

2001 AUVSI Intelligent Ground  
Vehicle Competition  
Design Report

# ALANV II

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**Adaptive Learning Autonomous Navigation Vehicle II**



A DIVISION OF VEHICULAR TECHNOLOGIES

DeVry Institute of Technology Calgary Campus  
May 16, 2001

## **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 ALANV II is a continuation of the ALANV project which attended the 2000 Intelligent Ground Vehicle Competition. This report details the ALANV II project and outlines the differences between itself and the original ALANV project.

The intent of the ALANV II project is to give students experience working on a real world project within a multidisciplinary team. The ALANV II team consists of Electronics Engineering Technology, Computer Information Systems, and Business Operations students in a structured atmosphere as found in the workplace. The goal of the ALANV II team is create the best possible UGV while learning from the experiences gained along the way.

### 1. Team Organization

The ALANV II project focuses greatly on organization and structure after its return from the 2000 IGVC. It was found after much discussion that a proper chain of authority was not present in the prior team which led to much miscommunication. To help solve this problem, three new faculty advisors were recruited into the team and with their help; a new team structure was developed.

The new team structure that developed is comprised of three unique divisions, each with their own challenges to solve.<sup>1</sup>

- a) *Mechanical Division* – The Mechanical team is responsible for creating a new lightweight frame that could support an electric motor platform.
- b) *Programming Division* – The programming team is assigned the design of a software package that will interpret the surrounding environment and will control the ALANV II unit autonomously.
- c) *Electronics Division* – The goal of the electronics division is to provide a control system for the electric motors. The electronics division is also given the task of implementing a GPS unit into the vehicle.

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<sup>1</sup> A copy of the ALANV II project organization chart can be found in *Appendix A*.

- d) *Business Division* – The business division is responsible for planning the logistics for the trip down to Michigan. The business division also plans fundraising events and handles the team’s media relations.

To decide on matters critical to the success of the ALANV II project, division leaders first meet with their respective teams to decide on key issues. Division leader meetings are then held where the heads of each division present the concerns and views of their fellow teammates. The division heads then hold a binding vote that is supervised by one of the faculty advisors.

## 2. Project Timeline

Work on the ALANV II project started before the team had left for the 2000 IGVC. A team of students was given the task of creating a prototype for an electric vehicle that could replace the previously gas powered unit. This allowed the team to return from the 2000 IGVC with a plan for the next twelve months already in the works.

The schedule for the ALANV II includes a large amount of time for testing the vehicle before heading down to the competition<sup>2</sup>. This is done to resolve a crucial mistake in the strategy of the last year’s time management, as many components headed down without adequate testing and analysis. The schedule for the ALANV II project also is more generous than the original ALANV project, as the team has twelve months to prepare, compared to six months for the previous year.

In terms of total man hours, the team estimates that well over 375 hours of student labor was contributed to date in the creation of the ALANV II vehicle. This does not include the hours of administration and fundraising, which easily pushes the total over the 600 hour mark.

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<sup>2</sup> A timeline for the ALANV II project can be found in *Appendix B*.

### 3. Financial Considerations

The ALANV II unit is again designed with a focus on keeping the project costs down.<sup>3</sup> An example of the fiscal reasoning behind technical decisions is the frame. The chassis of the vehicle is more expensive due to the use of aluminum, but the reduced weight saves the team when it came to shipping the unit to the competition. This type of decision making is present throughout the entire design process to allow the team to get the best design for their dollar.

The ALANV II project was once again able to find generous support within the Canadian Department of National Defense, who continue their loan of the Point Grey Digiclops camera to the team. DeVry also supports the group through its Student Development Committee, with cash donations, and the use of school equipment.

### 4. Mechanical Design

The design of the ALANV II is much less complex than what was attempted by the team last year. The mechanical portion of the vehicle should be as simplistic as possible, in terms of control, maintenance and assembly. With this in mind, a layout was made of all the equipment required for an autonomous vehicle to operate. From the layouts, a basic frame size and shape was derived. It was decided that a 36" by 24" frame would provide ample deck space to hold all of the required equipment as well as a solid structure for the drive components. This approach was much different from last year's design, when an attempt was made to adapt an existing vehicle to meet the design needs (see Figure 4.0.1).

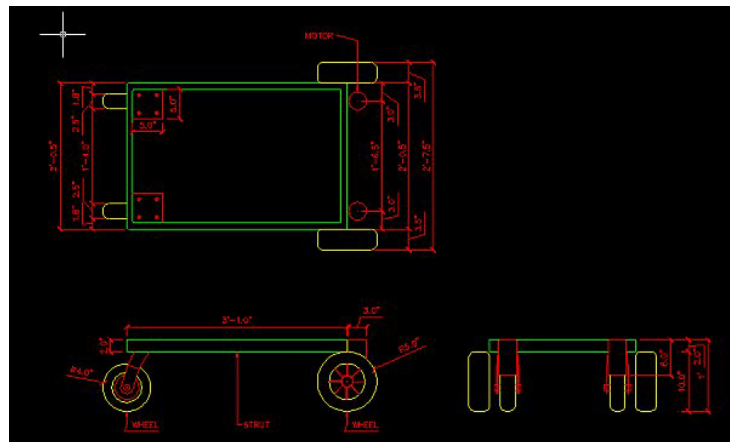


Figure 4.0.1

<sup>3</sup> A budget for the ALANV II project can be found in Appendix C.

#### 4.1 Chassis

The chassis for ALANV II is custom built to meet the needs of the project. The chassis has outside measurements of 24.5" by 35.5", formed using 1" by 2" rectangular tubing with a 1/8" wall thickness.



**Figure 4.1.1**

as it provides the strength and light weight required.

This simplistic design allows the batteries and motor controllers to be neatly tucked away below deck height and conserve space for navigation and computer systems. The design benefits are two fold as the center of gravity is lowered, in turn making the overall vehicle more stable during operation. Aluminum is used throughout the construction of the mechanical platform

#### 4.2 Drive System

The drive system is based upon two 24V / 5 amp gear reduced motors, which are mounted at the front of the vehicle using custom designed mounting brackets. This mounting point allows maximum space for other equipment and optimum maneuverability.

The forward location was determined to be the best through modeling conducted on a reduced size prototype unit. Alterations were also made



**Figure 4.2.2**

to the wheel shafts to accommodate for individual

speed sensors and monitoring systems. This is a dramatic change in comparison to the previous gas powered vehicle design, as we feel it creates a more stable and controllable platform.



**Figure 4.2.1**

### 4.3 Wheels

Rubber tires were chosen for the vehicle to provide maximum grip and vibration suppression. The front drive wheels have a diameter of 10" and are hard mounted to the motors. The trailing, rear wheels have a diameter of 8" and are mounted on an angled caster; this allows for more responsive turning. Two wheel types were selected to be compatible with each other while providing optimum driving characteristics. This layout is similar to the previous



**Figure 4.31**



**Figure 4.32**

ALAN V entry, but we choose to have the drive wheels at the front of the vehicle, giving the vehicle better mobility and tighter turning.

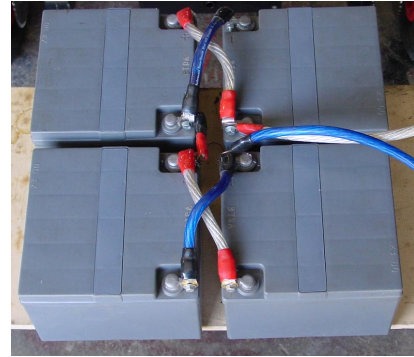
## 5. Systems Design

The objective of the ALANV II's Electronics division is to give the programming team a reliable platform on which to develop and test software. The power and motor control systems of the first ALANV were centered around a gas powered lawnmower and proved to be cumbersome in implementation. ALANV II, based upon an electric drive system improves upon the gas-based design in a number of ways. The only system remaining intact on board ALANV II is the Digiclops stereo vision camera from Point Grey Research which is used for navigation.

### 5.1 Power Supply and Regulation

Power to the ALANV II system is supplied by four +12V DC 28Ah Sonnenschein Dryfit A200 Batteries (Figure 5.1.1). To supply the 24 V DC power to the motors and electronic equipment the batteries are wired serially to double the voltage and then in parallel to increase output power of the battery system.

The regulation of the battery system for the electronics and computing systems is carried out with the use of the Genesys Rack® PS2 DC to DC power supply; model BPS-300DX/24 (Figure 5.1.2). The BPS-300DX/24 will power the PC system controlling the ALANV II, and supply external 12 V DC lines for peripheral components.



**Figure 5.1.1**

Power consumption on-board ALANV II is rated using

maximum consumption values, where each motor runs at 24 V at 5A and the power supply at 24 V at 12.5A, giving a total of 22.5A of possible drain on the battery system at any one time. The combined amp/hr capabilities of the batteries is 112 Ah at 24 V DC, therefore give us a total run time of 5.5 hours on one charge.



**Figure 5.1.2**

for the ALANV II system was found to be cleaner and more efficient than that of the previous ALAN V system. ALAN V used a gas powered alternator coupled with a single 12 V gel cell and 120 V AC inverter.

By using a completely electric system, the power supply

## *5.2 Command and Control*

The visioning and navigation computer has been upgraded to a dual-processor desktop system. The component breakdown of the computer is shown in Table 5.21.

PC Component Breakdown	
•	Two Intel® Pentium® III 866 MHz
•	1GB SDRAM
•	15 GB Hard Drive
•	32X CD Rom
•	3.5" floppy drive
•	Two IEEE 1394 Ports
•	10/100 Wireless Ethernet

**Table 5.2.1**

### *5.3 Motor Controller*

The propulsion implemented on ALANV II is fundamentally different from that of the original ALAN V design. ALANV II is based upon an electrical configuration, which warranted redesigning the electric motor control system.

The motor controller designed for ALANV II is comprised of two main components. The first is a Motorola 68HC11-based control circuit which accepts and implements all requests for motion control. The second part of the motor control system consists of two pulse width modulated (PWM) motor control boards used to actuate the two 24 V DC motors used for driving ALANV II.

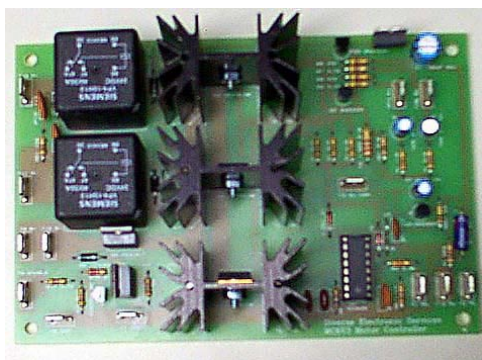
#### *Motorola 68HC11 Control Circuitry*

The control circuitry accepts all requests for movement from ALANV II and returns the speed of each motor to the navigation computer. Two modes of operation are possible in order to efficiently implement the control system. The first mode is manual control via a 2 channel Futaba™ RF transmitter and the second mode is via serial communication through a standard RS-232 COM port.

The circuit works by first receiving a command from either the RF transmitter (default) or from the serial interface. The 68HC11 first polls the RF input port, and if no signal is found, the controller is immediately sent into serial communication mode. Upon receiving a motion request, the processor converts the input data into a format capable of communicating with the motor control boards. This conversion is implemented by separating the direction and speed information, then transmitting the speed via a digital to analog converter and the direction via digital output.

The speed control system is designed to constantly feedback the speed of each wheel to the 68HC11. To implement this design two rotary encoders are attached to each wheel base to monitor the rotations of the each wheel. The output of the rotary encoders is sent to a BasicX microcontroller that translates the number of gear rotations into the actual speeds of the wheels. The 68HC11 then polls the data from the BasicX, by means of 8 bit digital communications.

### Motor Control Boards



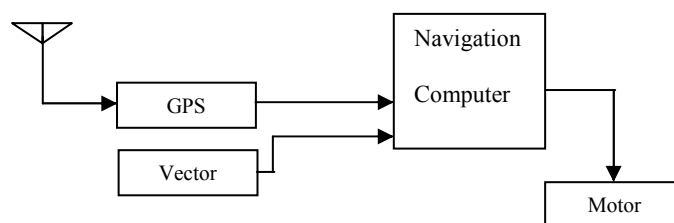
The motor control boards used to implement the drive motors onboard ALANV II are the MC6-24 PWM boards manufactured by Diverse Electronic Services (see Figure 5.3.1). The MC6-24 boards receive input signals from the control circuitry and supply the appropriate speed and direction to each motor.

Pre-manufactured boards were chosen to save design time and to increase reliability.

**Figure 5.3.1**

### *5.4 GPS Navigation*

A Motorola M12 GPS receiver is used to pinpoint the unit's location. ALANV II's coordinates are sent to the computer via serial communications in standard National Marine Electronics Association (NMEA) format. A Vector 2XG compass is used to determine the heading of the stationary ALANV II. The compass is connected to the parallel port of the navigation PC. (see Figure 5.4.1).



**Figure 5.4.1**

### *5.5 Communications*

A wireless Ethernet connection is onboard the ALANV II for testing purposes. The network connection provides a virtual PC environment that allows ALANV II to be tested from remote stations.

An RF unit from Linx Technologies is used to communicate remotely with the vehicle, to ensure that the vehicle can be safely stopped in case of an emergency. The RF unit consists of a receiver that contains a relay which will halt the vehicle instantaneously.

## **6. Software Design**

An extensive analysis of the rules of the competition and its previous competitors reveals three elements required for developing of an autonomous vehicle. The first element consists of a vision and image recognition system, which allows the vehicle to detect lines and objects. The second element is a range-finding system, which allows distance measurement of physical obstacles. The third element is a decision-making algorithm, which uses data from the first two elements to navigate through the course. A flowchart representing the software implementation for the obstacle avoidance course is shown in Figure 6.0.1. It shows the basic structural organization of the software on the ALANV II system.

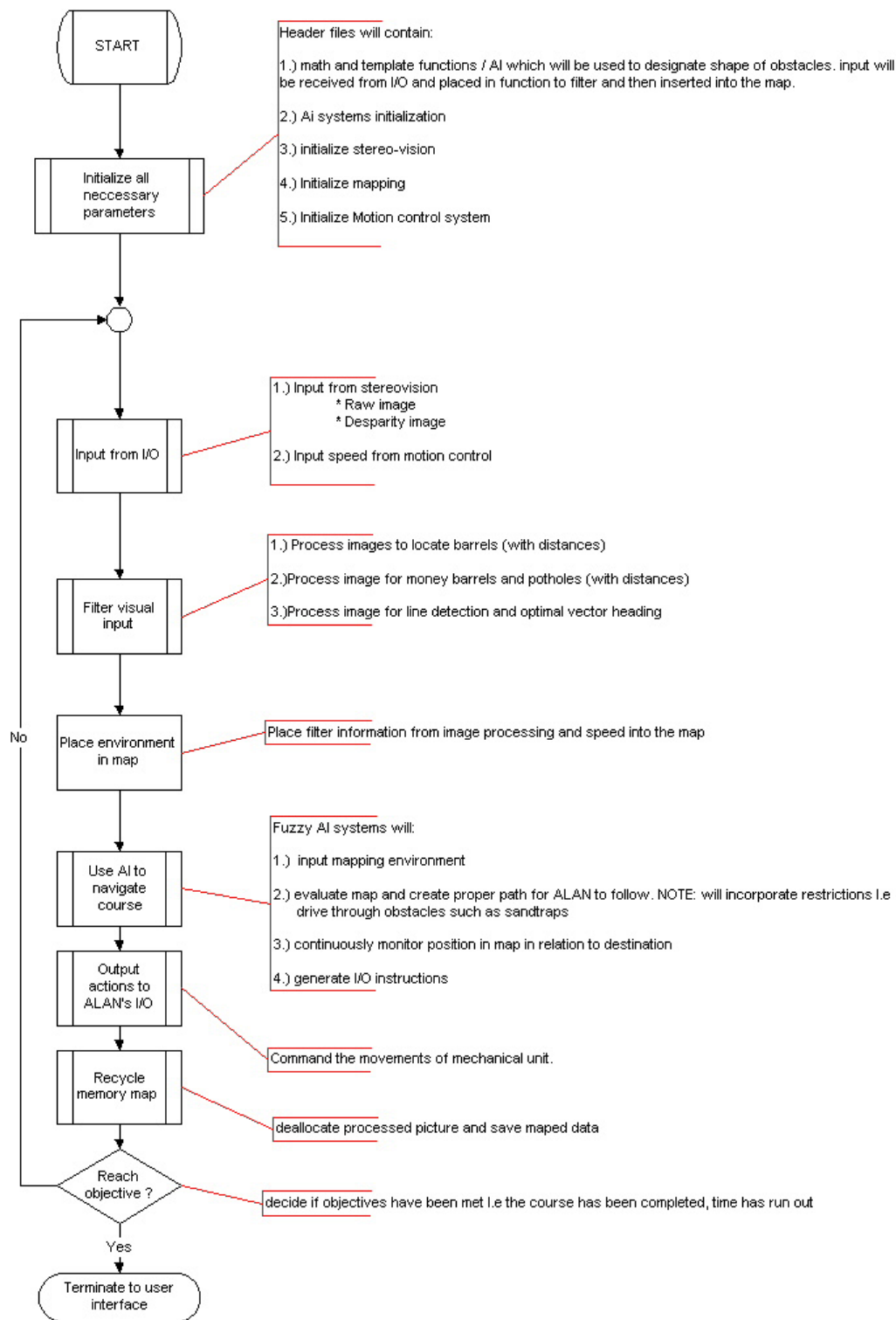


Figure 6.0.1

## 6.1 Computer Visioning System

The central visioning component onboard ALANV II is the *Digiclops<sup>TM</sup>* stereo vision system. The *Digiclops<sup>TM</sup>* is a 3 charged coupled device (CCD), IEEE 1394 Standard camera which is capable of providing gray scale raw images and distance array for calculating object distances. A distance array is a data structure which contains three dimensional coordinates of each pixel on the raw image.

The initial step of the ALANV II visioning system is acquiring a raw image and correlating a distance array for that image. After this step a series of visioning algorithms are used to define all of the given parameters of the obstacle course. The algorithms used to isolate the obstacles can be separated into three distinct processes which include barrel detection, line detection, and pothole detection.

The process of barrel detection takes a raw image and performs blur and thresholding algorithms to extract the characteristic pale lines of the construction barrels and of the course boundaries. This preprocessed image is then stored in memory for future use. The image is then converted into a binary form which is processed by a Fast Fourier Transform (FFT) algorithm using a binary template correlating to the two white lines found on the barrels. The resulting image now represents only the areas which most likely to correlate the FFT template, i.e. the barrels. The image is again threshold to extract any extraneous data in the image. Bounding boxes are formed around the resulting data which completes the detection of the barrels. To add a 3D dimension to the algorithm, the bounding boxes are then superimposed on the distance array and the resulting distance to the barrel is computed.

Pothole and money barrel detection is performed in the same manner as the barrel detection, the only difference is the template used in the correlation of the objects. By reusing the same algorithm the speed characteristics of the FFT are fully utilized and allows for more efficient code.

The line detection starts in the same manner as barrel detection, this means that saved blur and threshold image is extracted from memory. The image is then processed with a lateral scanning technique to isolate the slope of each line in relation to ALANV II. Once the slope of the line is determined, trigonometric functions are utilized to determine a vector which dictates the optimal heading and position of ALANV II. This algorithm also takes into account any possible absence of

lines on either side of the course. If no line is found an imaginary coordinate is dictated which corresponds to the 7 foot minimum clearance between obstacles.

## *6.2 Mapping System*

The ALANV II decision making process is designed to be proactive rather than reactive. The reason supporting the necessity of a proactive system lays in the avoidance of the traps in the course design. 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, one realizes 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 rather than acting upon it immediately, files it in a map (short-term memory) and leaves for analysis by the decision making aspect of the software. This addition to the software allows for better planning by the unit in avoiding obstacles and allows the advanced detection of traps. The problem with this type of system however, lies in memory consumption, with estimates of roughly one gigabyte of memory being constantly required, far too large to handle effectively. This problem is overcome through the use of a dynamic hashing algorithm that stores only the pertinent data about objects and only does that when objects exist. Additionally, this algorithm was designed such that it would set up a virtual grid of the course, giving the effect of a larger map without the costs associated with high memory consumption. One final benefit of this algorithm is that it simplifies navigation through the fuzzification of obstacle locations allowing quick decisions while still storing the exact details of the location if they are required as well as allowing a quick check for the existence of obstacles. Overall, this system increases unit performance through creating the primary element of a proactive navigation system, and through increasing the efficiency of navigation decision analysis.

### *6.3 Decision Making*

The decision making algorithms for ALANV II will use a Fuzzy Logic based process which has been upgraded for the new ALANV II design.

Accepting variables designated as inputs, a fuzzy inference system (FIS) uses a set of predetermined rules to decide upon the best possible output for the system. Each input encompasses a fuzzy set, where all likely conditions of the input are defined. Every condition possesses a membership to the set within a range of 0 to 1, with a 1 being 100%. The rules compare the members of one fuzzy set to those of another. Depending on the methods of integration used, the rules consider either the maximum or the minimum membership of all members considered. Correlating this member to the appropriate output condition of the fuzzy set, the decision is made for the FIS.

The ALANV II Fuzzy Logic process is used to make decisions for the motor controller. The input fuzzy sets to the FIS used for ALANV II include:

- The closest object to ALANV II
- The next closest object to the left of ALANV II
- The next closest object to the right of ALANV II
- The current position from both the left-hand line and right-hand line
- The current speed at which ALANV II is traveling

Each of the object fuzzy sets include an FIS of their own, as there are additional parameters to consider for the each object, such as lateral distance, distance off center from ALANV II, and distance around the object.

**Input:**

The inputs to an object FIS are derived from the data stored in the object map. Lateral distances from ALANV II to the objects are measured using the camera's stereoscopic abilities of depth perception. The distance from the center of ALANV II to the object is extracted from the parameters stored in the map. Detecting the distance between the object and anything surrounding the object is determined from data stored within the map. The individual FIS for each of the objects determines a heading in which ALANV II must travel around the object, in order to avoid the obstacle.

Though object avoidance is the main concern of fuzzy logic, the relation between ALANV II and the lines as well as the speed that ALANV II is traveling at are important factors to consider.

**Output:**

The output to the ALANV II motor controller includes both a heading and speed. The rules for the overall FIS for ALANV II govern what degree of angle the vehicle must turn in order to avoid all obstacles while remaining within the lines. The speed to perform these turns is crucial, so that they may be performed before it is too late.

### 6.4 Navigation Software

The navigation software will accept a list of five predetermined waypoints which the ALANV II will follow. The Global Positioning System (GPS) unit will determine the current location of the ALANV II.

Once the software has a fix on its location, it calculates the bearing and distance to the next waypoint. The software then receives the current bearing from the compass and

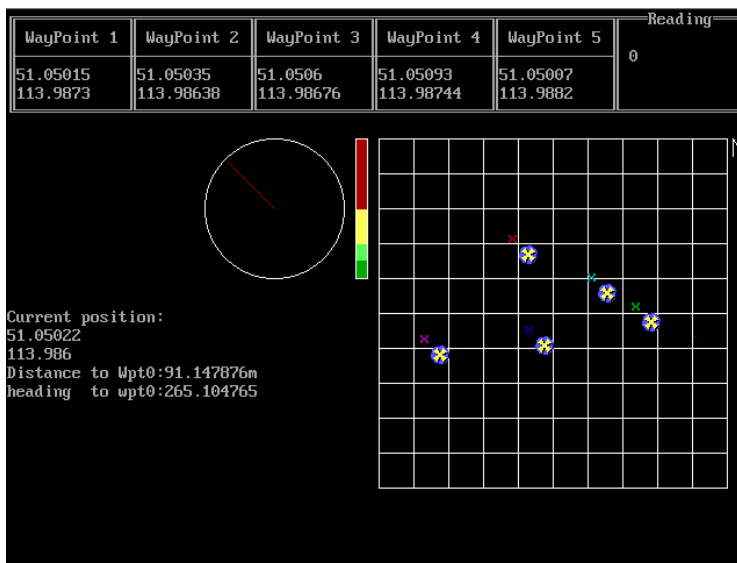


Figure 6.4.1

turns itself until both readings match. Once within an acceptable range of the waypoint it switches to the next.

The screen shot, (Figure 6.4.1) shows the graphic interface of the GPS navigational software. The lines in the circle represent the calculated bearing and the compass bearing (not shown). The GPS coordinates of the vehicle's location are plotted on the grid along with the designated waypoints.

## **7. Safety and Object Awareness**

A paramount factor in the design of the ALANV II system was integrating safety precautions into the unit. In order to ensure the safe operation of ALANV II, an emergency stop button is placed at the rear. In addition to the onboard e-stop, two RF stops are also included. The first RF system works by cutting power to the motors. The second RF safety feature incorporated into the motor controller system overrides the Navigation Computer when data is received from the RF transmitter. This enables users to manually control the ALANV II system.

ALANV II is equipped with a blue beacon which will show observers that various obstacles have been detected. This system works through an ISA expansion slot and simply activates timed relay witch for every object detected.

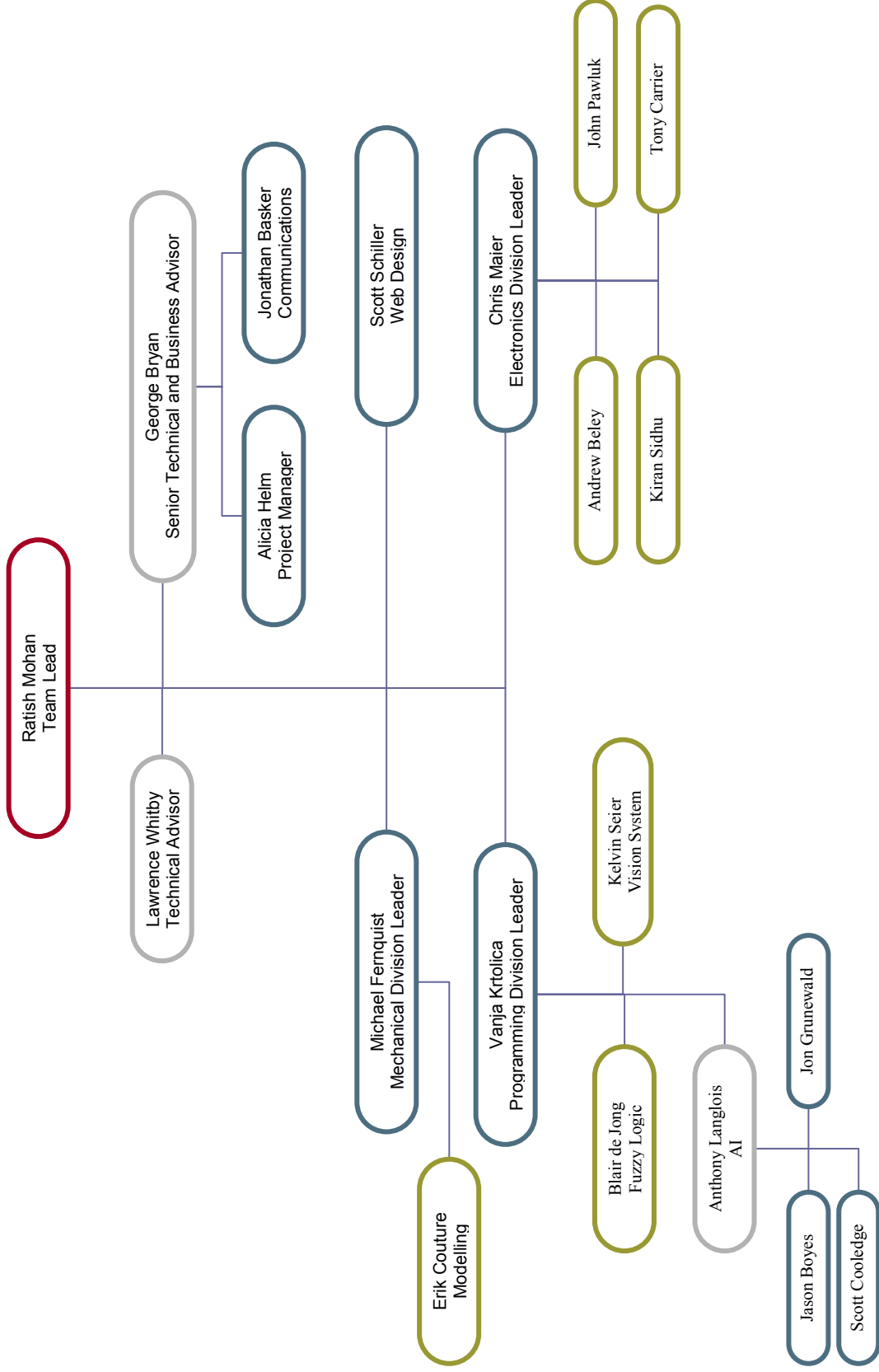
## **8. Conclusion**

The process of design, education, and real world applications are all fundamental concepts that the ALALNV II team has embraced. Throughout the past two years of IGVC competitions, many valuable lessons have been learned that could not be achieved by any other means. ALANV II team members have learned valuable lessons in team organization, funding allocations, and engineering design.

While the team is very proud of the ALANV II project, planning is already underway for the development of ALANV III by a bright, new team. With continued commitment, dedication, and support, the ALANV project will continue to advance the field of Vehicular Technologies for years to come.

## **Appendix A**

Organization Chart



Team Roster

<b>Member</b>	<b>Academic Department</b>
A.J. Basker	Business Operations
Alicia Helm	Business Operations
Andrew Beley	Electronics Engineering Technology
Anthony Carrier	Electronics Engineering Technology
Anthony Langlois	Computer Information Systems
Blair de Jong	Electronics Engineering Technology
Chris Maier	Electronics Engineering Technology
Erik Couture	Electronics Engineering Technology
Garnet Klatt	Administration
George Bryan	Electronics Engineering Technology
Jason Boyes	Computer Information Systems
John Pawluk	Electronics Engineering Technology
Jon Grunewald	Computer Information Systems
Kelvin Seier	Electronics Engineering Technology
Kiran Sidhu	Electronics Engineering Technology
Lawrence Whitby	Faculty
Michael Fernquist	Electronics Engineering Technology
Ratish Mohan	Faculty
Scott Cooledge	Computer Information Systems
Scott Schiller	Computer Information Systems
Vanja Krtolica	Computer Information Systems

## **Appendix B**

Condensed Project Timeline

ID	Task Name	Duration	Start	Finish	Predecessors
1	<b>Prototype</b>	45 days	Mon 25/09/00	Fri 24/11/00	
8	<b>Mechanical</b>	62 days	Mon 27/11/00	Tue 20/02/01	7
9	<b>Body</b>	57 days	Mon 27/11/00	Tue 13/02/01	
17	<b>Power Plant</b>	39 days	Mon 27/11/00	Thu 18/01/01	
24	<b>Motor</b>	25 days	Mon 27/11/00	Fri 29/12/00	
31	<b>Outer Shell</b>	57 days	Mon 04/12/00	Tue 20/02/01	
36	<b>Electronics</b>	148 days	Mon 27/11/00	Wed 20/06/01	7
37	<b>GPS</b>	126 days	Mon 27/11/00	Mon 21/05/01	
47	<b>Sensors</b>	78 days	Mon 27/11/00	Wed 14/03/01	
52	<b>Motor Controller</b>	66 days	Thu 07/12/00	Thu 08/03/01	27
59	<b>Computers</b>	91 days	Mon 27/11/00	Mon 02/04/01	
70	<b>Compass</b>	91 days	Mon 27/11/00	Mon 02/04/01	
80	<b>Camera</b>	19 days	Wed 14/02/01	Mon 12/03/01	
84	<b>Power Supply</b>	148 days	Mon 27/11/00	Wed 20/06/01	
85	Research Power Supplies	14 days	Mon 27/11/00	Thu 14/12/00	
86	<b>Accumulate Power Needs</b>	66 days	Tue 20/02/01	Tue 22/05/01	
93	Design Power Source	7 days	Fri 27/04/01	Mon 07/05/01	87,90,91,92
94	Impliment Complete Power Supply System	14 days	Tue 08/05/01	Fri 25/05/01	93
95	<b>Misc</b>	85 days	Mon 27/11/00	Fri 23/03/01	
96	<b>Design Emergency Stop System</b>	85 days	Mon 27/11/00	Fri 23/03/01	7
97	<b>Option 1 - In House</b>	72 days	Mon 27/11/00	Tue 06/03/01	
108	<b>Option 2 - Purchase</b>	85 days	Mon 27/11/00	Fri 23/03/01	
116	<b>Blinking Light</b>	72 days	Mon 27/11/00	Tue 06/03/01	
122	<b>Programming</b>	130 days	Mon 27/11/00	Fri 25/05/01	7
123	<b>Visioning</b>	130 days	Mon 27/11/00	Fri 25/05/01	
124	<b>Decide on Imaging options</b>	130 days	Mon 27/11/00	Fri 25/05/01	
125	<b>Option 1 - In House</b>	130 days	Mon 27/11/00	Fri 25/05/01	
131	<b>Mapping</b>	28 days	Mon 27/11/00	Wed 03/01/01	
134	<b>AI (fuzzy logic)</b>	43 days	Mon 27/11/00	Wed 24/01/01	
144	<b>GUI</b>	61 days	Mon 27/11/00	Mon 19/02/01	
148	<b>Sensors</b>	16 days	Mon 27/11/00	Mon 18/12/00	
149	<b>GPS</b>	16 days	Mon 27/11/00	Mon 18/12/00	
151	<b>Decide distance measurement device</b>	7 days	Mon 27/11/00	Tue 05/12/00	

## **Appendix C**

Estimated Project Budget

Team	System	Part	Cost	
			CND \$	US \$
Electronics				
	Command & Control			
		Main Computer	\$2100	\$1340
		Power Supplies	\$450	\$290
	Sensors			
		Speed Sensors	\$120	\$76
		Microcontrollers	\$250	\$160
		Compass Module	\$180	\$115
		Digiclops	\$7265	\$4875
	Power Supply			
		Batteries	\$450	\$287
	Communication			
		Wireless Ethernet	\$900	\$576
		RF Controls	\$170	\$109
Programming				
	Software			
		Matlab	\$404	\$259
Mechanical				
	Body			
		Frame	\$1400	\$895
		Equipment	\$450	\$287
		Fiberglass	\$900	\$576
	Propulsion			
		Motors	\$1000	\$640
		Motor Controllers	\$330	\$211
		<b>Total Cost</b>	<b>\$16,369</b>	<b>\$10,696</b>