P545 Autonomous Cart
Cart Overview

- The P545 Cart is designed to allow students to explore embedded system design and development through the control of an autonomous vehicle.
Cart Overview

- The vehicle is controlled in autonomous mode from a student’s laptop which is connected to cart through a standard Ethernet port.
- The laptop will run a “driver” program that receives information about the cart’s state from a command server running on the cart.
- The driver program sends information back to the cart command server to initiate changes in the cart’s control parameters (turning radius, speed, etc).
Cart Control Frame

- Control Frames are exchanged at 20 hz between the driver and the cart.
- Command frames are plain comma delimited ASCII.
- Example:

  ```
  {MsgLength=0474, VehMsgCount=00000006, TimeStamp=0000000329, 
  CmdTurnRadius=0.0005, StatusTurnRadius=0.17993, 
  StatusSteeringPosLimitError=none, CmdVehSpeed=01.500, 
  StatusVehSpeed=00.000, StatusPercentThrottle=004.00, 
  StatusVehSpeedLimitError=none, GPSLat=3910.93526, GPSLon=-08631.36226, 
  GPSSpdE=0.00, GPSSpdN=0.02, GPSEstimatedPositionError=1.8, 
  GPSStatus=active, StatusSystemMode=auto, StatusErrorCode=000, 
  StatusCom=ready, 7F}
  ```
Cart Modes

- Basic Cart Modes
  - **Manual:** In this mode, the safety driver is in full control of the vehicle. The electronic vehicle control systems are disconnected from cart through relay logic. This mode can be entered by releasing the manual/automatic button, pushing the brake pedal, or pressing the ESTOP button.
  - **Automatic:** In this mode, the electronic control system is allowed to control the speed of the vehicle and manage the cart’s steering system. This mode is entered when the safety driver presses and holds the manual/automatic button.
Manual/Automatic Button

☐ Button must be held down to remain in autonomous mode.
ESTOP Button

- Pressing the ESTOP button disables autonomous mode
Cart Relay Logic

- Relay logic is used to implement manual/automatic button and ESTOP functionality.
Electronic Component Overview

Key Cart Component Block Diagram

- Driver Laptop
- WRT54GL Router
- ARM Linux Head Node
- Vehicle Control Module (VCM)
- GPS
- Throttle Voltage
- Speed Pulses
- Steering System
- Obstacle Detection System
Driver Laptop

- This student is controlling the cart through his laptop connected to the cart.

Safety driver is mandatory. Caleb Hess is pictured here.

A notebook with a wired Ethernet connection is used to communicate with the cart.
WRT54GL Router

- Router used to provide Ethernet connectivity between the cart and the driver.
WRT54GL Router

- Standard Linksys device running DD-WRT v23 SP2 firmware.
- This version of DD-WRT is based on a 2.4.34 linux kernel.
- DHCP Server
  - Cart Communication Node is at 192.168.1.200.
- Client Wireless Mode
  - The router access point functionality has been disabled in favor of using the wireless portion of the device in client mode.
  - Router maintains a connection to the IU VPN. Permits IU network access while using the cart.
  - Allows remote access to the cart while it is in storage at the Woodlawn house (across from the Informatics building).
ARM Linux Head Node

- 400Mhz Linux node.
ARM Linux Head Node

- Arcom Viper Embedded Control board.
- 400Mhz Intel Xscale (ARM) Processor.
- Runs a Debian Linux variant based on a 2.6.16 kernel.
- Includes a touch panel LCD Monitor with a 320x240 pixel resolution.
- Peripherals are connected through 3 unallocated serial ports.
Vehicle Control Module (VCM)

- VCM is designed to expand the system IO availability along with implementing low level, hard real-time functions.
Vehicle Control Module (VCM)

- Custom IUCS hardware based on the MSP430 controller.
- Head Node Communication
  - Connects to ARM linux node via an RS232 serial port.
- GPS Data Management
  - Parses GPS serial data from a Garmin GPS 18.
- Vehicle Throttle
  - Outputs a digital voltage to control the throttle.
- Vehicle Speed Measurement
  - Measures the period of speed pulses from the cart motor.
- Implements a PID loop to control the speed of the cart at the desired set point.
Vehicle Control Module Features

- Basic block diagram of the VCM feature usage.

![Vehicle Control Module Diagram](image-url)

- **Garmin GPS18 Component**
- **Cart Throttle Input (1V-3V)**
- **Motor Speed Pulses (50 wheel Rev)**

**VCM**

- **MSP430F169 Microcontroller**
  - UART0 (115k)
  - UART1 (19.2K)
  - Digital-to-Analog Converter
  - Timer Capture

Serial Link to ARM Linux Node
GPS

- Garmin GPS18 5hz puck with RS232 serial output.
Steering System Block Diagram

- Arm Linux Server
- Roboteq AX2850HE Amplifier
- Gear Motor
- Pulley
- Steering Wheel
- Steering Rack
- Linear Pot
- AC Clutch
- RS232 Comm
- Wiper Voltage
- Power Signals
- Auto/Man

Auto/Man parameters: Wiper Voltage, Power Signals
Steering System Components

- Steering Actuator
  - Wheel Chair Gear Motor
- AC Clutch and Pulley
  - Automotive Air Conditioning System
- Amplifier
  - Dual Channel 120 Amp Motor Controller
- Linear Potentiometer
  - Provides a resistance that is proportional to the length of the device.
Steering Actuator

- Salvaged from a wheel chair. A custom mount was designed for the cart.
An automotive air conditioning clutch is used to electrically control the coupling of the steering motor to the steering wheel shaft via a belt and pulley.
Steering Amplifier

- Allows the front wheels to be positioned based on a commanded turn radius. (Roboteq AX2850 Power Amplifier)
Linear Potentiometer

- Provides a resistance that is proportional to the extension of the device.