must be fully built and fully operational. Although we are quite an organized group and very efficient in completing all the tasks set before us, not all problems have easy solutions. Dependent on the difficulty of the task set before us, it could potentially hinder the precious time we have to work on realizing this robotic lawn mower.
3. As with the build of any robotic, there is always the chance for an electrical or mechanical part to fail, whether it be on arrival from the manufacturer, or from user error from a bad connection etc. The risk is always prevalent for hardware to malfunction.
4. Money - Although this project is sponsored, the majority, if not all, of our costs should be covered while researching and constructing this project. However, if for whatever reason we reach the maximum amount allotted to Group 26, and extra parts become astronomically expensive, problems could arise for our group if a solution is not made.

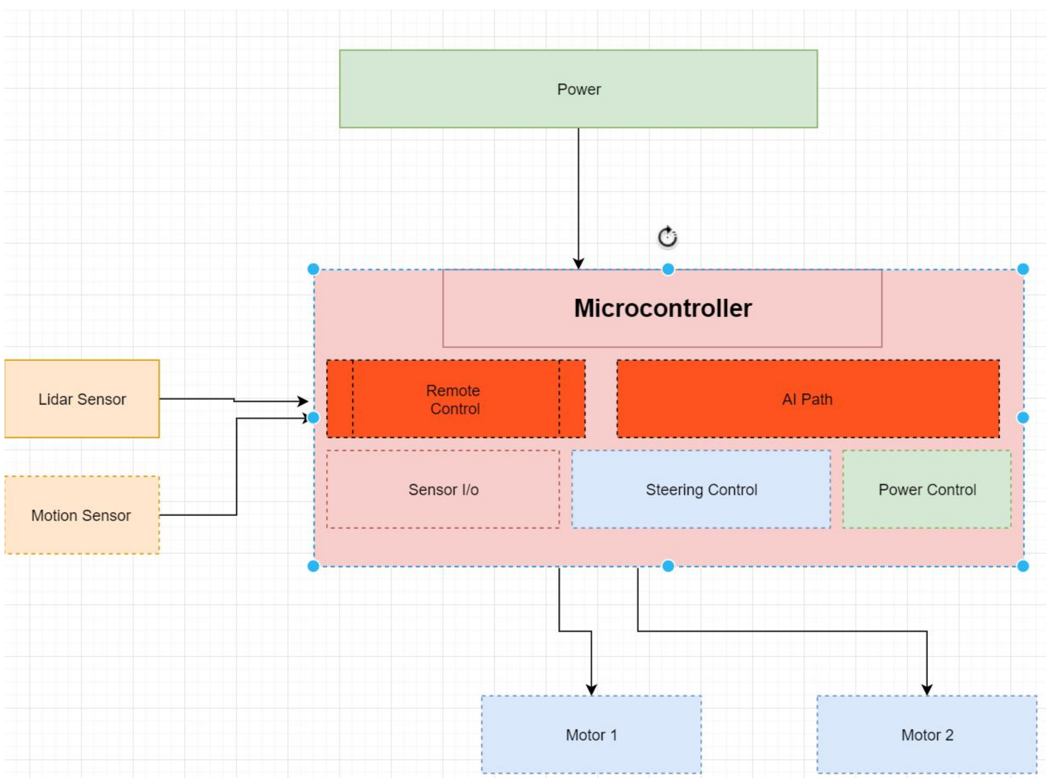



FIGURE 1-Navigation and Control System Block Diagram

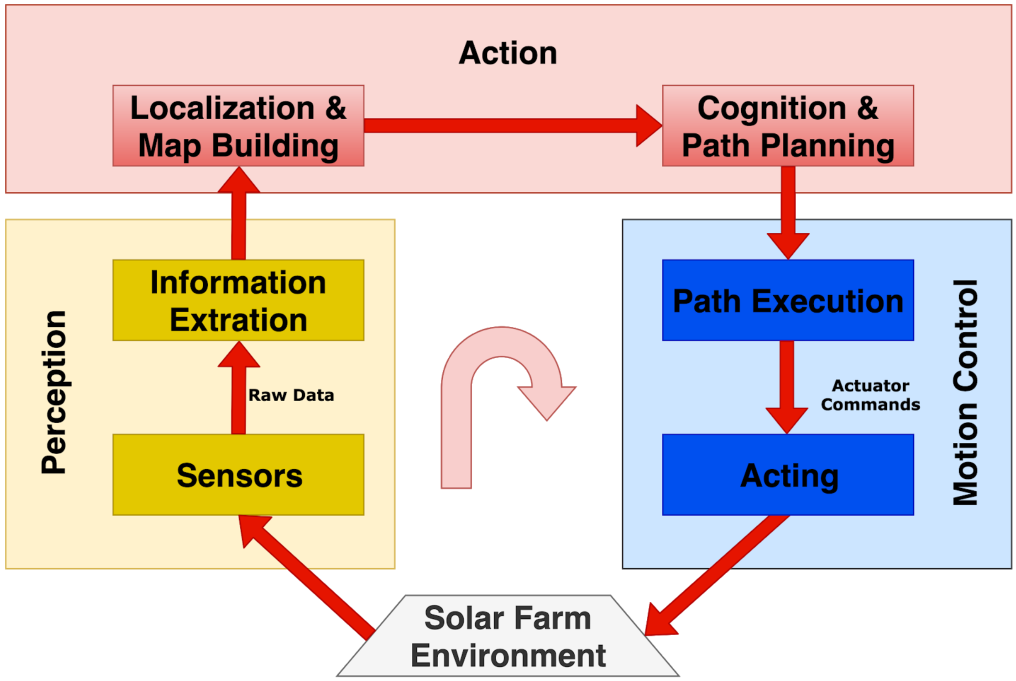



FIGURE 2- High Level Software Control Scheme for E-Goat Rover Bot

The following legend applies to “FIGURE 1” - Jordan, Eduardo, Jonathan, Steven,Davis

**Estimated Project Budget and Financing**

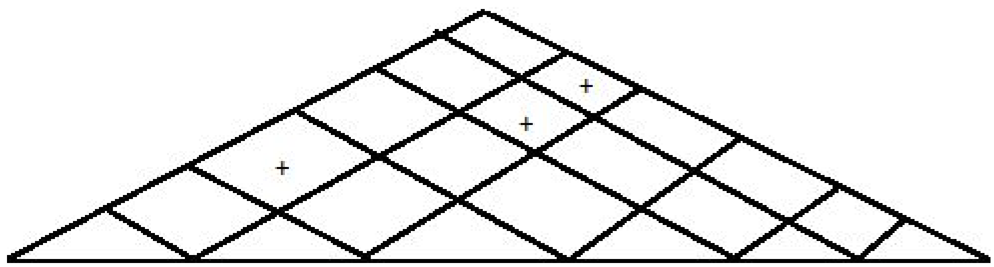
| Parts | Cost Estimate | Quantity |
|---|---|---|
| Battery | $110 | 1 |
| Environment sensor | $110 | 1 |
| Camera | $50 | 1 |
| Single Board Computer | $75 | 1 |
| Neural Compute Stick | $85 | 1 |
| Transceiver | $25 | 1 |
| Solar Panel | $50 | 1 |
| Power Supply PCB | $50 | 1 |
| Remote Relay | $30 | 1 |
| Total cost: $585 | | |

Table 2- Cost of parts

The cost estimate for the boards are listed in the table above.As you can see it is quite expensive buying all the different parts,but we are fortunately being funded by Duke energy for this project. We are planning on obtaining batteries,receivers,solar panels so that the lawn mower can operate. We are also planning on getting several different sensors and cameras so it can visualize its environment and do a good job at it, and a lot of other things. With a budget of only $1500 we will try our best to provide the highest quality at a really low price.

**House of Quality Table**

To ensure the highest possible quality, our product must achieve a balance between our engineering requirements and marketing requirements. The following House of quality diagram allows us to allocate a level of importance and devise a strategy on how to achieve our requirements.




| | | **Budget** | **Mowing Capability** | **Remotely Controlled** | **Setup Period** | **Mowing Time** | **Form Factor** |
|---|---|---|---|---|---|---|---|
| | | - | + | + | | | - |
| **Cost** | - | ↑↑ | | ↓ | ↑ | ↑ | ↑ |
| **Safety** | + | ↓ | ↓ | ↑↑ | ↑ | | ↑↑ |
| **Efficiency** | + | ↓↓ | ↓ | | ↑↑ | ↓ | ↑↑ |
| **Autonomy** | + | | | ↑ | ↑ | ↓ | |
| **Size** | - | ↑ | ↓ | | ↓ | | ↑↑ |
| **Durability** | + | ↓ | | | ↓ | | |
| **Target for Engineer Requirements** | | $1500 | 10’x50’ lawn | 50’ | >=5min | >=15min | h-20” |

Legend

(+ Positive Polarity, - Negative Polarity, ↑↑ Strong Positive Polarity, ↑ Positive Polarity, ↓ Negative Polarity, ↓↓ Strong Negative Polarity)

**Project Milestone**

| Task | Due Date | People |
|---|---|---|
| Form Group | 8/30/19 | Group 26 |
| Project Idea | 9/11/19 | Group 26 |
| Meet with Dr. Steiner | 9/11/19 | Group 26 |
| Initial Report | 9/20/19 | Group 26 |
| Idea Review with Dr. Richie | 9/24/19 | Group 26 |
| **Milestone 1 - Idea Finalized** | | |
| Updated Initial Report | 10/3/19 | Group 26 |
| Product requirements explored | 10/21/19 | Group 26 |
| **Milestone 2 - Full requirements and specifications defined** | | |
| Purchase test equipment and components | 10/22/19 | Group 26 |
| 60 page Draft Senior Design 1 Documentation | 11/1/19 | Group 26 |
| Test equipment & components | 11/2/19 | Group 26 |
| 100 page document submission | 11/15/19 | Group 26 |
| Final Document submission | 12/2/19 | Group 26 |
| **Milestone 3 - Research and Final Document completed** | | |
| Build Prototype | 2/1/20 | Group 26 |
| Testing and Redesigning | 2/15/20 | Group 26 |
| Finalizing Prototype | 3/1/20 | Group 26 |
| Peer Presentations | TBA | Group 26 |
| Final Report | TBA | Group 26 |
| Final Presentations | TBA | Group 26 |

## Software Tasks - Gantt Chart

Software Tasks

| TASK TITLE | TASK OWNER | PCT OF TASK COMPLETE | October | November | December | January | February | March | April |
|---|---|---|---|---|---|---|---|---|---|
| Remote Control - Bluetooth | Undecided | 0% | | | | | | | |
| Remote Control - App | Undecided | 0% | | | | | | | |
| Autonomous Research | Undecided | 10% | | | | | | | |
| Steering control | Undecided | 0% | | | | | | | |
| Sensor IO Research | Undecided | 0% | | | | | | | |
| AI/PathFinding Development | Undecided | 0% | | | | | | | |
| Integration | Undecided | 0% | | | | | | | |
| Testing | Undecided | 0% | | | | | | | |

**Citations:**

Duke Energy, “Innovation gets in the weeds under solar panels,” illumination. [Online]. Available: https://illumination.duke-energy.com/articles/innovation-gets-in-the-weeds-under-solar-panels. [Accessed: 20-Sep-2019]