NEW MEXICO TECH
8 OCTOBER 2009

A Model Based Design for The WSMR Ground Vehicle Target Control Subsystem (GVTCS)

ABSTRACT

A Model Based Design (MBD) methodology supported the development of the WSMR Ground Vehicle Control System (GVTCS). The four basic MBD phases (1) system identification (2) plant modeling, (3) controller development, (4) simulation of the plant and controller, facilitated the data analysis, reduced the system development time and the overall cost of the system.

BRIEFING OUTLINE

1. GVTCS Overview
2. Control System Block Diagram
3. Theoretical Models for Lateral & Longitudinal Control Axes
    1. Steering Actuator Model, Heading Rate Model, Heading Hold Controller
    2. Cross Track Control
    3. Throttle Actuator Model, Acceleration model, Speed Ho
    4. Along Track Control

4. GVTCS External Simulation Program
5. Hardware in the loop Simulation
6. Videos
7. Questions and Point of Contact

GVTCS OVERVIEW

- GVTCS is the control element of the 21st Century WSMR Target Control System (21st C WSTCS) designed to control different ground target types including: small trucks, 5-Ton Trucks, Russian Tanks T-72, BMP, 2S3, and some US Tanks
- The 21st C WSTCS is also capable of controlling full scale (QF-4) and subscale aerial targets (MQM-107E, MQM-107D, BQM-34A) using different data link frequencies in the UHF and L-band range

QF-4

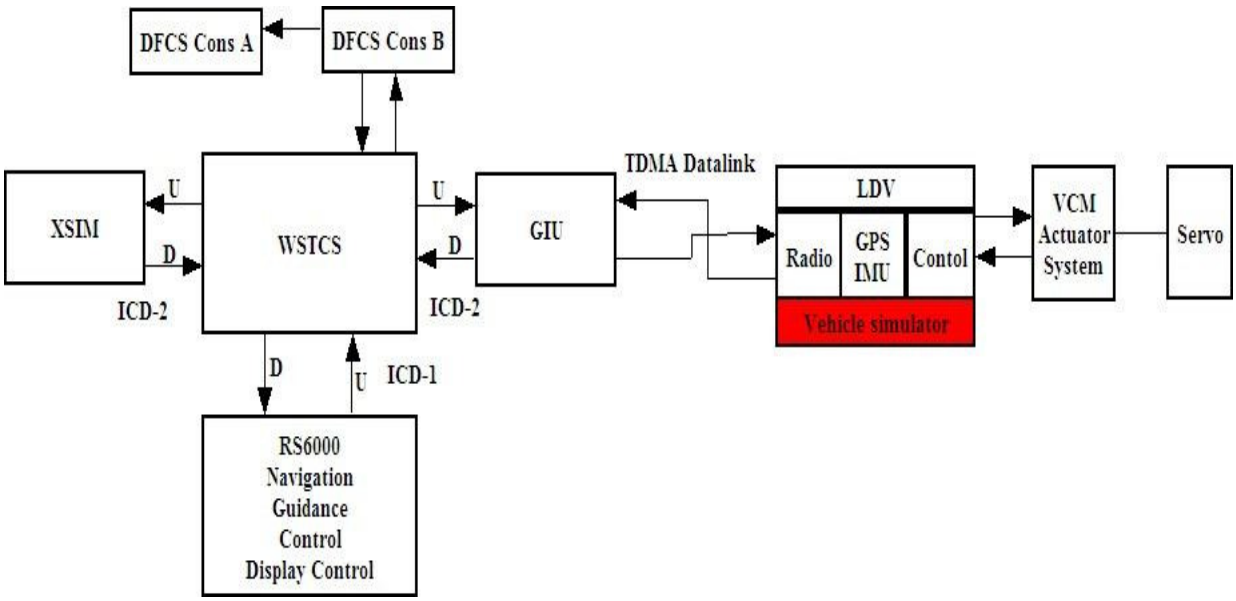
MQM-107E

M60 Tank

Small Truck

GVTCS OVEVIEW (cont)

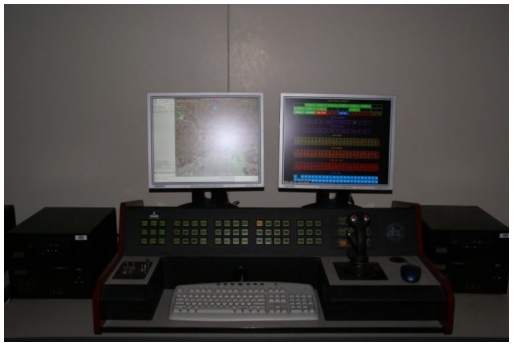
GVTCS ARCHITECTURE

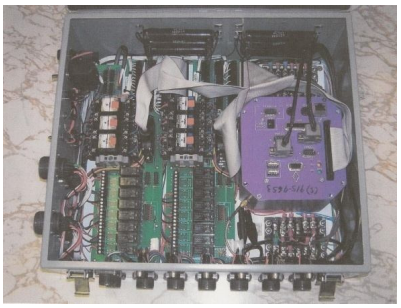


GVTCS OVEVIEW (cont)

1. WSTCS – PC Linux Based Data Link Manager Computer
2. NGC – RISC6000 AIX Based Navigation Guidance and Control Computer
3. XSIM – PC Linux based External Simulator Computer
4. CONS – PC Windows based consoles
5. GIU – PC Linux Ground Data Link Unit
6. LDV – Low Dynamic Integrated unit; L-band radio, GPS, IMU, PC
7. VCM – Servo controller
8. L-Band Frequency (1369MHz – 1386MHz)
9. Time Division Multiple Access (TDMA)
10. GPS and L-band Antennas and Cables

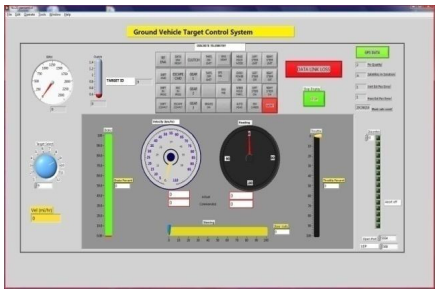
GVTCS OVEVIEW (cont)



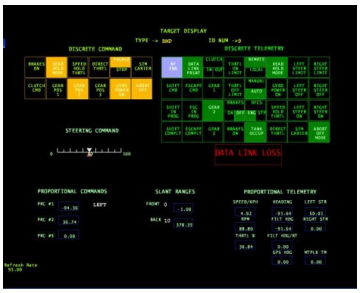


GVTCS OVEVIEW (cont)

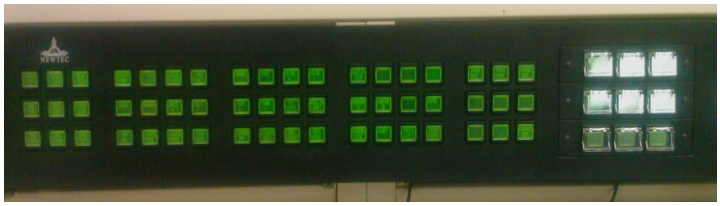
Tank Formation



Telemetry Downlink Display



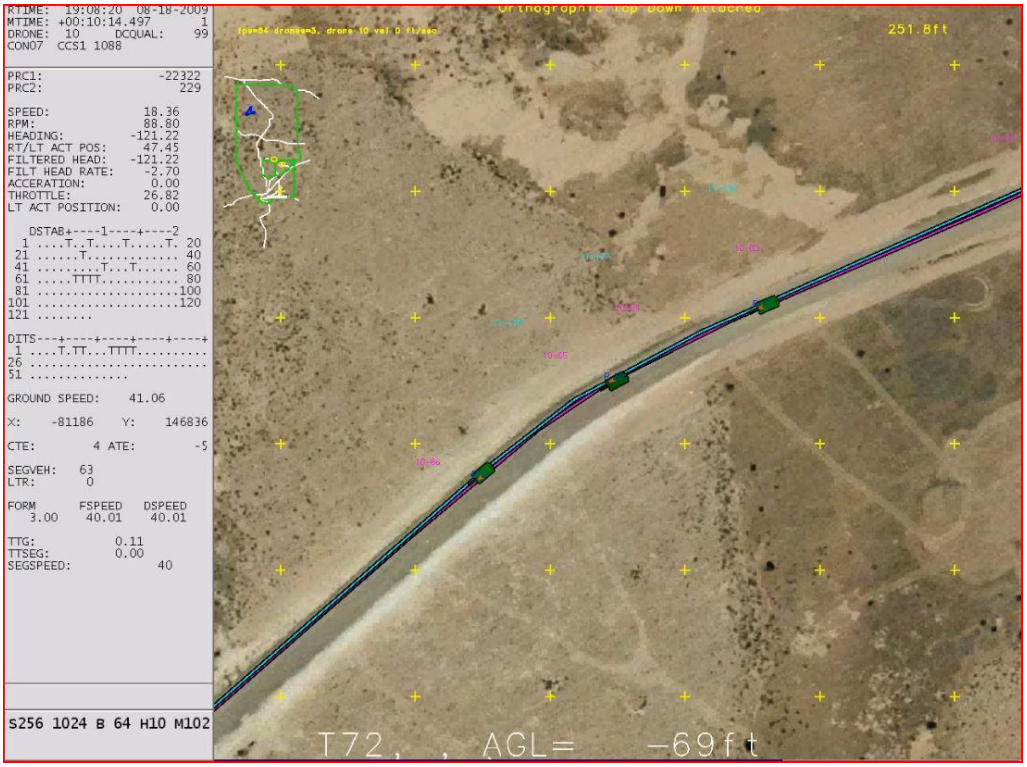
Tank Heads Down Display



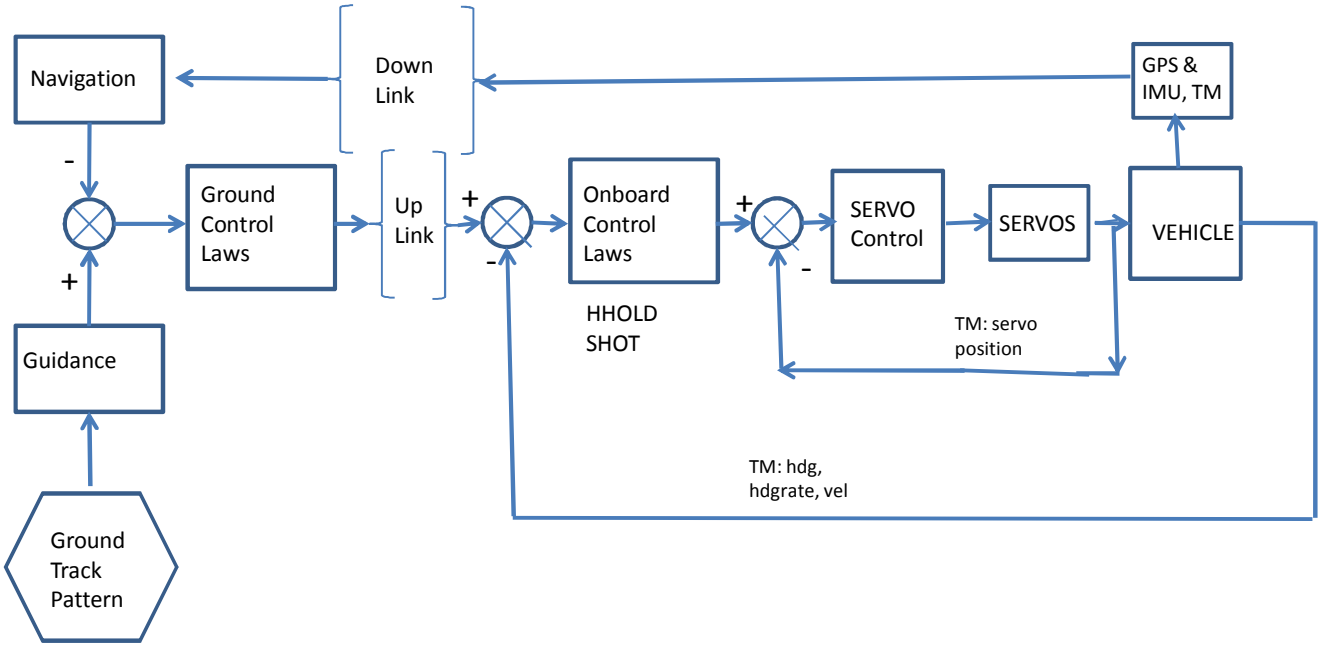
Switch Light Interface

Joystick

GVTCS OVEVIEW (cont)



Control System Diagram

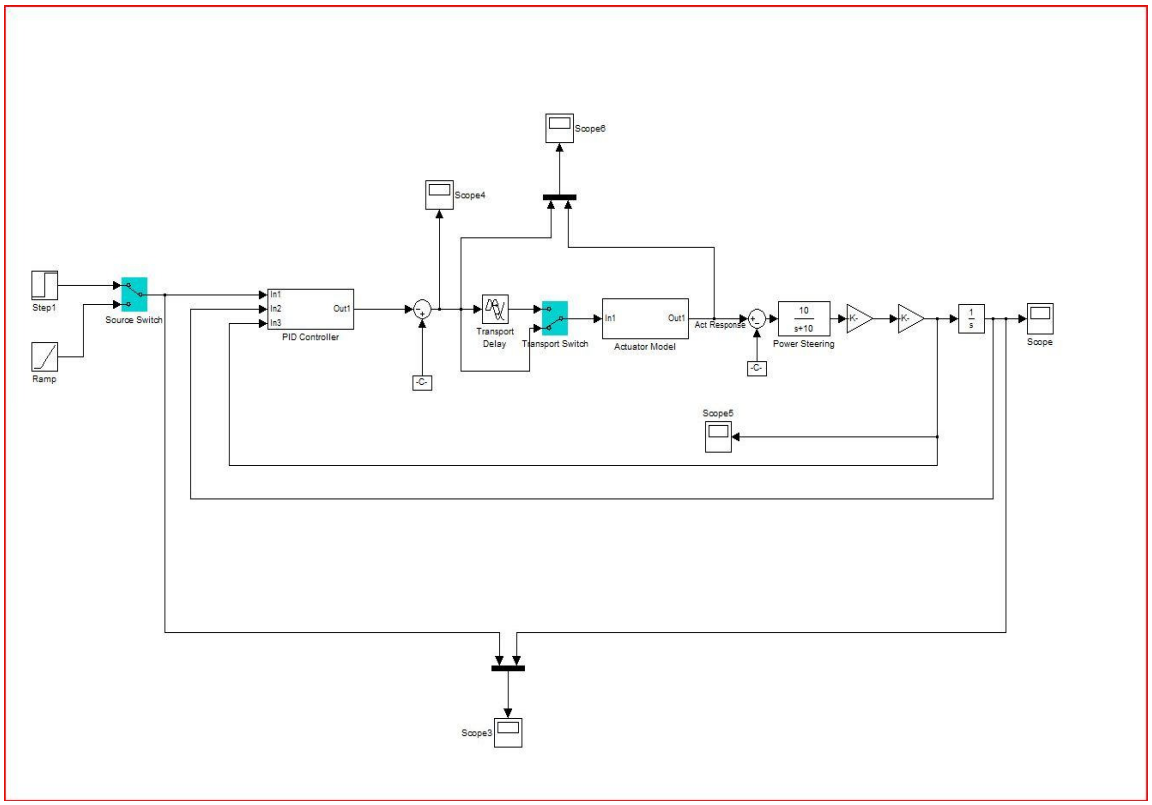


Ground Vehicle Control Axes

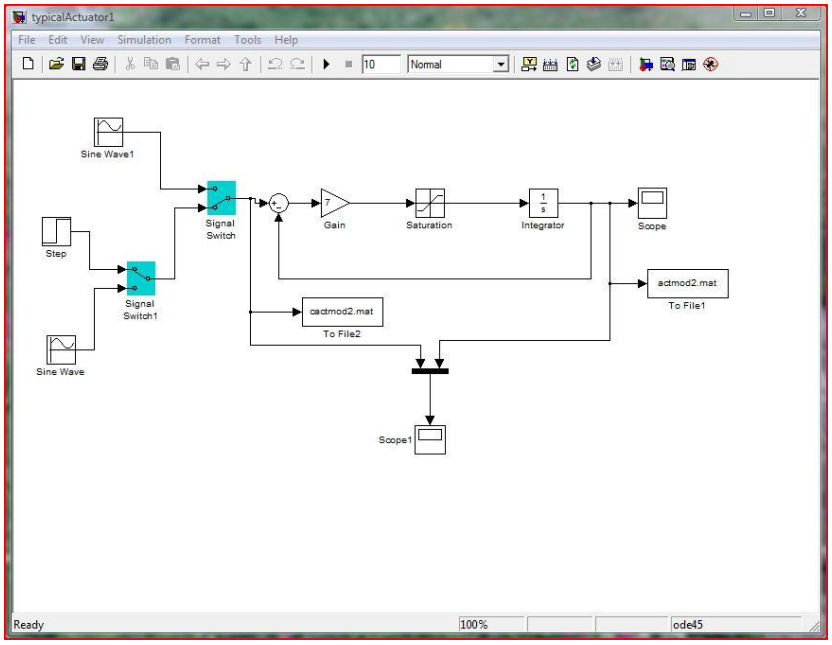
1. Lateral Axis
    1. Heading Hold Control
        1. Steering Actuator Model
        2. Heading Rate Model
    2. Cross Track Control

2. Longitudinal Axis
    1. Speed Hold on Throttle
        1. Throttle Actuator Model
        2. Acceleration model
    2. Along Track Control

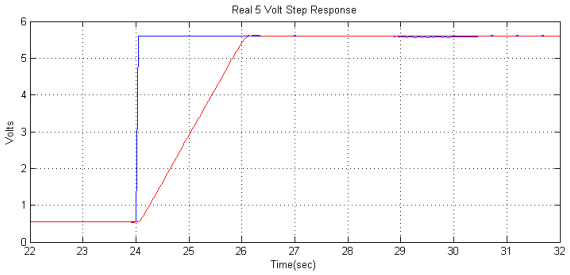
Heading Hold Model

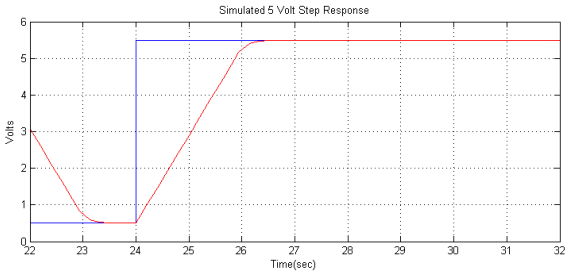


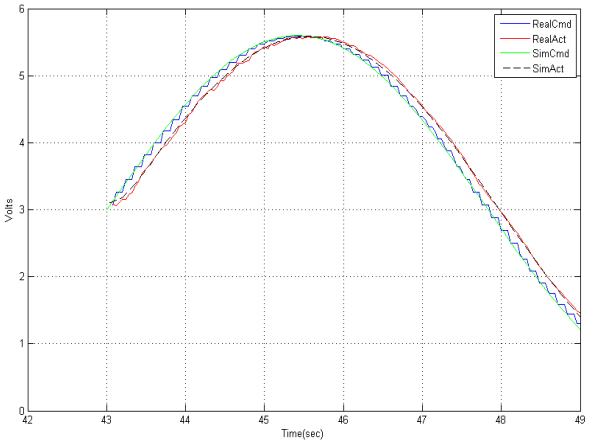
Steering Actuator Model



System Identification
Steering Actuator Model







Heading Rate Model

Heading rate is inversely proportional to vehicle turn radius and directly proportional to ground speed as indicated in Equations 1 and 2.

$$\frac{ds}{dt} = turn\ radius * heading\ rate = ground\ speed \quad (EQ\ 1)$$

$$heading\ rate = 57.3\ \frac{ground\ speed}{Turn\ radius} (EQ\ 2)$$

Table 2 shows the data collected for one of the trucks. The first column shows steering voltage and the second column shows the truck turn radius for that particular steering voltage. The last column indicates the turn slope, that is the ratio between the inverse of the turn radius and the steering voltage multiplied by 57.3.

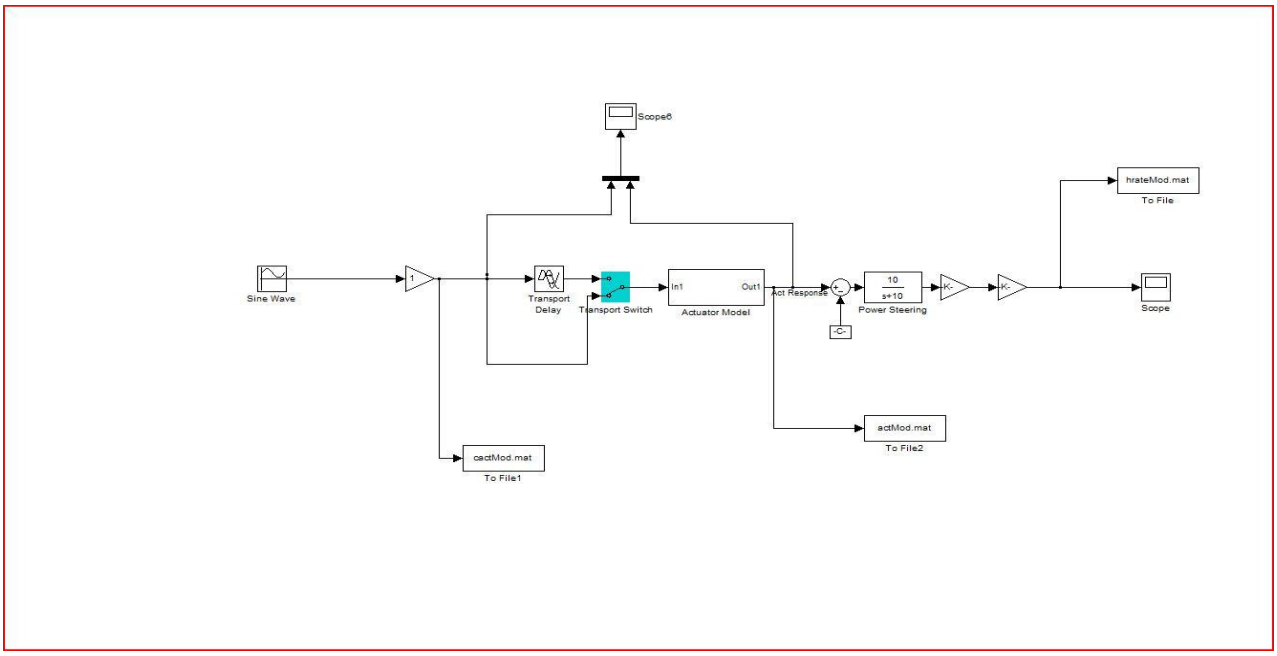
Table 2 Heading Rate Model Data

Steering	Turn Radius	57.3/Turn Radius	Turn Slope
5.15 volts	75 feet	0.764	0.764/(5.15-4) = 0.663
6.30 volts	32.5 feet	1.763	1.763/(6.3-4) = 0.766

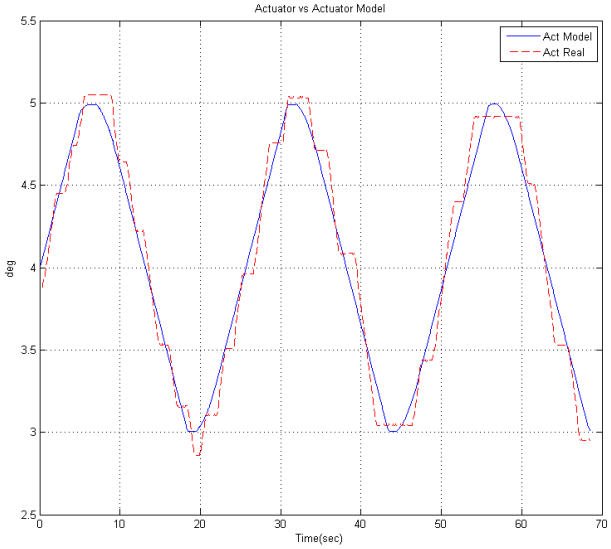
Equation 3 shows that heading rate can now be calculated by multiplying the computed turn slope times the ground speed in feet per second times the steering voltage.

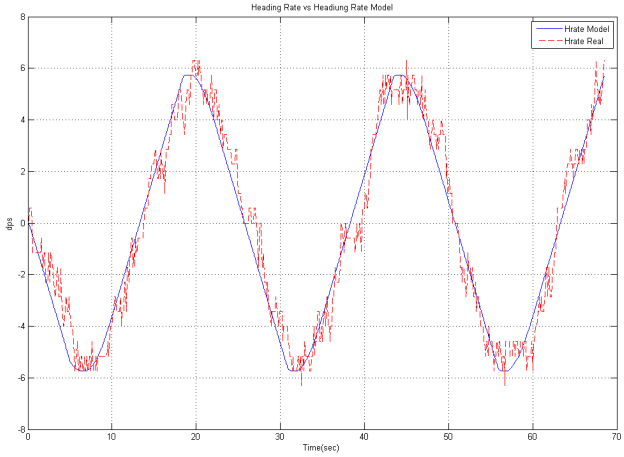
$$Heading\ Rate(dps) = (actuator(deg) - 4) * Turn\ Slope * ground\ speed(fps)\ (Eq3)$$

Heading Rate Model

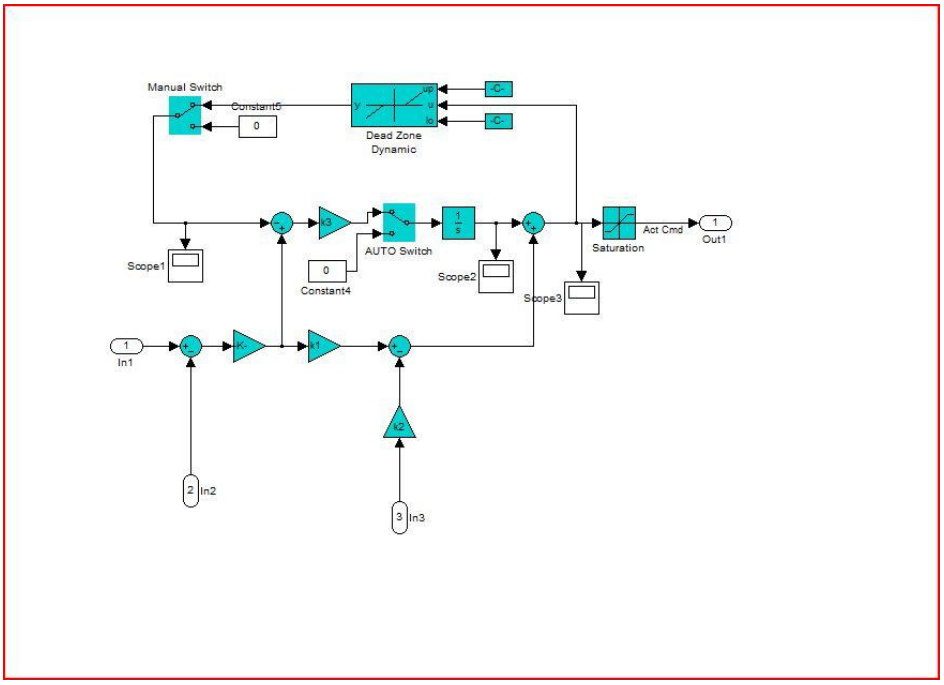


System Identification
Heading Rate Model

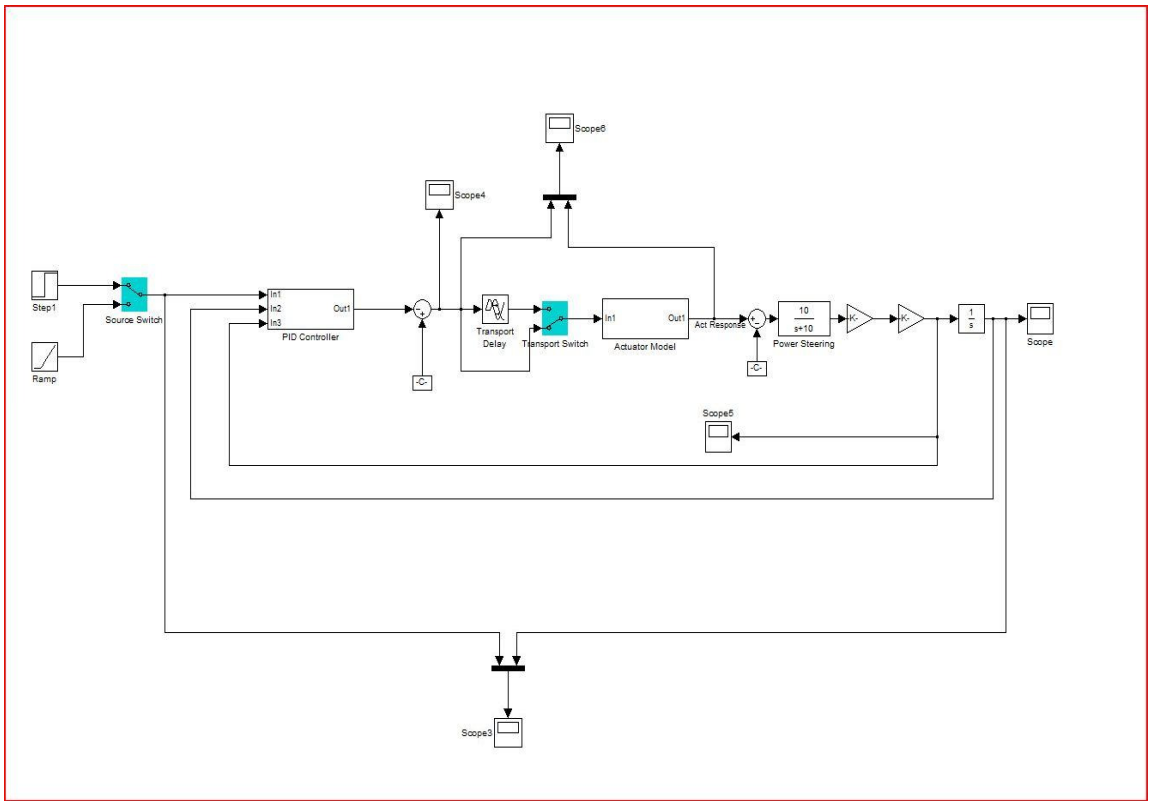




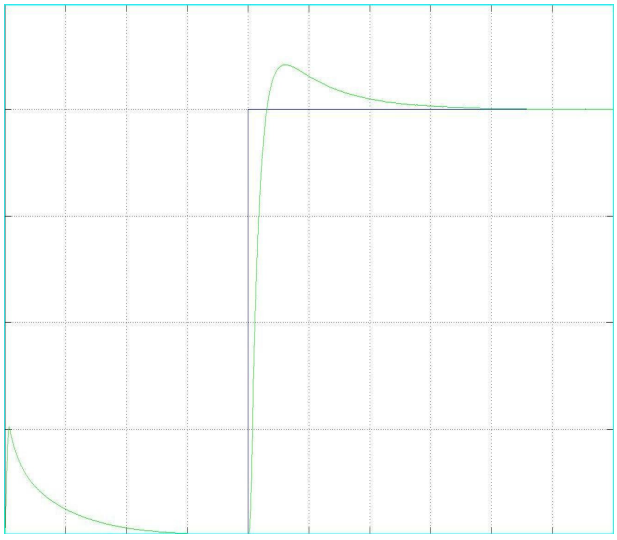
Heading Hold PID Controller



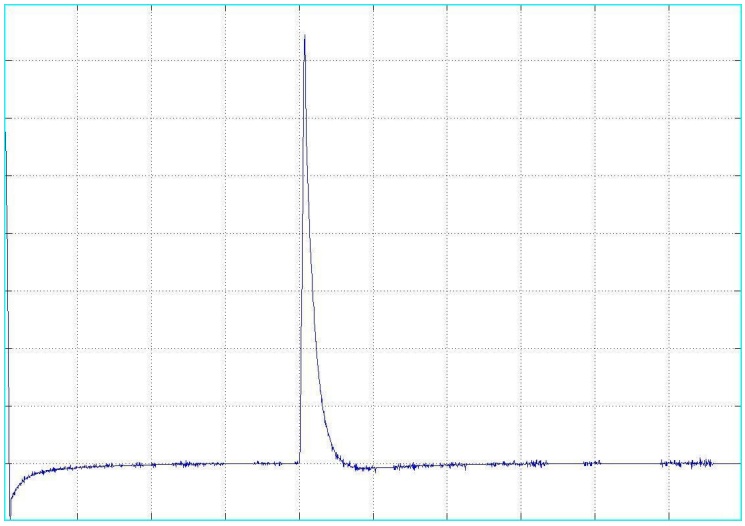
Heading Hold Model



System Identification
Heading Hold Model

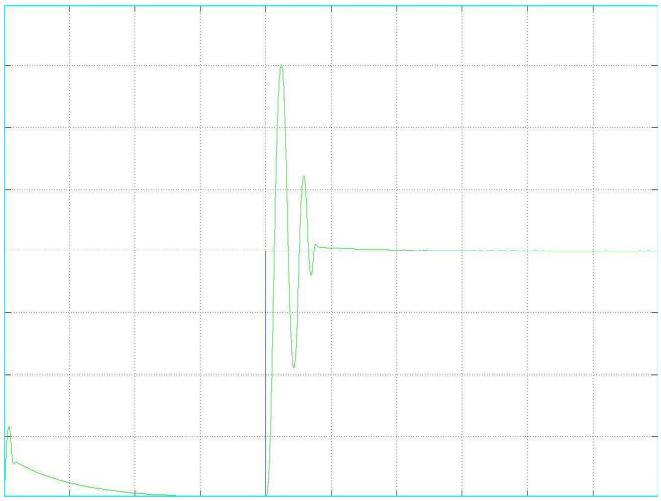


Heading Step Response

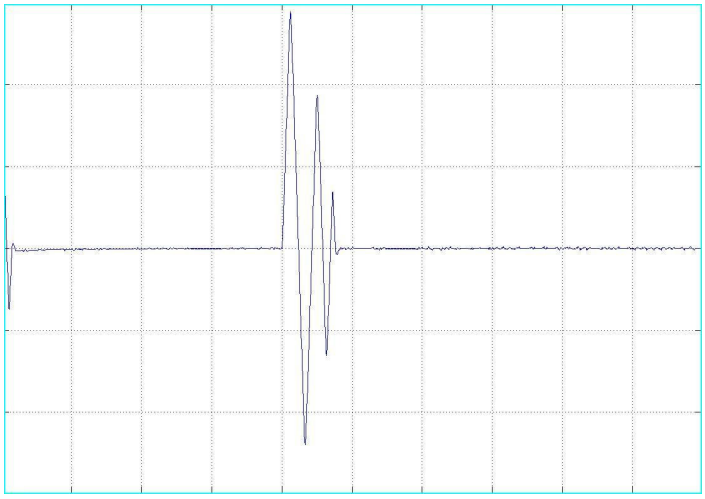


Heading Rate Response

System Identification
Heading Hold Model (cont)

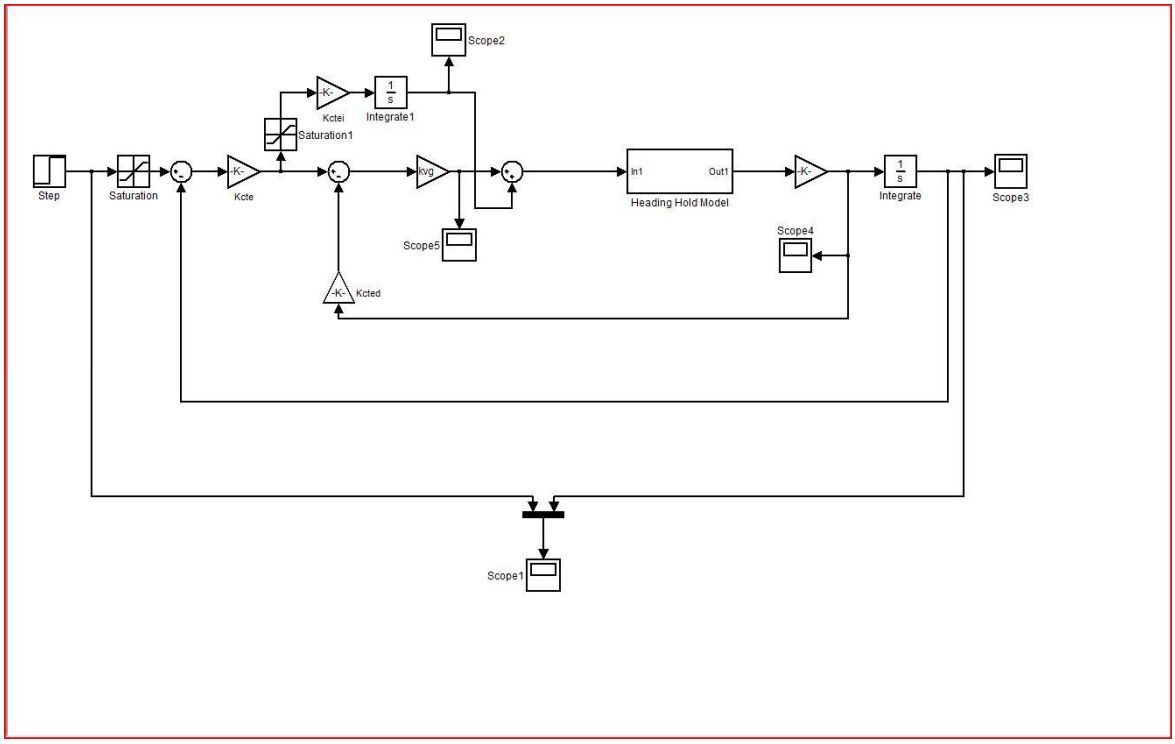


Heading Step Response
Kv=0

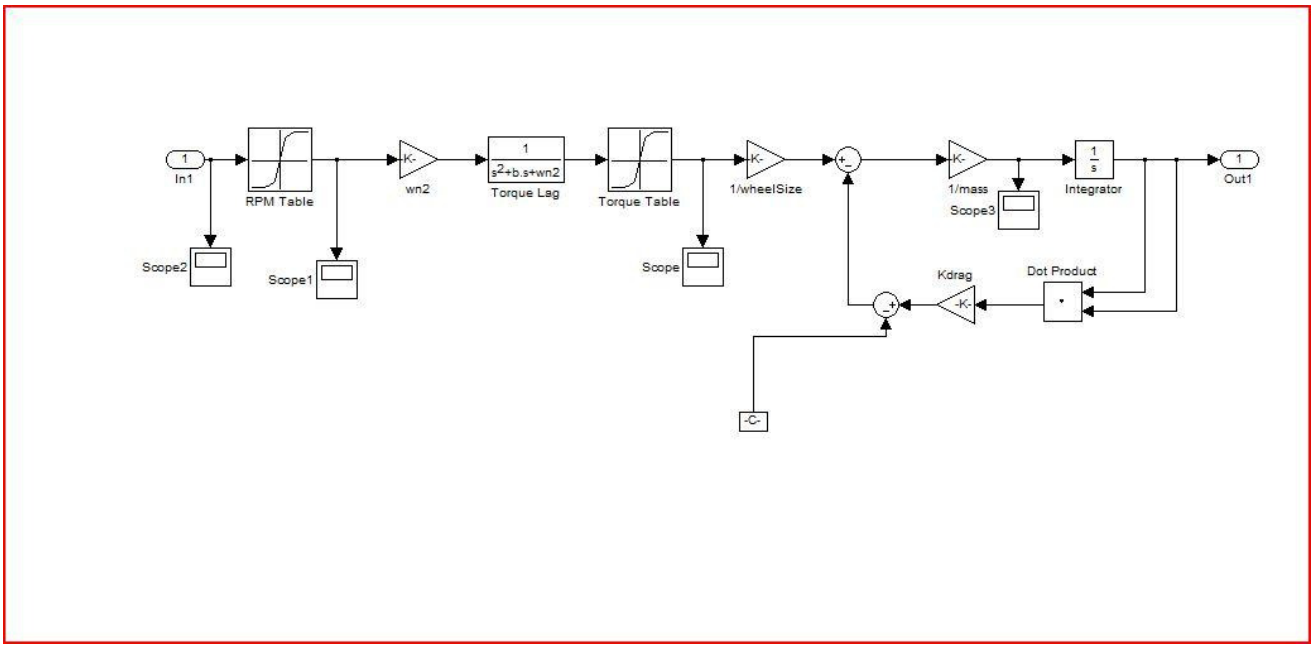


Heading Rate Response

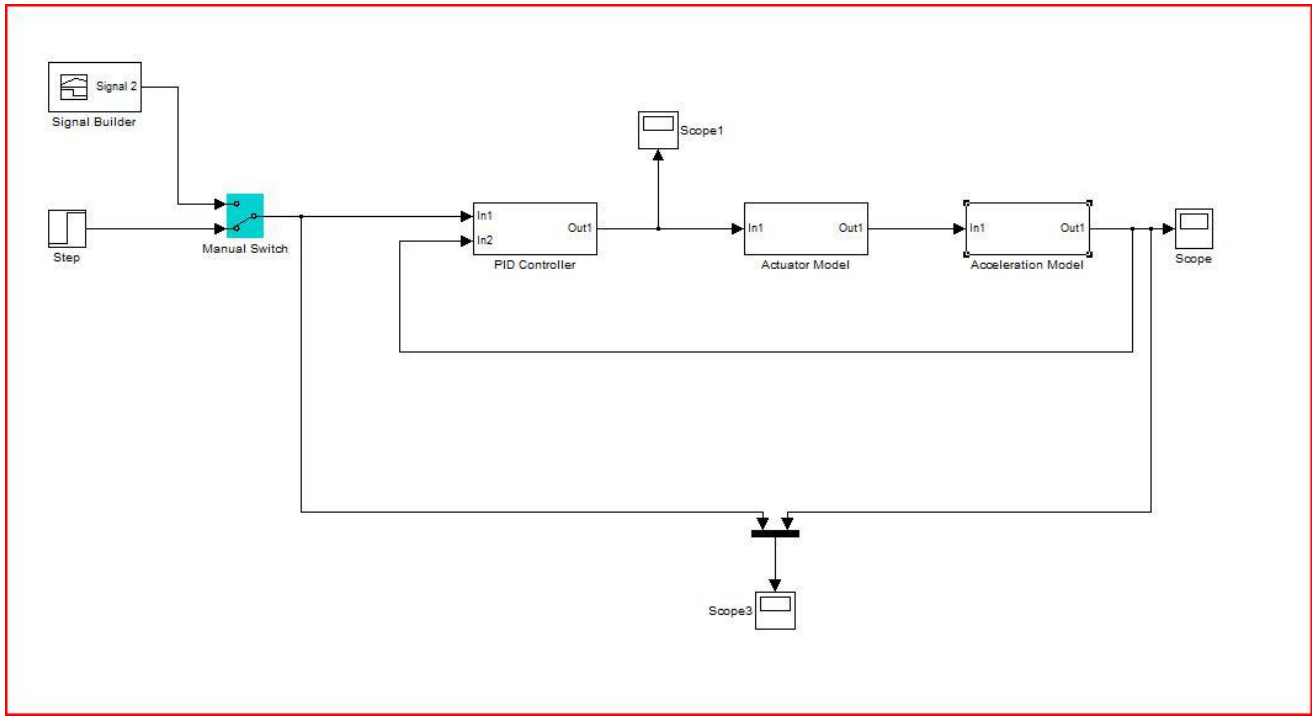
Cross Track Control Model



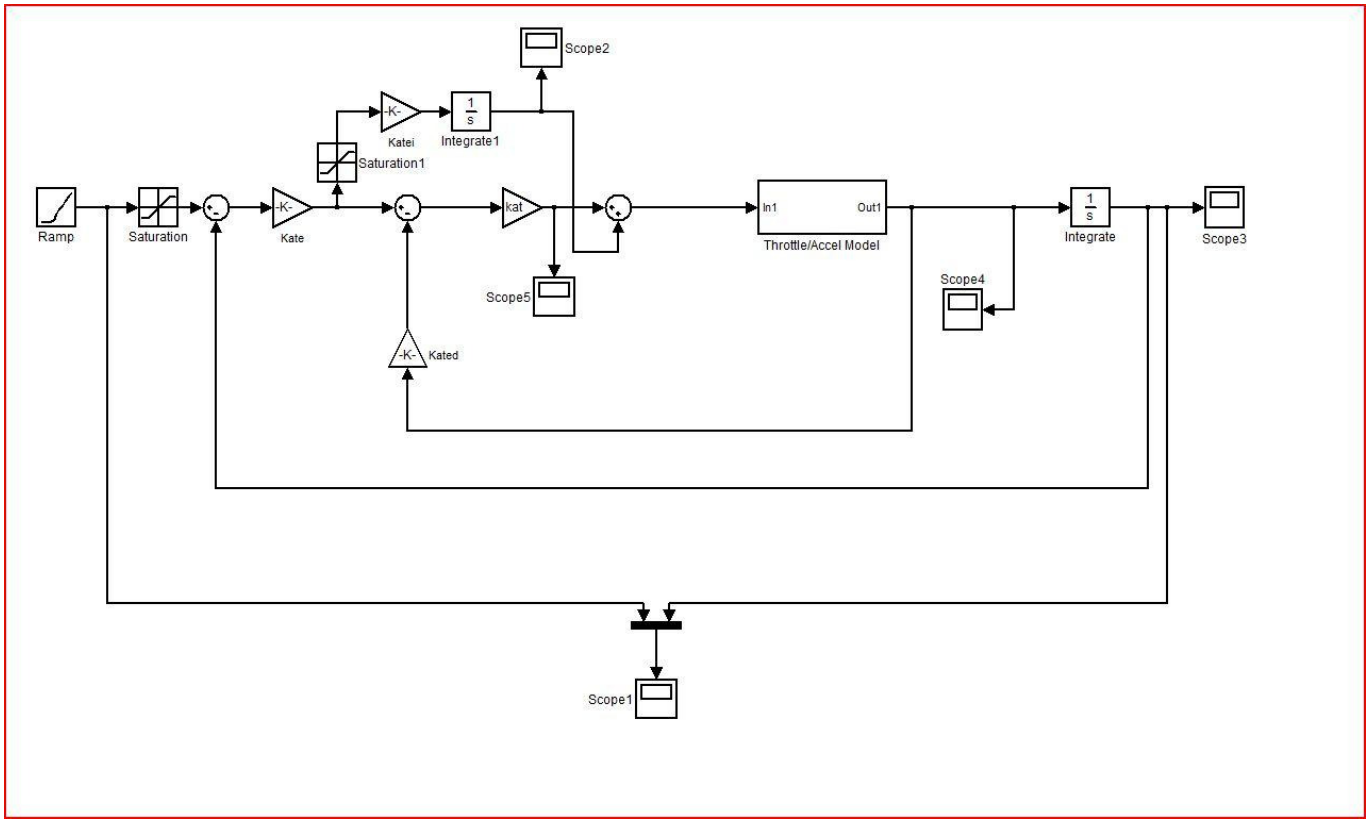
Vehicle Acceleration Model



Speed Hold Model

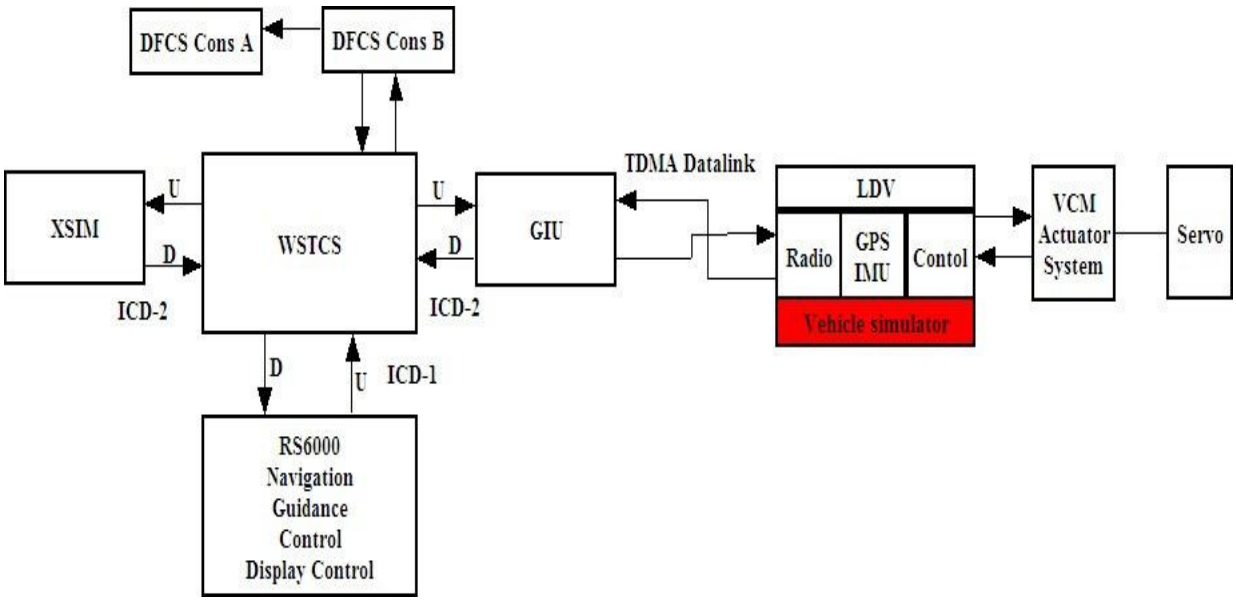


Along Track Control Model



External GVTCS Simulator "XSIM"

GVTCS ARCHITECTURE

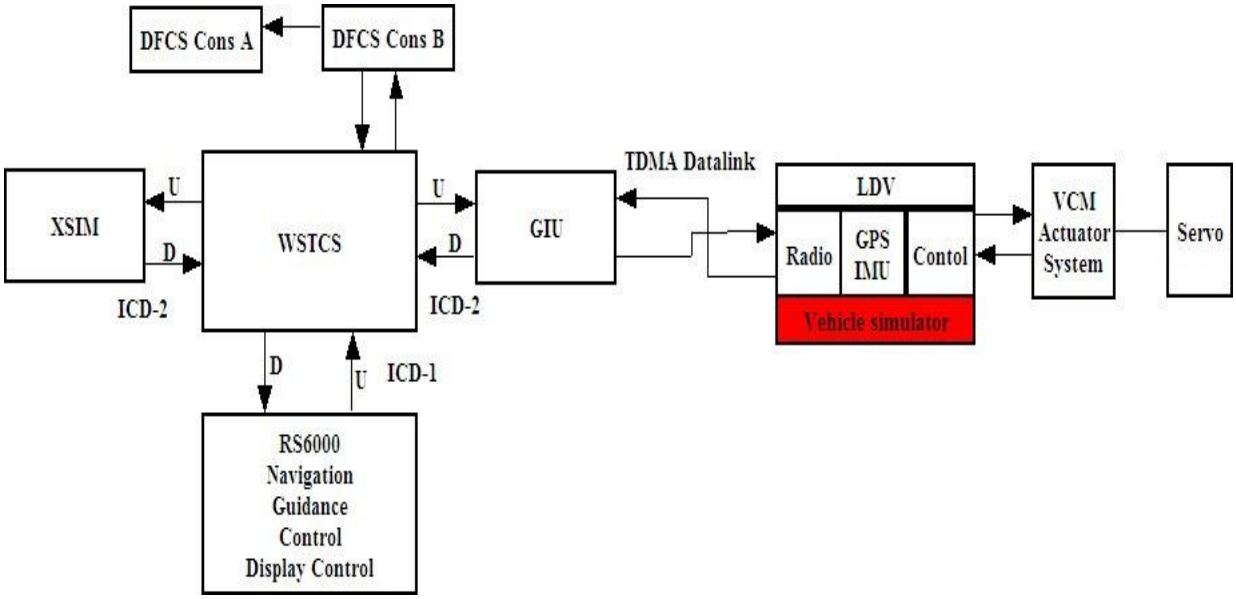


External GVTCS Simulator "XSIM"

- **Resides in a LINUX Dual Pentium PC, written in "C"**
- **System does not know if talking to XSIM or real vehicle**
- **Uses the LDV code to simulate the LDV functions**
- **Steering and throttle dynamics developed using real data.**
- **Simulates all hardware and software**
- **SIMULINK and MATLAB Models available for Simulation and Post Mission Analysis.**
- **Simulates small and 5 Ton Trucks, T-72, BMP, 2S3 tanks**
- **Capability to simulate multiple ground vehicles of different types and in different formations**

Hardware in the Loop

- **Hardware in the Loop Simulation Program**



VIDEOS

Questions & POC

Questions ?

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