Modeling and Simulation of a Skid-Steer UGV in Simulink

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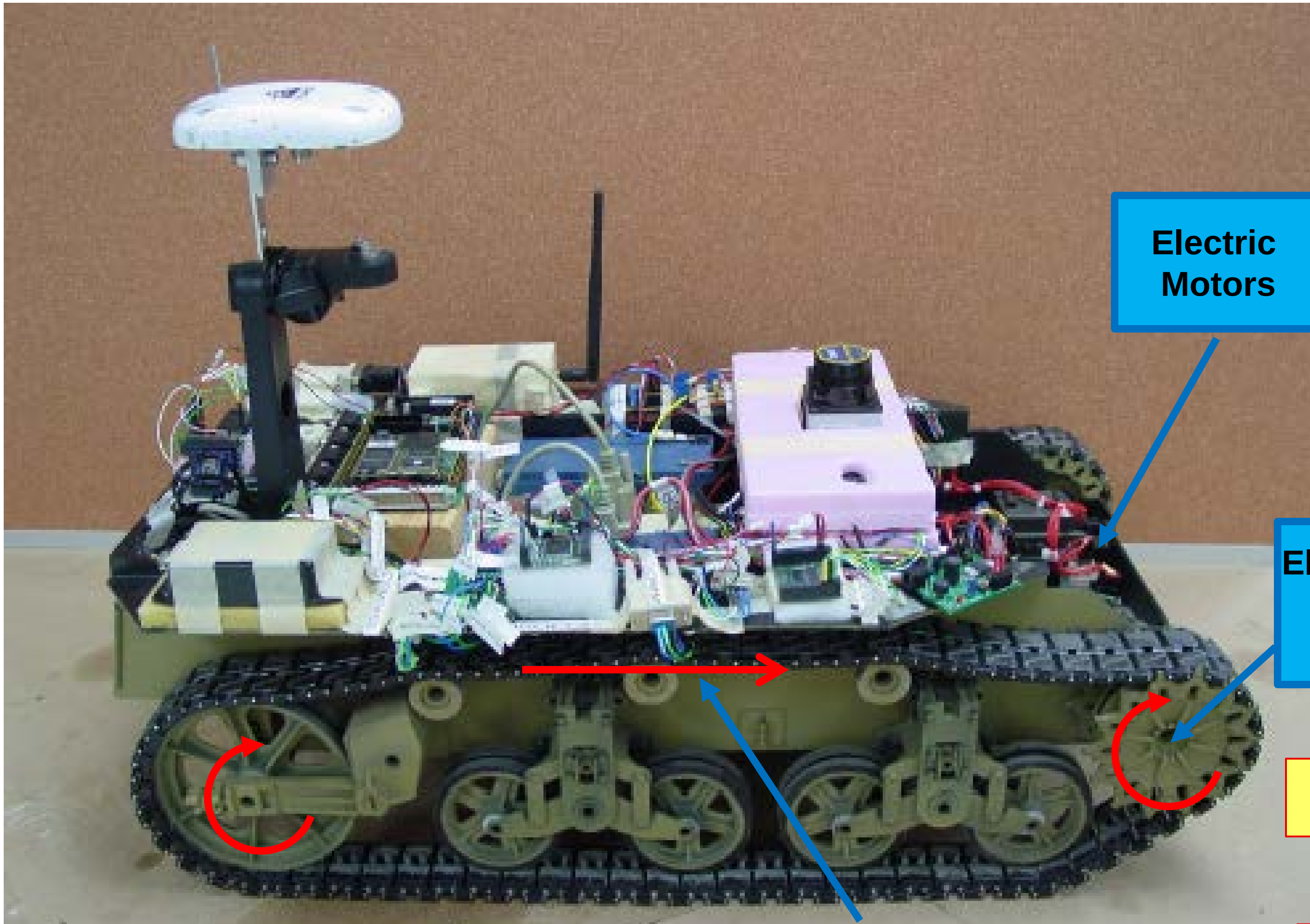
XX4378 and XX5378 - Fall 2017
Introduction to UVS
September 25, 2017

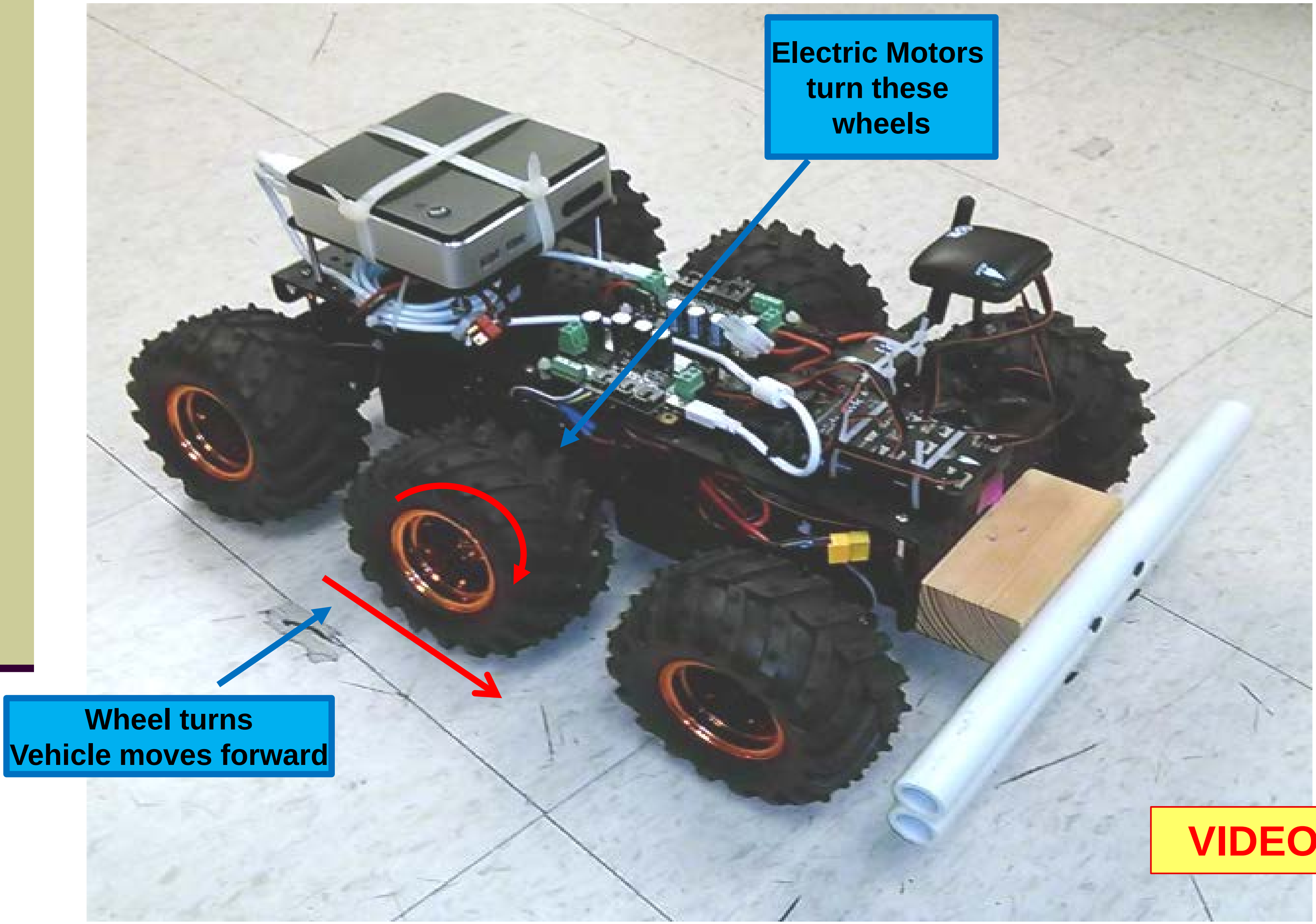
Motion Mechanism (Skid Steer Track Platform)



VIDEO-1

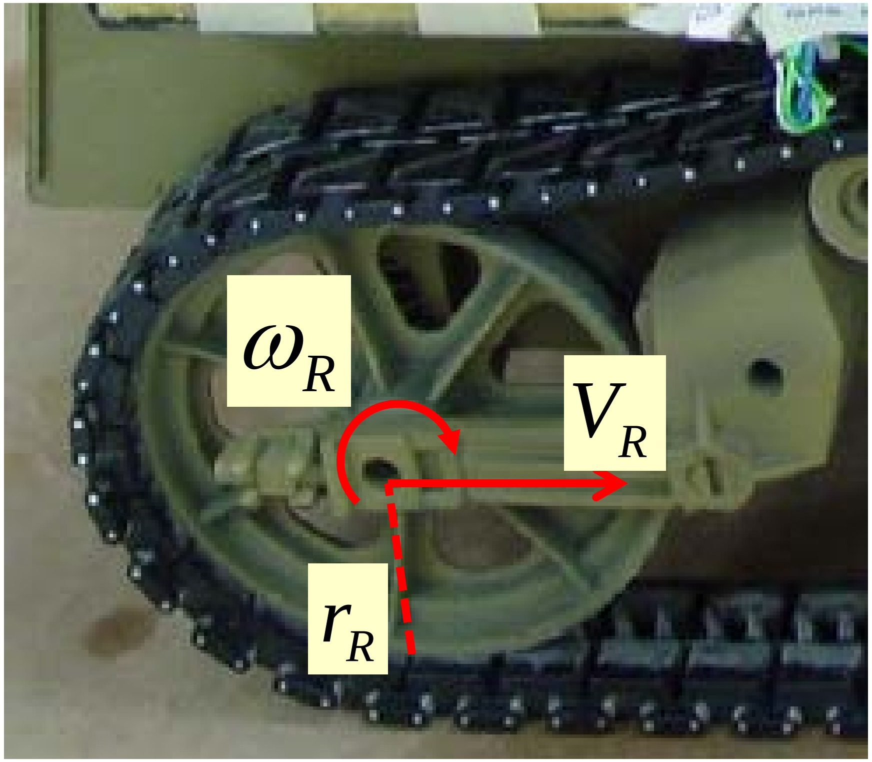
VIDEO-2

Motion Mechanism (Skid Steered Wheel Platform)



VIDEO - 3

Wheel Rotation & Forward Speed



ω_R : wheel angular speed

r_R : wheel radius

$\omega_R r_R$: wheel forward speed if there is no slippage

$0 \leq s_R \leq 1$: slippage factor

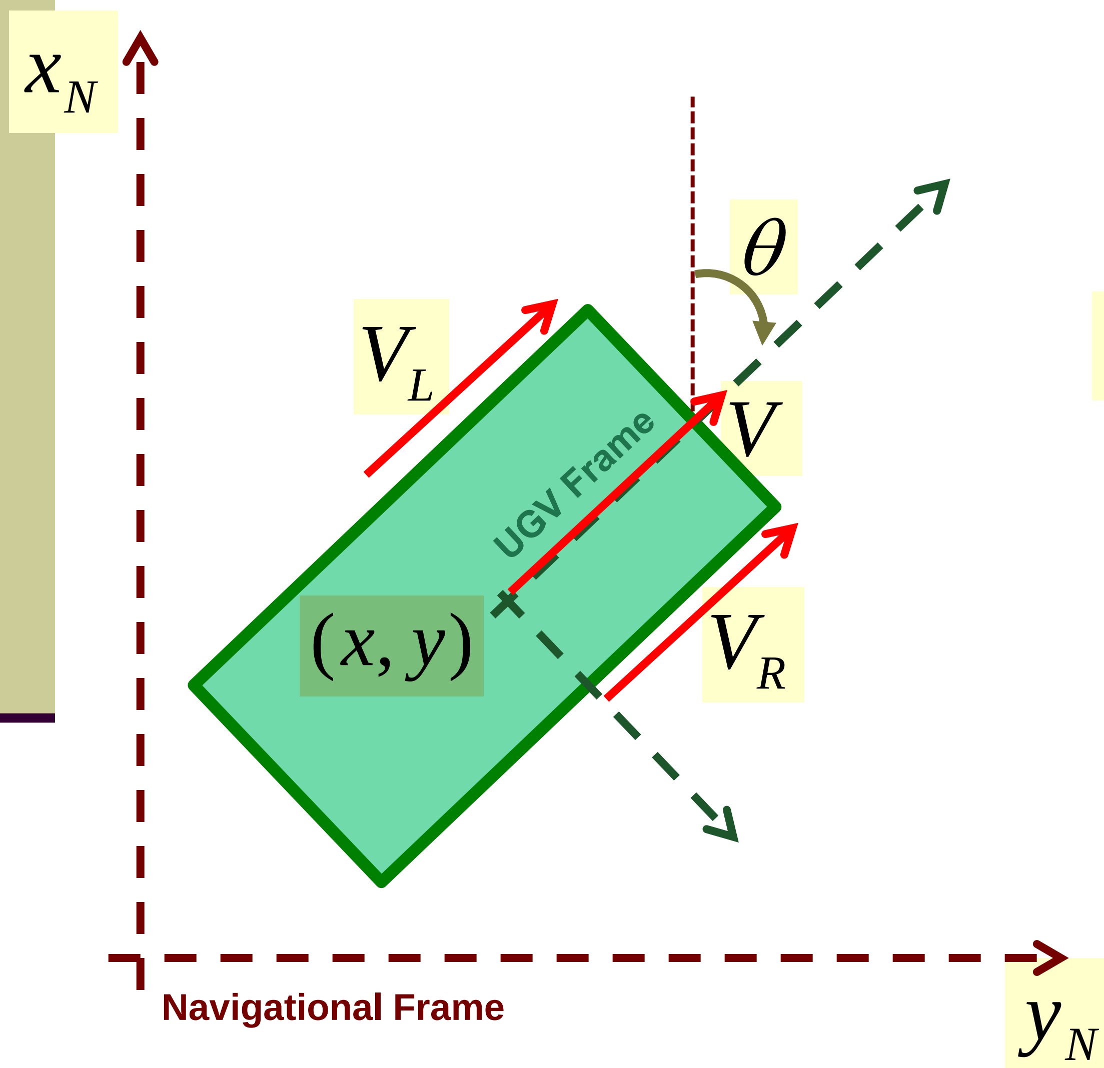
$s_R = 0$: no slippage

$s_R = 1$: full slippage

Wheel forward speed with slippage :

$$V_R = (1 - s_R) r_R \omega_R$$

Wheel Forward Speed & Platform Motion



V_L : Left track speed

V_R : Right track speed

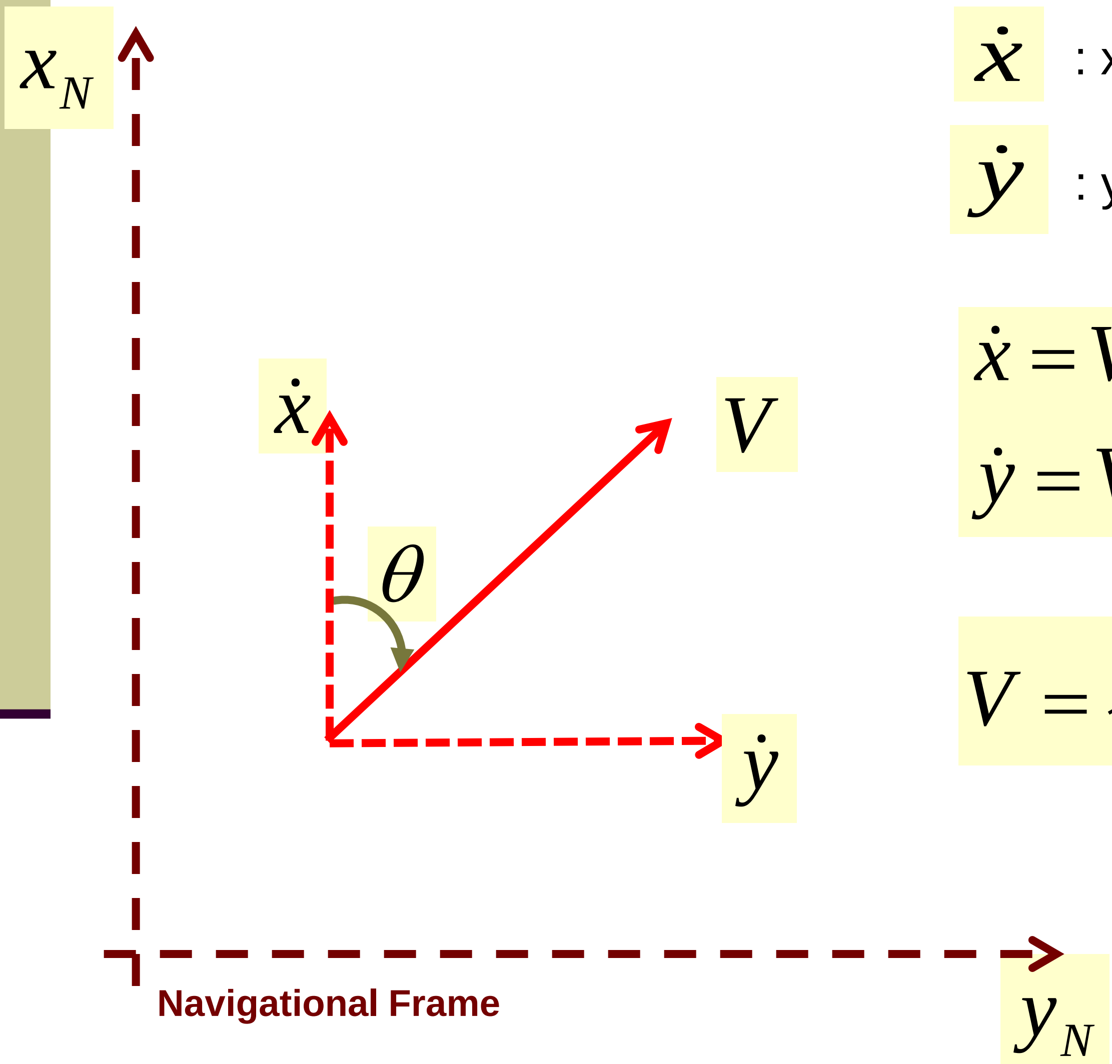
(x, y) : position of UGV

V : UGV forward speed

θ : angle of UGV

$\dot{\theta}$: angular speed

Forward Velocity Components



$\dot{x}$: x-component of forward velocity

$\dot{y}$: y-component of forward velocity

$$\dot{x} = V\cos\theta$$

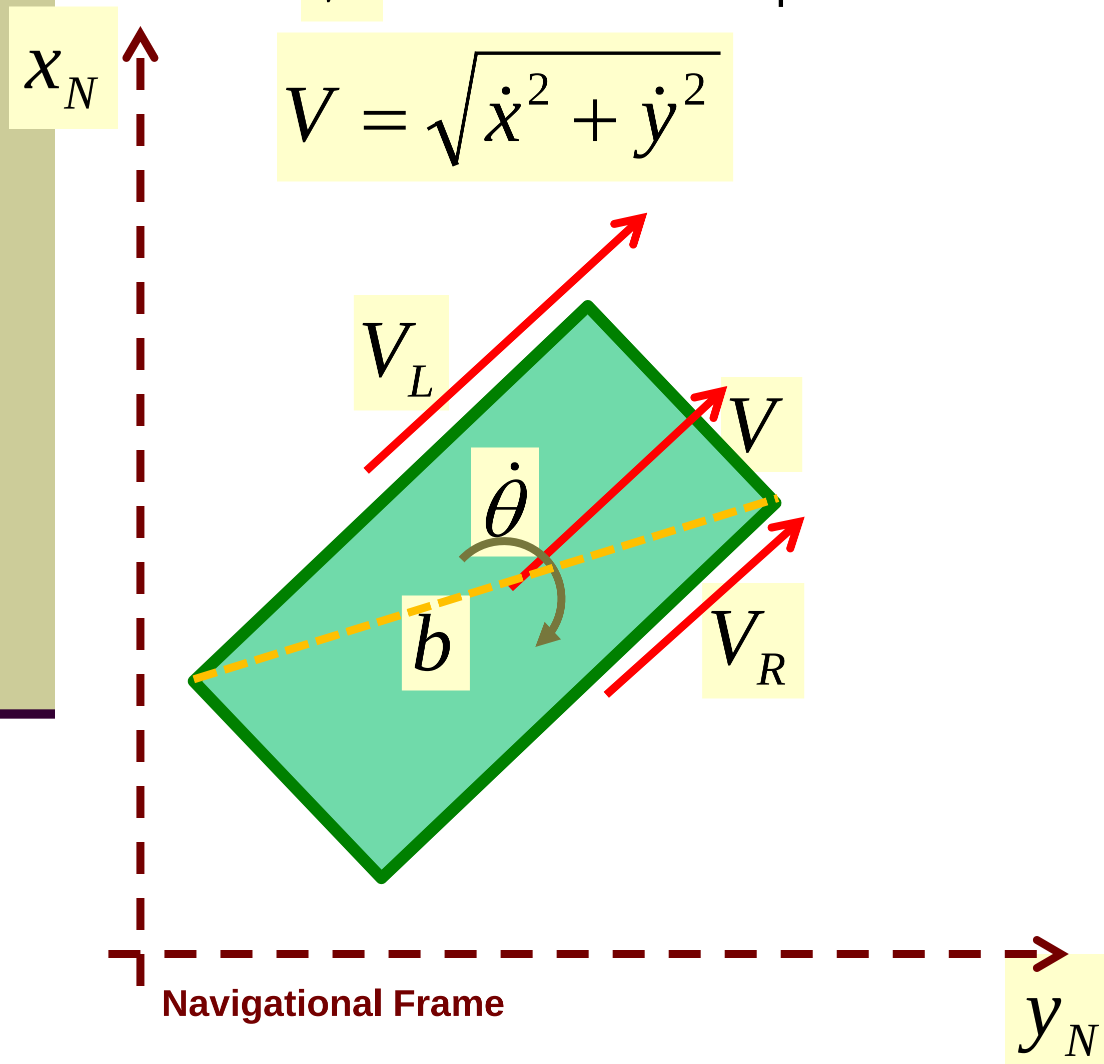
$$\dot{y} = V\sin\theta$$

$$V = \sqrt{\dot{x}^2 + \dot{y}^2}$$

Track Speed & Platform Motion

V : UGV forward speed

$$V = \sqrt{\dot{x}^2 + \dot{y}^2}$$



UGV forward speed is the average of left and right track speeds

$$V = \frac{1}{2}\left(V_L + V_R\right)$$

UGV angular speed is due to the difference between left and right track speeds

$$\dot{\theta} = \frac{1}{b}\left(V_L - V_R\right)$$

b : reference length

Kinematic Equations of Motion

$$\dot{x} = \frac{1}{2}\left[(1-s_L)r_L\omega_L + (1-s_R)r_R\omega_R\right]\cos\theta$$

$$\dot{y} = \frac{1}{2}\left[(1-s_L)r_L\omega_L + (1-s_R)r_R\omega_R\right]\sin\theta$$

$$\dot{\theta} = \frac{1}{b}\left[(1-s_L)r_L\omega_L - (1-s_R)r_R\omega_R\right]$$

Given the left and right wheel speeds,
we can compute translational and angular speed

By integrating translational and angular speeds,
We can compute position and orientation of the UGV

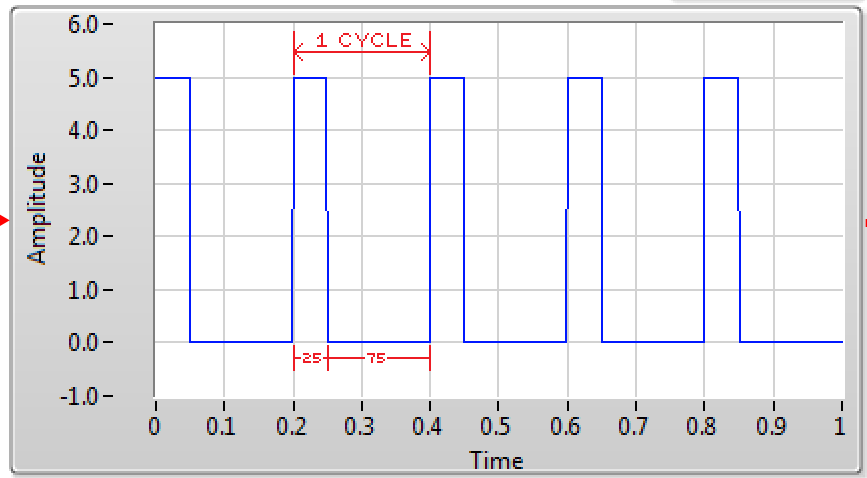
Pulse Width Modulation (PWM)*

- PWM Signal is a method for generating an analog signal using a digital source.
- Two main components
  - **Duty Cycle (DC):** Amount of time the signal is in a high (on) state as a percentage of its one complete cycle.
  - **Frequency:** How fast the PWM completes a cycle
- By cycling a digital signal ON and OFF at a fast enough rate, and with a certain duty cycle,
  - the output will behave like a constant voltage analog signal when providing power to devices.

* http://www.ni.com/tutorial/2991/en/

PWM (Pulse Width Modulation)

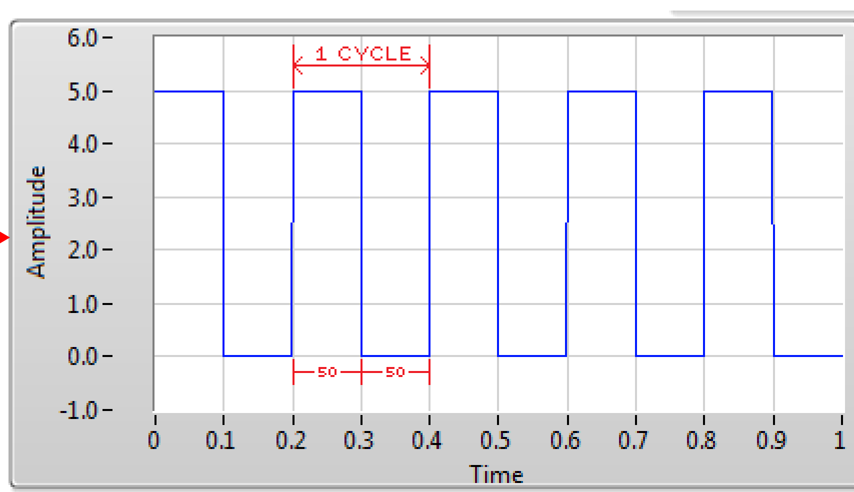
5 V



25% Duty Cycle

5*(1/4) = 1.25 V

5 V

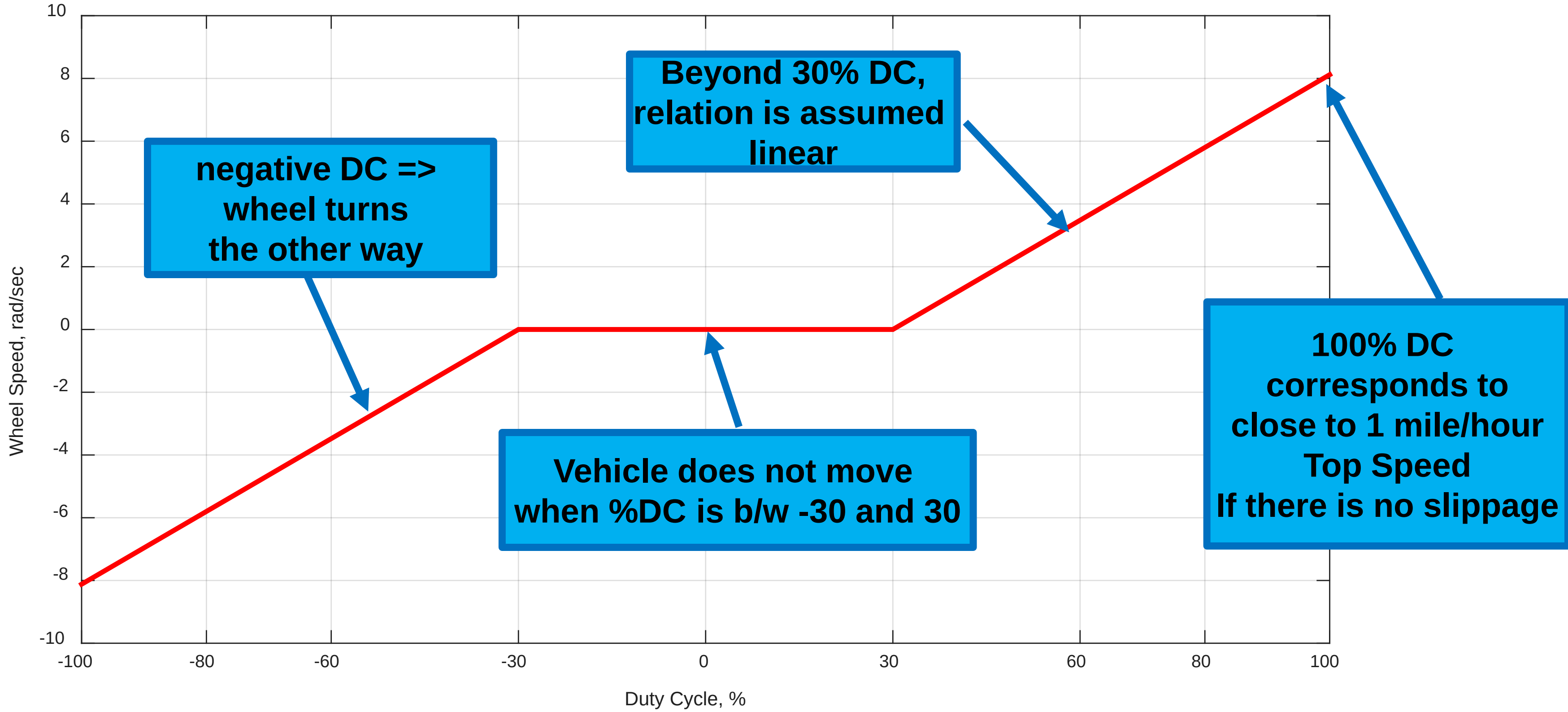


50% Duty Cycle

5*(1/2) = 2.5 V

Electric Motor Speed Control

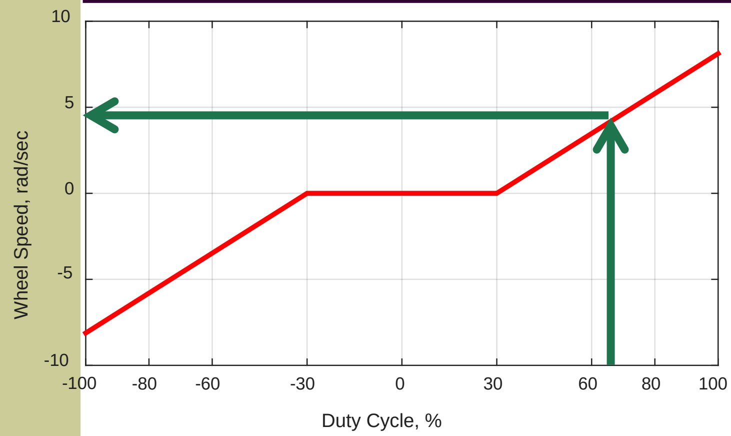
- PWM signal to control electric motor speed and thus wheel speed
- Experiments done to determine relation between duty cycle and wheel speed



Electric Motor Speed Control

- There are two electric motors, each driving left or right wheels
- Total Two Input Signals
  - %DC Left Wheel
  - %DC Right Wheel

Powertrain Dynamics



There will be some delay in the actual speed to reach the desired speed due to the dynamics

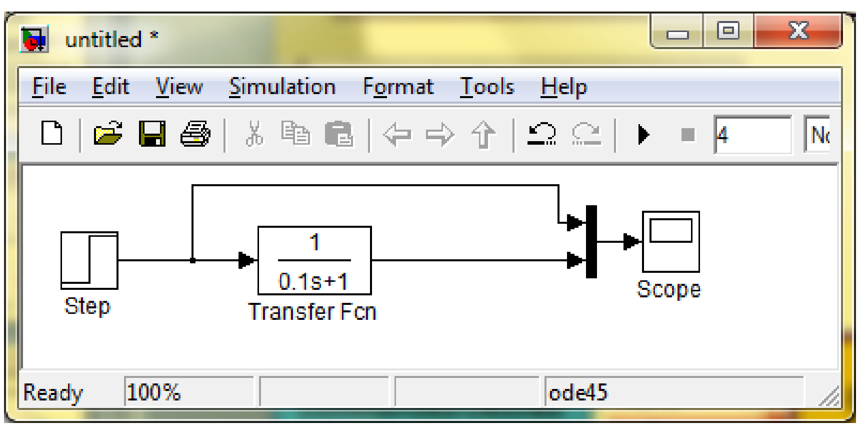
Commanded/Desired Forward/Reverse Track Speed

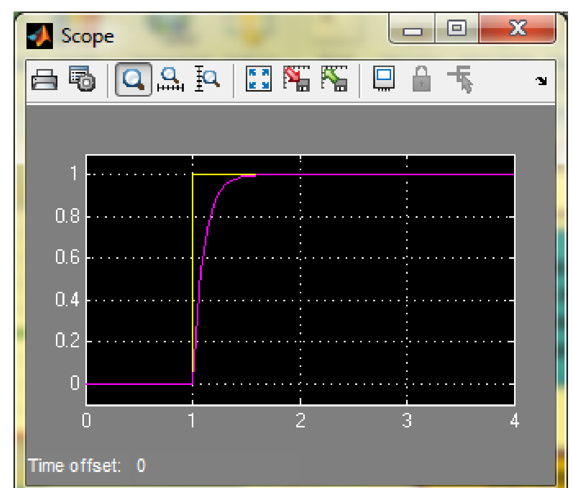
%DC

Dynamics of Electric Motors, Gears, Tracks

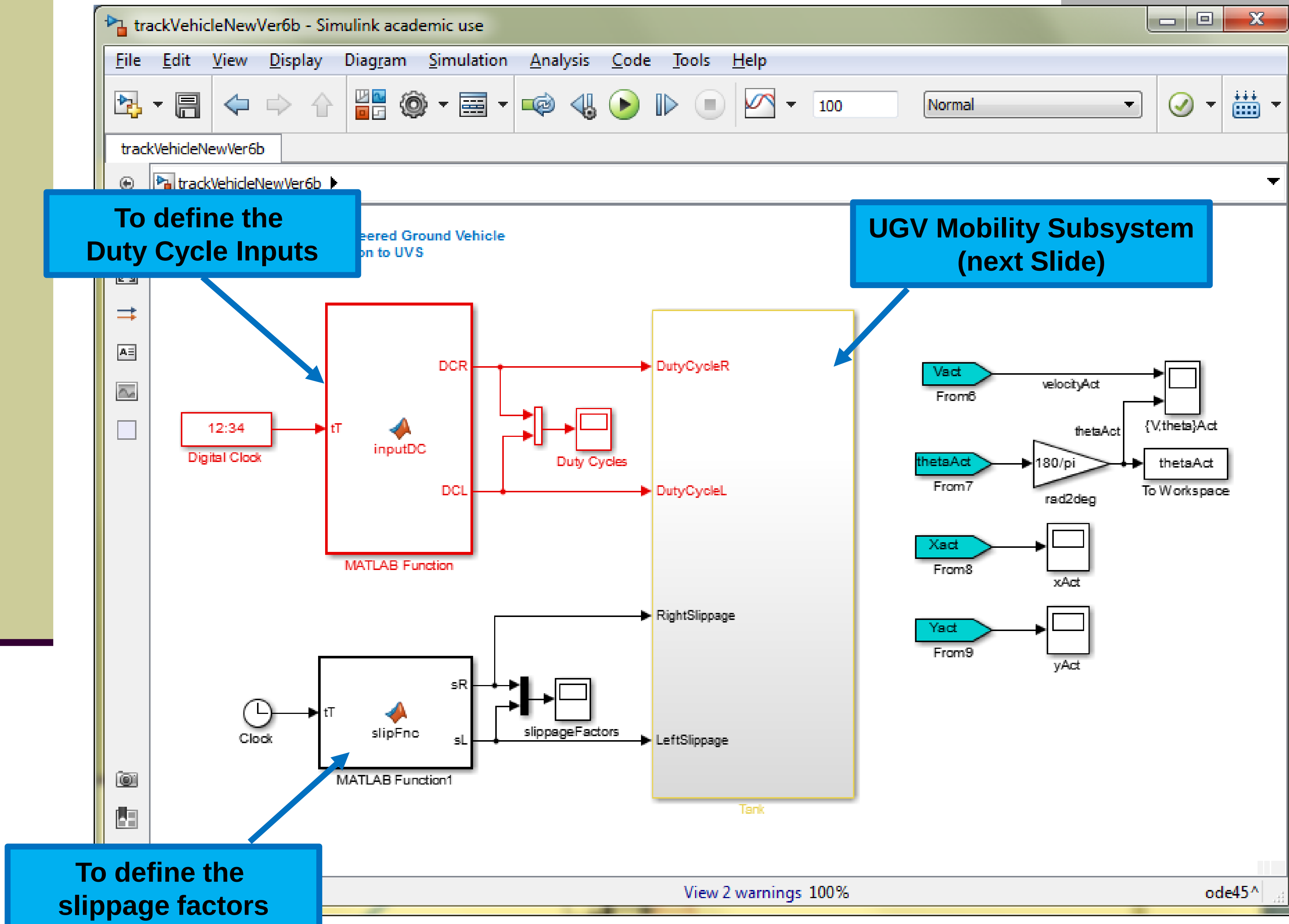
Track Forward/Reverse Speed

This is modeled by a 1st order TF (Transfer Function) or Filter with a time constant (τ), determined by experiment

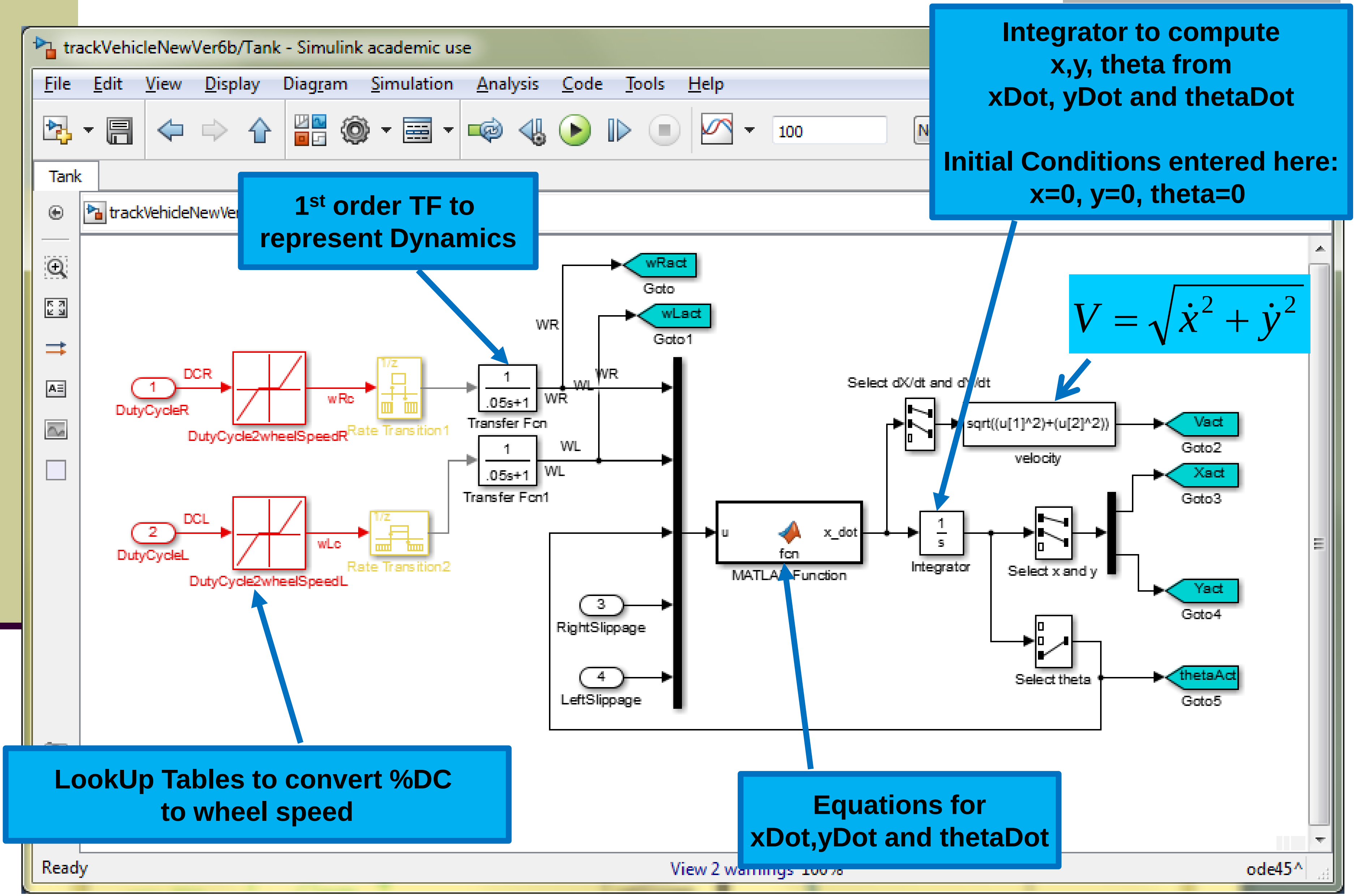




Simulink Model (Top Level)

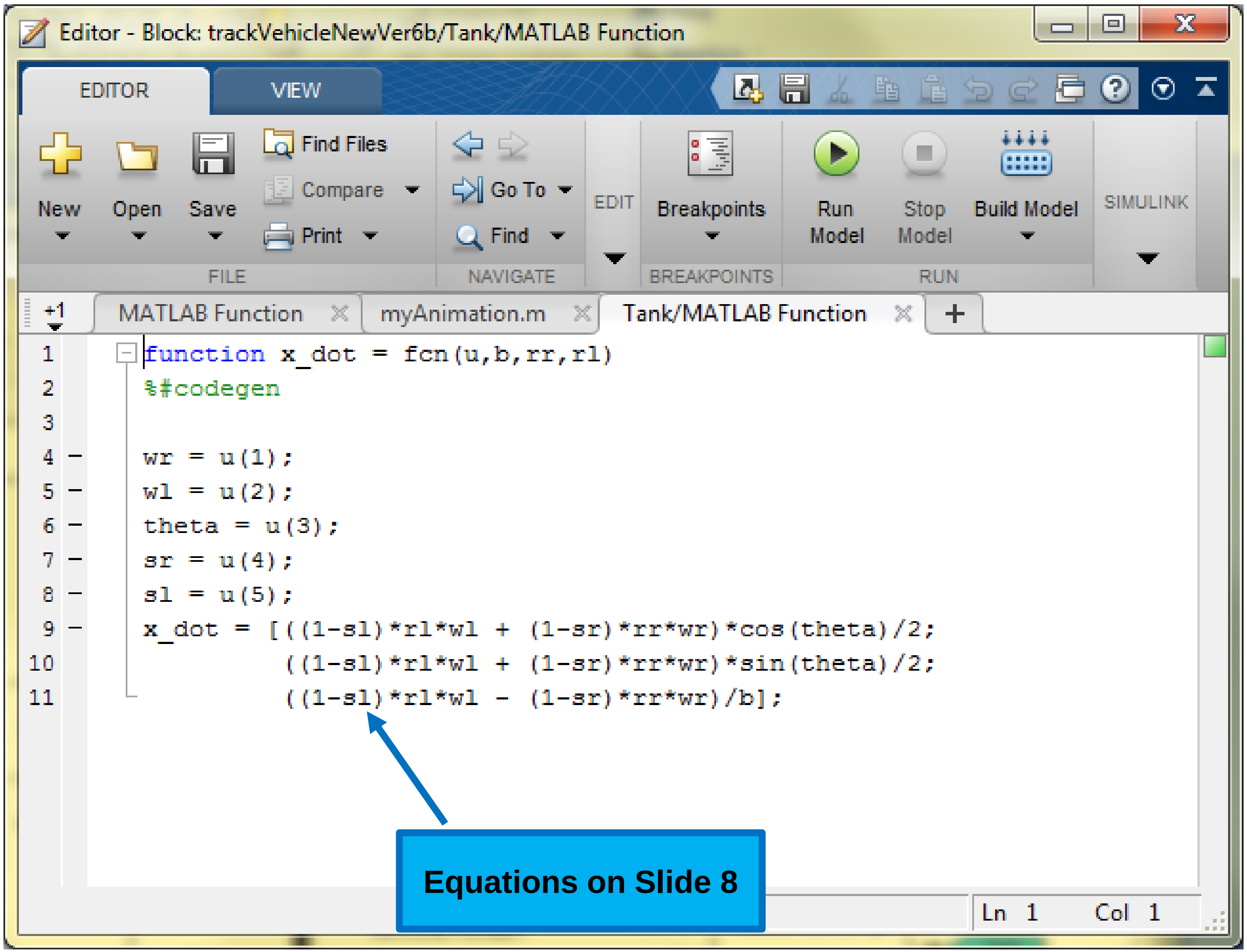


Simulink Model

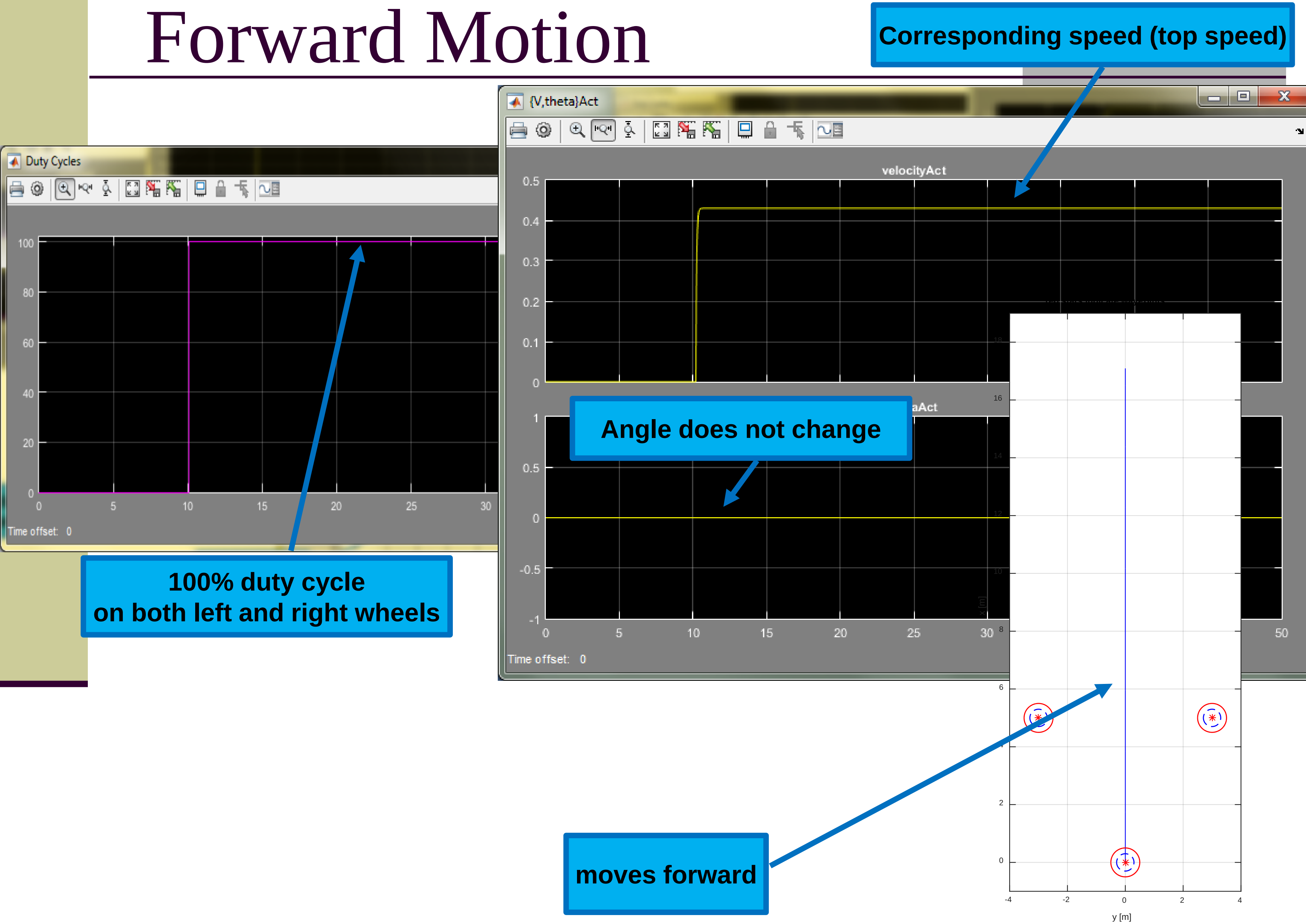


Simulink Model

- MATLAB Function

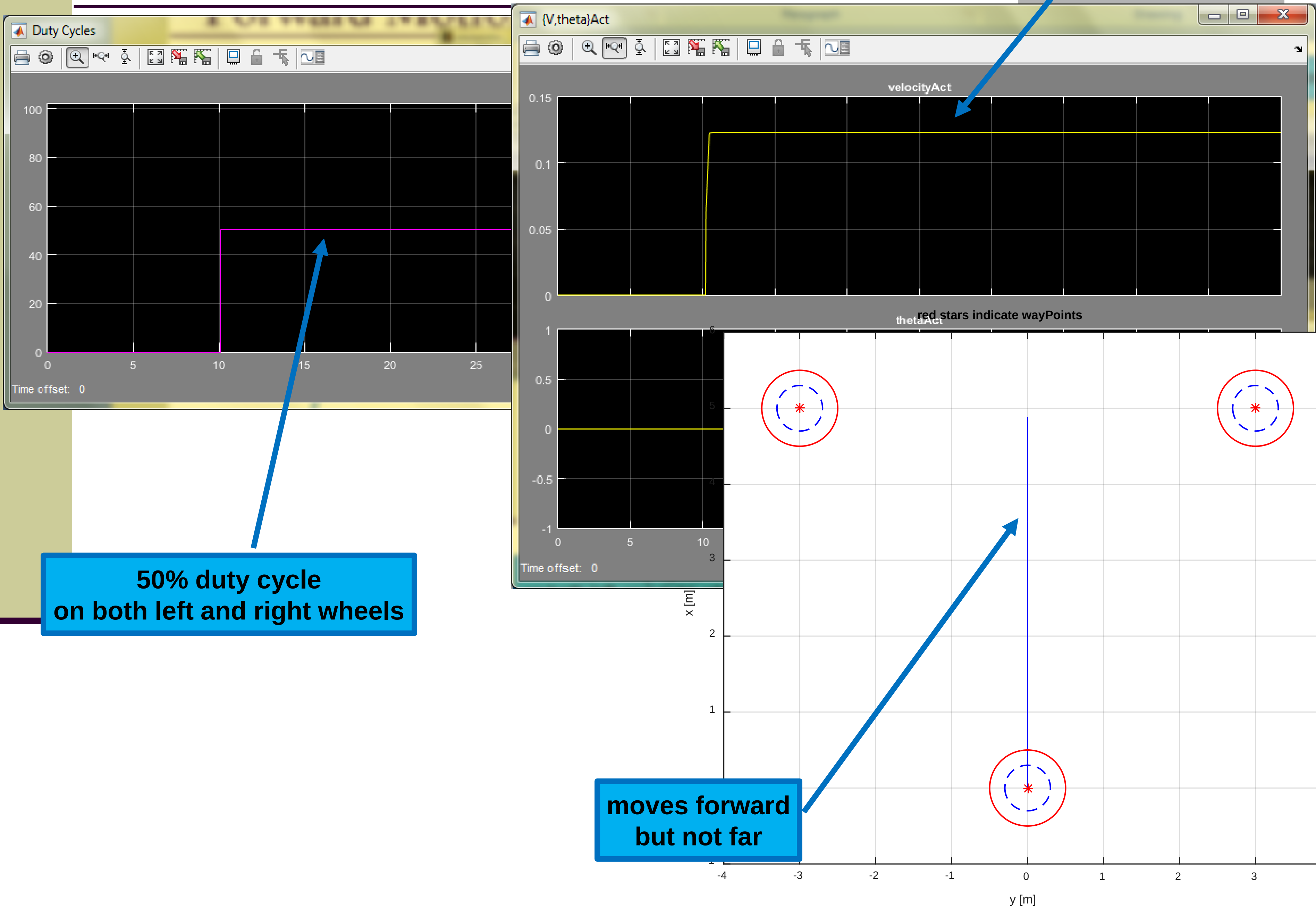


Forward Motion



Forward Motion

Corresponding speed (lower than before)

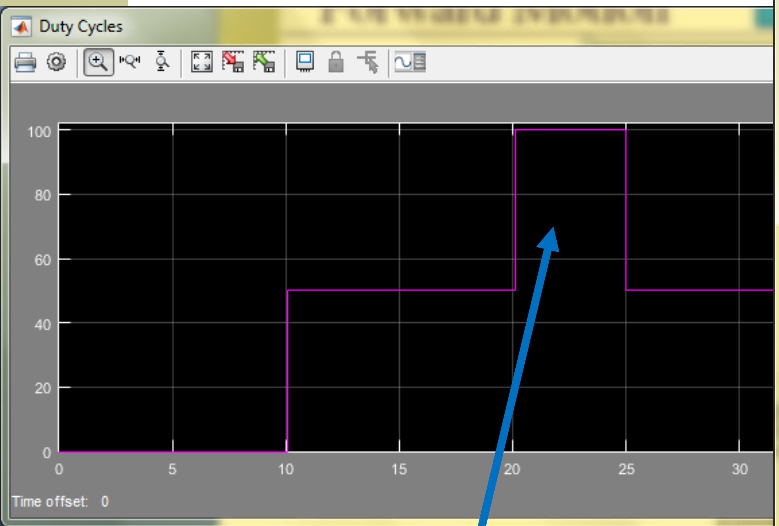


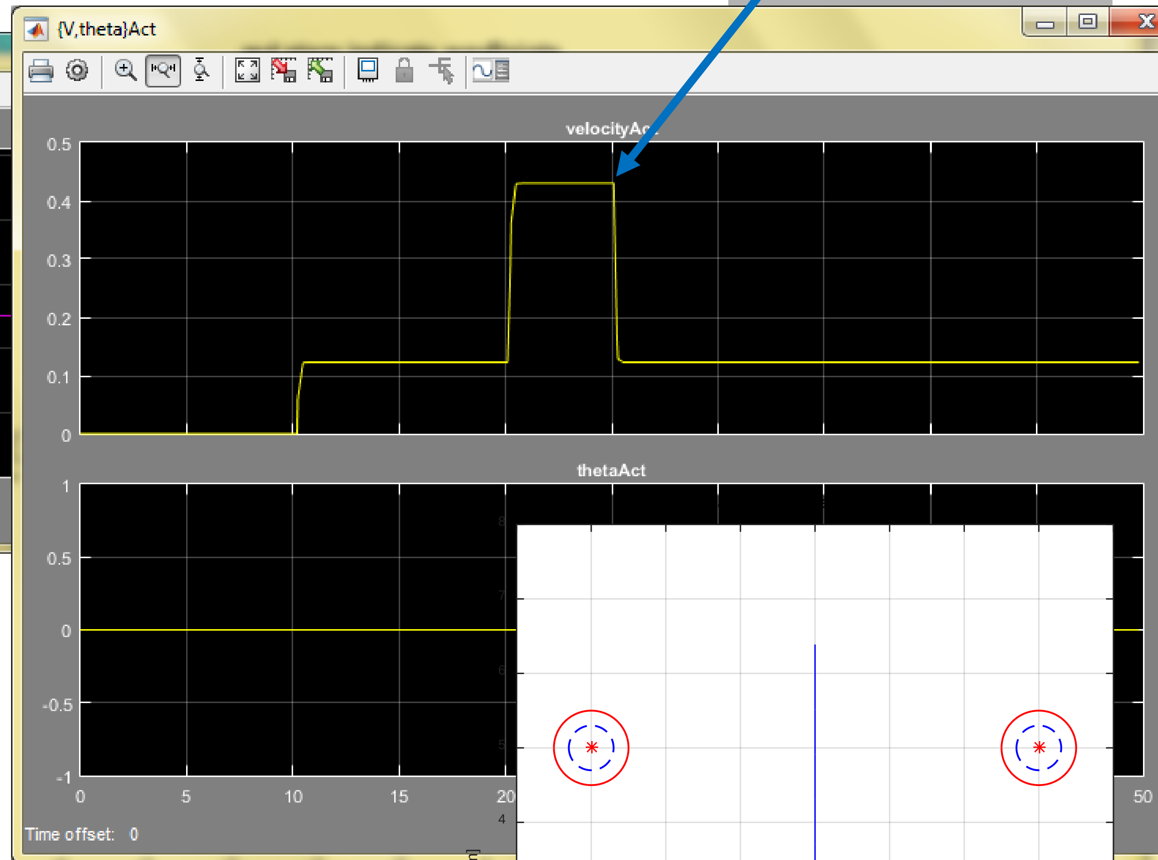
50% duty cycle
on both left and right wheels

moves forward
but not far

Forward Motion

Speed changes



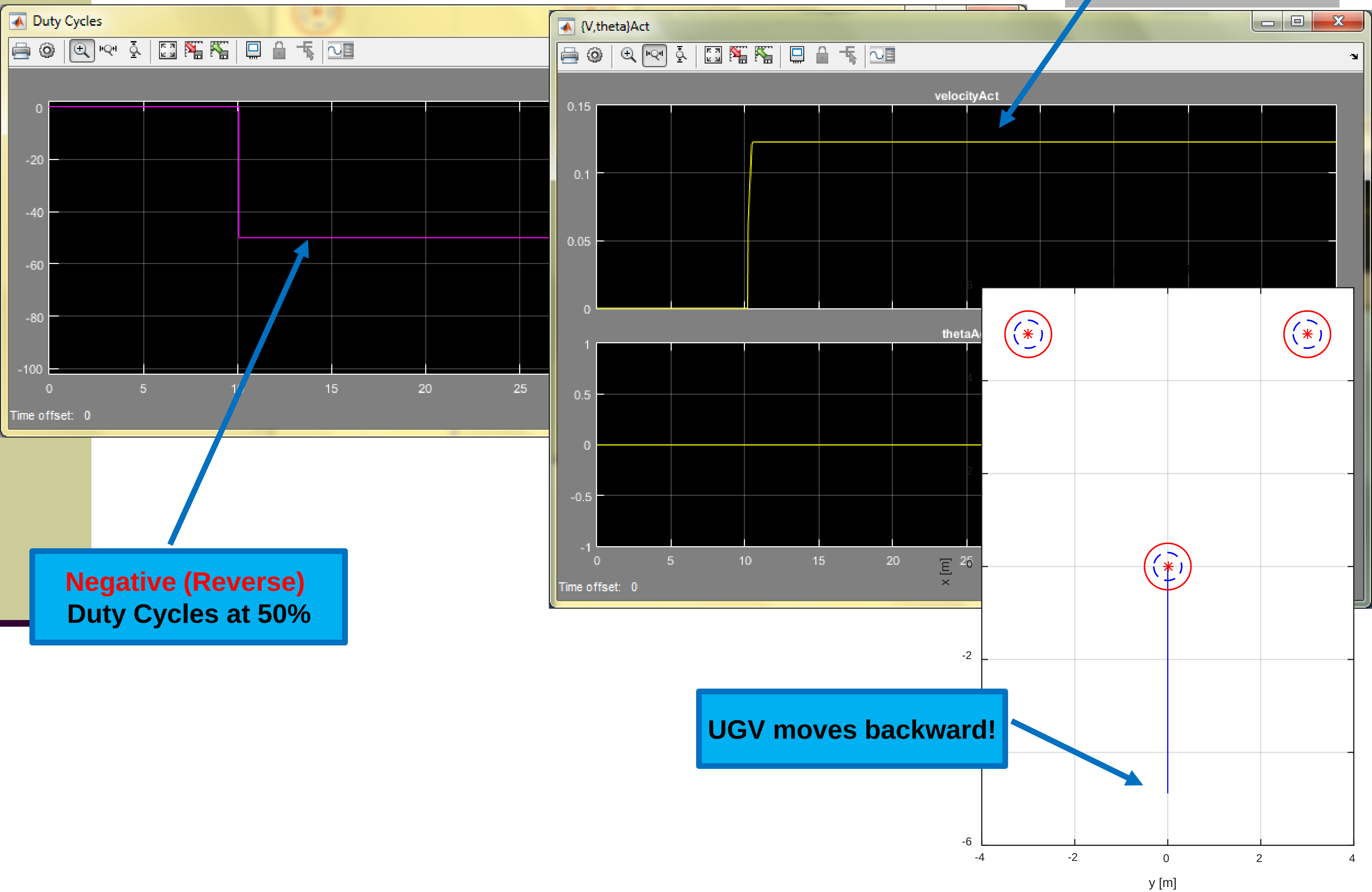


Change Duty Cycle to speed up the UGV while moving forward

Distance traveled changes

Backward Motion

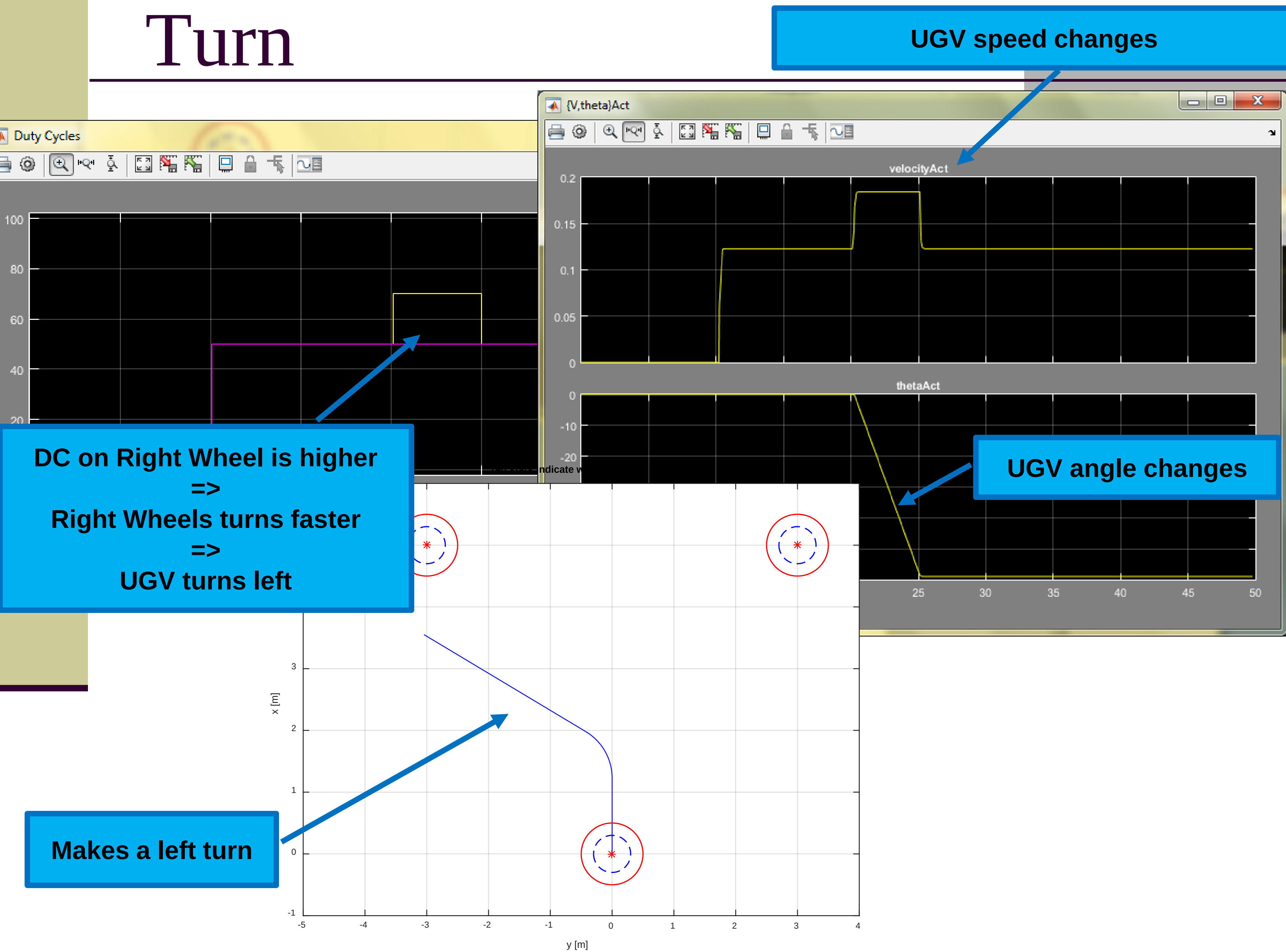
Speed is magnitude of velocity



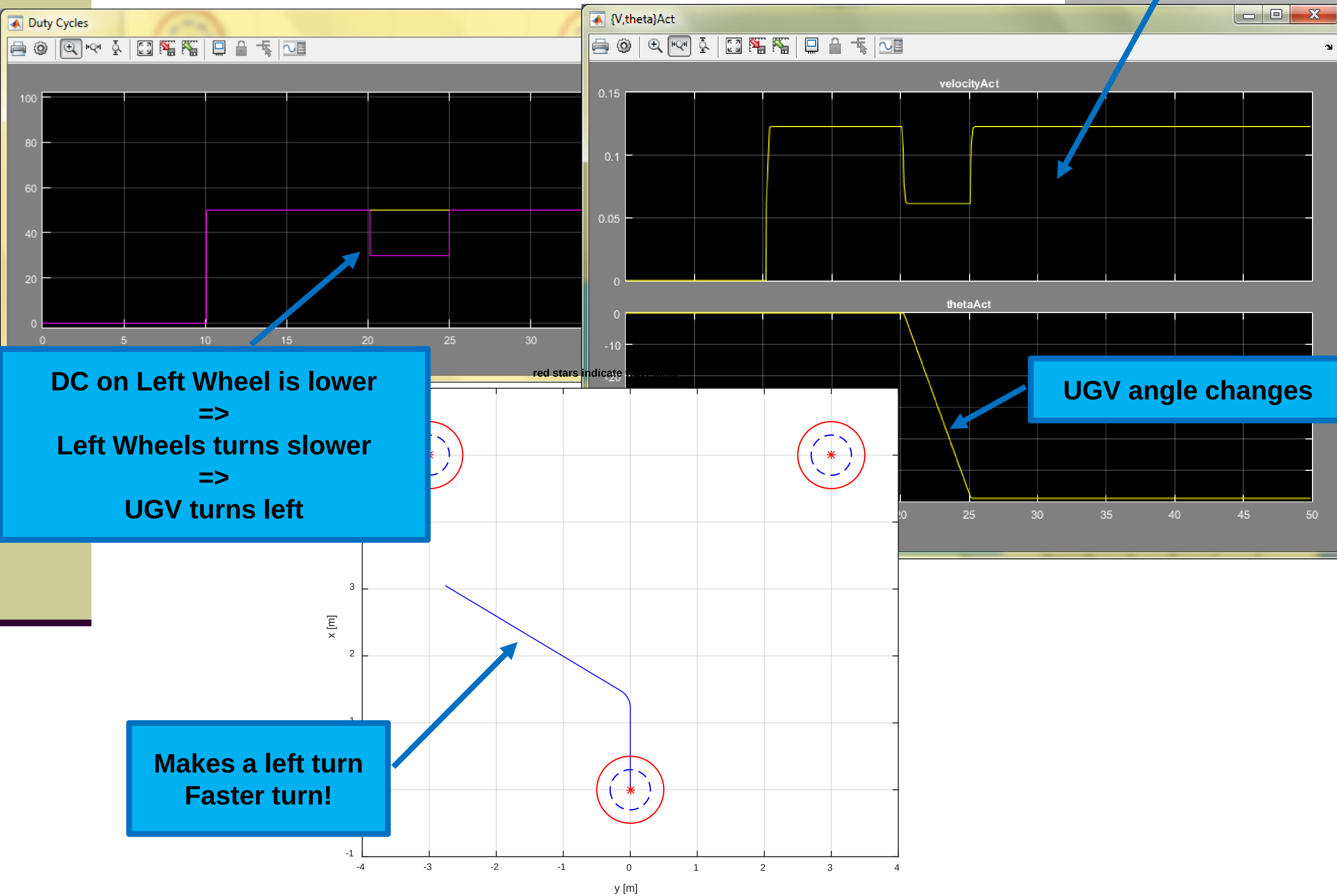
Negative (Reverse) Duty Cycles at 50%

UGV moves backward!

Turn


UGV speed changes
{V,theta}Act
velocityAct
thetaAct
Duty Cycles
DC on Right Wheel is higher
=>
Right Wheels turns faster
=>
UGV turns left
UGV angle changes
Makes a left turn
x [m]
y [m]

Turn



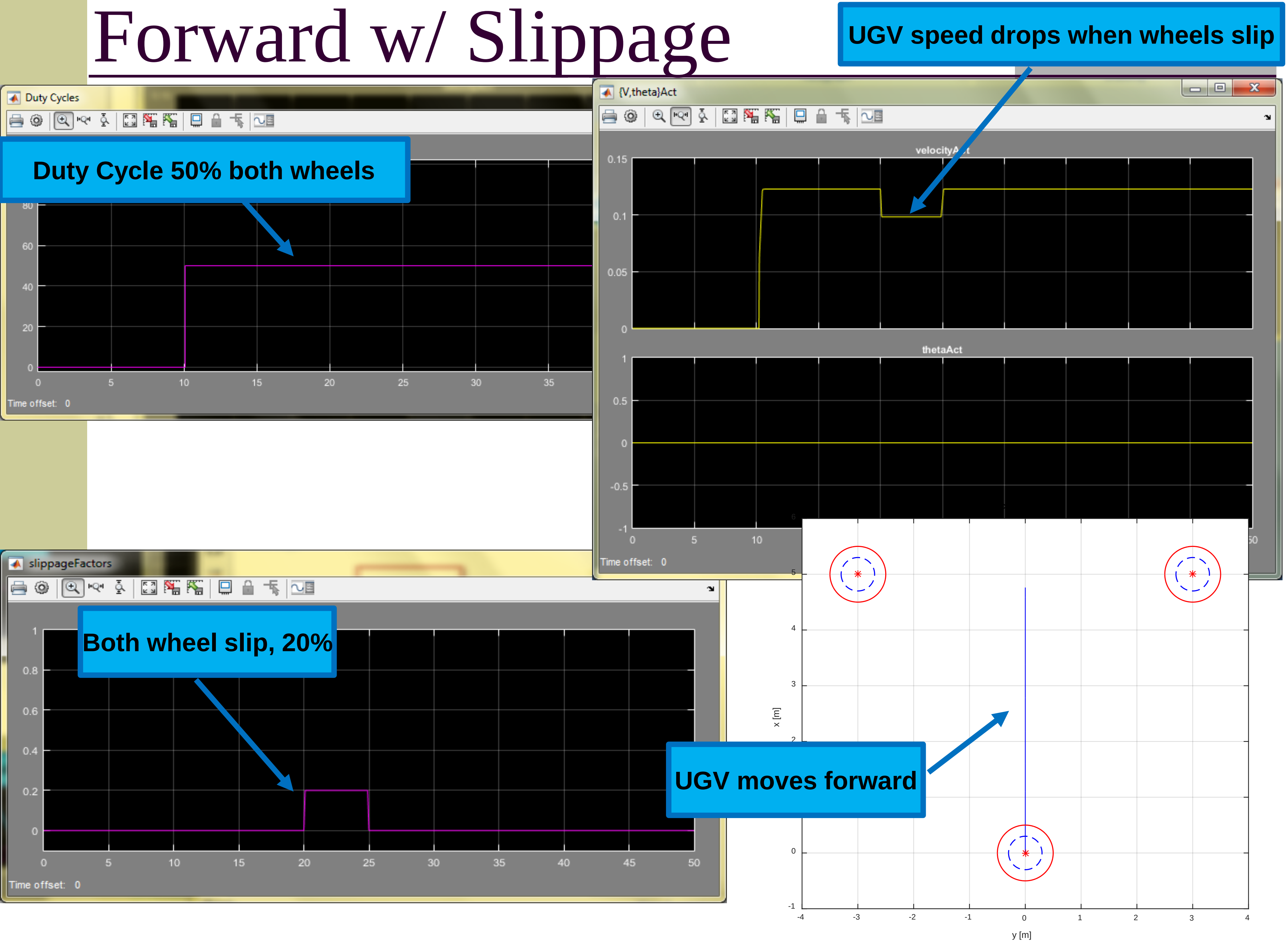
UGV speed changes

DC on Left Wheel is lower
=>
Left Wheels turns slower
=>
UGV turns left

UGV angle changes

Makes a left turn
Faster turn!

Forward w/ Slippage



Uneven Slippage