ATTACHMENT

TO: Federal Advisory Committee Act (FACA) MOVES Model Review Work Group

FROM: US Environmental Protection Agency, Office of Transportation and Air Quality, Assessment and Standards Divison, Air Quality and Modeling Center

SUBJECT: Re: Comments Regarding the Presentations Made at the July 9th MOVES2013 Workshop

In response to the comment regarding the use of fabricated driving cycles of over 70 miles per hour in MOVES, we have run some simulations with the EPA's Greenhouse Gas Emissions Model (GEM) for medium- and heavy-duty vehicle compliance. GEM is a forward-looking full vehicle simulation tool that calculates fuel economy and GHG emissions from an input drive trace and series of vehicle parameters. One of the aspects of forward-looking models is that the driver model is designed to demand torque until the vehicle drive trace is met. If the target drive trace cannot be met due to the limitations of the vehicle and its powertrain, then the maximum speeds and accelerations are output. Our results indicate that the simulated vehicles should be able to follow the speed demands of the proposed driving cycles without exceeding maximum torque or power. Therefore, we plan to use the following cycles with the noted average speeds as originally proposed during the FACA meeting on July 9, 2013 (255, 355, 396, and 397 are driveScheduleIDs in MOVES):

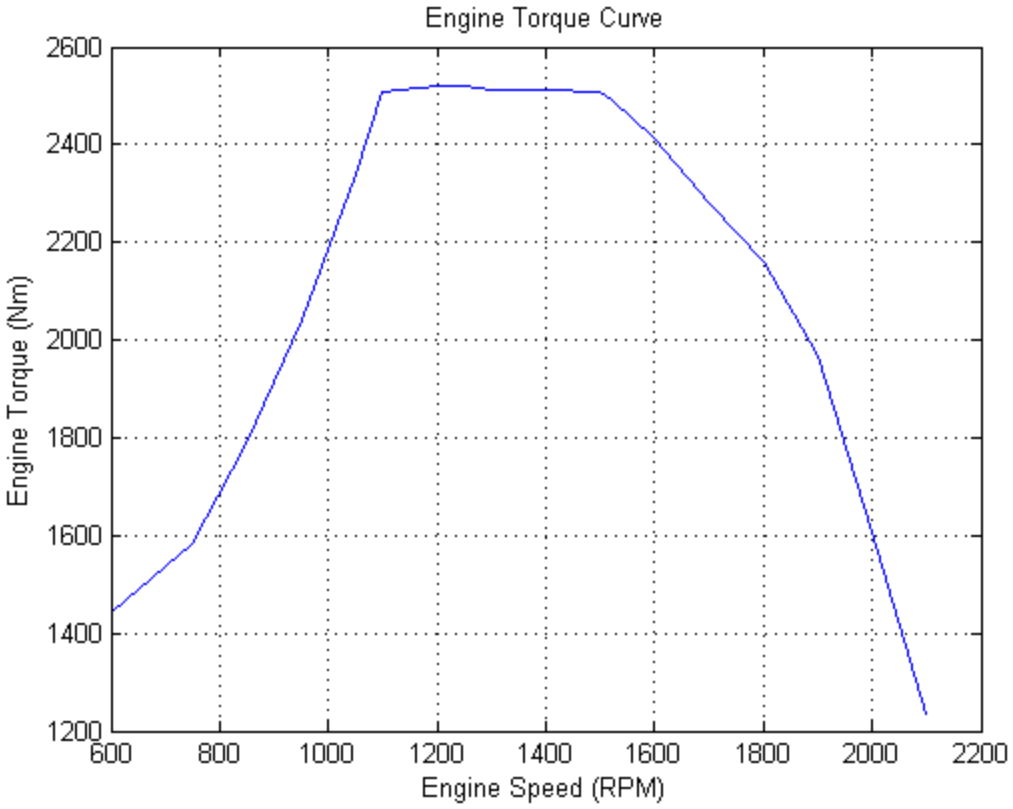
1) 255 – medium-duty high speed (72.8 mph)
2) 355 – heavy-duty high speed (71.7 mph)
3) 396 – heavy-duty high speed plus (76.7 mph)
4) 397 – medium-duty high speed plus (77.8 mph)

More details about the vehicle simulations are discussed below. Vehicle masses were calculated from the default values in the MOVES2010b sourceusetype table, where the average of HPMSVtypeid 50 represented medium-duty trucks and the average of HPMSVtypeid 60 represented heavy-duty trucks. Assumptions on maximum *torque*, transmission ratios, and masses are summarized below:

Heavy-Duty Truck

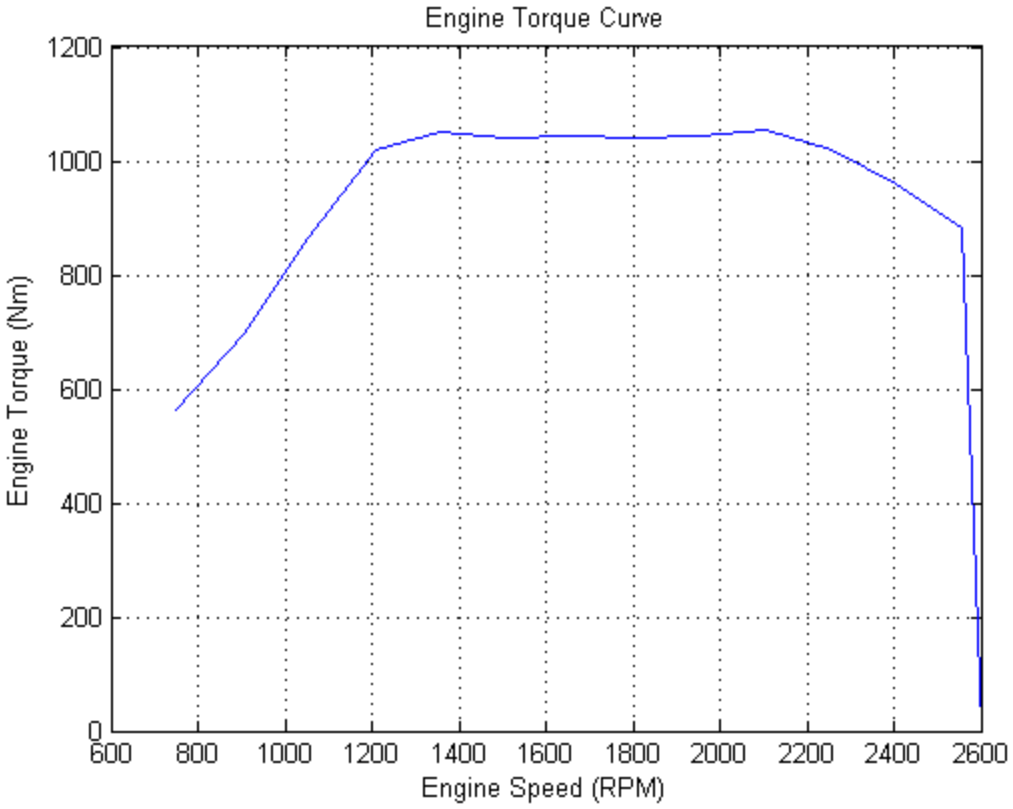
- The vehicle weight was set to 30,366 kg.
- The engine max torque curve was adjusted to represent "PACCAR MX-13 Engine" with rate power of 380-500 HP and rated torque of 1965-2550 Nm. The exact torque curve used during the simulations is shown below.
- The transmission ratio was adjusted to represent "UltraShift PLUS Model – LAS 10B" with ratios of 15.42, 11.52, 8.55, 6.28, 4.67, 3.30, 2.46, 1.83, 1.34, 1.00 corresponding to 1st-10th gears, respectively.[1]

[1] Some minor adjustments were made to update the base GEM parameters - to the maximum torque curves and transmission ratios based on specifications of current on-road vehicles.

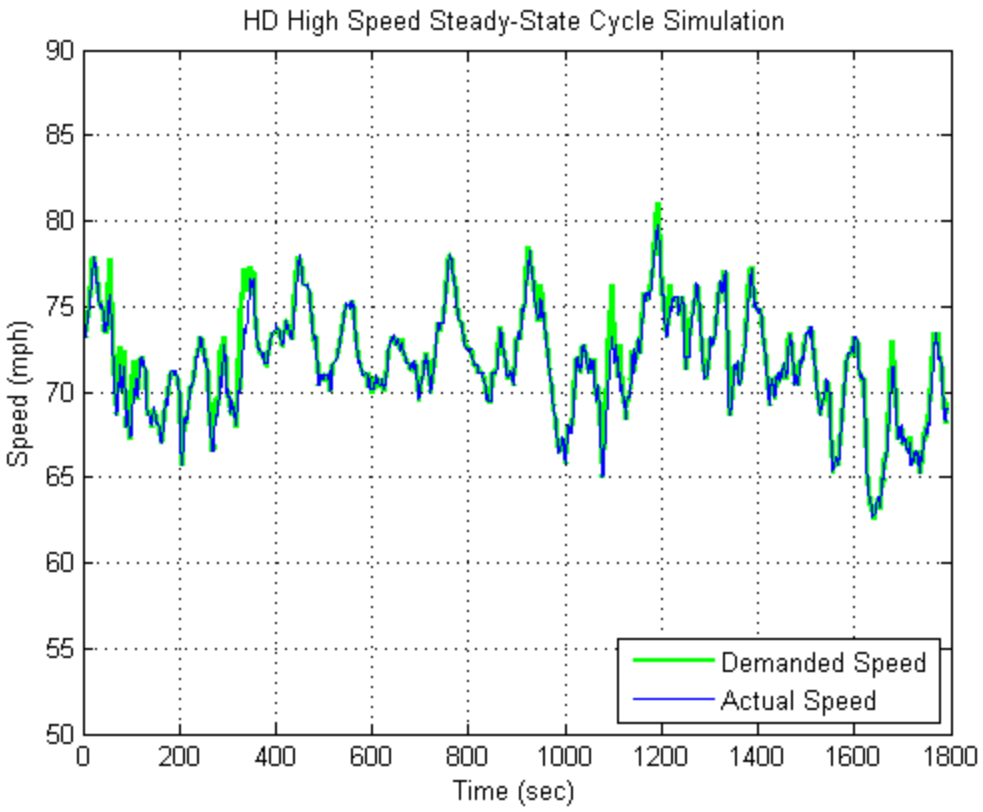


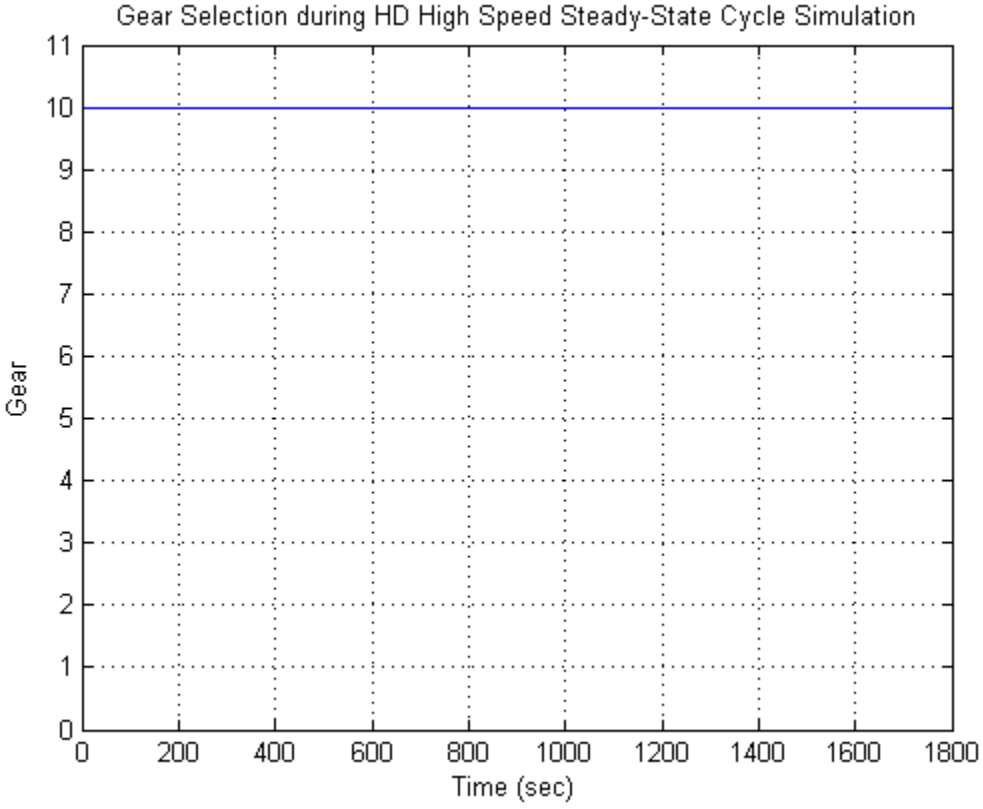
Medium-Duty Truck

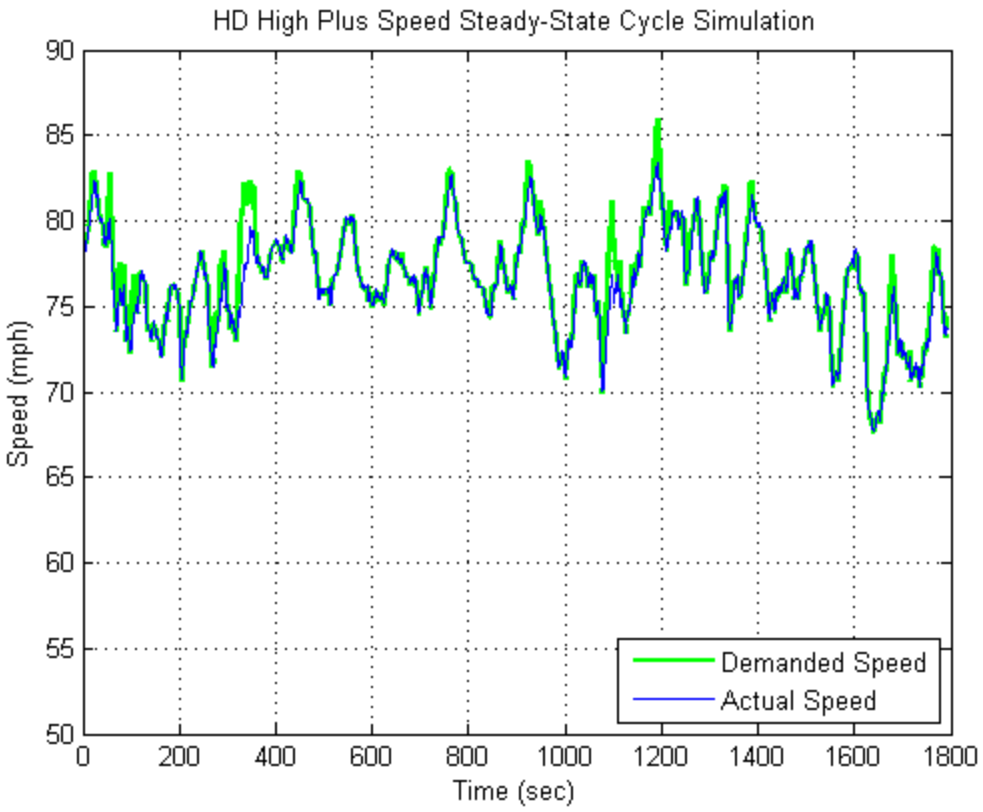
- The vehicle weight was set to 10,328 kg.
- The engine max torque curve was adjusted to represent “PACCAR PX-9 Engine” with rated power of 260-450 HP and rated torque of 720-1250 Nm. The exact torque curve used during the simulations is shown below.
- The transmission ratio was adjusted to represent “Fuller, FSO-8406A” with ratios of 7.05, 4.13, 2.52, 1.59, 1.00, 0.78 corresponding to 1st-6th gears, respectively.

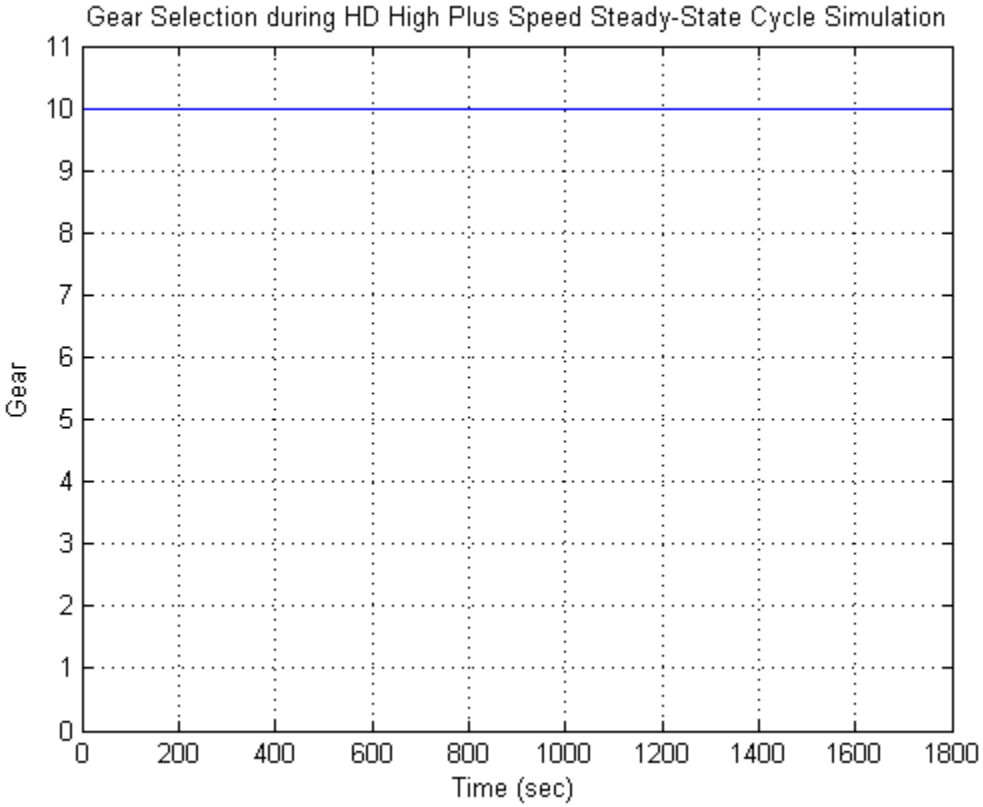


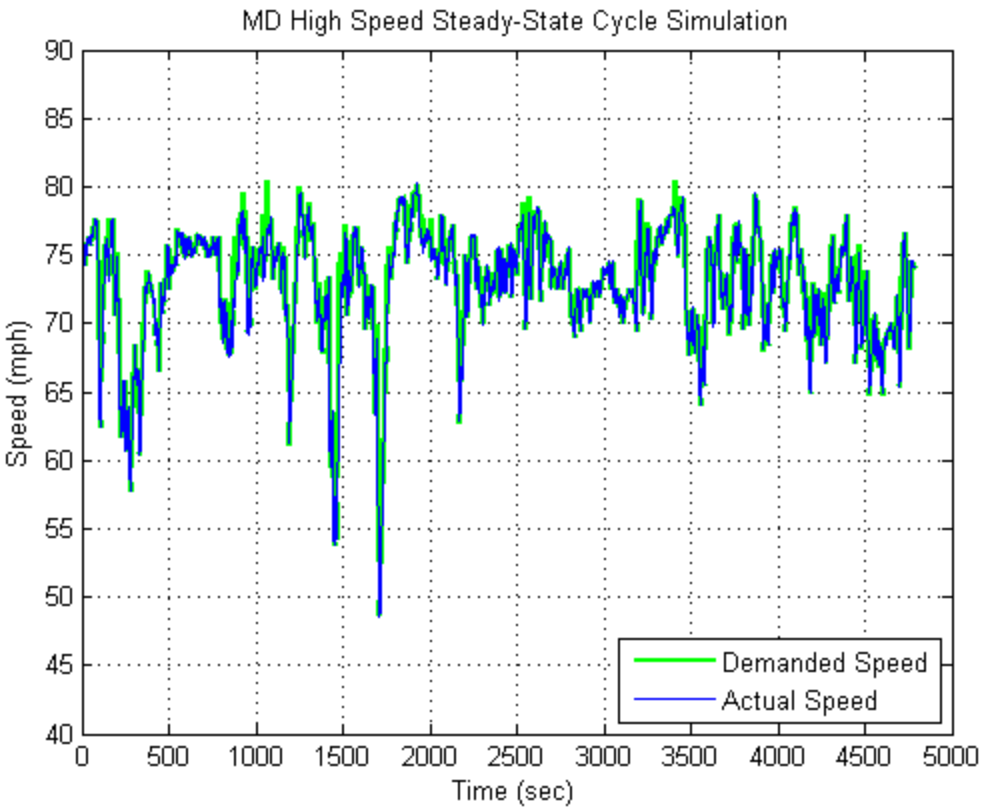
The aforementioned driving cycles and vehicle assumptions were input into GEM to create second-by-second speed traces, as shown on the following pages. While there a few occasions that the instantaneous actual speed does not perfectly match the demanded speed, this is due primarily to the model's limitations rather than the capabilities of the vehicles. The version of GEM (v2.0) used in this analysis uses a driver that is based on engine torque demand instead of wheel torque demand and a simple gear shifting strategy that is based solely on vehicle speed. The newer version of GEM (v3.0) addresses both of these limitations and should be able to further eliminate discrepancies between the demanded and actual speeds in future simulations. For instance, as you can see in the figures shown below, the transmission stays at its highest gear, 10th for HD truck and 6th for MD truck, during the driving cycles due to the model's simple gear shifting strategy. This is a primary reason why there are a few occasions where the simulation was not able to meet the demanded vehicle speed defined by the driving cycle. But, it is important to note that the shortfall in the trace is slight. GEM is currently being updated to incorporate a downshifting strategy during high acceleration regions, so the model will be able to better follow the demanded speed trace. We believe that this is more representative of how truck transmissions are shifted in the real world.

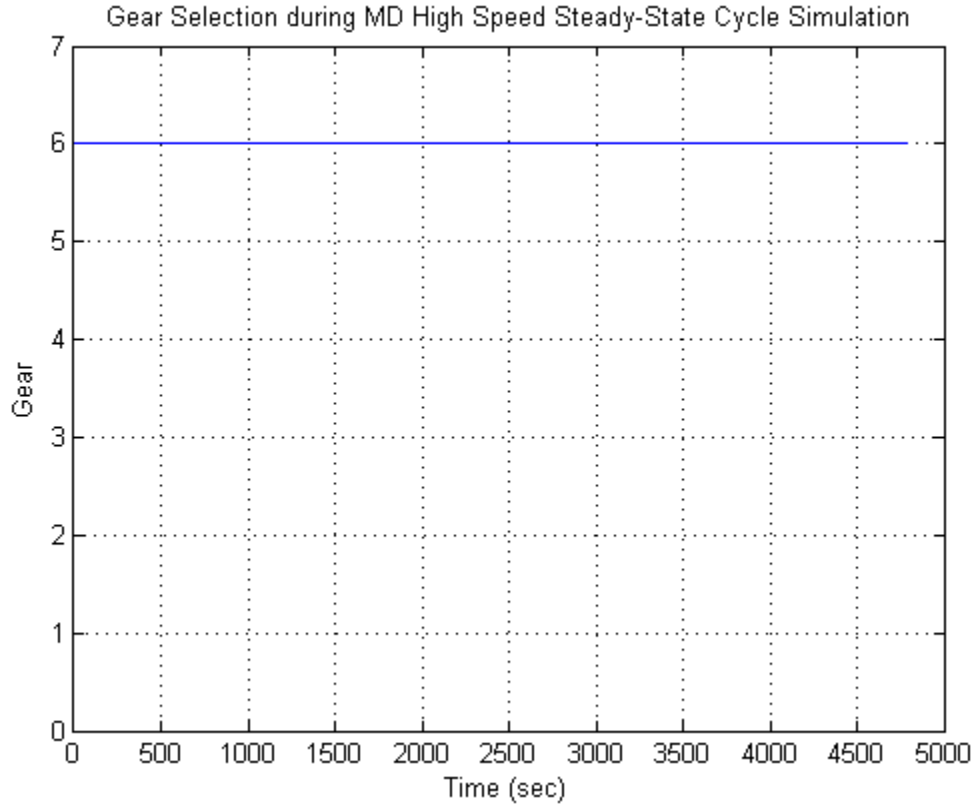

HD High Speed Steady-State Cycle Simulation
Speed (mph)
Time (sec)
Demanded Speed
Actual Speed
90
85
80
75
70
65
60
55
50
0
200
400
600
800
1000
1200
1400
1600
1800

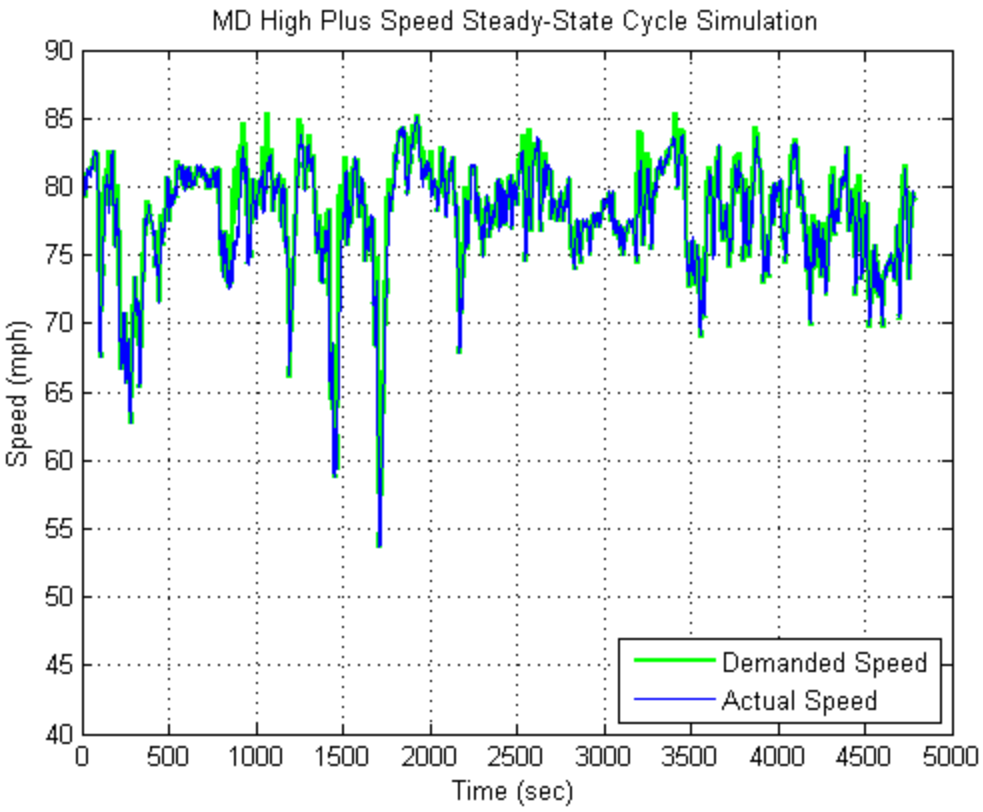

Gear Selection during HD High Speed Steady-State Cycle Simulation
Gear
Time (sec)
11
10
9
8
7
6
5
4
3
2
1
0
0
200
400
600
800
1000
1200
1400
1600
1800

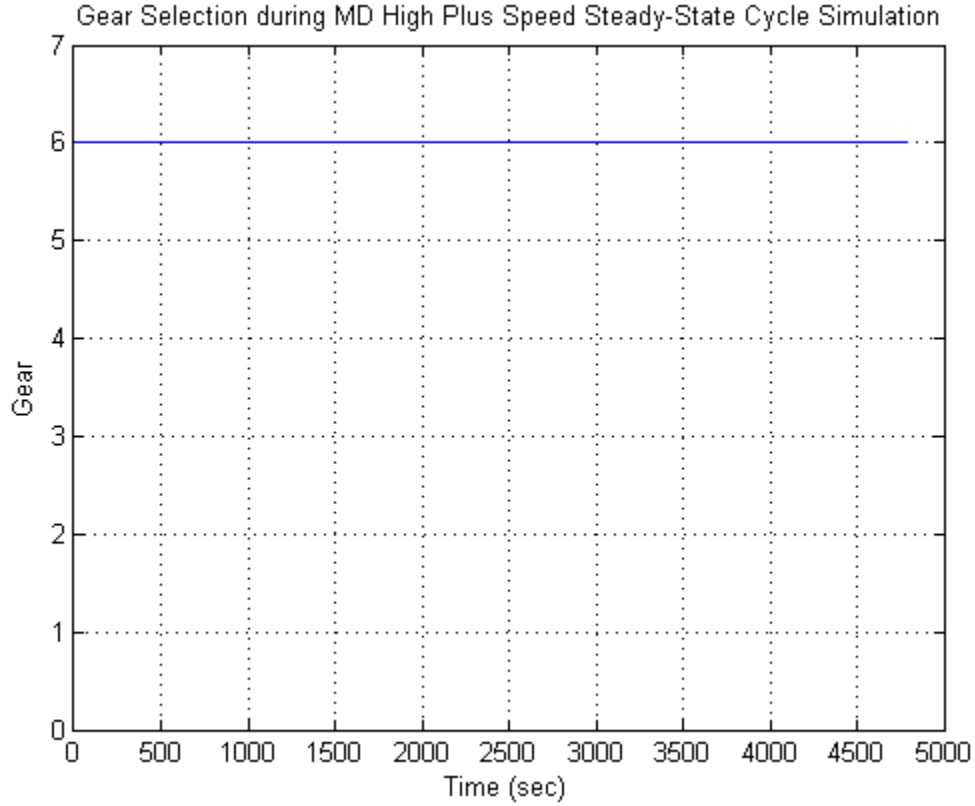

HD High Plus Speed Steady-State Cycle Simulation
Speed (mph)
Time (sec)
Demanded Speed
Actual Speed
90
85
80
75
70
65
60
55
50
0
200
400
600
800
1000
1200
1400
1600
1800


Gear Selection during HD High Plus Speed Steady-State Cycle Simulation
Gear
Time (sec)
11
10
9
8
7
6
5
4
3
2
1
0
0
200
400
600
800
1000
1200
1400
1600
1800


MD High Speed Steady-State Cycle Simulation
Speed (mph)
Time (sec)
Demanded Speed
Actual Speed
90
85
80
75
70
65
60
55
50
45
40
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000


Gear Selection during MD High Speed Steady-State Cycle Simulation
Gear
Time (sec)
7
6
5
4
3
2
1
0
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000


MD High Plus Speed Steady-State Cycle Simulation
Speed (mph)
Time (sec)
Demanded Speed
Actual Speed
90
85
80
75
70
65
60
55
50
45
40
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000


Gear Selection during MD High Plus Speed Steady-State Cycle Simulation
Gear
Time (sec)
7
6
5
4
3
2
1
0
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000