**Project Title: Self Stabilizing Motorcycle**

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**3. PROJECT DESCRIPTION**

The proposed project will be a redesign of an electrical motorcycle that will operate as an RC-controlled self-righting vehicle. The goal of this project will be to successfully re-engineer the existing prototype so that it is able to drive indefinitely without the need for external support. As of now, the motorcycle can only drive for approximately ten feet before falling over. This is due in part to slow response time in the controller that manipulates the center of gravity of the motorcycle.

The reason for this project is a proof-of-concept to expand the knowledge base of the robotics field. A self-righting motorcycle has several military applications including the ability to get vehicles and supplies into areas where a large four-wheeled vehicle would not be able to access. Additionally, the military could use this as a platform for mobile terrain reconnaissance missions. In the civilian sector, as robotics become more and more advanced, the need to have a robot that is able to operate on a two-point-of-contact basis is becoming increasingly demanded. This ability would allow a wider range of applications related to the service-based industry. A self-righting motorcycle would be able to prove one way in which this would be accomplished for a translating device.

**4. ESTABLISHED WORK**

There have been two projects that have successfully made a self-righting motorcycle. The first was a submission by a Berkeley team to the DARPA Autonomous Vehicle challenge. This group successfully made a motorcycle that could drive itself without external input and placed in the DARPA challenge. The other was by a Master’s Thesis candidate in Technion, Israel. This project made a RC-controlled scooter that would self-right itself, even against significant external disturbances. Both projects maintained stability by manipulating the front wheel rapidly to cause the vehicle to torque upright. Each project, additionally, used linear approximations for their control theory.

As of now, the SDSU AutoMoto project has been completed once for a senior design project. As of now, the entire motorcycle has been built with all working motors, controllers, and RC controls. The prototype, however, is nonoperational, being able to drive for only approximately ten feel without falling over. The system currently has no way to turn, being able to only achieve straight-line motion. This senior design project will be renaming the project to “Self Stabilizing Motorcycle” and will be reworking the design in such a way that the drive time will be significantly increased as well as have the ability to turn properly.

**5. SCOPE OF WORK**

This senior design project will consist of the redesign of the motorcycle to accomplish three goals: be able to drive for an indefinite amount of time without external support, be able to drive on a 5% incline, and be able to execute a 10-foot radius turn. The completion of this project will involve extensive research into control theory as well as the exploration of the Newtonian equations of motion.

The first stage of the project will be to determine the exact state of the build. We will need to acquire all previous documentation from the original team. Reverse engineering will be necessary for the undocumented build areas of the motorcycle as all previous team members have graduated. We will compare the current design with the two existing builds to better judge what needs to be adapted to better suit the project.

Once the current state has been established, the primary goal will be to design the bike in such a way that we can manipulate the center of gravity (CG) of the vehicle. The previous two builds had much taller bikes that allowed for more manipulation of the CG; the current design has a very low center of gravity, making it difficult to achieve stability because of the rotational inertia of the vehicle.

The current method of achieving stability is to change the angle of the front wheel in such a way that the torque caused by the turning of the wheel makes the vehicle self-right itself. This requires very fast acting controllers as well a very quick acting stepper motor. After initially reviewing the design, this does not appear to be the case on our motorcycle. As part of this design, we would like to explorer the use of actually physically moving the center of gravity by using a device that can shift a weight laterally back and forth on the motorcycle. This will physically cause the CG to move beyond the points of contact and, in theory, provide a way to achieve stability.

MATLAB/Simulink software may be used to simulate the output response of our control systems for a variety of input signals as well as external disturbances to our prototype. Design techniques via root locus may be implemented for proportional-integral-derivative (PID) controls to improve steady state error and time response for our stability criteria. Analog circuits interfaced with programmable integrated circuit (IC) chips to function the actuators of our system will need to execute quickly and accurately to self-sustain the vehicle’s performance.

If the weight-shifting design proves necessary due to the current restriction of the vehicle, this will be the primary focus of electromechanical design and fabrication. Additionally, we will have to digitally redesign the controllers so that their responses are more in line with existing Newtonian models. Because of the Master’s Thesis that was completed on the design of one of the existing builds, there is extensive documentation available to correlate our design with proven techniques.

During the first semester we will do the primary design portion. This will involve determining if the current setup is capable of stability by testing the device as well as examining the state of the coding in the controllers. Additionally we will have to experimentally determine the center of gravity of the motorcycle so that we can accurately control the stability of the vehicle. The second semester will involve all build-related activities involving all electrical fabrication and the possible build of the weight-shifting device. Testing will be completed near the end of the semester.

**6. DELIVERABLES**

This project will have several documents that we will be able to produce so that we can judge the success of the build. This includes all project reports, engineering notebooks, derived equations of motion, existing academic research, schematics of circuits, drawings of mechanical design, and final report. Additionally we will be able to supply a prototype with recommendations for future revisions. During all tests of the vehicle, we will record extensive data that will be presented in a fashion that will make it easy to recommend changes to the design to better achieve stability. If the project is 100% successful, we will have a working prototype to report on at the end of the year. A logbook will be kept throughout the next several months to chronologically document the design process of this project.

**7. TARGET DATES**

This project will be developed on a monthly basis. For the first semester, the project will be broken up into the following months:

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| September 30st | October 31st | November 30th | December 16th |
| Determine the exact state of the build. Reverse engineer any unknown design aspects. | Derive linear equations of motion. Determine if a weight-shifting device is necessary for linear stability. | Determine requirements for curved motion. Again, determine if a weight-shifting device is necessary for curved motion. | Report on design aspects and requirements of the build. |

Each deadline is not permanent; as sections get completed we will move on to the next section.

**8. FUNDING**

The project will be primarily funded initially from the startup fund from the College of Engineering grant. This amounts to a $500 startup fund. We will be soliciting external sources that have a vested interest in autonomous motion for funding options and or equipment donations.