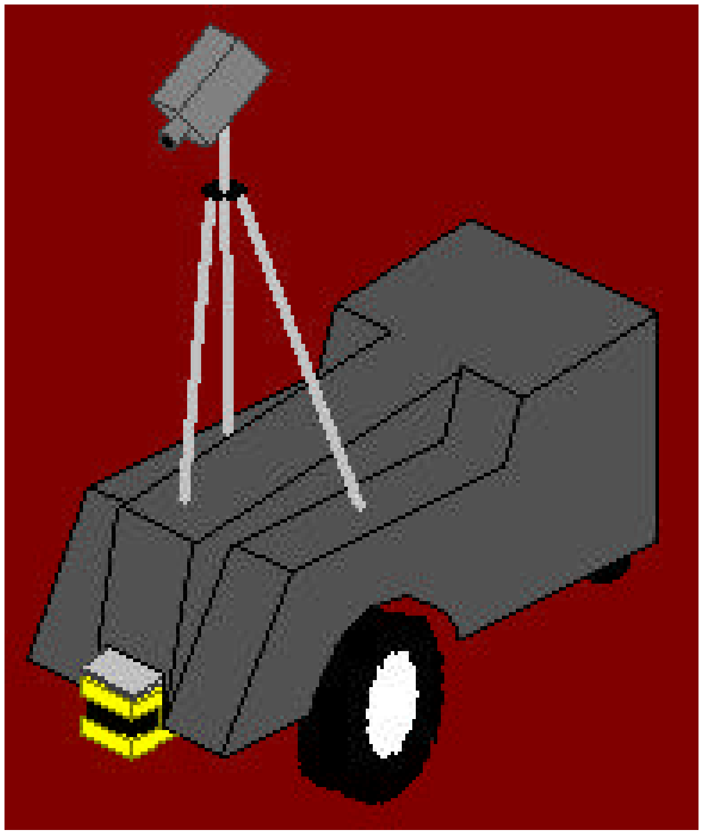
Artemis 2001

On the Forefront of Autonomous Technology



Virginia Tech

Required Statement:

Artemis 2001 is a significantly modified version of the vehicle entered in last year's competition. I hereby certify that the work done by the students working on Artemis 2001 is equivalent to a senior-level design course.

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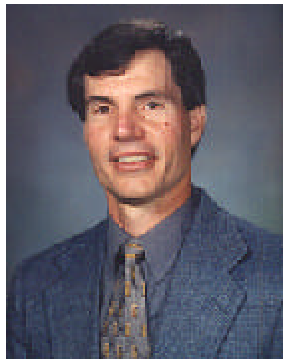
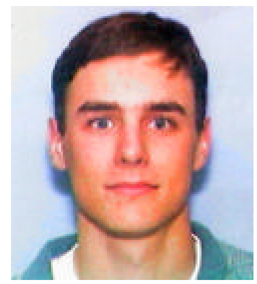
Introducing the Artemis 2001 Team



Dr. Charles F. Reinholtz
Faculty Advisor

Michael Avitabile

Timothy Judkins
Lead Software Engineer



Charles Lamb
Lead Mechanical Engineer

Photo
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Robert McNeal

Jamie Riggins

Brijesh Sirpatil

Team Organization

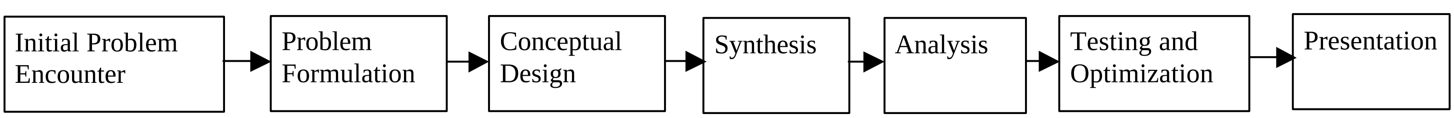
Using the expertise and experience of several team members, the Artemis 2001 Team excelled in all aspects of the design process. Every team member contributed equally to problem solving, design, and implementation. This diverse team-oriented design served two main purposes. First, the diverse background of each individual promoted many innovative ideas. Second, the interaction of all team members allowed an individual's area of expertise to be understood by all of the team members. This interaction facilitated a good understanding of the overall vehicle design by all team members. In addition, the unique nature of having a team of all volunteers, whose dedication and hard work was above and beyond the expectations of the team, demonstrated a different kind of thought and ingenuity that went into the design of Artemis 2001.

The New, Improved Artemis 2001

As a fourth generation autonomous vehicle, Artemis 2001 offers all the benefits of its predecessors. Artemis 2001 is the culmination of years of research in autonomous robotics. Rebuilt from the original Artemis, which dominated in last year's Annual International Ground Robotics Competition, Artemis 2001 retains all of the best features of the earlier versions combined with all new innovative modifications. After 1000 man hours, the Artemis team and its faithful product look forward to a very successful showing in the 9th Annual International Ground Vehicle Competition.

Design Process

In developing and improving a complex product such as an autonomous vehicle, the design process becomes critical to the organization of the design team and to the ultimate success of the design. Again, the Artemis team chose to use the seven step process developed by Sandor[1].



The Seven Stages of Engineering Design

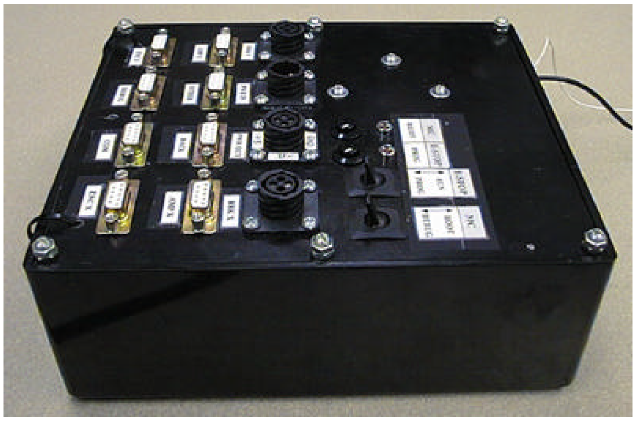
This year's team decided to modify the previous Artemis vehicle. Artemis was originally designed to meet the challenge of completing all four events at the Annual International Ground Vehicle Competition. Although it won all three performance events, it was not able to complete the Autonomous Challenge and Road Debris courses. This year's team worked to improve the vehicle significantly in order to carry out its original mission. Hardware, software, and mechanics were considerably altered in order to overcome existing problems and achieve the ultimate goal of completing every event.

[1] Sandor, G.N., "The Seven Stages of Engineering Design," Mechanical Engineering, April, 1964, pp. 21-25.

Artemis 2001 Enhancements

Electronics

Several electronic components aid the successful operation of Artemis 2001. Those components include:



- Main Component Box
- RF Transmitter
- E-Stop System
- Power Control Box
- Camera Motion Control Box

Main Component Box

In order to simplify the electrical system, all of the motor control electronics and remote and E-stop circuitry is contained within a single 'component box' that has eight 9-pin connectors (DB-9) and four sealed 4-pin AMP connectors for easy attachment and removal. In this way, most of the complex circuitry is hidden from view and day-to-day operation. Additionally, the entire electrical system can be disassembled in only a few minutes, which greatly enhances the serviceability of the vehicle.

RF Transmitter

The RF Transmitter allows Artemis 2001 to be driven manually. This allows the team to drive Artemis under its own power for transporting it.

E-Stop System

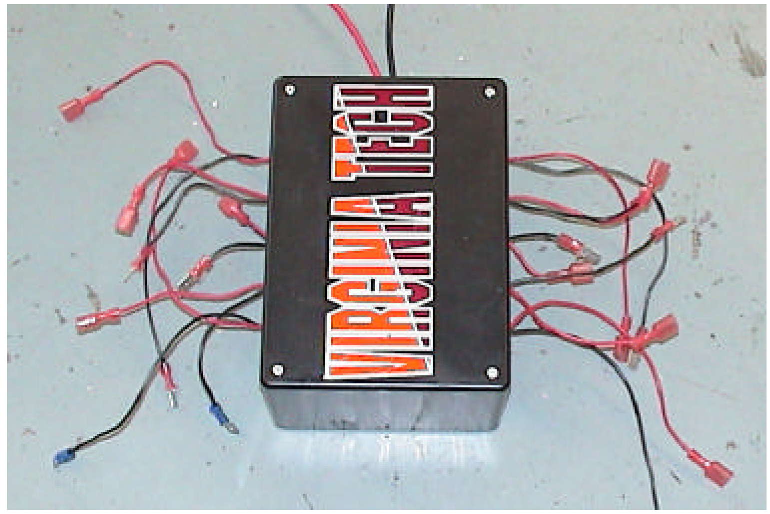
Artemis has several parallel systems, each of which can E-stop motion. E-stopping involves removing power from the fail-safe brakes, causing them to lock, and inhibiting the amplifiers from powering the motors. The remote system, manual switch, and software switch all input into a logic circuit, any of which can cause the vehicle to E-stop. The use of a simple logic circuit eliminates the possibility of E-stop failure due to mechanical problems or software errors. Power failure to the E-stop circuit also causes the vehicle to E-stop.

The remote E-stop subsystem is implemented via a commercially available product, the Street Smart Security Hunter 6-Channel Receiver. This device uses a small remote transmitter, similar to a garage door opener transmitter. The range of the system is 200-600 feet in open air.

Manual E-stop is implemented via a large red button located in the center rear of the vehicle. If the switch is depressed, or is somehow ripped from the vehicle, the E-stop will be activated. The controlling software also has the capability of causing an E-stop, if desired.

Power Control Box

The power control box houses the hot-swappable and battery monitoring circuits. This box interfaces to the ten 24-Volt Dewalt batteries and provides the 24-volts needed to power the entire vehicle. The hot-swappable circuit allows the batteries to be changed without turning the vehicle off. The battery monitoring circuit interfaces with the easy-to-use interface panel and indicates when a battery needs to be changed.



The hot-swappable circuit consists of several diodes and capacitors to eliminate noise in the power bus when changing batteries. The battery monitoring circuit uses a PIC microcontroller and analog to digital converters to monitor all ten battery voltages and indicate a low-battery on the interface panel.

Camera Motion Control Box

A new capability of Artemis 2001 is the ability to rotate the camera to any angle while navigating. A pan/tilt camera motor along with the camera control box gives the computer this capability. This unique approach allows the camera to point in a direction other than the direction the vehicle is facing thus enabling Artemis 2001 to see around curves. This enhances Artemis' navigation algorithms by giving more look-ahead capabilities than previously possible.

The camera control box uses a PIC microcontroller to control the pan and tilt motors. The computer sends an angle through the parallel port and the control box in turn moves the camera to the desired position.

Hot-swappable Battery System

Why lug around heavy, hard-to-change batteries when you can change the batteries with just one hand?

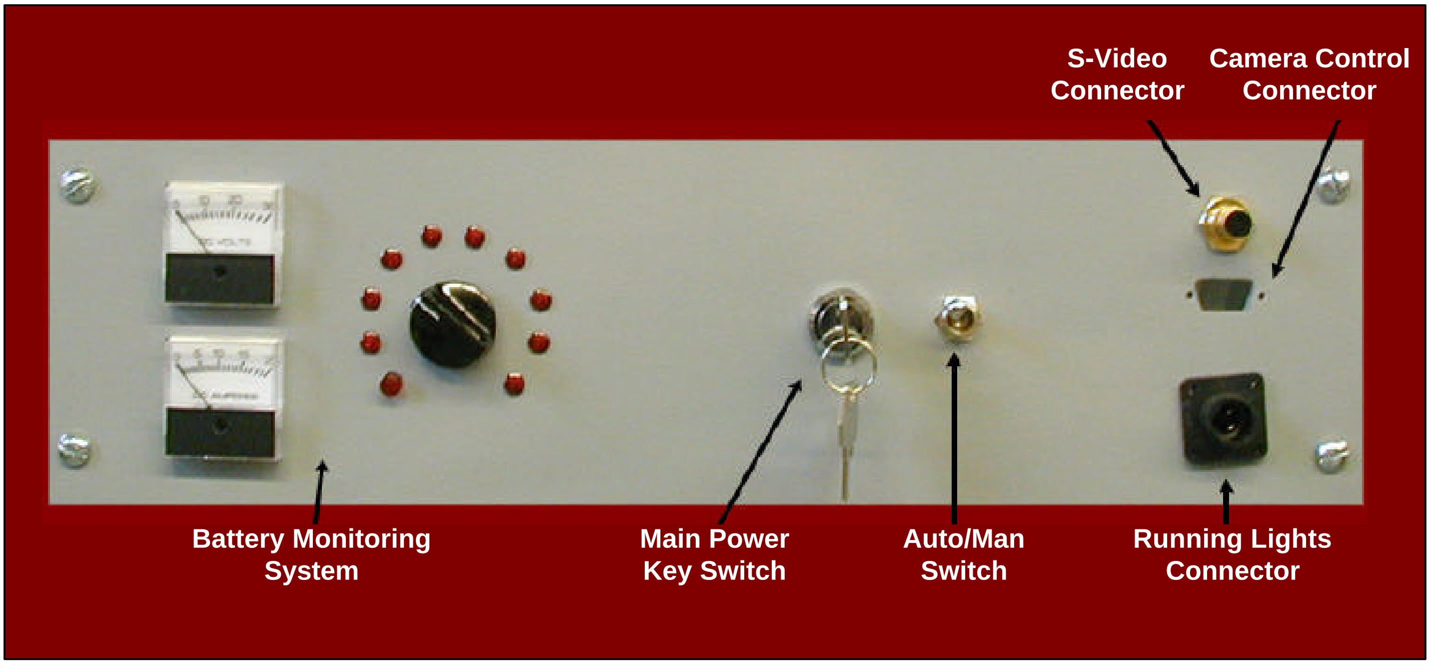
The hot-swappable battery system has three main features:

- Artemis 2001 does not have to be turned off to change the batteries.
- The shell does not have to be removed to change the batteries.
- It only requires one hand to change the batteries.

With Artemis 2001's Dewalt-based hot-swappable battery system, changing batteries is easy. A custom power management circuit allows the 24 Volt batteries to be hot swapped without turning off the vehicle. Strategic placement of the batteries along the rear sides of the vehicle allow the batteries to be changed without removing the shell. The small, lightweight size of the Dewalt 24 Volt batteries make it easy to change the batteries with just one hand.

In addition, a custom battery monitoring system indicates when a battery needs to be changed. An additional rotary switch allows the user to check the voltage level of each individual battery. Finally, a current meter continuously measures the current draw of the entire vehicle.

Easy-to-use Interface Panel



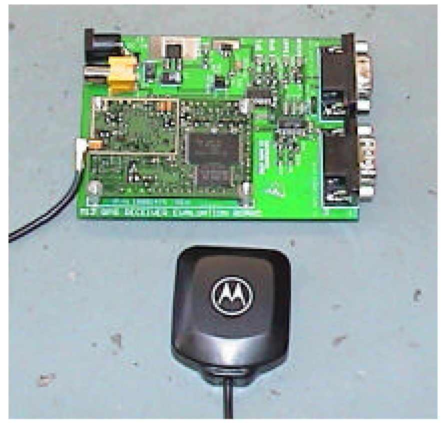
The interface panel on Artemis 2001 serves many purposes. Similar to the original panel, the new panel is the power control center for the vehicle. It is here that the main power to the vehicle is controlled through a key switch. The capability to switch between manual radio control and autonomous navigation is also provided through a toggle switch.

In order to accommodate the multiple batteries of Artemis 2001, a new monitoring system was devised. The current draw of the entire vehicle is monitored with an ammeter. The voltage of each battery can be monitored using just one voltmeter and a rotary switch. The battery monitoring system is completed by a low-voltage monitoring circuit. A low battery is indicated by one of the ten LED's around the rotary switch. This innovative feature indicates low batteries without switching to each battery individually.

Another innovative feature of the interface panel is the S-video and running light connectors. In order to prevent wires running from the vehicle to the shell, all wires that run to the shell plug in to the interface panel. This allows easy removal of the shell without the possibility of pinching wires between the shell and frame.

Sensors

Artemis now uses three sensors to obtain external data: a color video camera, a Sick LMS laser range finder, and a Motorola GPS receiver. Both the camera and the Sick remain unchanged, as they are still in good working condition. The GPS is a new addition, added in order to complete the newest event—the Navigation Challenge.



The GPS is the only means of determining vehicle location during the Navigation Challenge. The GPS receives the vehicle's location, heading, and direction from orbiting satellites. The GPS receiver then sends that data to the computer for processing.

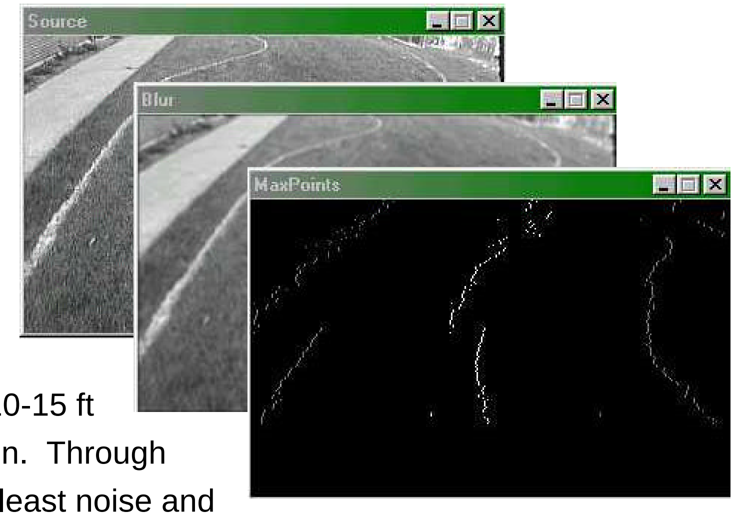
Artemis 2001 uses the SICK Optics laser range finder to find all obstacles. With a 180 degree field-of-view and 30 meter range, obstacle detection is easy. The laser range finder sends the computer 361 measurements corresponding to the distance of an obstacle at each 1/2 degree increment in the field-of-view. The computer can then use that data to determine the location of any obstacle within 30 meters.

The camera is used to find lines during the Autonomous Challenge. Using image processing algorithms that will be described later in the report, Artemis 2001 extracts lines from the image and uses those lines to successfully navigate the Autonomous Challenge course.

New, Improved Algorithms

Autonomous Challenge Algorithm

The look-ahead sensing with near-proximity decision-making navigation algorithm enhances last year's proven image processing techniques by looking ahead for sensor data and maintaining a history for steering decisions. Not only does a history eliminate errors of a reactive algorithm, but also makes sensor fusion easier.



The algorithm works on the principle of looking 10-15 ft in front of the vehicle to collect sensor information. Through testing, it has been found that an image has the least noise and most reliable data in this range. Image processing finds the center of the course easily in the image and determines an optimal goal to reach. After determining the goal, the navigation algorithm searches the surrounding area for obstacles detected by the laser range finder. If any obstacles are too close to the navigation goal, the goal is adjusted to avoid the obstacle while staying within the course bounds. Because the goal is 10-15 ft away from the vehicle, it is not an optimal goal for steering; therefore, the goal is saved in a history for later processing. The history forms a trail, or path, for the vehicle to follow. Finally, the vehicle steers along this path.

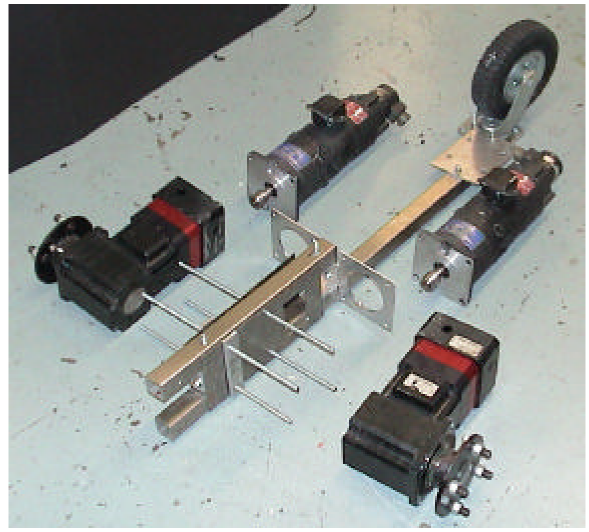
Follow-the-leader Algorithm

The follow-the-leader algorithm uses only the laser range finder to track the target. All other obstacles detected using the laser range finder are designated to be avoided. Using the same path-following techniques as the Autonomous Challenge algorithm, the algorithm maintains a history of the path the target follows. At this point, Artemis 2001 simply follows the path at the designated following distance.

GPS Algorithm

Using an innovative vector-based algorithm, Artemis 2001 uses GPS data to successfully navigate to four designated GPS coordinates. By determining the vector from the vehicle's current position to the current GPS goal, Artemis 2001 determines the desired heading to reach the goal. By adjusting its current heading, Artemis 2001 maintains a straight heading towards the desired goal. If any obstacles are detected while navigating, Artemis 2001 adjusts the heading to avoid the obstacle.

Vehicle-stablizing Frame



In order to fix the problems of the previous frame and accommodate the modifications to the vehicle, a new frame was designed and constructed. The strength of the frame comes from the one and one-half inch, square, 1/8 inch wall stainless steel tubing. Consisting of two tubes, the main support tube runs the length of the vehicle. The shorter second tube is located underneath the main support tube and aids in the support of the gearboxes and motors.

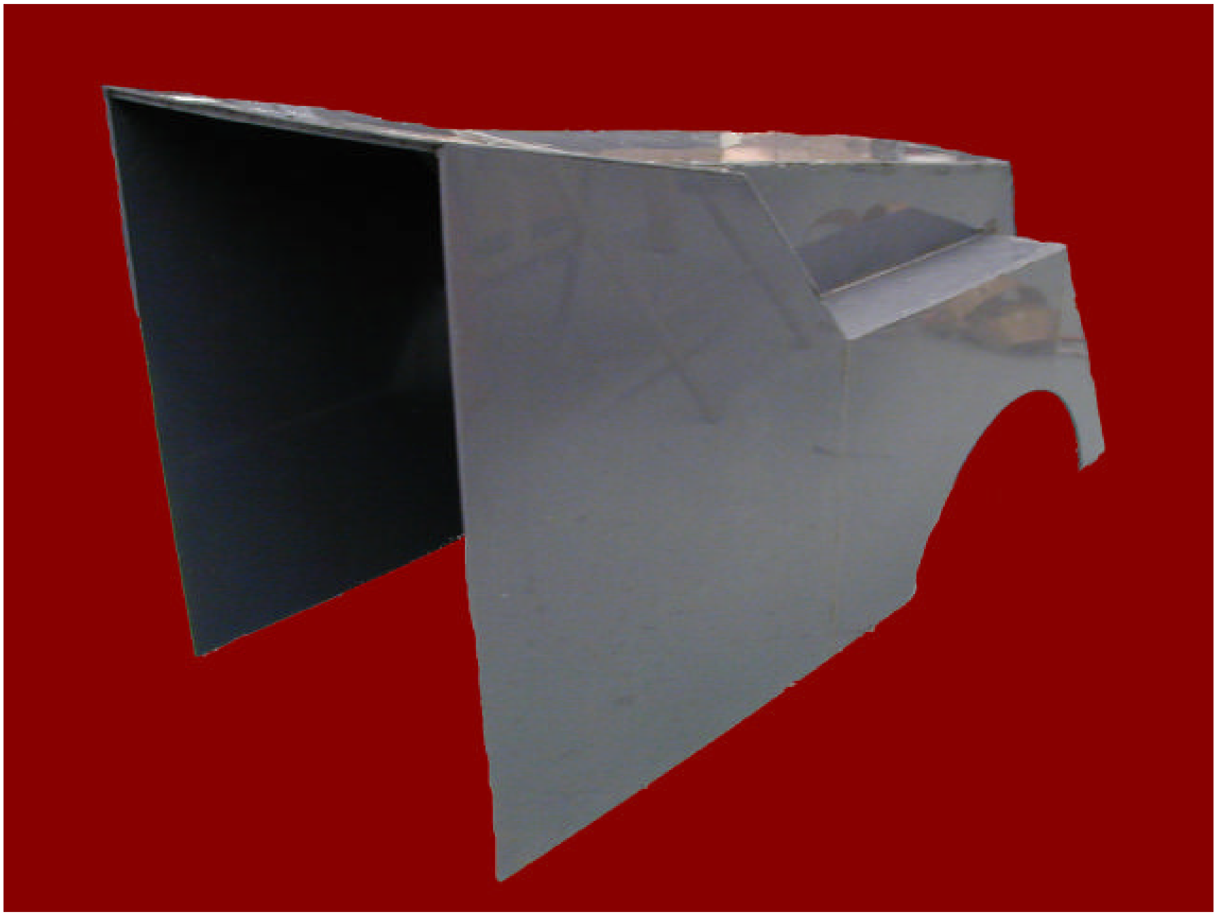
The new frame design moves the center of gravity further back and lower to the ground than the previous frame, and this results in a more stable vehicle. The new frame design accommodates room for the batteries in the rear of the vehicle. This new location of the batteries as well as a lower center of gravity solve the problem of rocking forward that was common in the original Artemis. The entire vehicle, from the laser range finder to the caster wheel, is supported by the main steel tube. This provides a simple but strong base that provides flexibility for future modifications.

Center of Gravity Comparison

Old Artemis

Artemis 2001

Sleek, Weatherproof Shell



Several modifications and enhancements have been added to the external cover of Artemis 2001. Keeping with the Artemis tradition, the shell of Artemis 2001 is constructed solely of PVC. The PVC offers an inexpensive and durable material that can be cut to fit the individual need. The original shell was too small for all the changes that were made to the inner workings of the vehicle. The new shell has been expanded to afford plenty of room for future changes, as well as the recent modifications. The shell is plastic welded together, which provides both strength and a tight waterproof seal.

Built to accommodate the multiple batteries of Artemis 2001, located on each side of the shell are doors that hinge up and allow the batteries to be changed while the shell is still secured to the body of the vehicle. Since efficiency is the goal of Artemis 2001, even the payload can be easily slid into the vehicle without removing the shell. Located at the top of the vehicle, the shell rises up to accommodate the payload. The payload then can be easily slid into place from the back of the vehicle.

Innovations

Several innovations resulted from the design of Artemis 2001:

- Camera Control Capabilities
- Hot-swappable Battery System
- Functional, Easy-to-use Interface Panel
- New, Improved Adaptive Algorithms
- Vehicle-stabilizing Frame
- Sleek, Weatherproof Shell

In addition to these features, an interactive CD player has been installed for demonstration and to promote interest in autonomous vehicles.

Predicted Performance

Speed

Because the same motors are being used in Artemis 2001 as in the previous Artemis, the max speed will remain at 5 mph. As with last year's vehicle, the two 1.5 horsepower motors can easily maintain 5 mph up a 15% incline.

Reaction Time

Artemis 2001 has different reaction times based on the particular course and the limiting sensor being used:

- Autonomous Challenge - limited by frame grabber running at ~8 Hz
- Follow-the-leader - limited by laser range finder with 80 ms scan time
- Navigation Challenge - limited by GPS running at 1 Hz

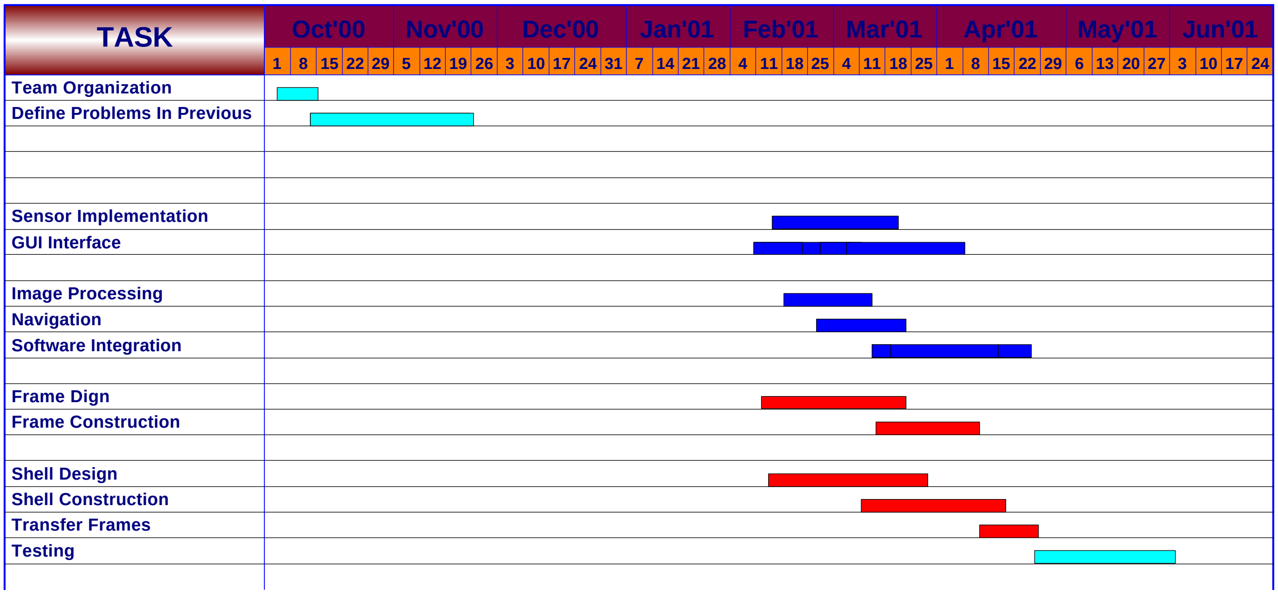
Battery Life

The new batteries allow for approximately an hour of continuous runtime. The laptop computer can operate up to 4 hours when using the main and backup battery.

Obstacle Detection Range

Objects can be detected by the laser range finder up to a distance of 30 meters. The range is actually reduced in software to approximately 20 feet.

Timeline



Cost

Item	Vendor	Cost	Purchase	Donation
24 VDC Servo Motors	Kollmorgen Industrial Drives	$7,980		X
120A5 Servo Amp, PWM Output (2)	Advanced Motion Control	$1,600		X
Pentium II 266 MHz Laptop Computer	Quantex Microsystems Inc.	$2,699	X	
MRT VideoPort PCMCIA Frame Grabber	The Imageing Source	$250	X	
EdgePort II USB to RS-485 Converter	B & B Electronics	$259		X
Motion-DAC-AE Version Motor Controller	Tern Inc.	$1,100	50%	50%
Hunter 6-Channel Relay Receiver	Home Automation Systems	$180	X	
Power Relay	Newark Electronics	$37	X	
5 amp Dual-Pro Battery Charger	Charging Systems Int.	$250		X
MF3106F 18-1S Encoder Plugs (3)	BEI Industrial Division	$60	X	
90-Degree DuraTRUE Gearboxes 20:1 (2)	Thomson Micron	$1,600		X
8” Inch Swivel Caster Wheel	Trendlines	$23	X	
Scanning Laser Range Finder	SICK Optic Electronics	$3,400		X
16” x 4” Trailer Tires (2)	B.F. Goodrich	$60	X	
Assorted Hub Assembly Ports	CT Farm and Country	$53	X	
Frame Steel and Aluminum		$400	X	
Fiberglass Sheet	AIN Plastics	$90	X	
Sealed Power and Signal Connectors	AMP	$89		X
PVC Sheet	USA Plastics	$90	X	
Assorted Electrical Connectors and Wire		$50	X	
Assorted Hardware (screws, bolts, etc.)		$25	X	
Pan/tilt Camera Assembly		$130	X	
Interactive CD Components		$100	X	
Total		$20,346		