Bluefield State College

Anassa Design Report 2008

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I, Dr. Robert Riggins, Professor of the Department of Electrical Engineering Technology Department at Bluefield State College do hereby certify that the engineering design of the vehicle, Anassa IV, has been significant and each team member has earned at least two semester hours credit for their work on this project.

Signed, Date

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l. Introduction

The robotics team at Bluefield State College (BSC) is pleased to present Anassa IV for entry into the 16th annual Intelligent Ground Vehicle Competition (IGVC). Anassa IV has evolved from previous IGVC robots, Anassa I, Anassa II, and Anassa III. Each subsequent generation of Anassa has incorporated design innovations that improve overall performance. Anassa IV is no exception; the robotics team has imbedded a number of design innovations in Anassa IV, these include:

- Design of a new locomotion controller with many features
- Integration of an Inertial Measurement Unit (IMU) with the compass
- Installation of a new and improved compass
- Incorporation of many software upgrades
- Addition of two more camera types to extend Anassa's vision versatility
- Incorporation of voice reception and synthesis to aid in testing
- Installation of a wireless mouse and keyboard
- More rugged design of the hardware, especially the main computer
- Elimination of all components requiring power inverters
- Addition of two more ways of manually controlling the robot for safety

The report will elaborate in more detail on these design innovations.

The robotics team took a radical new approach to the design planning process for Anassa IV. Therefore, this report will focus on this new planning process and how it affected the design of Anassa IV. Crucial to the process was a documented performance review and failure analysis of last year's Anassa III robot, completed by the Anassa III team in the days immediately following the 2007 IGVC. The design innovations listed above originated from this review and analysis.

This report will describe both the design process and the product of the process in detail; however, we will first discuss briefly our intended audience, our contributors and sponsors, and budget considerations.

2. Audience/Customers

Although the judges and other participants of the Intelligent Ground Vehicle Competition (IGVC) event remain our primary short term focus, there are several secondary programs that benefit directly from the efforts made on Anassa IV. First and foremost is the benefit that designing a robot such as Anassa IV for IGVC has had on the individuals on the team. Team members, some who have been to many IGVC events, have benefited greatly from the knowledge and experience gained. So, in a sense, we are our own consumers! Another consumer for Anassa IV would be the Bluefield community's team that participated in last year's Defense Advanced Research Projects Agency (DARPA) Urban Grand Challenge. The Center for Applied Research and Technology (CART), Inc. is our technology transfer affiliate and it is currently involved with autonomous vehicle research, mining safety, power utility maintenance, and other projects. Thus, CART is definitely one of our consumers also.

3. Contributors and Sponsors

The Anassa IV team continues to benefit from local industries. These businesses have a great relationship with the robotics team, and often hire previous team members before and after graduation. These local industries have made donations of parts, discounted product, or provided assistance in some way that has greatly benefited our projects. For Anassa IV, these industries are Pemco, Inc., ConnWeld Industries, WalMart (Bluefield, Va.), Bucyrus, Miller Associates, and Charlatte America.

4. Funding and Budgetary Considerations

In addition to the sponsors listed above, BSC and CART also provided funds for Anassa IV. Funding for the project was limited and so we operated within tight budgetary constraints. Expense was many times the determining factor in our equipment selections. To reduce the expense of the project, we used inventoried components when available and solicited donation of parts as much as possible. Nevertheless, the reduction in cost techniques did not reduce the performance capability of Anassa IV. Components used in the project are itemized in Table 2 along with their actual and replacement costs.

5. Design Planning Process

Our current design process for Anassa IV began with evaluating Anassa III's performance in the 2007 competition. This evaluation was done by Anassa III's IGVC team in the days following the competition. That team fully documented the performance analysis, a failure analysis, and possible solutions for the failures in a report. The robotic team used this document as a starting point for two robotic designs: one for a modified Anassa III (called Anassa IV) and a new robot (called Archon). Archon's design will address all of the previous team's evaluation points, while Anassa IV will focus on a few of the most important (determined by the Anassa IV team). Archon requires a radically new design and is unproven, while Anassa IV will keep most of Anassa III's proven basic design. Archon is presented in another report by the Archon team.

5.1 Performance Review and Failure Analysis of Anassa III

Anassa III did not navigate the course well enough to complete the entire course during the competition; however our observation of Anassa III's behavior reveals several problem areas. Later in this section we will disclose our efforts to correct Anassa's problems. The highlights of Anassa III's failure analysis are as follows:

- Early in the course Anassa III turned around 180 degrees and began navigating the course backwards. Our program was unable to detect a "turn around".
- Many times, the main computer re-booted in the middle of autonomous and navigation runs, causing the robot to run in unpredictable ways. The computer was not rugged enough. We had many intermittent problems associated with a loose serial board, vulnerable hard drive, and the motherboard flexing and shorting out on the bottom of the case.
- Anassa III responded properly to the wireless E-Stop but the E-Stop would inexplicitly shut down the robot in the middle of autonomous and navigation runs.
- Although Anassa III performed flawlessly in tests and simulations, the robot had frequent collisions with obstacles and often penetrated barriers.
- Anassa III seemed to have trouble computing proper heading when close to waypoints, causing the robot to overshoot and circle the waypoints.
- Anassa III was plagued with communication failures between the computer and input/output devices, possibly caused by interference.
- The main computer was at times overloaded and may have caused cycle time to exceed our goal of 100 milliseconds per cycle.
- The rough terrain of the course was not absorbed well by Anassa III. All vibrations caused by the terrain were transmitted to the internal circuits and exposed many problems with poor connections and connectors.
- The Anassa III control panel hosted many control switches which were confusing to the operator who must make switch setting decisions quickly and in the correct sequence. This problem delayed the initial start-up on the robot.
- The recorder on the camcorder malfunctioned, allowing no recording of the course for post-review and performance corrections.
- The two main batteries did not supply all robot power (for example, the camera operated on battery too). The team had to remember to charge all batteries.

- When Anassa III tried to back up, the swivel wheels would occasionally bind.
- The robot could be deployed without the sensors operating and the operator would be unaware until Anassa III's behavior revealed that it was navigating without sensor information.

5.2 Possible Solutions to Anassa III Shortcomings

- Our solution to the control panel problem was to automate all set-up tasks and reduce the controls to a single switch to initialize set-up. This prevents human error and/or confusion.
- A solution to not knowing the functionality of sensors is an on-screen checklist for diagnostic testing (including sensors) to be done automatically by the robot. Now upon start-up we will know if the sensors are operational before deployment.
- We propose to convert the hard drive to solid state flash drives, however in the interim we mounted the hard drives in a vertical position to reduce the influence of vibration causing the read/write heads to crash on the discs. All plug-in cards are now latched in place and we have non-conducting matting underneath the motherboard to prevent electrical shorting to the case.
- We propose distributed computing to ease the burden of the main computer. For example, an 8-bit microprocessor now controls the two motors, freeing up the main computer to perform tasks such as sensor integration and path finding. Also, by implementing distributed computing and control it is possible to do failure detection, isolate the problem and recover from a computer failure. For example, a special "floating" controller or computer could monitor outputs and take over a task it deviant behavior is detected.
- To fix the problem of not being rugged enough, we propose to improve the suspension system by the addition of oil filled shock absorbers. Also questionable connectors should be replaced with rugged ones.
- The heading problem would be solved by acquiring a new compass and integrating IMU data with the compass to give heading data much more rapidly.
- To fix the camcorder's recording malfunction, we proposed to either purchase another camcorder or a better outdoor fire wire camera, we implemented both.
- Having to charge multiple batteries would be alleviated by building and installing DC-to-DC converters for all separately-powered devices.

- We propose to use software to interpret sensor data from the compass, GPS, and the IMU to inform the robot when it has turned 180 degrees on the course.

Anassa IV implements all of the above proposed solutions.

6. Design Considerations

6.1 Safety

Anassa III's hardware and software incorporate several safety features. First, the hardware utilizes multiple E-Stops to provide several levels of control. Anassa IV now has three ways to manually E-Stop the robot, and three wireless ways. Second, software programs continually monitor the system for errors in control, communications, and battery charge levels. Third, "Heartbeat" (fault monitoring) signals are measured at critical points in the system. Finally, the software has the inherent "failsafe" ability to abort the current mission and shutdown the vehicle in the event an error is detected.

6.2 Computer-Aided Design

AutoCAD, Inventor, and Solid Edge computer-aided drafting packages were used in the mechanical design of the vehicle. A sample of Solid Edge modeling of Anassa III's body is shown in Figure 1. Pemco, a local industrial sponsor, used our designs to fabricate most of Anassa's body parts.

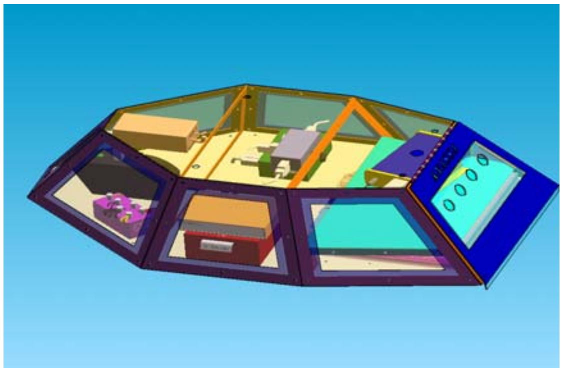

Figure 1 Solid Edge Modeling of Anassa's Body

6.3 Computer Simulation

The software simulation that the robotics team had written for previous robots is still being used to test new integration and path finding routines. Computer simulation of sensor data was utilized to provide a controlled environment for testing and debugging algorithms associated with autonomous navigation. Using this simulator greatly accelerated the programming process. Figure 2 shows the main screen used by the simulator. It is clear from this figure the simulator emulates an actual IGVC course from the past (IGVC 2005 at Traverse City).

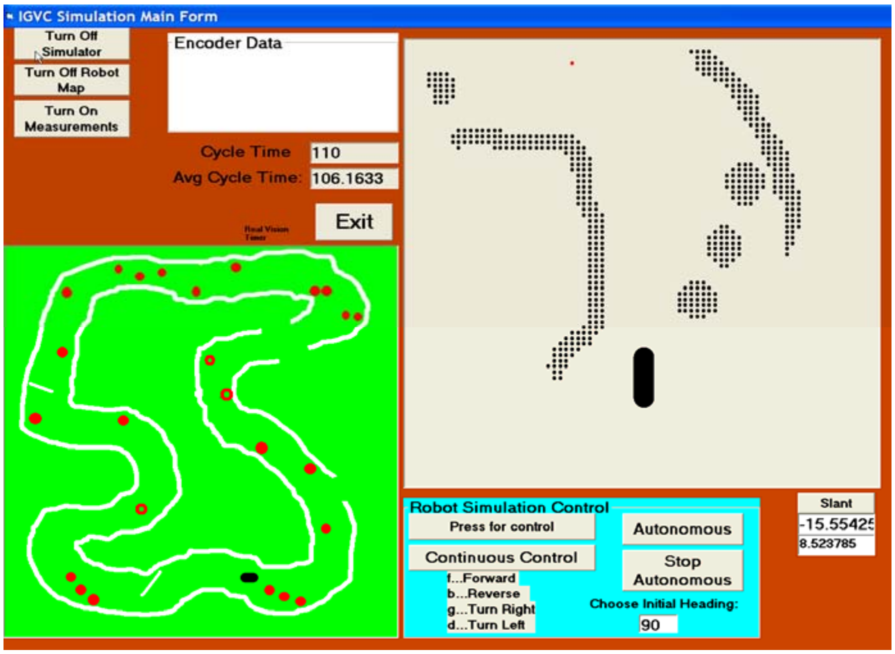

Figure 2 Screen Capture of Simulation

7. Mechanical Design

7.1 Vehicle Frame and Chassis

Anassa IV retains the sturdy frame and chassis from Anassa III. For purposes of identification and completeness we will describe the frame and chassis in detail.

Anassa IV uses a modified frame and chassis of a Jazzy 1170XL electric wheelchair. The frame is constructed of fourteen-gauge milled square steel tubing that is built to sustain a payload of four hundred pounds. Both the frame and chassis components are weatherized with a primer coating and multiple layers of enamel paint.

The chassis components include an active-track suspension system that allows all wheels of the drive system to travel independently as the vehicle moves across uneven terrain. The vehicle is elevated by sixteen-inch pneumatic tires (the drive axle), adjustable nine-inch rear articulating caster wheels, and adjustable eight-inch anti-tip wheels for stability. The arrangement of the wheels provides a four and one quarter-inch ground clearance which generates a low center of gravity. This, coupled with the active-track suspension system, gives the robot a curb-climbing height of six inches. The overall robot base of twenty-two and one-half inches wide by forty-five inches long provides a tight turning radius of twenty-three inches.

Comment [JLF1]: "Active-track" is probably a company coined name given to the suspension system and probably should be in quotation.

7.2 Drive System

Comment [JLF2]: Need some indication of vehicle top speed and ramp climbing ability. These suggestions are in the predicted performance section of the rules.

Anassa IV retains the successful drive train of Anassa III. The drive train consists of two twenty-four volt DC motors that provide vehicle locomotion. The motors are connected through a speed reducer to the drive axle. The speed reducer converts the high speed, low torque output of the motors to a low speed, high torque required to move a four hundred pound payload.

The robot is equipped with two braking systems. The regenerative braking system slows the vehicle down and a mechanical disk parking brake prevents the vehicle from moving.

7.3 Body

Anassa IV incorporates structural modifications to allow rapid separation of the body from the chassis. The body provides easy access and protection of the instrument compartment from the weather. The overall design of the body contributes to the aesthetics of the robot, with the clear, tinted lexan plastic panels revealing the interior components of the instrument compartment while sealing out dust and moisture.

All the frame components of the body are made of aluminum to provide strength with minimum weight. To maintain rigidity, the aluminum elements are TIG-welded together to form a single unit construction. The body seals the instrument compartment with weather stripping, rubber grommets, and sheet metal skirts. The mast and body are removable from the chassis to facilitate the loading and transportation of the robot.

8. Electrical Design

8.1 Power System

Comment [JLF3]: Could use some more info here on battery life (suggested in rules).

Unlike Anassa III, the two deep-cycle 12-volt batteries supply all power to the components of Anassa IV. This has several advantages. First, a single battery charger now charges the entire robot. Second, a 12-volt to 5-volt DC-to-DC converter was eliminated, giving Anassa IV more available interior space.

8.2 E-Stops

Anassa IV has both a Soft E-Stop and also a Hard E-Stop located on the rear instrument panel. The on-board Hard E-Stop switches all power on/off. The on-board Soft E-Stop and the wireless E-Stop both switch the controller on/off, but they do not switch the main power. These two systems are independent of each other for additional safety. The wireless radio controlled (RC) E-Stop has been installed that extends our control range to fifteen hundred meters.

8.3 Wiring

The team completely moved and changed the components and wiring inside Anassa IV's body. Some of the component changes in Anassa IV include the addition of a new control system box, an IMU, the elimination of one of the power converters, and the elimination of three components associated with the old control system.

8.5 Special Strobe Lamp

Another feature of Anassa IV is its strobe lamp. The strobe lamp is basically an attention grabber and it is attached to the mast for maximum visibility. Visibility is also enhanced because the strobe is very bright and can easily be viewed in full sun. This strobe is programmable and can indicate any condition we desire and can also alternate between multiple parameters. Currently the strobe is activated when Anassa III detects an object in its path, and it also flashes to confirm when the vehicle has passed a waypoint location.

8.6 Sensors

The following is an itemized list of Anassa IV's sensors and a brief description of their function.

CSI Wireless DGPS receiver and antenna: Retrieves the latitude and longitude and determines velocity and heading.

Forward SICK Laser Measurement System (LMS): Sweeps 180 degrees for object avoidance. Although the LMS range is 80 meters, Anassa IV requires only 8 meters of this range.

Firefly camera: A fire wire camera that is optimized for speed, outside environments, and high resolution. It has a smaller field of view (FOV) than the camcorder.

Digital Camcorder: Provides the vision of Anassa IV and is used to detect markings on the ground as well as objects in the path. Has a wide FOV.

Digital Compass: Determines Anassa IV's heading in addition to the DGPS heading. The digital compass is important when the vehicle is stationary. The digital compass is redundant to the DGPS.

Encoders: Supplies distance traveled and the direction traveled. They are attached to the drive motor shafts.

IMU: Determines heading and is redundant to the DGPS.

Rear SICK Laser Measurement System (LMS): Sweeps 90-degrees to give the vehicle object avoidance ability when doing reverse locomotion.

9. Software Design

For IGVC 2007 the team had focused on designing a new and effective scheme for sensor integration and path finding. As indicated in our post-IGVC 2007 performance review and failure analysis, Anassa III did not take full advantage of this new program. The focus of the 2007 team was on design, and the focus for the current 2008 team is on performance and parameter tuning. The current team has high confidence in the previous sensor integrator and path finder; therefore, much time was spent this year on streamlining and perfecting the program. In this section we present details on this integrator and path finder, with emphasis on parameter tuning and optimization through simulation and testing. This section also covers other software design innovations that set Anassa IV above the previous generations of Anassa.

9.1 Sensor Integration

As with Anassa III, the sensor integration program places all sensor information available to Anassa IV on a single software map. Sensor data comes in two types: robot self information, and surrounding obstacle information. Both types are vital to the map. For the sake of the path planner described in the next section, the map needs precise robot position and attitude relative to the surrounding environment. All sensor data and their level of confidence are placed on the map. Signal processing of the sensor information has transformed the sensor data to a standard Cartesian coordinate plane surrounding the robot. Sensor information that is placed on this map comes from the camera, the rear LMS, the front LMS, the DGPS, the compass, and the IMU.

The attributes of the map were chosen to give Anassa IV an adequate field of view with a sufficiently small resolution, but not so small as to overburden the computer. The map surrounds the robot such that the map's horizontal field of view is six meters to the front, two meters to the rear, and four meters on each side. This field of view is more than adequate for the autonomous challenge. Testing has shown that Anassa IV's autonomous challenge program takes less than 100 milliseconds per cycle, definitely fast enough for a five-mile-per-hour robot!

Comment [JLF4]: Need some indication of the distance that obstacles can be detected (rules).

9.2 Path Following and Obstacle Avoidance

The output of the Sensor Integrator and the input to the Path Planner is a matrix of nodes called the "map." The map contains all information from Anassa IV's sensors, covering an eight-meter by eight-meter area. Path markings, obstacles, and the robot are represented on the map as nodes or groups of nodes. The sand, bridge, bridge glare, and bad spots in the grass can be included on the map.

The output of the Path Planner is a path from robot to a computed goal node. Two outputs sent to the controller module are the initial speed and direction that the robot needs to do to begin executing the path. The Path Planner recalculates the path on each cycle (total cycle time is kept less than 100 milliseconds) and outputs speed and direction after each program cycle.

The Path Planner used in Anassa IV is the same as used for Anassa III, except for the streamlining and parameter tuning described above. The Path Planner uses the following four-step process:

1. *Calculate the "map slope" and "slope confidence"*
2. *Set the goal node based on minimizing a cost equation*
3. *Find the optimal path between robot and goal*
4. *Execute the planned path by outputting speed and direction*

The first step determines the best direction to search for a goal node. The autonomous challenge has lanes that are roughly linear and parallel. The lanes are not perfectly linear or parallel but may have missing segments and curves, and obstacles may obscure the linearity of the lanes. Anassa IV uses a concept (as Anassa III did) called "map slope" to head in the right direction despite missing segments and curves. The map slope represents a rough estimate of the quantity of linear components on the map and measures their average slope. This process involves correlating computer-generated lines with real lanes detected by the vision module. Along with the map slope, a “slope confidence” is also computed. The slope confidence is based on the total amount of measurable linearity of these components. Knowing both slope and confidence helps Anassa IV choose the best direction to search for a place to assign the goal node and keeps the robot from exiting the path through a dashed line. To do this, these two values are used in a cost equation in the next step to help set a goal node.

The second step of the path planner is an algorithm that determines the goal node by minimizing the cost function for each node. The cost function was experimentally determined, is applied to each node, and is a function of many parameters, as shown below:

$$Cost = 1/\left\{A * B * \left[1 + C * e^{(-.05*(D-E)-(F/G))}\right]\right\}$$

Parameters include the distance between robot and node (A), a Boolean variable indicating whether the node lies between obstacles or markings (B), a weight indicating the amount of importance of map slope (C), map slope (D), the angle between straight ahead and the vector between robot and node (E), the importance of map slope correlation (F), and the actual map slope correlation (G). The node that minimizes this relation becomes the goal node for the current 100 millisecond cycle.

Once the algorithm chooses a goal node in Step 2, a modified “wave front” routine in Step 3 calculates the shortest path between the robot’s node and the goal node. Beginning at the goal and working back towards the robot, the wave front routine assigns values to all clear nodes, starting with a zero value at the goal and increasing the value until it reaches the robot. High values are assigned to the obstacle nodes. The more confidence we have that our sensors “see” an obstacle or marking, the higher the value for that node. Candidate paths flow “downhill” from the robot to goal. Another routine similar to the well-known A-star routine finds the most direct candidate path. The robot then chooses the best path to take to the goal and smoothes the sharp corners.

Finally, in Step 4 of the Path Planner, the program outputs speed and direction commands to the controller module. These commands are consistent with the calculated path described above. However, this path is re-calculated on each controller cycle since new obstacles and markings may be detected at any time. Thus, on each cycle, these two commands are the commands needed to execute the *initial* phase of the planned path. Thus, our plan is constantly evolving on each cycle.

Comment [JLF5]: Judges will be looking for how the bot will deal with switchbacks and dead ends.

9.3 Software Design Innovations

Comment [JLF6]: Pictures are worth a thousand words! Why no pictures?

The following is a summary of software design innovations in Anassa IV.

- The control software is implemented with a PIC microcontroller which simplifies the control functions, frees up processor time for other functions, and gives us another method of manual control.
- Voice control software supplies us with an alternative method of communication with Anassa, such as switching components on or off without physical switches. Also, Anassa IV can announce events to its listeners such as when passing waypoints and seeing obstacles, etc.
- The program allows the operator to select from three separate cameras. The program sets the parameters based on the particular camera we select.
- The vision program was completely rewritten. It still correlates measured color vectors to pre-stored hypotheses, but now the process is automated and more efficient than Anassa III.
- A software filter designed by the team blends IMU and compass data
- Using the compass, DGPS, and the IMU, the new program can detect and recover from unintentional 180 degree turns on the course.
- All functions have been consolidated into a single program. This avoids having to run separate programs and is less confusing to the operator when under competitive conditions.

10. Computers

Anassa IV uses a hardened version of the desktop-type computer that Anassa III used in IGVC 2007. As indicated in the performance review, at higher speeds, Anassa III's computer suffered resets and shorts due to flexing boards and physical damage in IGVC 2007 due to grass clumps and other unevenness. Also, Anassa III's computer was mounted outside and underneath the protective body. Since Anassa IV's new control system allows for a lot more room inside the body, the computer is now inside too. This gives better protection to the computer and allows much shorter connections. The desktop unit has been designed to operate with twenty-four volts DC. Other features of the desktop unit are: dual processors, two gigabytes of ram, and a one gigahertz front side bus. We use a wireless keyboard and mouse to operate and program Anassa IV, so we do not need to provide additional real estate for those items.

In addition to the main computer, we also use several microcomputers to handle various tasks. For example, a pic18F452 processor controls the locomotion of Anassa IV. This distributed computing allows the main computer more time to perform the sensor integration and path planning described in the previous section.

11. Reliability, Durability, and Performance

11.1 Reliability and Durability

Because of all these design innovations that are added to Anassa IV, the design team has made the robot more reliable and rugged. Many of the components, including the computer as described in the previous section, were made “tougher”. The new micro-controlled control system has fewer parts but adds a lot more capability to the robot. Also, the software has been “cleaned up”, streamlined, and optimized for IGVC.

11.2 Analysis of Performance

Design parameters and simulations indicate that Anassa IV should perform as indicated in Table 1. The table also records the results of actual testing. An analysis of components and performance is included for each prediction listed in the table. Some differences between Anassa III’s performance and Anassa IV’s performance are the maximum speed, turn reaction time, and battery life. Because of the new controller, the maximum speed is now very close to 5 mph, and the turn reaction time has increased. Actual battery life has fallen somewhat due to several reasons: the batteries are older, and we now power everything including the computer and the cameras from the same batteries.

Table 1 Anassa IV Performance

Performance Measure	Performance Prediction	Performance Results
Speed	5 mph	4.9 mph
Ramp Climbing	20-degree incline	20-degree incline
Turn Reaction Time	180 degrees/ second	180 degrees/second
Battery Life	5 hours	3 hours
Stop Reaction Time	Immediate	Almost Immediate
Object Detection	0 to 8 meters	0 to 8 meters
Dead-Ends and Traps	Path-planning avoids these	Works nearly 100%
Potholes	Chosen paths are clear of potholes	Works nearly 100%
Waypoint Accuracy	2 feet one sigma	2 feet one sigma

Table 2 Anassa IV Parts and Costs

QUANTITY	DESCRIPTION	OUR COST	Replacement COST
1	1170 Wheelchair frame(Used)	$1,037	$5,977
1	Desktop computer	$1,300	$1,300
1	Sony camera	$700	$700
1	180 degree LMS(SICK)	$3000	$5000
1	90 degree LMS(SICK)	$3000	$5000
1	DGPS-w/antenna/cables	$2100	$3000
1	Aluminum Platform	$0	$500
1	Wireless E-stop	$100	$100
1	Compass	$700	$700
1	Power monitor for JAUS	$12	$12
1	Heavy Duty 50-amp switch	$50	$50
1	24 to 12 volt dc to dc	$200	$200
1	Soft E-Stop	$20	$20
2	Heavy duty 24-volt charger	$300	$300
2	24-volt pc power supply	$250	$250
1	Pic18F452 and parts	$25	$25
5	Toggle Switches	$16	$16
1	Misc. Cables & Connectors	$50	$80
1	Misc. Screws & Hardware	$20	$50
1	Gyro and controller	$300	$500
1	USB Router 2.0	$20	$20
1	Fuse panel	$0	$20
1	Strobe light and electronics	$30	$30
Total		$13,230	$23,850

12. Cost

The cost estimates of each subsystem of Anassa IV are displayed in Table 2. Note, these are costs to duplicate Anassa IV, and do not reflect the team's actual costs.

13. Anassa IV Team

The Anassa IV team is displayed in Table 3. We include in the table the names of all the members, their academic department and class, and an estimate of the man-hours expended.

Table 3 Team Information

Team Member	Responsibilities	Class Level- Major	Est. Hrs Wrk
Justin Milam	Team Leader	Soph–Electrical	600
James Cardwell	Software Design	Soph–Comp Science	300
John Browning	Image Processing Mechanical design	Soph–Mechanical	300
Bryan Lemon	Software Design	Senior-Comp Science	300
Dwight Backus	Documentation	Senior–Electrical	100
Brad Fields	Software Design	Senior-Comp Science	100
Louis McAllister	Software Design	Soph–Comp Science	50
Tony McAllister	Electrical Design	Fresh–Electrical	20
Cailan Blankenship	Electrical Design	Junior–Electrical	20
Jason Williams	Electrical Design	Senior–Electrical	20
Weston Monk	Electrical Design	Senior–Electrical	20
James Martin	Mechanical Design	Soph–Mechanical	10
Anthony Johnson	Electrical Design	Senior-Electrical	10
Mike Handy	Electrical Design	Junior-Electrical	10
		Total Hours	1880