Prospect Eleven is the team name for Princeton University’s entry in DARPA’s Grand Challenge of 2005, a competition of truly autonomous vehicles traveling a prescribed course. The challenge of the “Challenge” is to “build or modify” an automobile-sized vehicle that can negotiate a prescribe course containing randomly place obstacles without any human intervention. The Challenge was originally contested in April, 2004; however, none of the entries completed the course. In fact, the most successful vehicle completed only the first seven (7) miles of the more than 150 mile course. As a result, DARPA (Defense Advanced Research Projects Administration), decided to organize a second Challenge that is to take place in October, 2005.

Princeton University did not participate in the first Challenge; however, upon learning, in May 2004, that a second Challenge would be contested, a group of undergraduates led by Ben Klaber ’05 approached Professor Alain Kornhauser with a desire participate in the 2005 Challenge. In May 2004, Princeton University officially enter a vehicle named “Prospect Eleven” with the stipulations that it be an undergraduate student, as opposed to a professional staff, activity AND that the principle objective be that it complement to the highest degree possible the students’ academic experience at Princeton. Bounded by those constraints, a multidisciplinary team of students and advising faculty volunteered to participate in the “DARPA Project”.

Throughout the design, build and test process the guiding objectives have been academic relevance, simplicity, elegance and minimal expenditure of funds. Academic relevance because it is Princeton; simplicity because it is too easy to make this Challenge so hard that it is undoable, thus the need for elegance. Finally, funds were to be used only for summer stipends for participating students and the purchase of needed computing, command and control apparatus. No funds were available for students during the
During the summer of 2004, a team of to-be Seniors from the class of 2005 did the original ground work for *Prospect Eleven*. Ben Klaber ’05 ORFE, Ben Essenberg ’05 MAE, Joel Mancl ’05 MAE, Trevor Brooks ’05 CS, Philip Wei ’05 CS, Daniel Chiou ’05 ELE, Michael Pasqual ’05 ELE, Each of these students went on to use their participation in the DARPA Project as an application basis for their Senior Thesis. Professor Kornhauser obtained, with the help of Rick Spina ’85, a salvaged vehicle from General Motors. Trimble Navigation and ALK Technologies donated GPS receivers. Otherwise, all student summer salaries and other equipment was purchased using the endowment funds from the CSX Transportation Research Fund and the Lion Transportation Senior Thesis Fund.

During the 2004-05 academic year, the participating seniors were joined by several underclassmen. Bryan Cattle ’07 ELE and Anand Atreya ’07 ELE actively participated as part of independent research activity. Freshmen Andrew Saxe ’08, Gordon Franken ’08, Josh Herbach ’08 and Brendan Collins ’08 joined on an extra-curricular basis. The faculty advising team, led by Professor Alain Kornhauser (ORFE), included Professors Stuart Schwartz (ELE), Bradley Dickenson (ELE), Sanjeev Kulkarni (ELE), Michael Littman (MAE), Clarance Rowley (MAE), Daniel Osherson (PSY), and Szymon Rusinkiewicz (CS).

Culmination of a year’s activity took place with the original DARPA Site Visit on May 6, 2005. The purpose of the Site Visit was for DARPA to measure the progress of each of over 100 entries and select the best 40 as “Semi-Finalists”. The Site Visit consisted of three (3) traversals of a prescribed 220 meter S-shaped course that contained two randomly-placed obstacles. The autonomous vehicle was required to stay within prescribed coordinates bounding the course while avoiding collisions with the obstacles. Each run was timed. Faster was better. The Site Visit took place at the West Windsor Fields where the prescribed course was properly laid out.

It was an enormous accomplishment for the *Prospect Eleven* team to, in one year, properly modify a production vehicle that could autonomously control its throttle, brake and steering utilizing inputs from a GPS receiver, hood-mounted camera, digital compass and stock sensors such as wheel ticks and throttle settings. All was accomplished under the Princeton guidelines that it be entirely an undergraduate student project focused on academics, elegance, simplicity and the minimal use of funds.

During the Site Visit, the first run was brought to an emergency stop immediately after *Prospect Eleven* failed to avoid the first obstacle. It was unfortunate that the emergency stop was activated, because, as was subsequently learned, it was also important to determine if the vehicle would stay within the prescribed boundaries, irrespective of its ability to avoid obstacles. More points could have been earned by completing the run. During the second run, *Prospect Eleven*, successfully avoided the first obstacle, “nicked”
The second obstacle and completed the course in a very fast time of 56 seconds without violating the course boundaries. The third run had Prospect Eleven nicking the first obstacle, running right over the second and quickly completing the course once again without violating the course boundaries. Thus, the results were mixed. On the positive side, the automated throttle, brake and steering systems were well integrated with GPS, machine vision and other sensors. Unfortunately, Prospect Eleven had serious problems with obstacle detection and tracking which resulted in its poor performance in collision avoidance.

When the top 40 Semi-finalists were announced in early June, Prospect Eleven was not included; however, it did come very close. So close, that upon further consideration, DARPA decided to offer the Prospect Eleven team “Alternate” status.

The Alternate status provides Prospect Eleven a second chance Site Visit, scheduled for 8:00 am, Tuesday, August 16, 2005 at West Windsor Fields. Repeated will be the first Site Visit with three runs down a similar S-shaped course containing randomly placed obstacles. An optional fourth run choreographed by the Prospect Eleven team will also be traversed. Practice session will be run on Monday, August 15, 2005 from 8am until 6pm. Remote web viewing of the practice session and the site visit will be available on the CoPilot|Live site: http://live.alk.com Use Account Name: Prospect11 and Password: Princeton to monitor Prospect Eleven’s position every five seconds.

A team of seven (7) students, advised by Prof. Kornhauser, have been working since May as summer research assistants, funded by the CSX Transportation Research Fund. Students are Scott Schiffres ’06 MAE, Kamil Choudhury’06 CS, Bryan Cattle ‘07 ELE, Anand Atreya’07 ELE, Andrew Saxe ’08, Gordon Franken ’08, and Brendan Collins’08. These students have completely rebuilt Prospect Eleven. They have ruggedized the throttle, braking and steering systems, shock-mounted the computers, redid all of the wiring, installed a stereo vision system for object detection and identification and rewrote the longitudinal and lateral control functions. In pre-site visit tests, Prospect Eleven has been able to detect objects, avoid them and stay within prescribed courses most of the time. Some problems still exist. Not all bugs are out of the code; however, performance is promising. Prospect Eleven has been able to successfully negotiate a 750 meter long closed course several times without incident. Unfortunately, each attempt has ended with some type of computer crash. Enormous additional progress has been made; however, reliability is still a serious issue.

Prof. Alain L. Kornhauser
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