
# Team LoGHIQ
# Technical Proposal
# 2004 DARPA Grand Challenge

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1. System Description
    a. Mobility.
        1. The physically existing vehicle consists of a 6061 aluminum space frame with attached hardware as described below. The vehicle has four wheels, each approximately 3 feet in diameter and 1 foot wide. The wheels are Hutchinson Industries alloy wheels with runflat system. A 2 HP DC motor is used to power each wheel. Steering is done via “tank steering”, meaning that the wheels do not pivot in order to steer. The steering is done through differing the speed of the drive wheels. For instance, by causing the right drive wheel to rotate faster than the left, a left turn is initiated. Braking is accomplished through the use of brakes on all four wheels, as well as electronic braking through the motors. The brakes are actuated by an array of solenoids.
        2. Each of the wheels is connected to a drive shaft which is connected to the drive motor. The speed of the motors is controlled by the motor controllers through feedback from the optical tachometers. The brakes are actuated by solenoids.
    b. Power.
        1. The vehicle is a series gasoline-electric hybrid. The generator charges the main battery pack, which delivers power to the drive motors and other electronics. The generator runs on standard gasoline, and the battery bank is comprised of 8 sealed lead acid batteries.
        2. The vehicle’s maximum power consumption is approximately 6 kW.
        3. The vehicle will be carrying approximately 30 pounds of gasoline.
    c. Processing.
        1. Our computing system consists of one VIA Epia Mini-ITX mainboard with associated peripherals. We are using a solid state hard drive for memory.
    d. Internal Databases.
        1. The system incorporates satellite imagery and topographic maps, both freely available through the efforts of the United States Geological Survey. The maps will be preprocessed within the 2 hours before the race by members of Team LoGHIQ to eliminate areas which are out of bounds (as defined by the RDDF). Further areas will be eliminated as possible route segments at the discretion of Team LoGHIQ. This is to prevent the vehicle from entering an area of treacherous terrain if possible. Both the satellite imagery and topographic maps have a resolution of 5 meters.
    e. Environment Sensing.
        1. The system uses three ultrasonic rangefinders, a laser rangefinder, and a stereo vision system. The ultrasonic and laser rangefinders are active, while the stereo system is passive. The ultrasonic and laser rangefinders have an effective range of approximately 35 feet, and are very useful at slow to medium speeds. The range of the stereo vision system is limited mainly by the visibility on the course. In the event of severely limited visibility (i.e. dense dust clouds) the vehicle will slow

and rely on the active rangefinders. The sensing horizon of the laser rangefinder is simply a ray extending forward from the front of the vehicle. The 3 ultrasonic sensors emit their pulse as a 15 degree cone. The cone is angled upwards 5 degrees from the horizontal to minimize unwanted ground interference. The laser rangefinder complements the readings of the forward looking ultrasonic sensor. The stereo vision system has an extremely wide field of view (~180 degrees) and an effectively infinite depth of field. The stereo system is used for both long range and close range obstacle detection and avoidance, while the laser and ultrasonic systems are for close to mid range (<30 ft) navigation only. The system is also capable of sensing the terrain through the use of its optical encoders. When one wheel begins to move significantly faster than the other (not as a result of a turning command) the wheel is determined to have lost traction with the ground and power to it is decreased until traction is reestablished. The false distance readings obtained during this slippage are accounted for, which greatly increases the accuracy of the DRS over rough terrain.

2. The sensors are mounted on the front of the vehicle. See Fig. 4 for diagram. The sensors are all controlled through the serial, parallel, and USB ports of the computer.

f. State Sensing.

1. The vehicle uses a digital compass to detect heading, and optical encoders on the two rear wheels to determine the speed of each wheel. The heading information, together with the speed of the wheels, combine to give high speed latitude-longitude position of the vehicle.
2. This information is fused with the GPS data to correct the drift errors associated with the DRS.

g. Localization.

1. The current vehicle uses a Trimble *Ag*GPS 122 DGPS, Part Number 29837-00. It has a quoted differential accuracy of "less than one meter horizontal RMS", which we have verified. The data from the GPS unit is fused with the data from the dead reckoning system to both compensate for GPS outages and help correct GPS inaccuracies. An oversimplified example would involve the GPS system determining that the vehicle moved 20 feet in one second while the DRS determines a move of only 10 feet. The DRS system data, which is highly accurate over short periods, can be intelligently fused with the GPS data to give a much more accurate location. The two systems complement each other, since one suffers from a high drift error rate (the DRS).
2. GPS outages and inaccuracies are compensated for by the dead reckoning system (DRS). The DRS is comprised of a Precision Navigation Vector-2X digital compass module integrated with two Oak Grigsby 900 Series optical encoders. The encoders are attached directly to the drive shafts of the two rear wheels. The DRS system is highly accurate over a variety of terrain, due to the systems ability to

account for wheel slippage. Over average terrain, the DRS system is capable of minimizing drift errors to less than two percent of distance traveled without an incoming GPS signal. Over unstable terrain the drift error rate increases slightly. With a GPS signal and at slow speeds the determined location of the system is reliable to less than a foot.

3. All out of boundary areas are treated as insurmountable obstacles. The GPS/DRS location system ensures that the vehicle stays within bounds, taking into account the dimensions of the vehicle. When the boundaries are marked physically (concrete barriers, snow fencing, etc.), and the vehicle is operating in close proximity to them, the rangefinder systems will help to keep the vehicle in bounds. When boundaries become very narrow, the system will slow down to increase the accuracy of the GPS/DRS data fusion algorithm. The vehicle may stop (for no more than 30 seconds) in order to obtain GPS data and process it to further optimize the fusion algorithm. This will only occur when the vehicle determines that it is a few feet or less from a boundary.

h. Communications
   1. No.
   2. The vehicle will receive only GPS signals and USCG differential corrections.

i. Autonomous Servicing
   1. No.
   2. No.

j. Non-autonomous control.
   1. The vehicle will be towed by truck and pushed by hand. We will not be implementing a remote control system.

2. System Performance

a. Previous Tests.
   1. We have performed accuracy tests with the GPS system as well as the INS system. We have done limited drive train testing, and have not yet fully tested the vehicles guidance systems under its own power. Our ultrasonic and laser rangefinder systems are working as expected. We are still working on our stereo vision system, and have not yet interfaced it with the vehicles computing system.

b. Planned Tests.
   1. We plan on doing full scale testing in the coming months using a sample RDDF file provided by DARPA. Testing at various speeds (up to 30 mph) and over various terrain will be conducted. Specifically, we will be testing navigation through 10 foot wide corridors. We are also looking forward to testing the robustness of our stereo vision system to determine how it handles dust and other airborne matter.

3. Safety and Environmental Impact

a. 30 mph
b. Depending on the terrain and conditions, the vehicle will carry enough

fuel to enable a range of approximately 250 miles.

c. Safety Equipment
    1. We are using a standard gasoline tank that is supplied with the generator. The tank is attached to the generator which will be attached securely to the frame using shock isolating rubber mounts.
    2. The tank is confined within the aluminum space frame structure to minimize the risk of rupture.
    3. Our visual warning system includes one flashing, rotating amber light, mounted on the top of the vehicle. It is visible from all angles and conforms to SAE Class 1 standards. Our brake lights are mounted on the back of the vehicle and conform to the rules. Our audio warning system is a siren that conforms to SAE Class 1 standards and produces sounds that are distinguishable from those produced by public-safety vehicles.

d. E-Stops.
    1. When the normal E-Stop mode is activated, the power to all four motors is cut. Simultaneously, a solid state relay (SSR) is closed which causes the brakes to lock up. This brings the vehicle to a quick halt. When the signal is cleared, the vehicle simply releases the brakes and continues as usual. When the disable E-Stop mode is activated, power is cut to the motors and the brakes are locked, as is the case with the normal E-Stop mode. However, the computer is also powered down. The only way to enable the vehicle is to physically reboot the system.
    2. The two manual E-Stop switches are large red momentary pushbuttons mounted on the front and back of the Challenge Vehicle. Depressing any of these switches immediately activates the disable E-Stop mode as described above.
    3. When the vehicle is shut down, it is in neutral mode, and is easily pushed by two people. It can also be pushed when on but not in driving mode. Only when the vehicle is in E-Stop mode will the brakes interfere with its ability to be easily pushed around. In this case, there is a manual switch to disable the brakes and allow the vehicle to be moved. The vehicle can be towed by a conventional tow truck.

e. Radiators.
    1. The only active EM radiator is the SICK Optic DME 2000 Class II red diode laser. The Class II has a power output of <1mW.
    2. The SICK Optic DME 2000 is an OSHA Class II unit. It also conforms to the following standards: IEC 825-1, EN 60825-1
    3. The laser module is clearly marked with an OSHA approved warning label.

f. Environmental Impact.
    1. The large tires on the vehicle and low ground pressure make it less likely to damage surfaces than conventional vehicles.

2. The maximum dimensions of the vehicle can be defined as a rectangular solid with approximate dimensions as follows: 8 feet (length), 6 feet (width), 5 feet (height). The maximum weight of the vehicle, including fuel, is 1500 pounds.
3. When at rest and laden with fuel, each wheel has a roughly elliptical contact patch with an area of approximately 125 square inches. In this state the vehicle exhibits a maximum ground pressure of approximately 3 psi.