

2000 AUVSI Intelligent Ground  
Vehicle Competition  
Design Report

# ALAN V

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**Adaptive Learning Autonomous Navigation Vehicle**



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## **Mission Statement**

*DeVry's Vehicular Technology chapter is here to explore the endless technological possibilities that our universe has to offer. Our goal is to explore and develop advancements in the field of transportation and to revolutionize the planet. With the growth of the world's population, careful considerations are necessary to assure the safety and economic feasibility of worldwide transportation needs. By carefully studying known technologies and exploring new concepts, the Vehicular Technologies group will make the unprecedented advancements in technology that the world has been waiting for.*

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## Introduction

The ALAN V project is a multidisciplinary project to create an autonomous vehicle for the 2000 AUVSI Autonomous Ground Vehicle Competition. This report details the organization of the ALAN V team, a timeline detailing the design process and the design specifications.

The intent of the ALAN V project is create a atmosphere of higher learning where the students involved can set their own pace. When the core ALAN V team assembled in December of 1999, the challenges that had to be confronted during the months leading up to the competition seemed overwhelming. These challenges were overcome by hard work, perseverance, and the wealth of talent available through the student body.

### 1. Team Organization

The ALAN V team was developed so that members could contribute their expertise to the area in which they excelled. Due to DeVry lacking a Mechanical Engineering program, students from the Electrical Engineering Technology (EET) program relied on their past experiences to complete the mechanical aspects of ALAN V.

The members of the ALAN V project organized themselves into three distinct teams that were composed of the key elements of an autonomous vehicle:

- a) *Mechanical* – The purpose of the mechanical team was to create a frame and body that hold the control systems.
- b) *Programming* – The programming team was given the task of creating a software package that would interpret the surrounding environment and control the ALAN V unit autonomously.
- c) *Systems* – The goal of the Systems team was to design a control package for ALAN V that would integrate with the objectives of both the Mechanical and Programming divisions. The control systems include sensory input, computer systems and power supply.

The active members of the ALAN V project from all teams then elected a team coach who served as a mediator between the groups ensuring that the project goals were being followed at all times. The team coach also served as a liaison between the marketing team and the rest of the group.

To decide upon the design of the vehicle, each team leader would consult their members to come upon a mutually agreed upon solution. The team leaders would then meet, and with the help of a team coach agree on the best design to be implemented. This structure allowed each team to function independently while ensuring the compatibility of design elements.

## 2. Project Timeline

The conception of ALAN V began in December of 1999 and construction began in late January. The team realized at an early stage that to have ALAN V ready for the 2000 competition would be a challenge but were prepared to sacrifice personal time to see it to completion. Another challenge that was presented was due to the fact that DeVry holds classes year round. This meant that the team could not rely on the standard April to September break. Instead, the team persevered through out the duration of classes and had just two weeks of time from the end of the current semester until the competition began. The Gantt chart used by the team is included as *Figure 3.0*.

**Figure 3.0**

| ID | ALAN V Teams      | Start Date | End Date  | Duration | 1999   |     | 2000 |     |     |     |     |     |     |  |  |
|----|-------------------|------------|-----------|----------|--|-----|------|-----|-----|-----|-----|-----|-----|--|--|
|    |                   |            |           |          | Nov  | Dec | Jan  | Feb | Mar | Apr | May | Jun | Jul |  |  |
| 1  | Mechanical Design | 11/15/1999 | 7/14/2000 | 175d     | [Blue bar spanning from Nov 1999 to Jul 2000]    |     |      |     |     |     |     |     |     |  |  |
| 2  | Software Design   | 3/18/2000  | 7/14/2000 | 85d      | [Teal bar spanning from Mar 2000 to Jul 2000]    |     |      |     |     |     |     |     |     |  |  |
| 3  | Systems Design    | 11/15/1999 | 7/14/2000 | 175d     | [Magenta bar spanning from Nov 1999 to Jul 2000] |     |      |     |     |     |     |     |     |  |  |
| 4  | Marketing         | 12/2/1999  | 7/14/2000 | 162d     | [Yellow bar spanning from Dec 1999 to Jul 2000]  |     |      |     |     |     |     |     |     |  |  |
| 5  | Logistics         | 6/1/2000   | 6/23/2000 | 17d      | [Red bar spanning from Jun 2000 to Jul 2000]     |     |      |     |     |     |     |     |     |  |  |

### 3. Mechanical Design

The ALAN V mechanical design had certain considerations that had to be attained. The implementation of the design had to allow for coding and actuation to be carried out with ease while still being available at a reasonable price, as our budget was quite small. Keeping these two factors in mind, a used Dixon ZTR lawn mower was chosen (*Figure 4.0*). This design was economically feasible and allowed for the forward, reverse, right, left, and speed control to be operated by only two actuators (much like a tank). Using only two actuators allows the programming and computer interfacing to be efficiently achieved with out the need of overly complicated control systems. ALAN V is powered by an 11 horsepower Honda motor, which supplies both the drive power to the rear wheels and electrical power via an alternator.



**Figure 4.0**

#### 3.1. Chassis Alterations

Although ALAN V is based off of an existing riding lawn mower chassis, many custom alterations were implemented (*Figure 4.1*). The level of mechanical design needed to create and maintain a successful and precise autonomous vehicle is extremely high, which served as a welcome challenge to ALAN V's mechanical design team.



**Figure 4.1**

In creating ALAN V, the frame was first stripped down and the mounting hardware, which once held the brackets for the mower deck, was removed. To prevent frame failure over time, high stress areas were reinforced on the ALAN V frame. An automotive size battery holder was built and added to the front of the frame to house a deep cycle marine battery to power the electronics equipment. Next, mounting platforms were implemented above the actuation

devices and transmission (*Figure 4.2*). These platforms served as a base upon which all electronic equipment could be placed and consisted of a three-step platform. The platforms were constructed of sheet metal separated by a 2.5cm space that is filled with polyurethane insulation. This design was chosen to prevent engine heat and EMF (Electro Magnetic Frequencies) from interfering with the computer system and other electronic hardware mounted above the platform.



**Figure 4.2**

In order to power the onboard electronics an automotive DC alternator was installed. Using old brackets off a Chevrolet car, a mounting area was built in a position to take advantage of the dormant PTO (Power Take Off). This system will then be used to supply rotational power from the engine to the alternator. The alternator was then wired to the battery box where it will be attached to the marine deep cycle battery.

## 4. Systems Design

The objective of the systems division was to give the programming team a solid foundation to develop and run software on. The systems on-board of ALAN V have to provide sensory input, power regulation / supply and control capabilities.

### 4.1. Power Supply and Regulation



**Figure 5.0**

The power that is supplied from the automotive alternator is +12V DC. In order to supply the computer with clean, 120V AC power an inverter designed for Ambulances was used. The Vanner 20-1000TUL (*Figure 5.0*) can provide up to 1050 Watts of clean, stable power. In order to provide battery back-up protection for the computer an uninterruptible power supply (UPS) was used. The UPS also

provides a secondary voltage regulation ensuring that the computer does not receive any power spikes or irregularities.

#### **4.2. *Sensory System***

Due to the transmission design of the Dixon lawnmower used as a base, the speed of the unit could not be guaranteed to always be the same. This is because the transmission works on a series of cones that provide power to the drive train. If the cones contract or expand due to heat, the amount of power transferred to the drive train could change. Another problem with the Dixon transmission is that each wheel is independently controlled. To have the vehicle travel in a straight line, both wheels must be providing the same amount of revolutions.

To overcome these problems a speed system was designed to constantly feedback the speed of each wheel to the CPU. To implement this design, two Hall effect sensors were attached to the transmission to monitor the gear rotations of each wheel. The output of the Hall effect sensors was then fed into a BasicX microcontroller that translated the number of gear rotations into the actual speeds of the wheels. The CPU could then access the microcontroller by serial RS-232 communications.

To help guide the vehicle, a digital compass module from Precision Navigation was used. The compass was implemented through a second BasicX microcontroller and communicates through the I2C serial communications standard. The addition of the compass module to the unit allows for precise bearings to be calculated for maneuvers such as turns and also to help the vehicle ensure that it stays on course.

#### **4.3. *Command and Control***

To control ALAN V a standard mini-tower computer was used. The computer has 256Mb of RAM, a Pentium III 500MHz processor and uses Windows 98se for an operating system. The computer is also equipped with an IEEE-1394 Firewire port to accommodate the Digiclops camera.

To display the current status of the vehicle and any other important messages a LCD panel from Matrix Orbital was implemented (*Figure 5.1*). The LCD is backlit and also allows for the connection of a membrane keypad for data entry. This LCD panel also serves to reduce power, as a monitor is unnecessary for the operation of the unit once the program is running since all pertinent data is displayed through the LCD.



**Figure 5.1**

#### **4.4. Actuator Controls**

To achieve autonomous control, linear actuators had to be installed to replace the human push control levers. Two linear actuators were purchased from AMSI Corporation and were incorporated into the ALAN V design. These actuators implement a stepper motor design, which the computer can control in increments of 0.0075". In order to implement the stepper motor design a control circuit was designed and built (*Figure 5.2*). The controller circuit consists of a parallel port input that is then attached to a tri-state buffer to hold the control signal from the parallel port. A series of transistor switches in conjunction with suppression diodes are then used to power the activators.



**Figure 5.2**

#### **4.5. Communication**

To ensure that the vehicle can be safely stopped in case of an emergency a RF system from Linx Technologies was used to communicate remotely with the vehicle. The RF system consists of two units, a relay unit that is used to cut power to the motor and a smaller receiver unit that is connected to the computer. Each of the units operate on the same channel but independent of the other so that if one unit fails that other will still halt the unit.

## 5. Software Design

In beginning the software design of ALAN V, an extensive analysis of the competition rules and the other competitors revealed three primary elements were required for development of an autonomous vehicle. The first element consisted of a vision and image recognition system, which would allow the vehicle to detect lines and potholes, as well as acquire the image for the follow the leader competition. The second element considered was a distancing system, which would allow reliable distance detection in order to recognize physical obstacles. The third element was the actual decision-making algorithm, which would use the data from the first two elements to navigate through the course. Further analysis of the competition through video footage of previous years led to another element. From the video footage, it seemed that most vehicles seemed to be running into problems because there was very little time/distance between when they detected obstacles and when they worked to avoid them. This led to the development of an extended mapping system that would act as a buffer between the input systems and the decision-making algorithm. This mapping system allows ALAN V to set its desired course path well before an obstacle is encountered and uses compensation from the sensory input as needed.

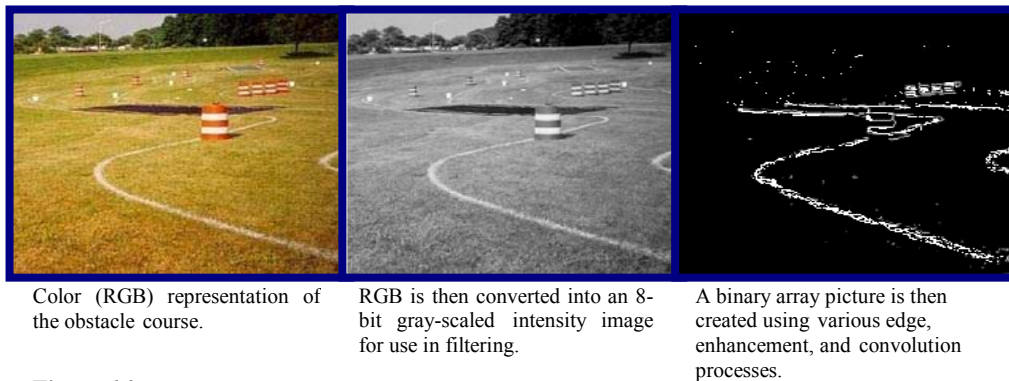
### 5.1. *Computer Visioning System*

When deciding what type of hardware should be used for image acquisition, the Digiclops™ Stereo Vision System came to attention. This system promised the ability to acquire all necessary images for image recognition processing, and as an added bonus, stereovision capabilities that allowed distance detection. This ability satisfied the first two software requirements through one piece of hardware, presenting the possibility for a shorter development cycle through a reduced learning period. As a result of the potential benefits, this system was chosen for use and development of this software element began. The Digiclops™ system was distributed with an Application Programming Interface, which allowed access to all of the system's features through a C/C++ programming environment. This system was used to capture images for processing by MATLAB™ for line detection, and for the creation of distance maps, which could be referenced in order to plot obstacles in the map. The

distance maps were also used as the source for object detection by searching for significant changes in the distance read ahead of the unit.

*Figure 6.0* shows an example of the Sobel edge detection algorithm used. This algorithm calculates the maximum approximation of the derivative to produce a binary representation of the lines and obstacles located on the competition course. This processed line representation is then combined with the distance representation to complete the imaging cycle.

## Image Processing for Line Detection



**Figure 6.0**

### 5.2. Mapping System

Once the need for this system was discovered, it was determined that it should be based upon a mechanism, which is arguably the most efficient at avoiding obstacles on the planet, i.e. humans. If you think about how humans plot their course through an area, it is quickly discovered that the eyes (replicated through Digiclops™) analyze what is a large distance ahead of the body, rarely what is right in front of it. The short-term memory stores what is needed and the brain picks its course long before arriving at the actual obstacle. This procedure not only allows obstacle avoidance, but also provides the ability to create an efficient course with a great deal of clearance past objects. To simulate this natural system, our system takes the input from the visioning system and only uses what is a large distance away. Detected obstacles are stored in the map, simulating the short-term memory. This led to the problem of memory consumption, with estimates on the size of the map getting over 1

Gigabyte, far too large to handle effectively. This problem was overcome by dynamically allocating obstacles and by not storing data on parts of the course that had no obstacles. This allowed us to cut a large amount of overhead from our mapping area and to decrease the amount of time that the map needs to spend saving data for the decision-making algorithm to use. One final aspect of the map is that it fuzzifies the location of all objects giving a greater degree of clearance to all obstacles and creating accommodation room for navigation errors.

### **5.3. Decision Making**

The decision-making algorithm, it was decided, needed to be as simple as possible. Therefore, using MATLAB<sup>TM</sup> Fuzzy logic toolbox, a neural-fuzzy algorithm was developed with careful consideration of two important factors. The first factor is that the decision making program has to run very quickly and efficiently, because it has to trade off processor cycles with the rest of the software. It needs to make a decision and to pass the processor back over to the visioning and vehicle control systems. Therefore, unlike the human brain which multitasks, the decision making program had to trade off processor time with the visioning system. The visioning system requires a lot of processor time to create and format the Digiclops<sup>TM</sup> input into a form that is usable by the map. Therefore, the decision-making algorithm is very small and simple. With the help of MATLAB<sup>TM</sup> the algorithm uses waveform to assign a “degree of central location” to obstacles that lie ahead of the vehicle. The vehicle then uses this information to determine the best possible path while avoiding the obstacles ahead of it. This combination of a simple decision making algorithm and an dynamically allocated map, when teamed up with the Digiclops<sup>TM</sup> Imaging system, will allow the ALAN V to successfully navigate the obstacle course.

## **6. Financial Considerations**

The ALAN V was designed to achieve the best performance for the lowest cost. Team members started to fundraise in January of '00 and had success gaining sponsorships from Ram River for a new gasoline engine and the Department of National Defense for the Digiclops camera. These primary

components were then augmented with moderate student funding to construct the ALAN V vehicle.

The cost of the vehicle is broken down in *Chart 7.0*.

| Team              | System            | Part             | Cost           |               |
|-------------------|-------------------|------------------|----------------|---------------|
|                   |                   |                  | CND \$         | US \$         |
| Systems           | Command & Control |                  |                |               |
|                   |                   | Main Computer    | \$800          | \$535         |
|                   |                   | Serial I/O Card  | \$90           | \$60          |
|                   |                   | Power Supply     | \$160          | \$107         |
|                   |                   | LCD Panel        | \$150          | \$100         |
|                   | Sensors           |                  |                |               |
|                   |                   | Speed Sensors    | \$120          | \$80          |
|                   |                   | Microcontrollers | \$250          | \$167         |
|                   |                   | Compass Module   | \$180          | \$120         |
|                   |                   | Digiclops        | \$7265         | \$5000        |
|                   | Power Supply      |                  |                |               |
|                   |                   | Inverter         | \$800          | \$535         |
|                   |                   | UPS              | \$268          | \$179         |
|                   | Communication     |                  |                |               |
|                   | RF Controls       | \$170            | \$114          |               |
| Programming       |                   |                  |                |               |
|                   | Software          |                  |                |               |
|                   |                   | Matlab           | \$404          | \$270         |
| Mechanical        | Body              |                  |                |               |
|                   |                   | Frame            | \$500          | \$334         |
|                   |                   | Equipment        | \$450          | \$300         |
|                   |                   | Fiberglass       | \$1000         | \$669         |
|                   | Propulsion        |                  |                |               |
|                   |                   | Engine           | \$1100         | \$735         |
|                   |                   | Actuators        | \$350          | \$234         |
|                   | Electrical        |                  |                |               |
|                   | Battery           | \$250            | \$167          |               |
|                   | Alternator        | \$75             | \$50           |               |
| <b>Total Cost</b> |                   |                  | <b>\$14382</b> | <b>\$9614</b> |

**Chart 7.0. – Detailed ALAN V cost breakdown.**

## 7. Conclusion

The design of the ALAN V unit is an on going developmental project that has taught its creators many lessons from its first conception in November of 1999. The Organization and commitment needed by all parties involved in a project of this magnitude is exceptional and has taught both technical a communication skills to the ALAN V team members.

The Technology used on the ALAN V project can be seen as both cutting edge and resourceful in design. Although only seven months have been invested into the project many avenues have been opened for the further development of the ALAN V project. Learning advances made by the team members will enable the project to refine its existing technology while incorporating new and better solutions to the proposed challenges of the International Ground Vehicle Competition.

## 8. Team Roster

| <b>Team Member</b>   | <b>Team</b>               |
|----------------------|---------------------------|
| Adam Krasniuk        | Mechanical                |
| Andrew Beley         | Systems                   |
| Anthony Langlois     | Programming               |
| Blair de Jong        | Marketing & Logistics     |
| Chris Maier          | Mechanical (Team Leader)  |
| Garnet Klatt         | Faculty Advisor           |
| George Bryan         | Systems (Team Leader)     |
| Jason Boyes          | Programming               |
| Jody van de Pypekamp | Marketing & Logistics     |
| John Pawluk          | Mechanical                |
| Kelvin Seier         | Programming               |
| Michael Fernquist    | Team Coach                |
| Peter Bovell         | Faculty Advisor           |
| Ratish Mohan         | Faculty Advisor           |
| Scott Cooledge       | Programming (Team Leader) |
| Scott Schiller       | Web Master                |
| Tony Carrier         | Mechanical                |