

Single and Multi-Vehicle Simulations

Team Name: taketwo

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Git Repo Link

https://github.com/kjgilder/taketwo_test_simulations/tree/main

Files Executed (with relative Git positioning)

1. Single Vehicle: single_sim.slx
 - a. single/single_sim.slx
2. Mode (Single Vehicle): taketwo_mode_sim.slx
 - a. modes/taketwo_mode_sim.slx
3. Multivehicle
 - a. constant_leader_sim.slx (multi/constant_leader_sim.slx)
 - b. oscillating_leader_sim.slx (multi/oscillating_leader_sim.slx)
 - c. random_leader_sim.slx (multi/random_leader_sim.slx)
 - d. switching_leader_sim.slx (multi/switching_leader_sim.slx)
4. [README.md](#)

Mode 0: No leader

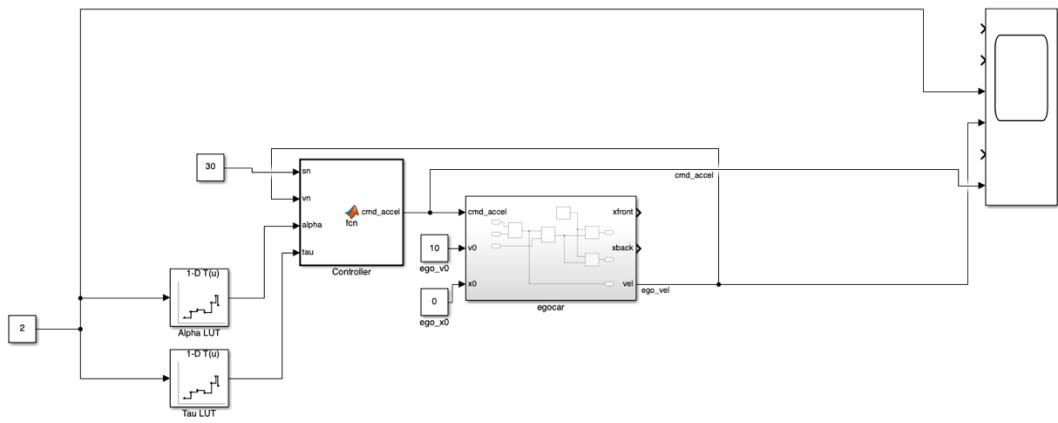
Mode 1: Leader, behavior unclassified

Mode 2: Smooth leader (Small tau, large alpha)

Mode 3: Erratic leader (Large tau, small alpha)

Single Vehicle Simulations (10+) – 5 Controller and 6 Mode Selector

Block Diagram



Stopped with No Leader:

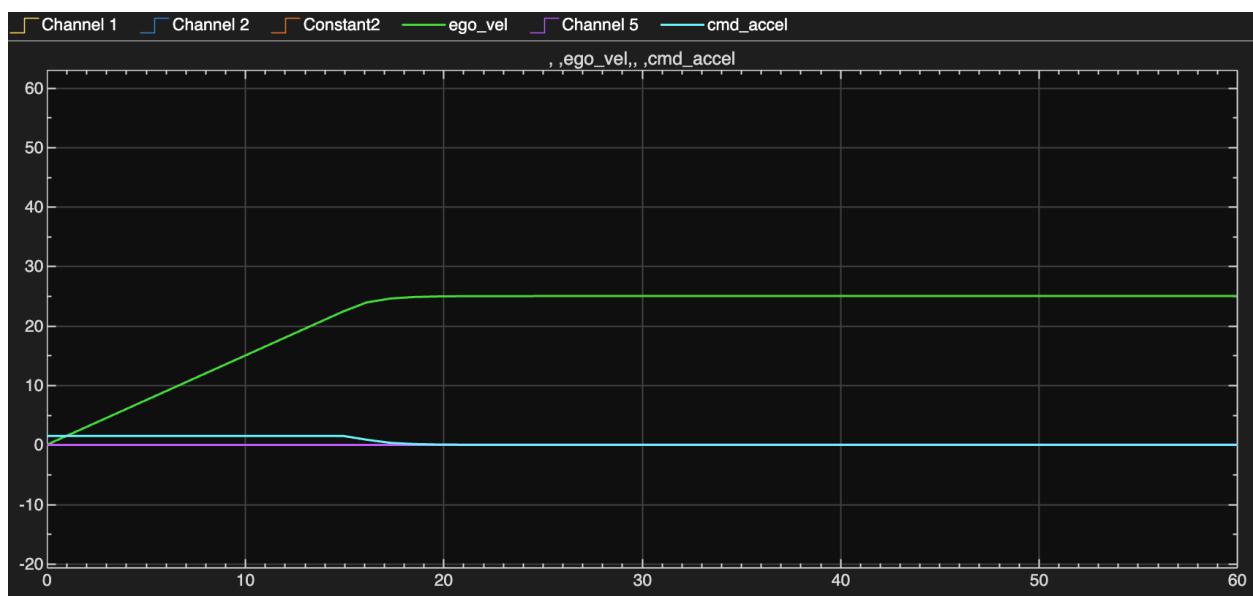
Expected to move to 25 m/s in all modes (v desired)

X0 = 0

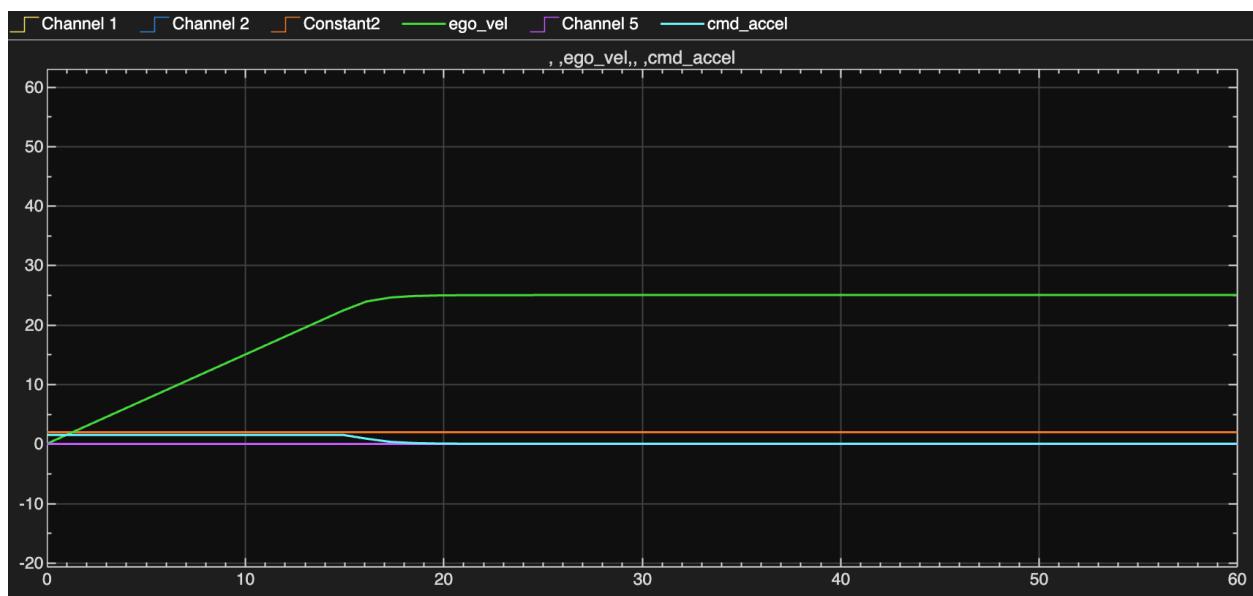
V0= 0

Sn = 10,000

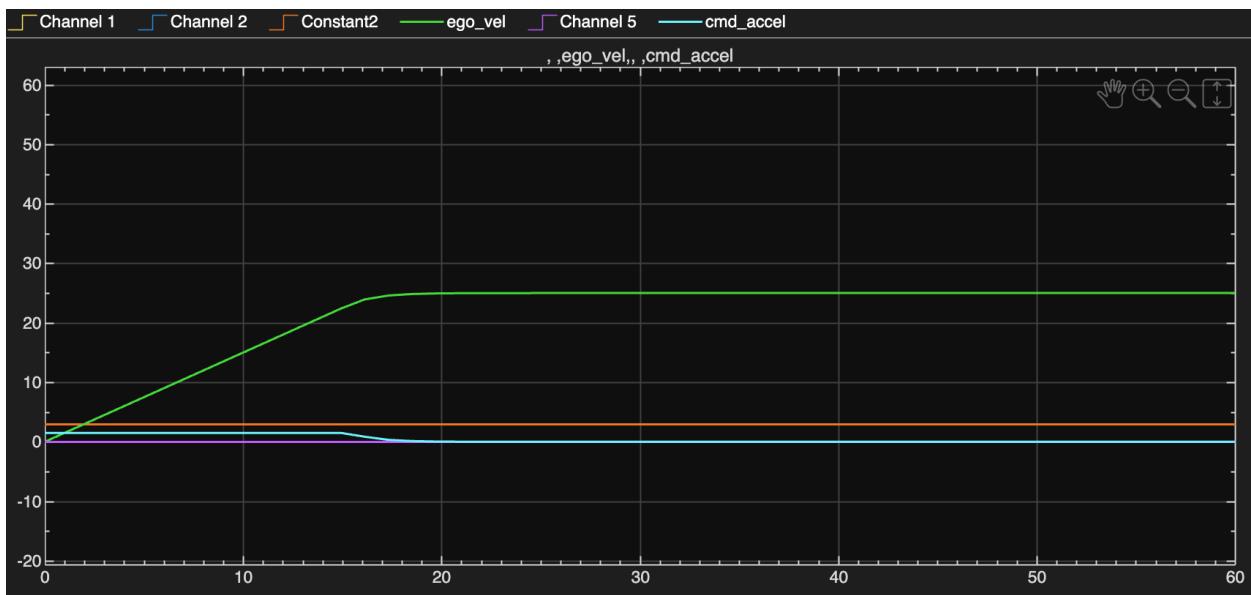
Mode 1 and 2 Behavior



Mode 3 Behavior



Mode 4 Behavior:



Safety and Sanity Checks:

- ✓ Acceleration remains within safe range
- ✓ All vehicles stabilize at v desired (25 m/s)

Stopped with $S_n = 0$:

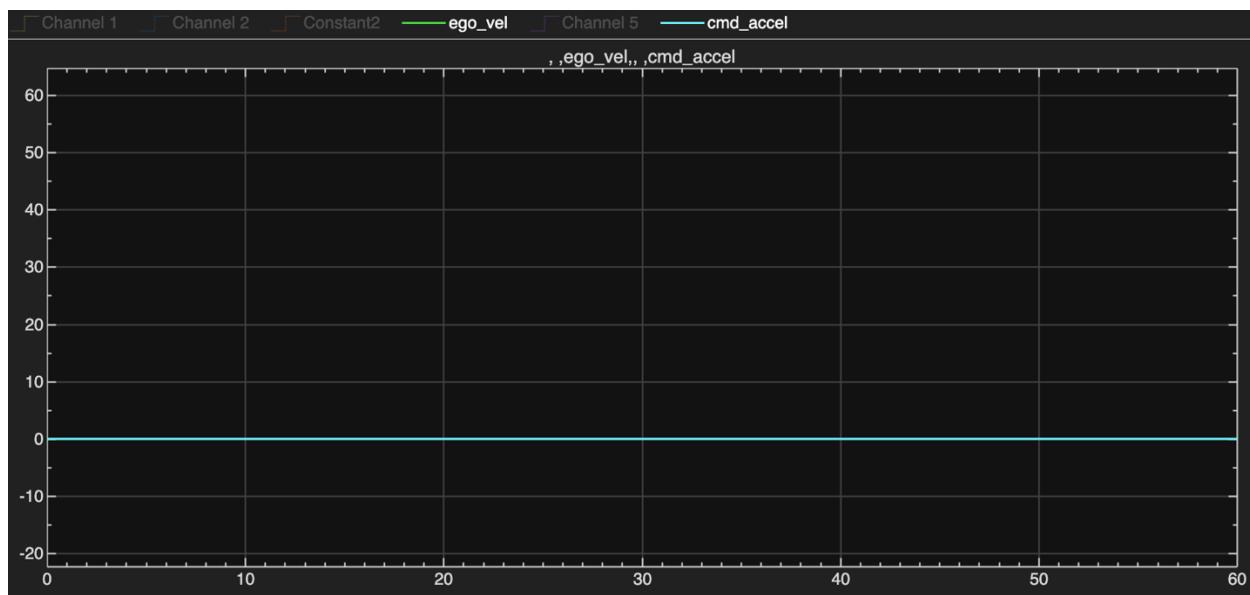
Expected to never accelerate

$X_0 = 0$

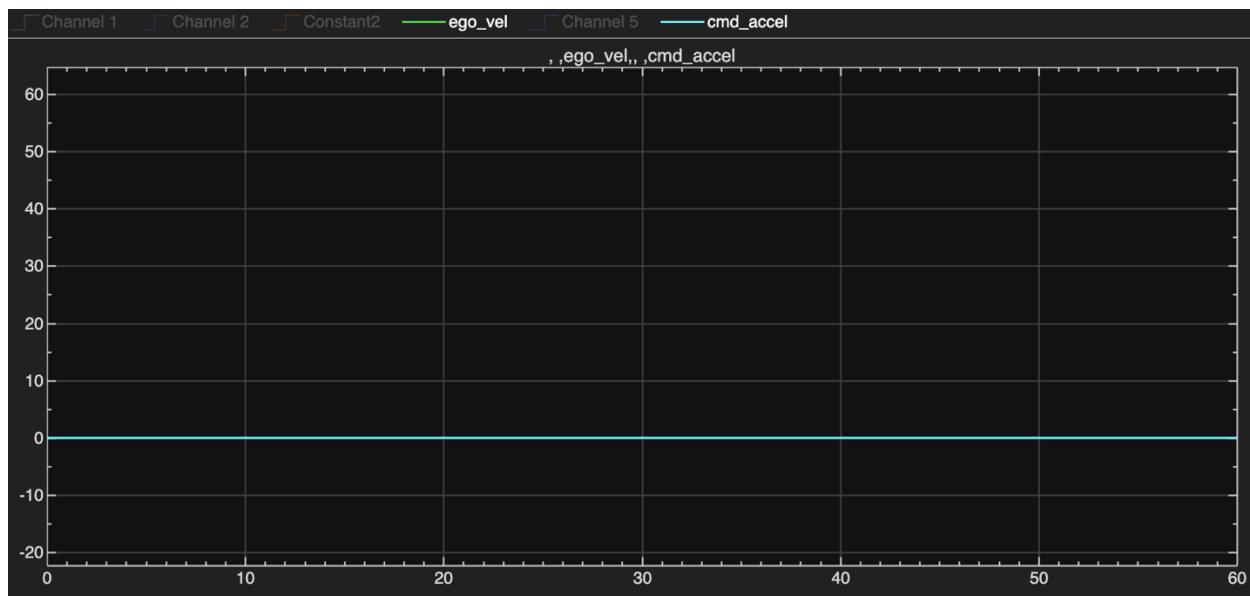
$V_0 = 0$

$S_n = 0$

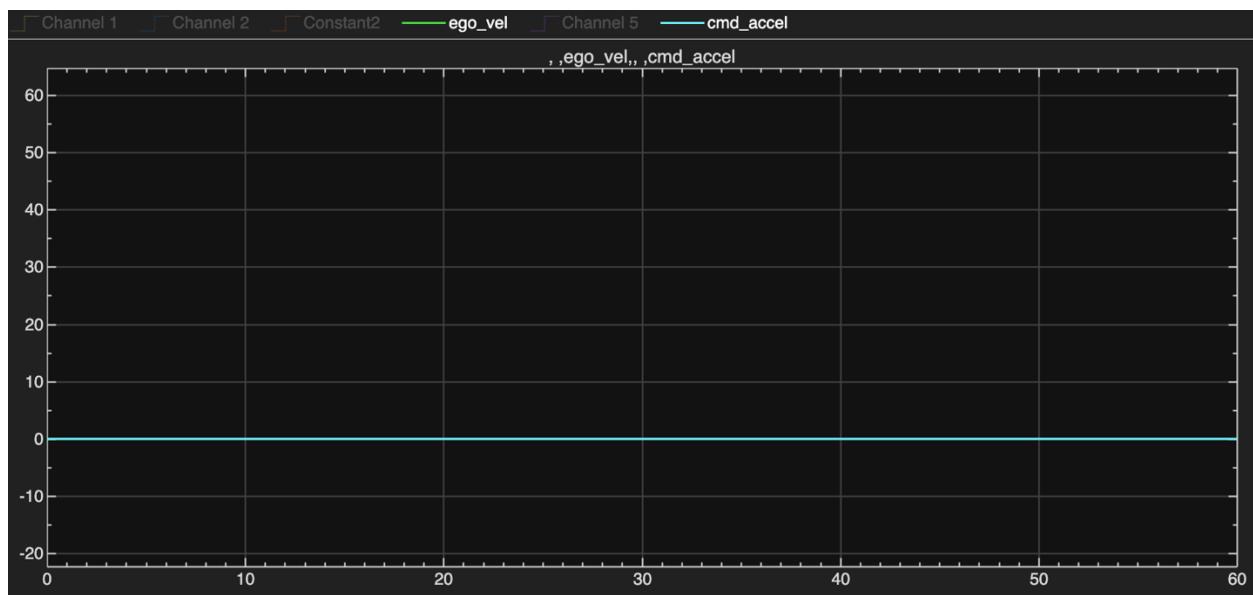
Mode 1 & 2 Behavior



Mode 3 Behavior:



Mode 4 Behavior:



Safety and Sanity Checks:

- ✓ All vehicles do not accelerate

No leader:

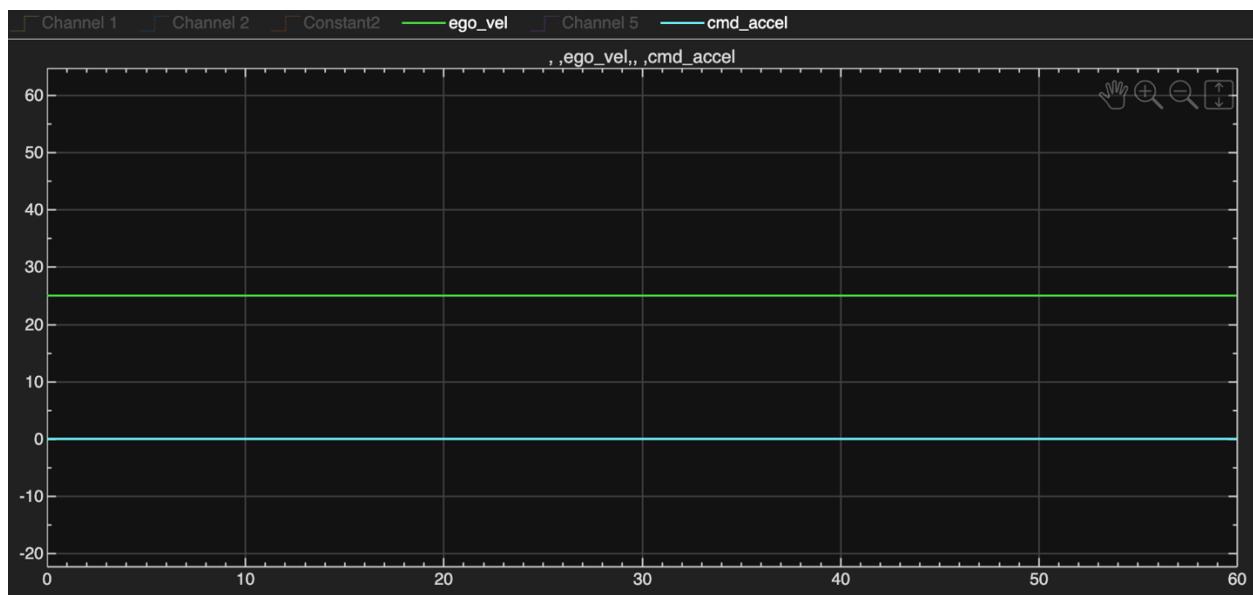
Stay at constant speed (v desired) for all modes

X0 = 0

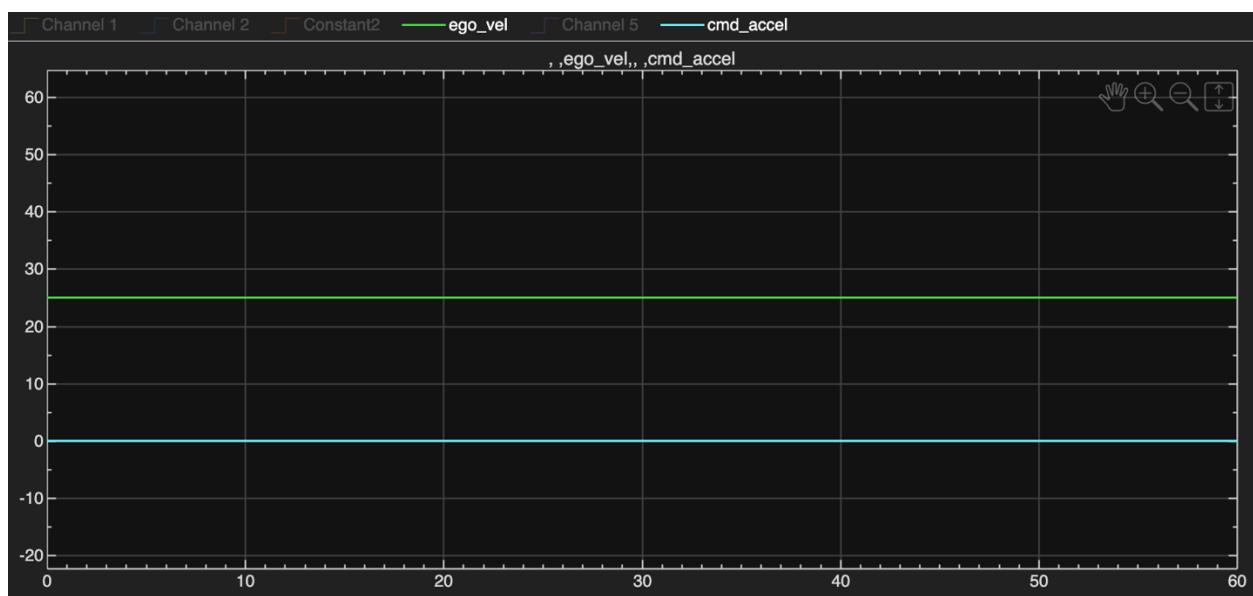
V0= 25

Sn = 10,000

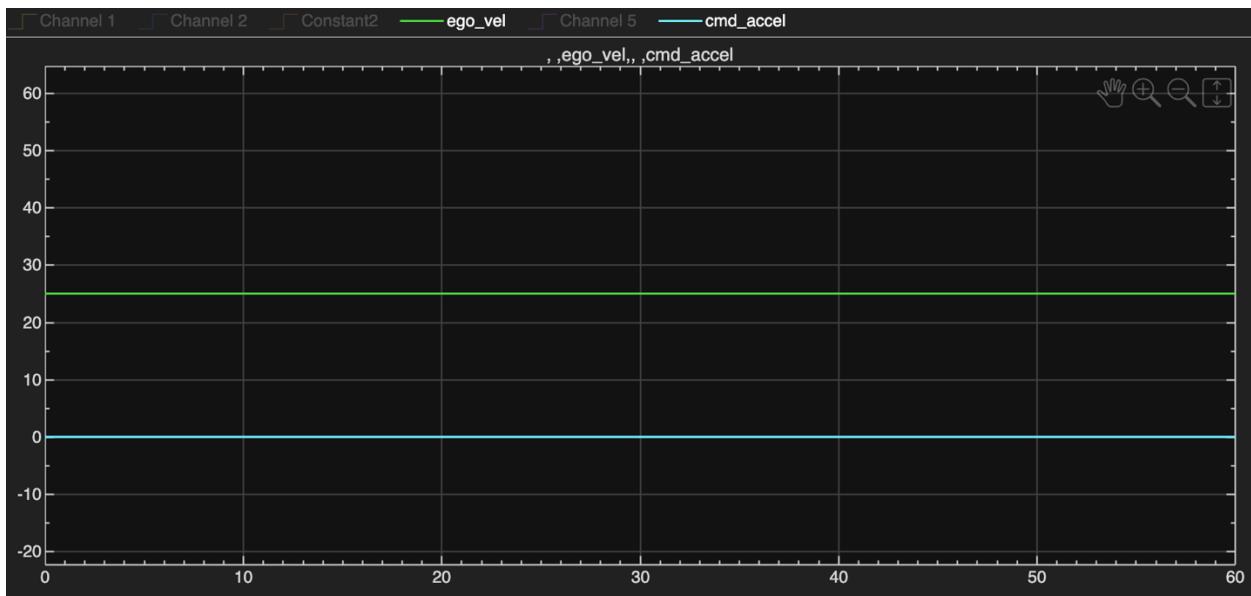
Mode 1 & 2 Behavior:



Mode 3 Behavior:



Mode 4 Behavior:



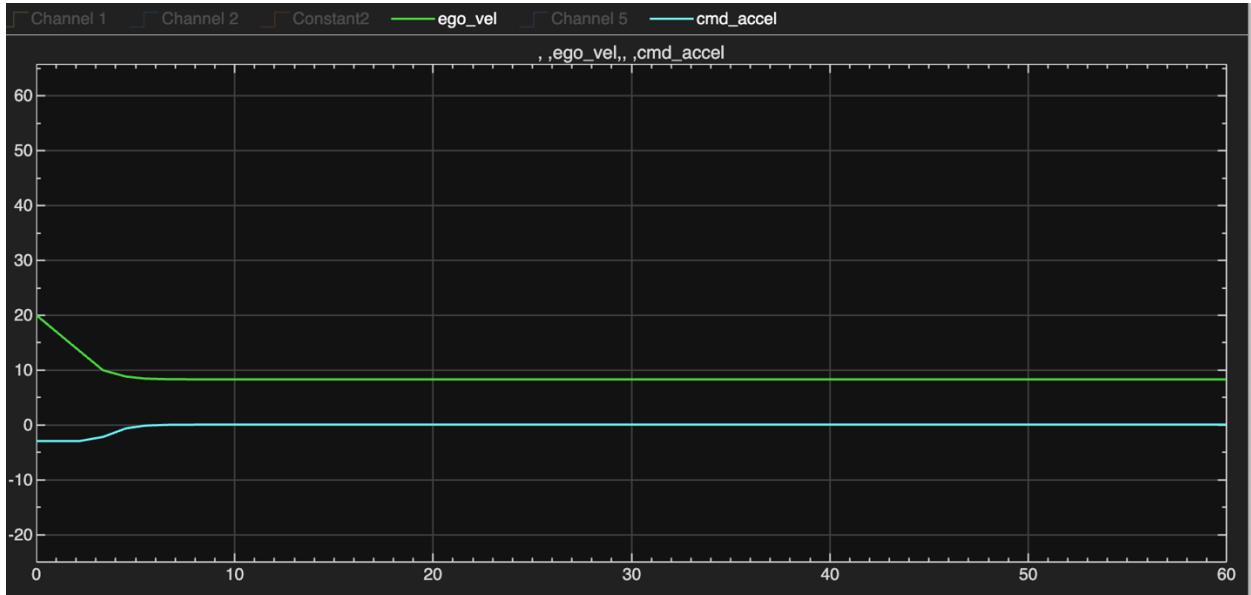
Small Space Gap:

Vn should be the lowest for mode 4 and highest for mode 3:

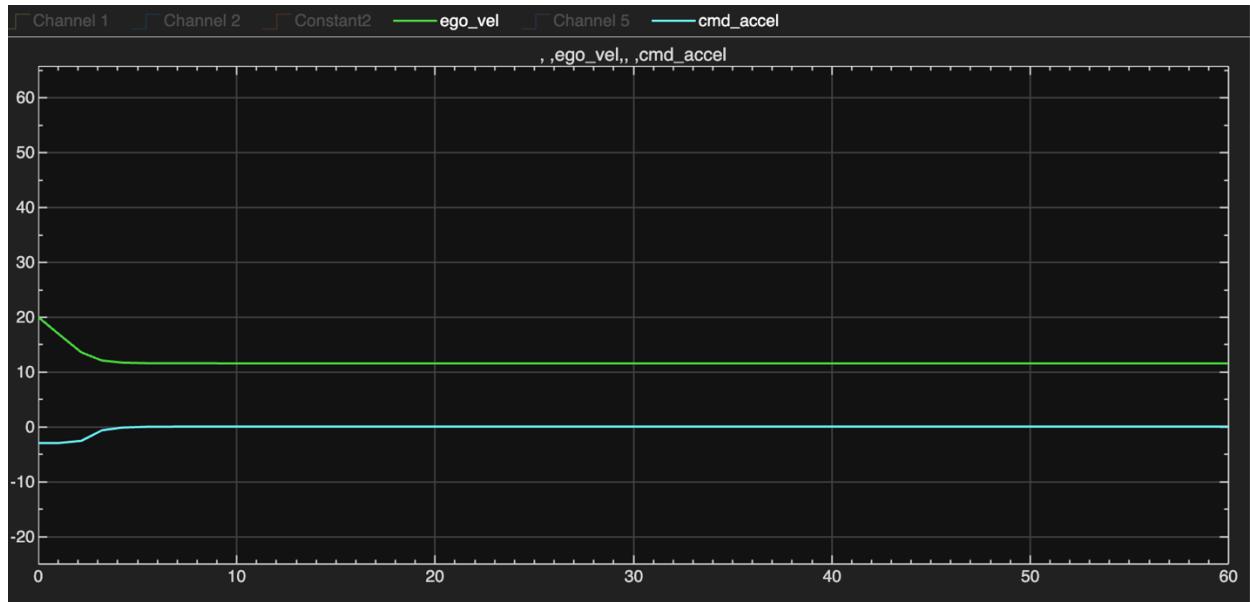
- Mode 3 has a smaller tau (0.5), meaning the desired space gap is less than all other modes
- Mode 4 has the largest tau (3.0), so the desired space gap should be the biggest, Vn smallest

$$S_n = 20, V_0 = 20, x_0 = 0$$

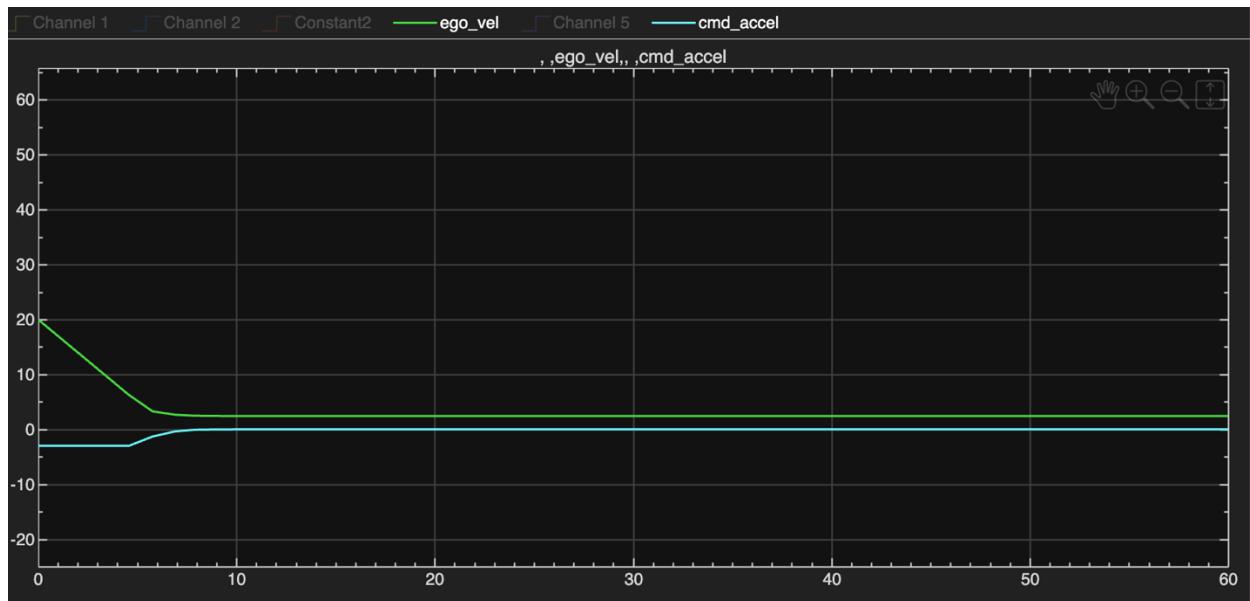
Mode 1 & 2 Behavior:



Mode 3 Behavior:



Mode 4 Behavior:

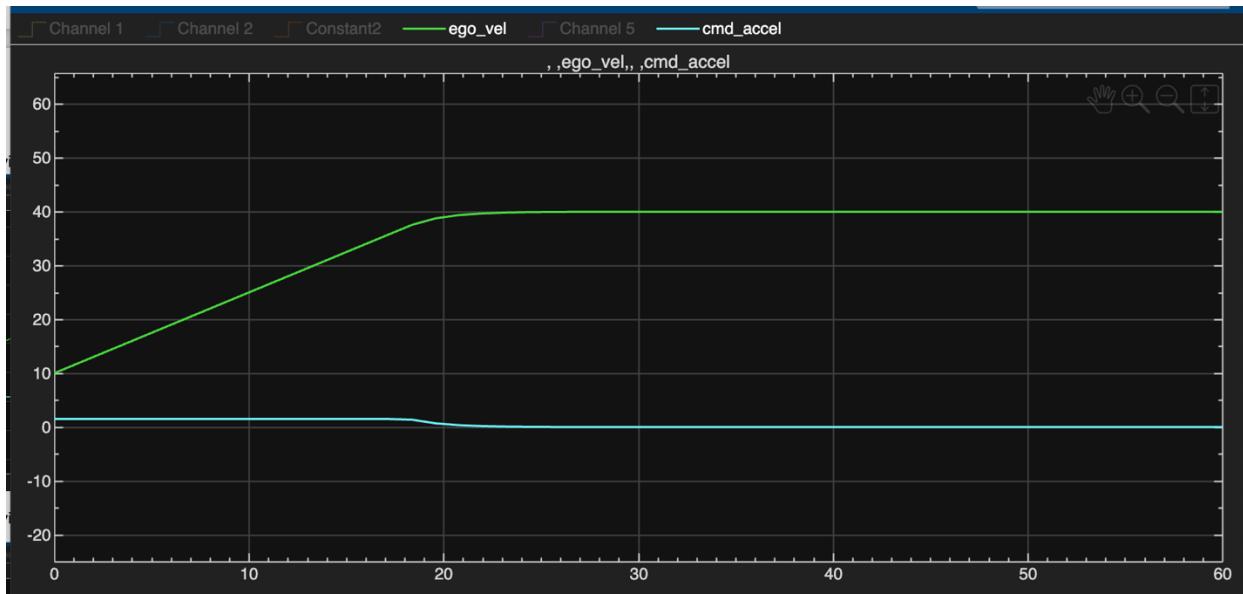


Larger Space Gap:

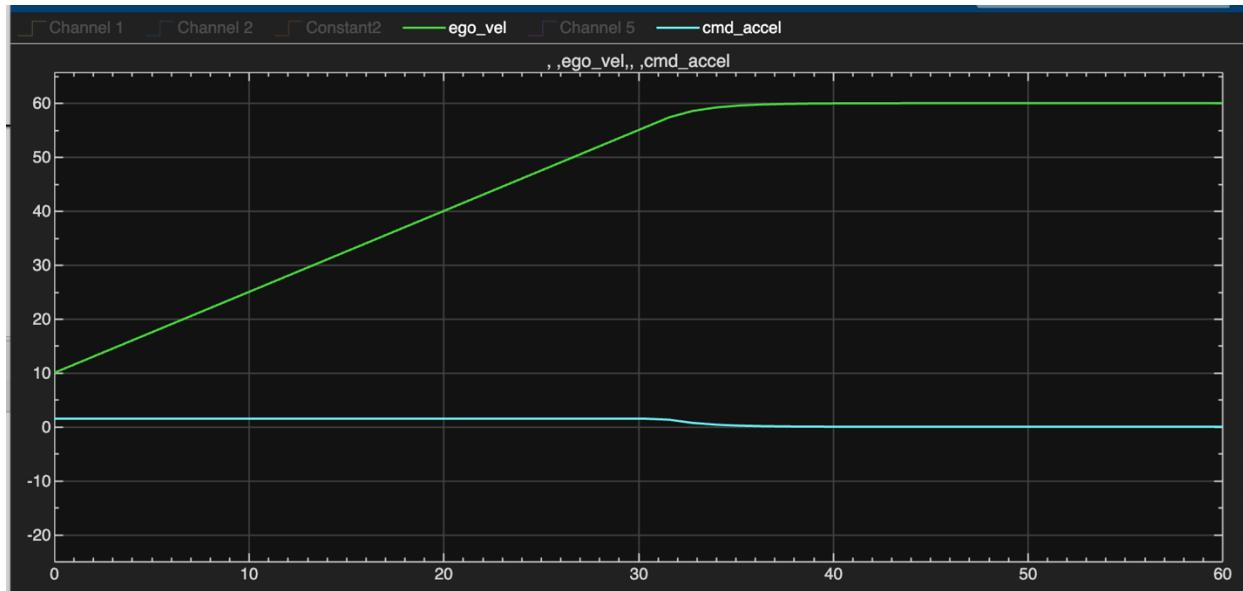
Space gap of 30 m and V0 of 10 m/s, x0 = 0

- Mode 3 has a tau of 0.5, so it should accelerate the maximum amount to attempt to get to 60 m/s. Mode 4 has a tau of 3, so the space gap = the desired space gap and should remain constant.

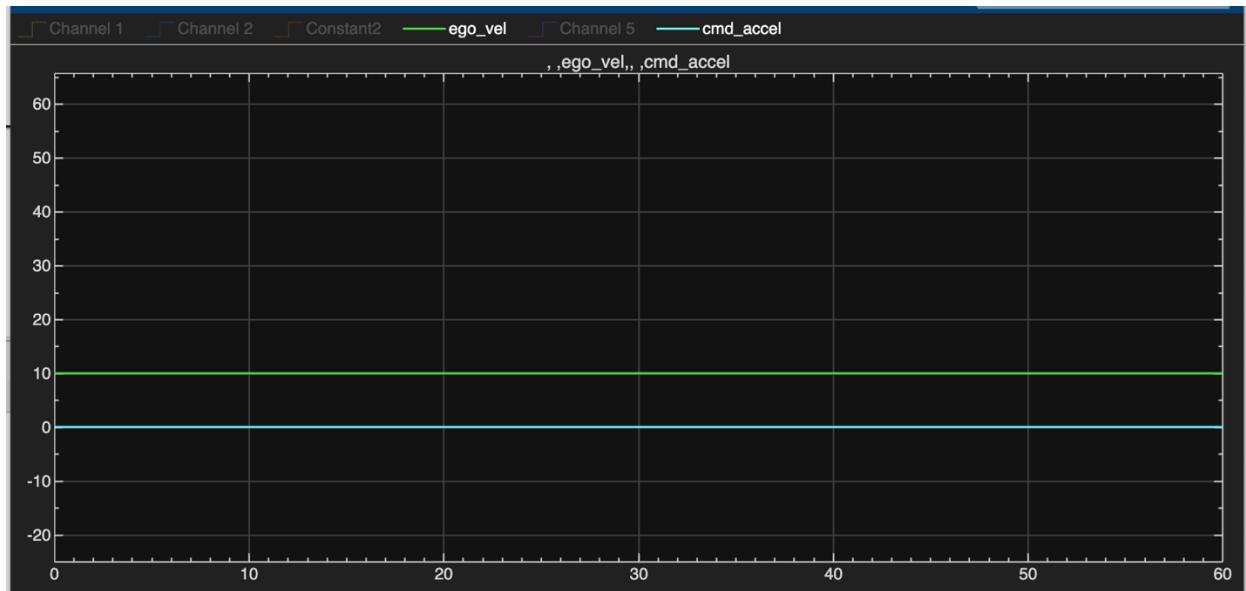
Mode 1 and 2 Behavior:



Mode 3 Behavior:



Mode 4 Behavior:



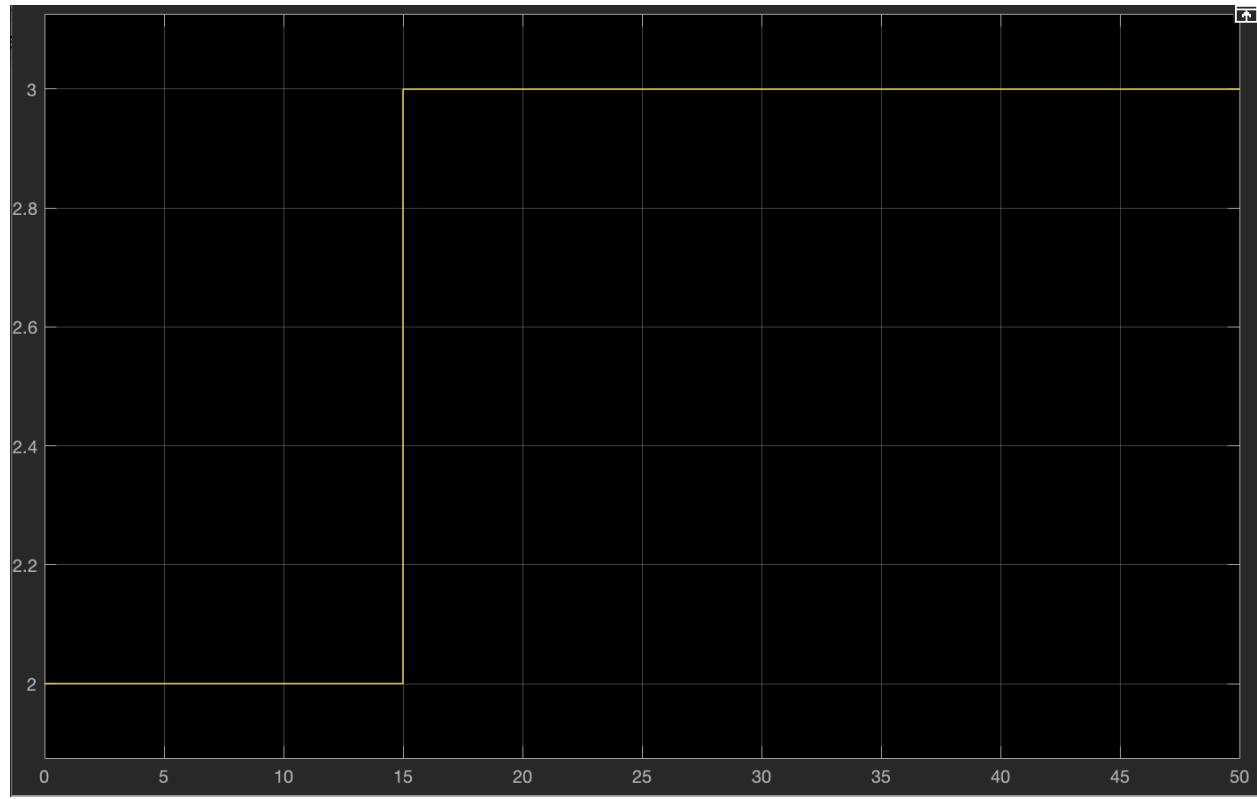
Mode Selector Tests:

Detecting Smooth Leader:

Space Gap: 30

Leader Velocity: Sine wave:

- Bias = 12 m/s
- Amplitude = 0.3 m/s
- Frequency = 0.2 rad/s

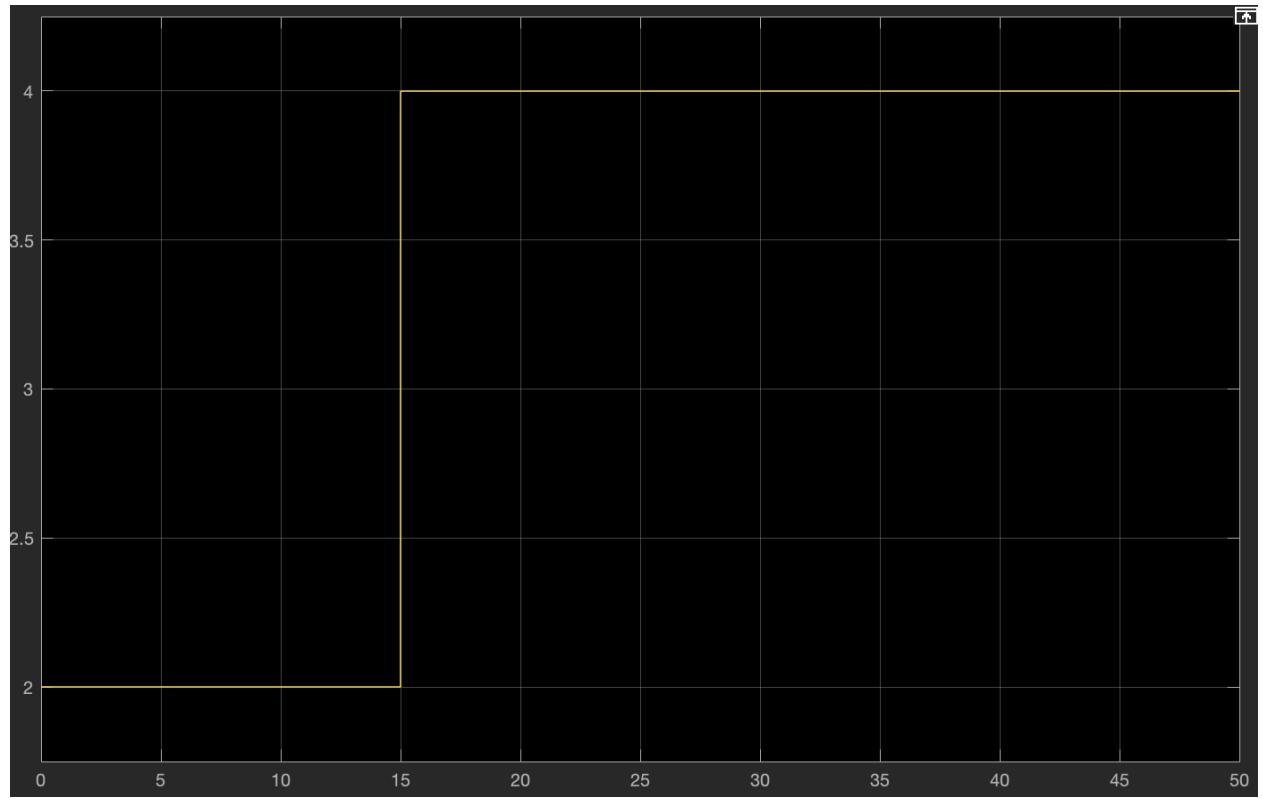


Detecting Erratic Leader:

Space Gap: 30

Leader Velocity: Sine wave:

- Bias = 12 m/s
- Amplitude = 2.0 m/s
- Frequency = 0.5 rad/s

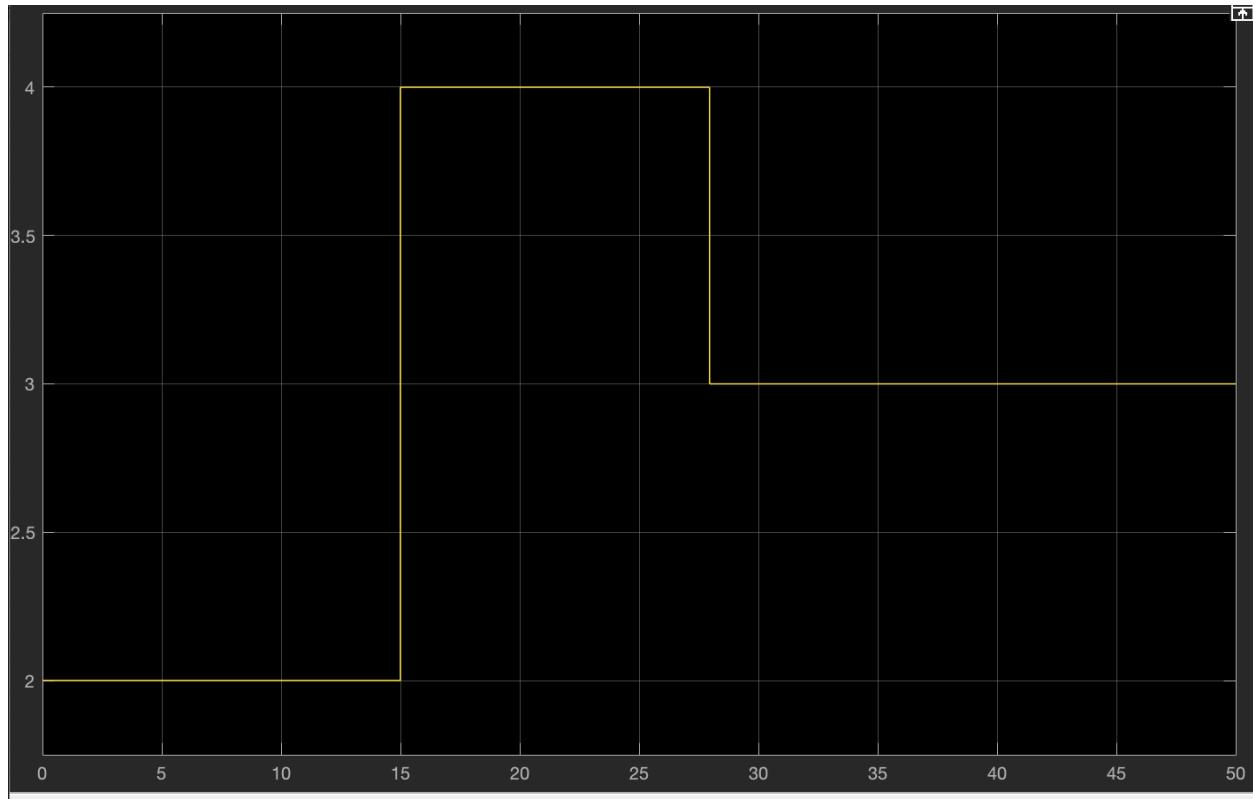


Detecting Changing Behavior from *Same* Leader:

Space Gap: 30

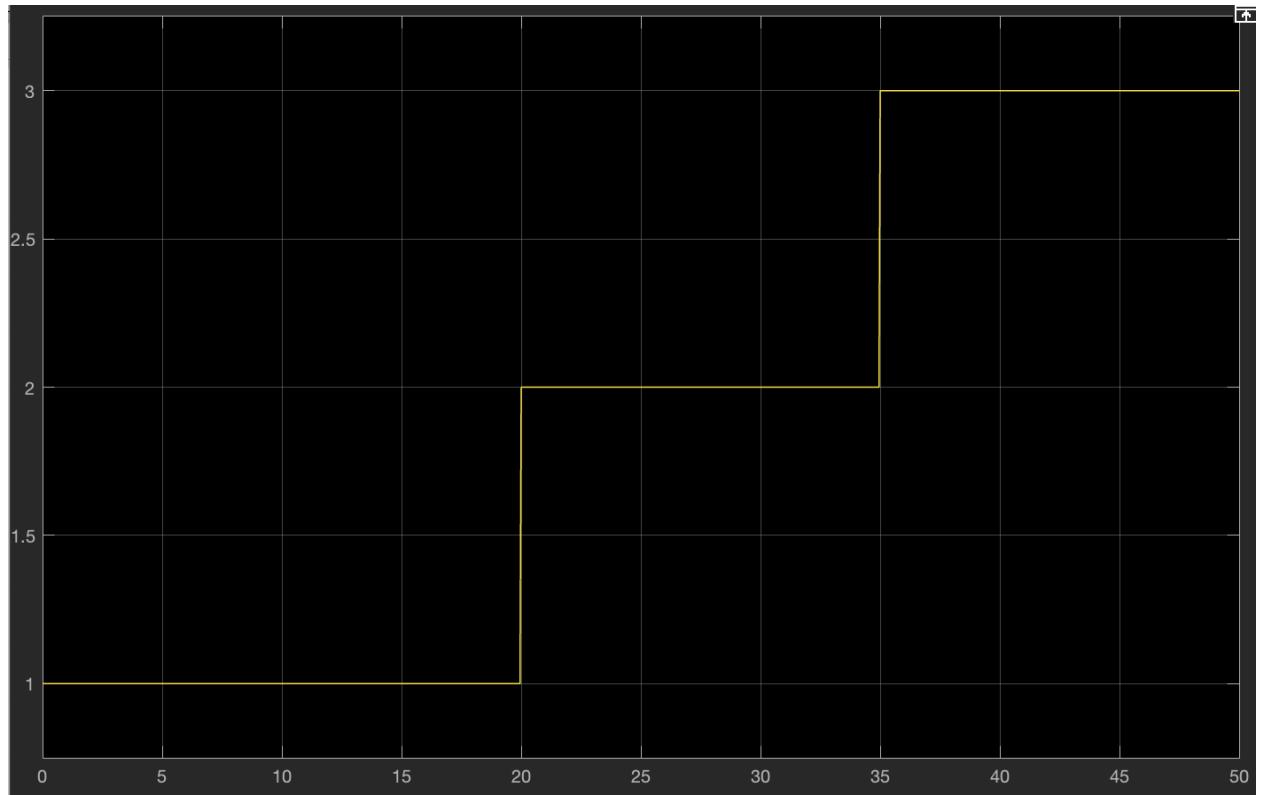
Leader Velocity:

- Switch between the erratic sinewave to smooth sinewave for leader velocity



Detecting Leader Entering:

Space Gap: Switch between large space gap to sudden small space gap
Leader Velocity: 12 m/s

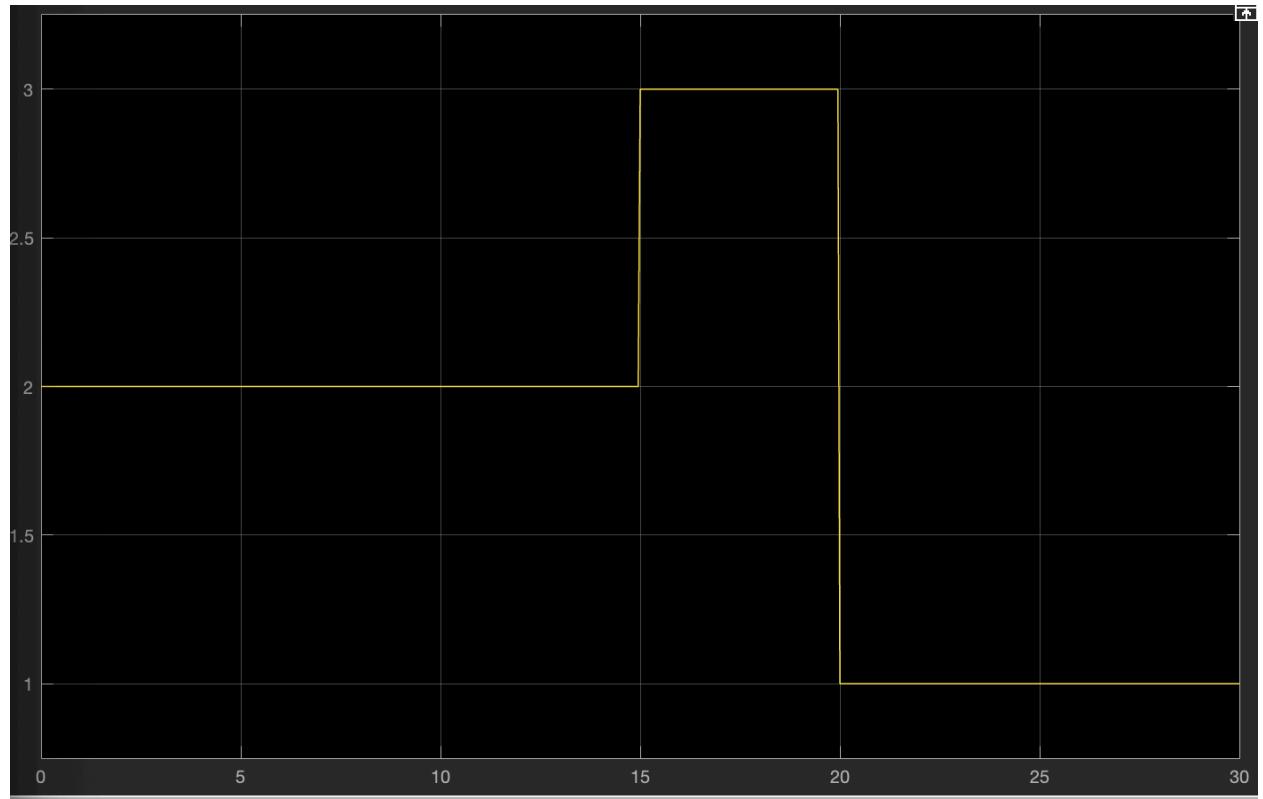


- Switches from mode 1 (no leader) to mode 2 (warm-up mode)

Detecting Leader Exiting:

Space Gap: Switch between small space gap to sudden large space gap

Leader Velocity: 12 m/s

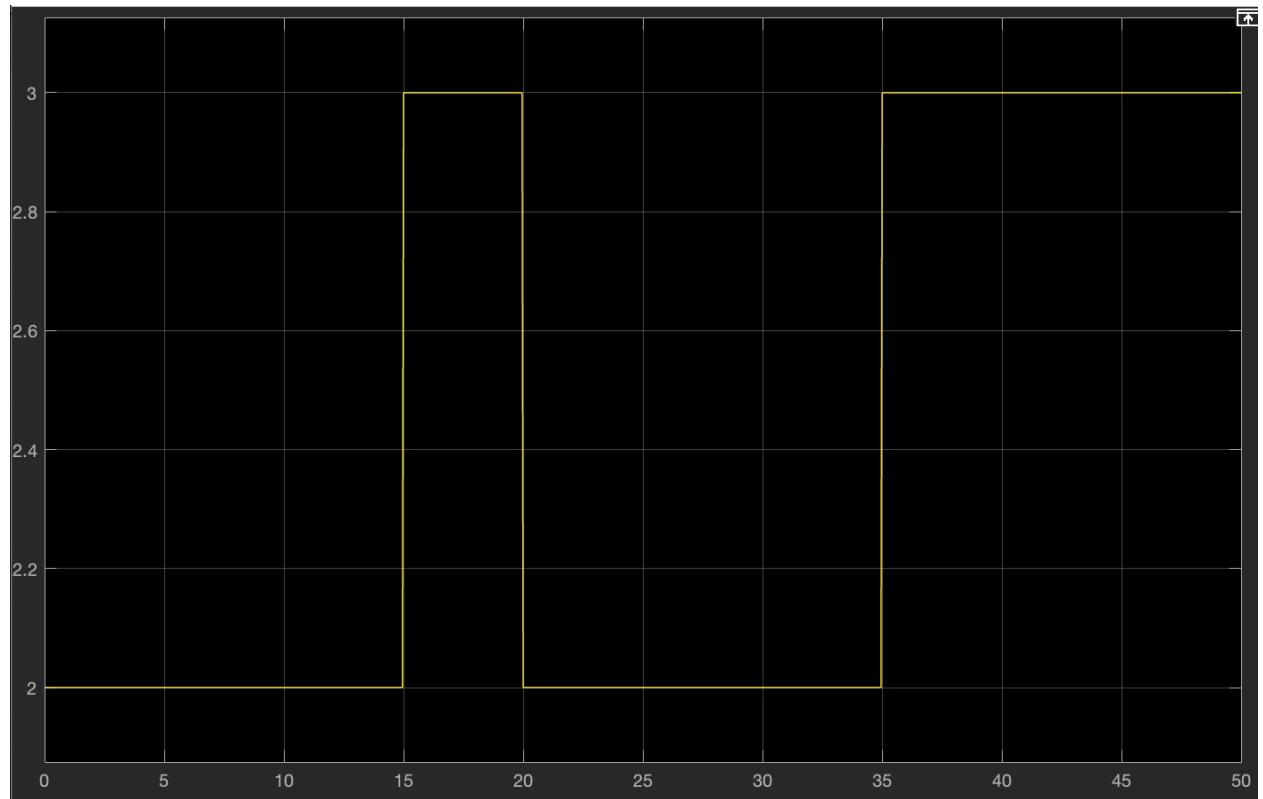


- Switches from mode 3 (smooth leader) to mode 1 (no leader)

Detecting *Different* Leader:

Space Gap: 10 m until 20 s, then changes to 25 m instantaneously

Leader Velocity: 12 m/s



- Resets to mode 2 when sudden space gap changes

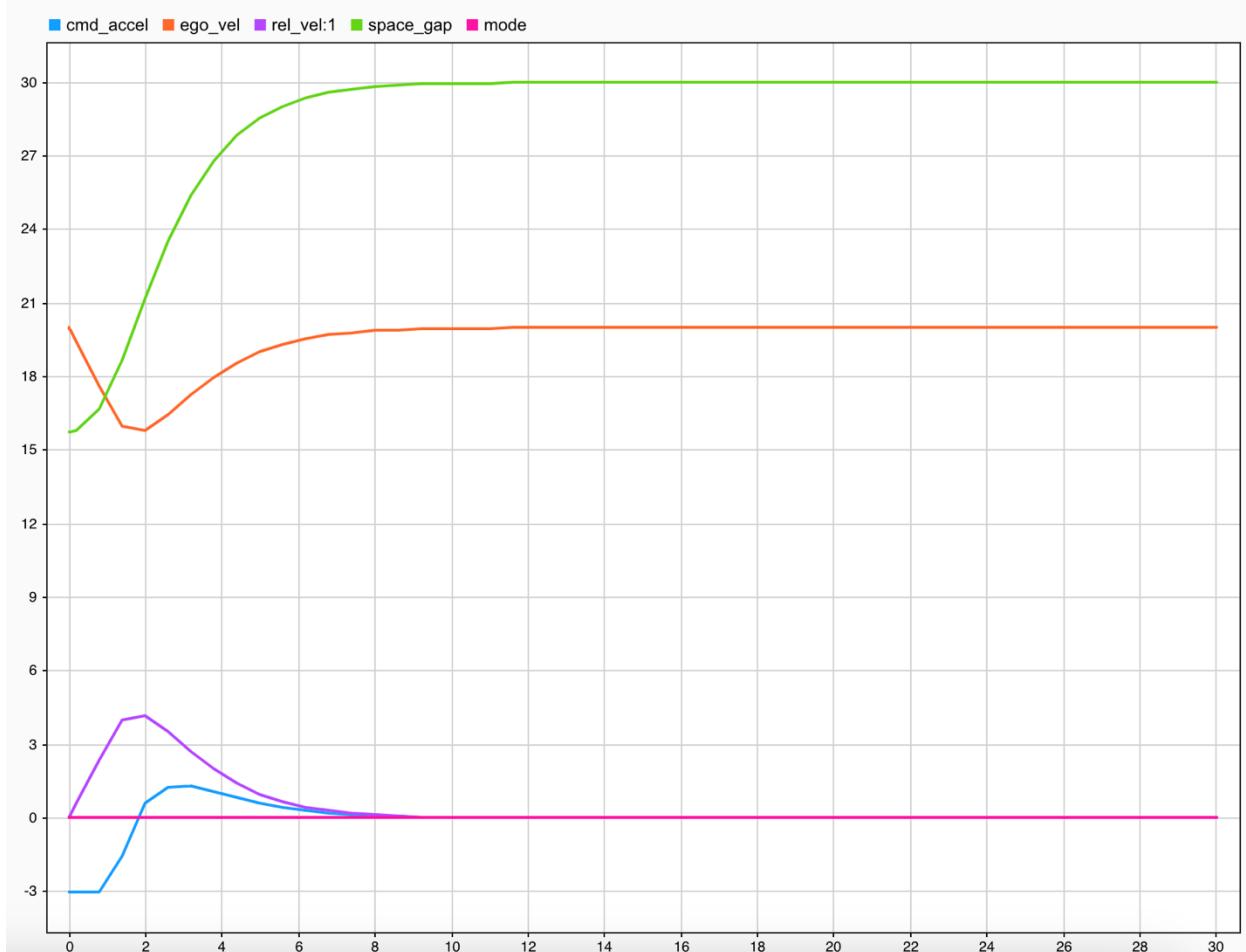
Multivehicle Simulations (10+)

Regular Leader with Constant Speed:

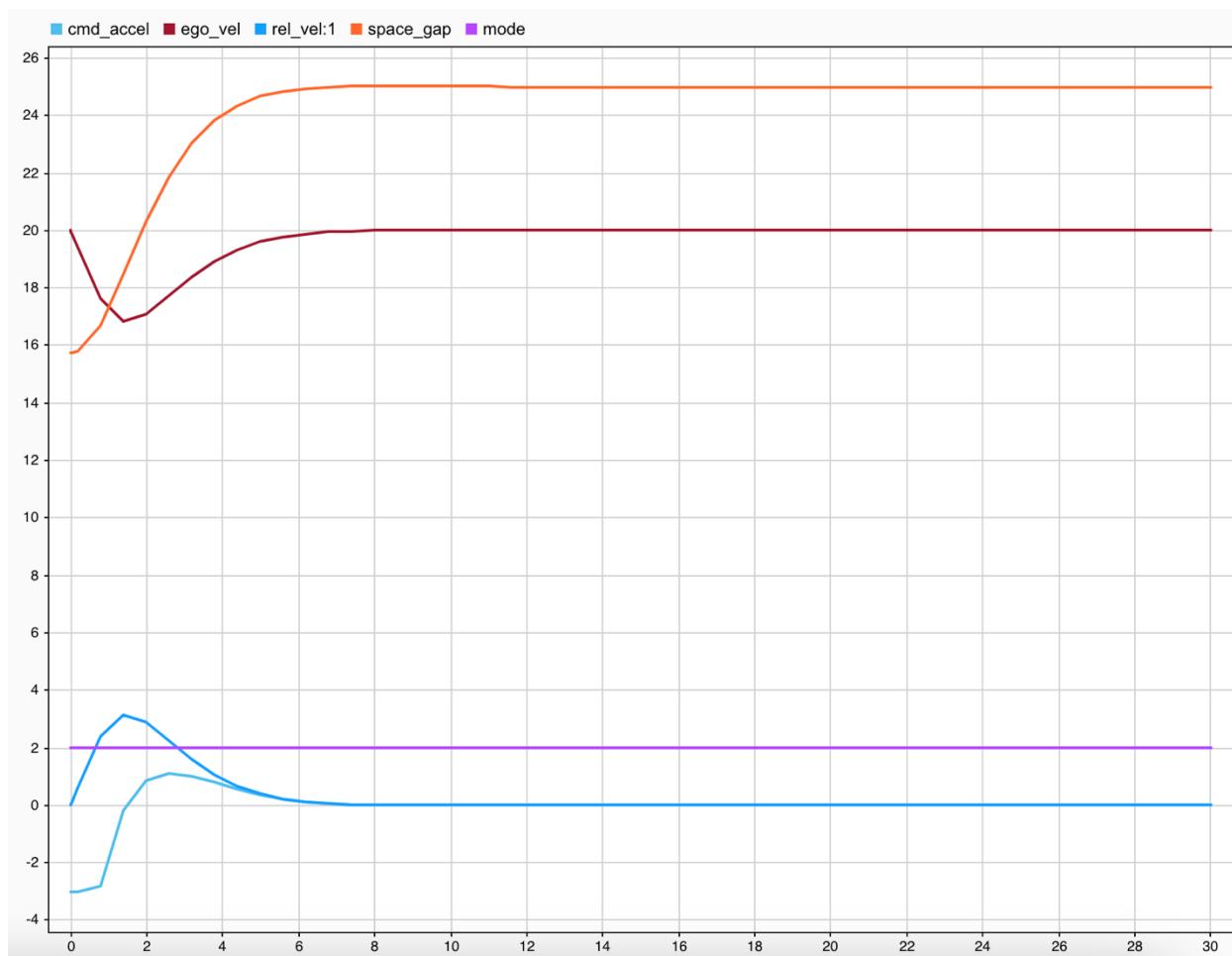
Leader: $a_0=0, v_0=20, x_0=20$

Ego: $v_0=20, x_0=0$

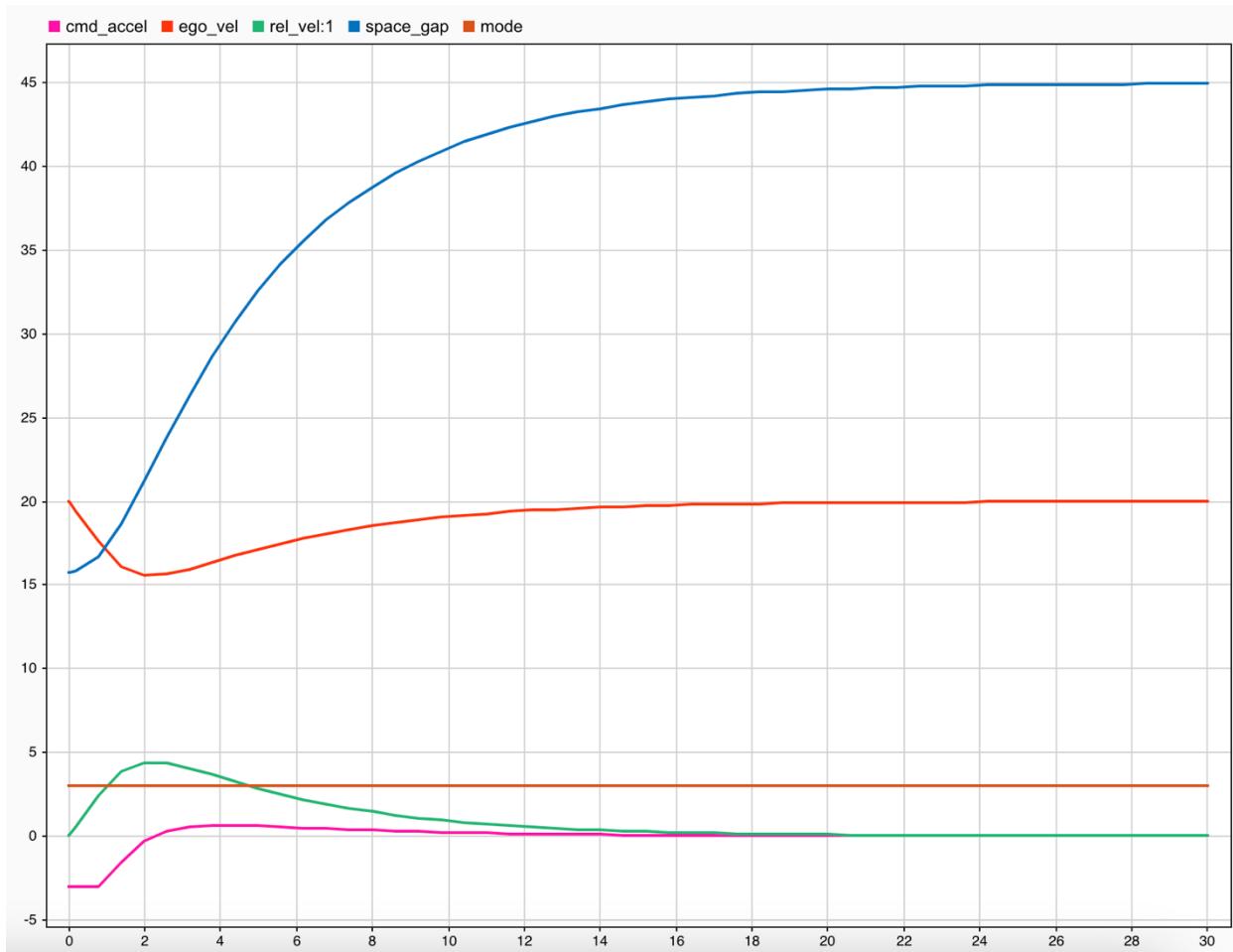
Mode 1 and 2 Behavior:



Mode 3 Behavior:



Mode 4 Behavior:



Safety and Sanity Checks:

- ✓ Acceleration remains within safe range
- ✓ Space gap stays positive (no collision)
- ✓ Relative velocity approaches 0 and acceleration approaches 0 to stabilize
- ✓ Ego velocity is never negative (doesn't go backwards)

Concerns:

- * Are space gaps too large? (do we need to adjust tau and alpha)

Stand-Still Leader:

Leader: $a_0=0, v_0=0, x_0=60$

Ego: $v_0=10, x_0=0$

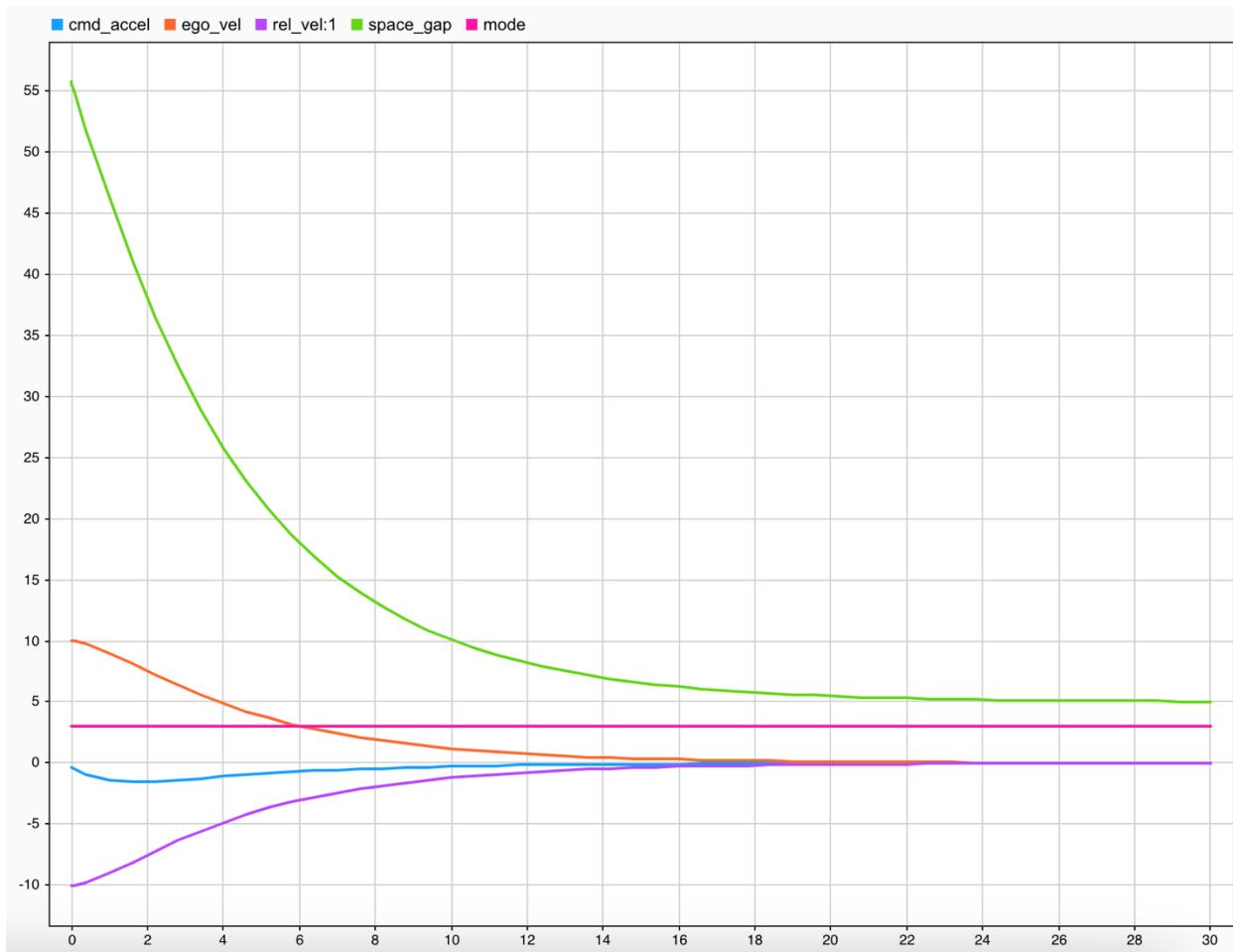
Mode 1 and 2 Behavior:



Mode 3 Behavior:



Mode 4 Behavior:



Safety and Sanity Checks:

- ✓ Acceleration remains within safe range
- ✓ Space gap stays positive (no collision)
- ✓ Relative velocity approaches 0 and acceleration approaches 0 to stabilize
- ✓ Ego velocity is never negative (doesn't go backwards)

Concerns:

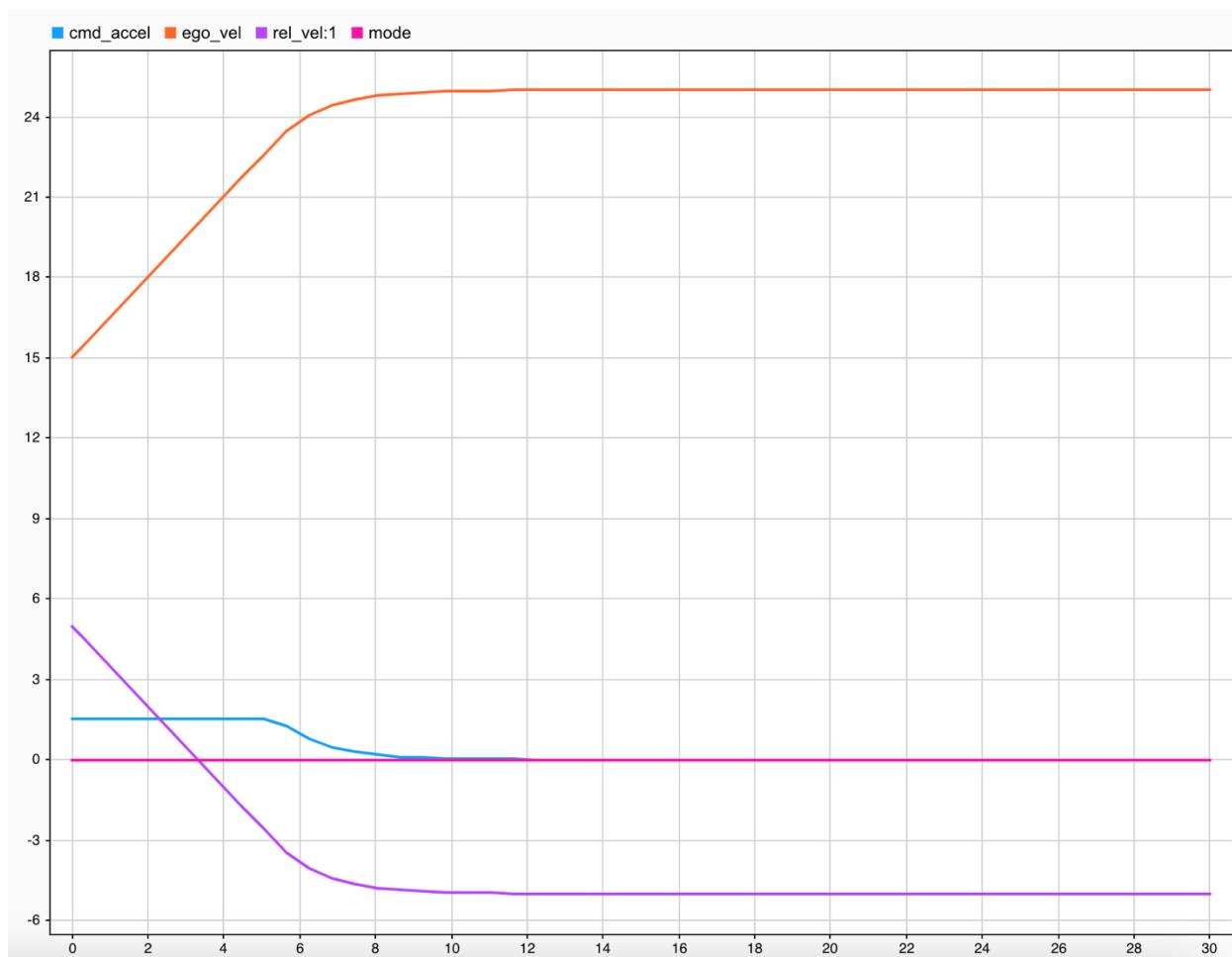
- ✗ Space gap for mode 3 gets awfully close to 0

No Leader:

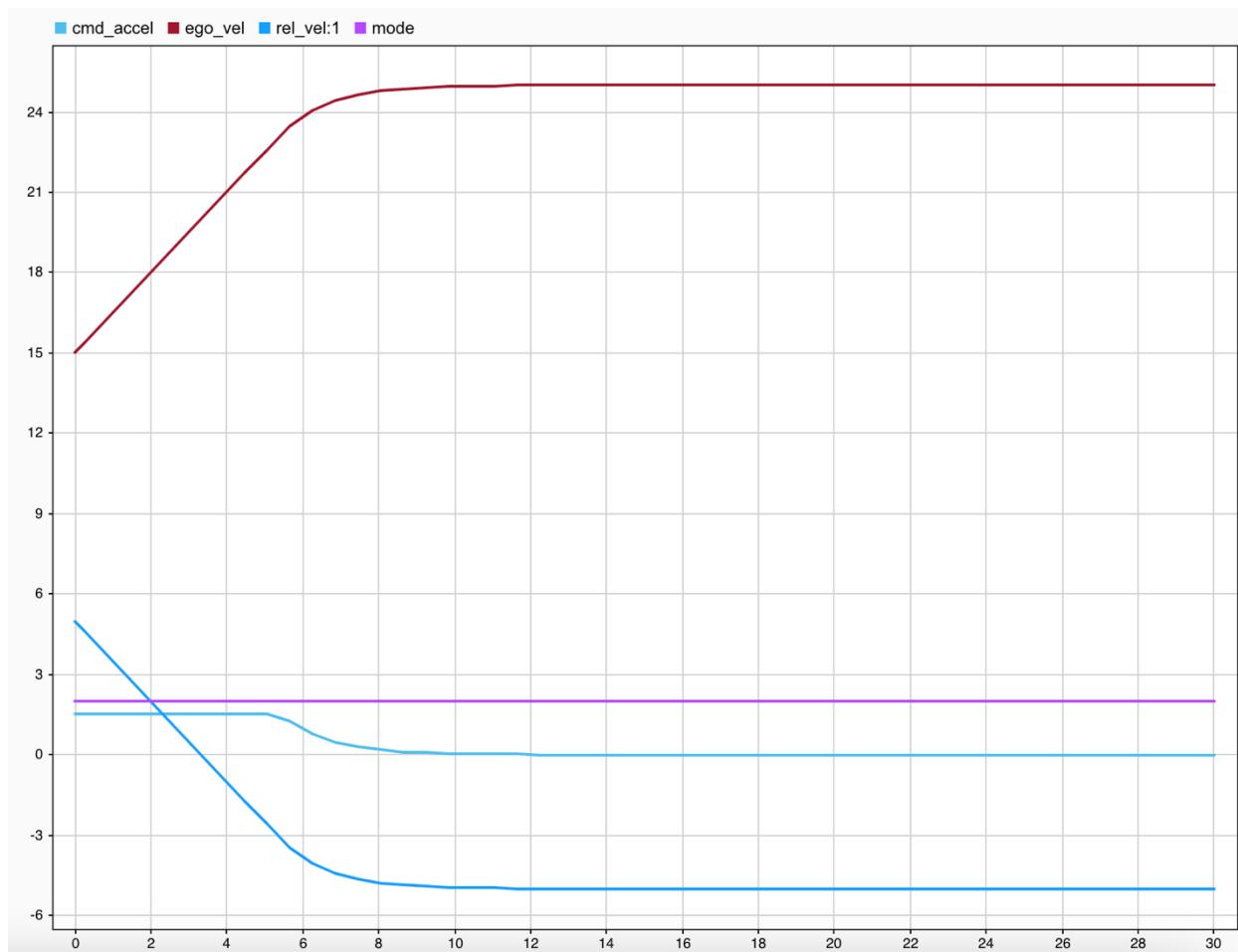
Leader: $a_0=0, v_0=20, x_0=1000$ (to indicate no leader)

Ego: $v_0=15, x_0=0$

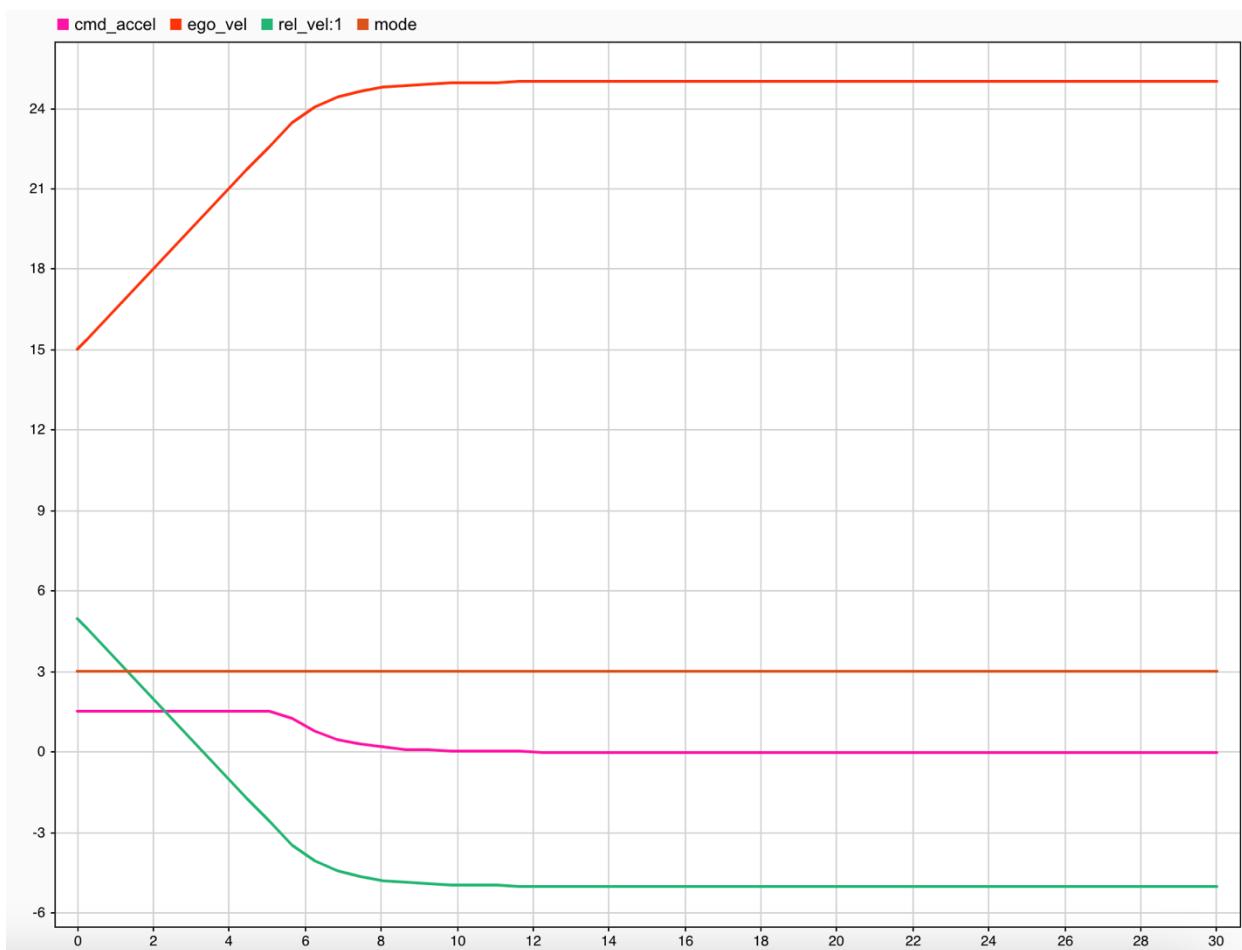
Mode 1 and 2 Behavior:



Mode 3 Behavior:



Mode 4 Behavior:



Safety and Sanity Checks:

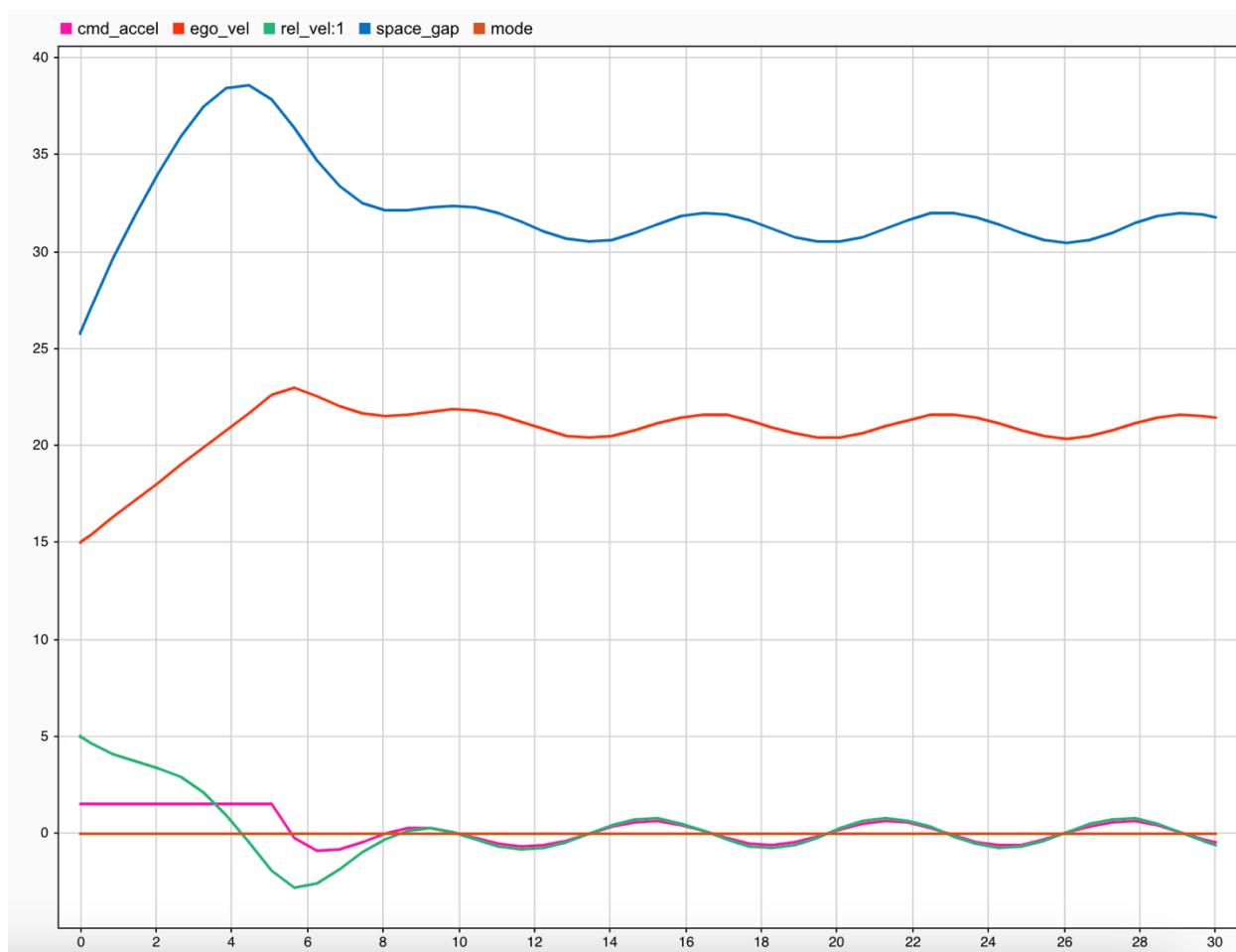
- ✓ Acceleration remains within safe range
- ✓ Relative velocity tries to get to 0
- ✓ Ego velocity is never negative (doesn't go backwards)
- ✓ Because no leader, ego vehicle stabilizes at a set desired 25 m/s

Smooth Leader Oscillations:

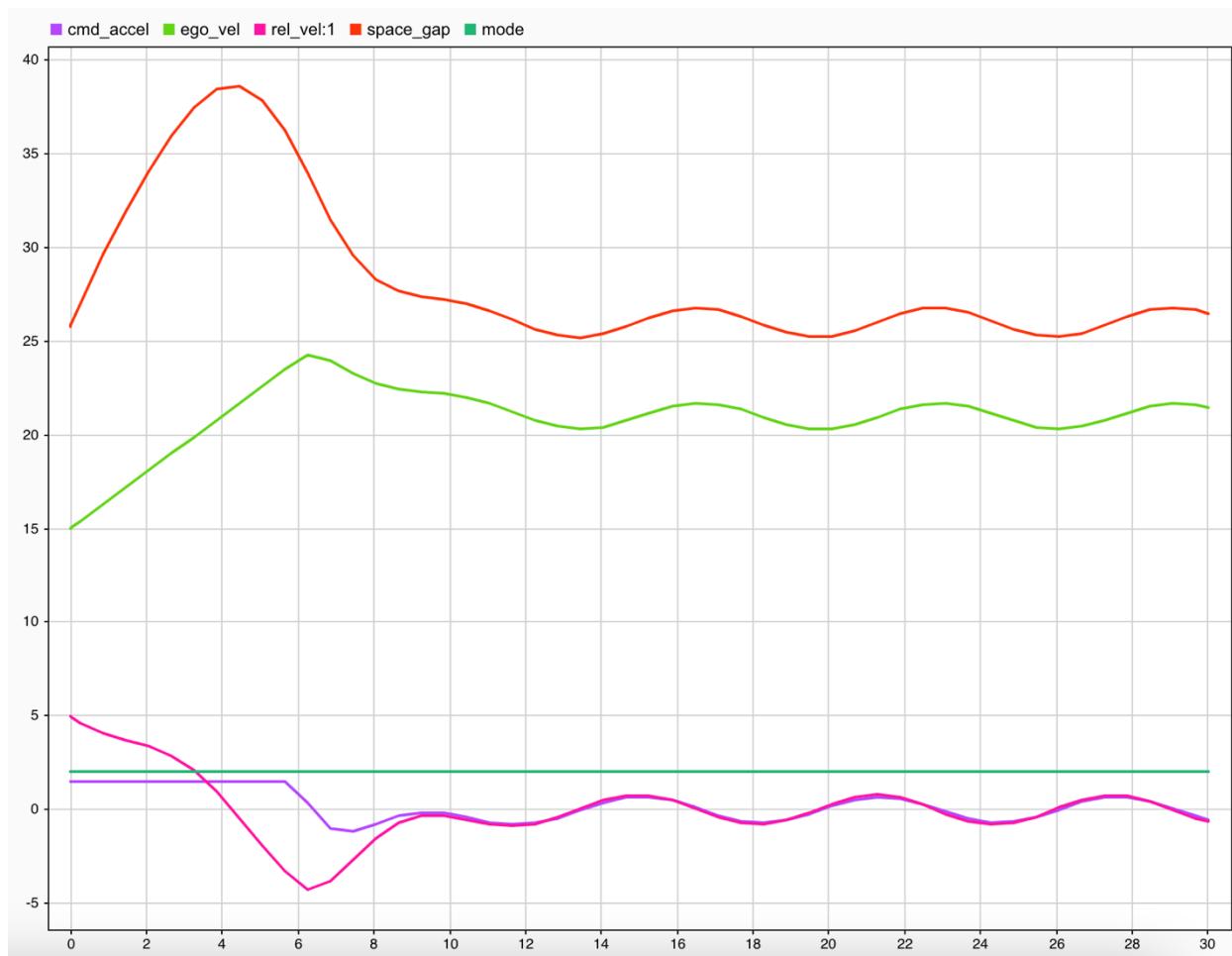
Leader: $a_0=\text{sinewave}(\text{amplitude} = 1, \text{frequency} = 1, \text{bias} = 0)$, $v_0=20$, $x_0=30$

Ego: $v_0=15$, $x_0=0$

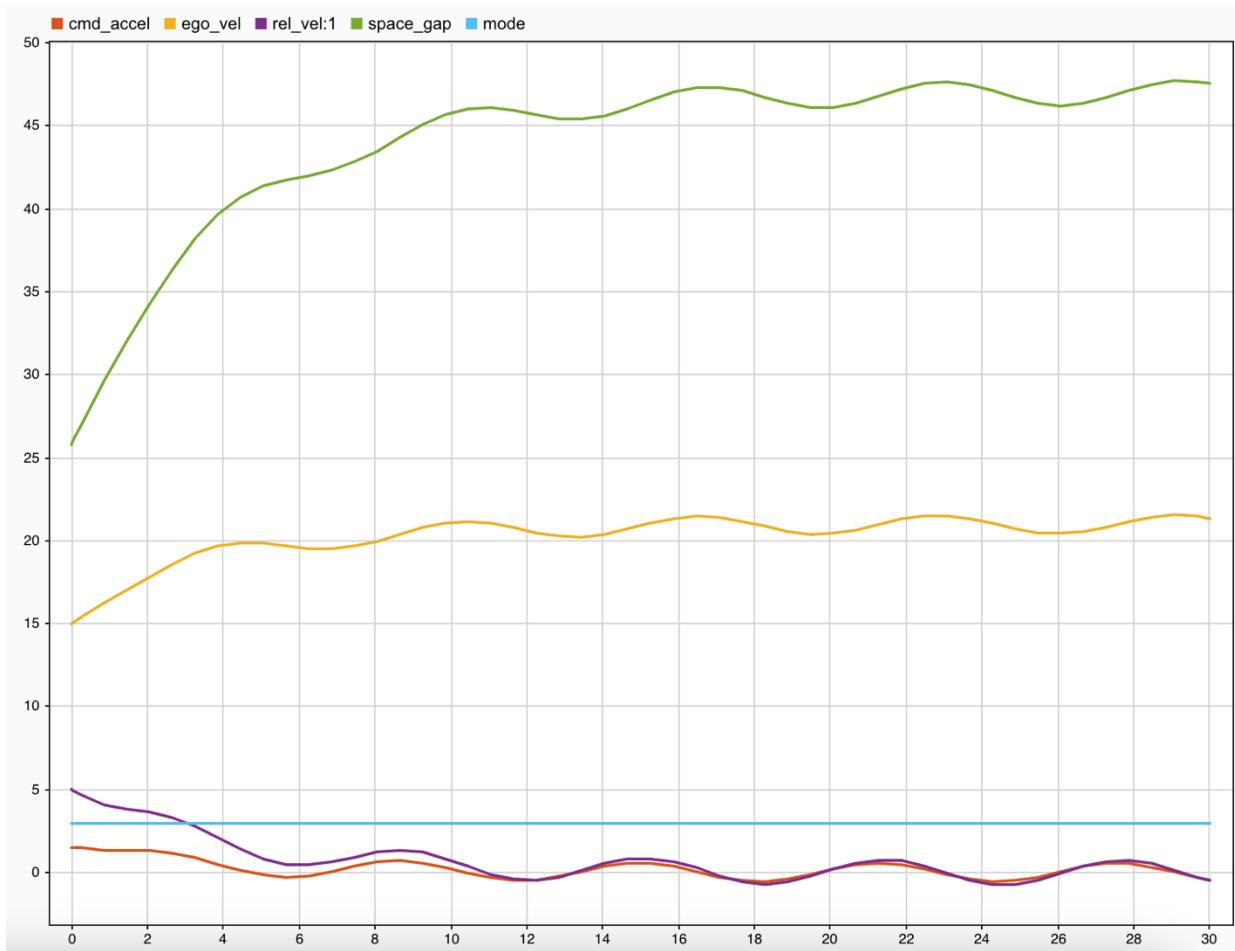
Mode 1 and 2 Behavior:



Mode 3 Behavior:



Mode 4 Behavior:



Safety and Sanity Checks:

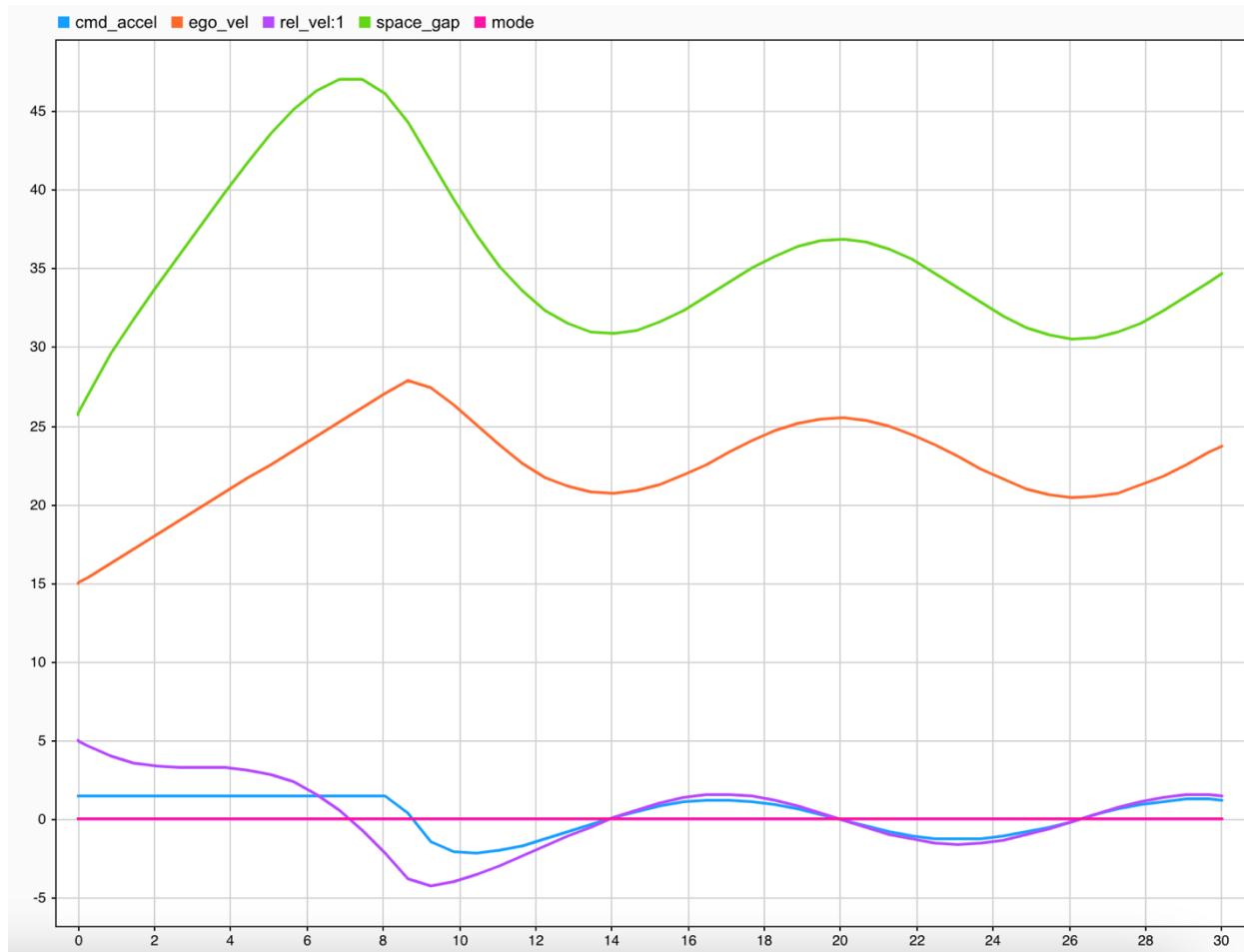
- ✓ Acceleration remains within safe range
- ✓ Space gap stays positive (no collision)
- ✓ Relative velocity tries to get to 0
- ✓ Ego velocity is never negative (doesn't go backwards)

Steep Leader Oscillations:

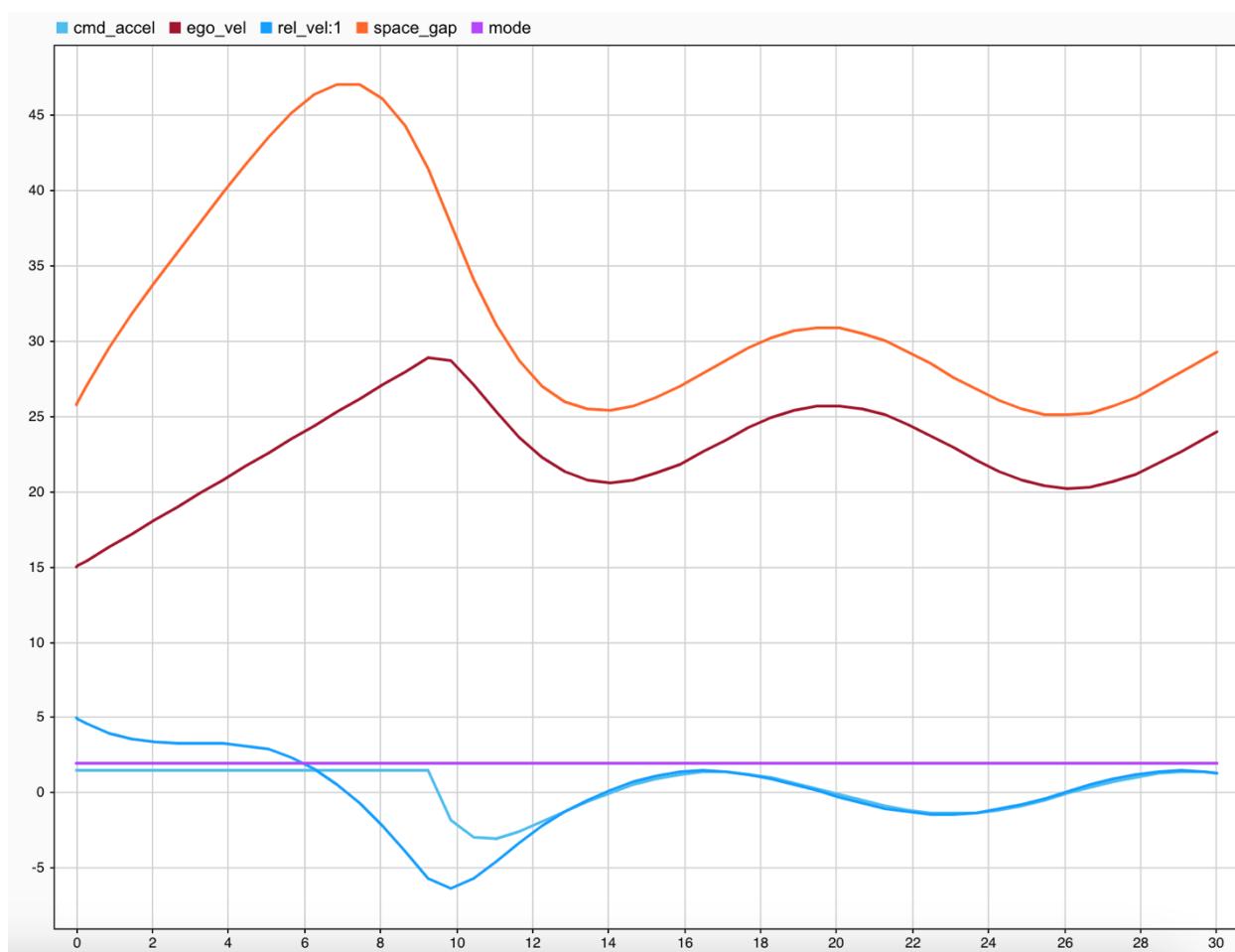
Leader: $a_0 = \text{sinewave}$ (amplitude = 1.5, frequency = 0.5, bias = 0), $v_0 = 20$, $x_0 = 30$

Ego: $v_0 = 15$, $x_0 = 0$

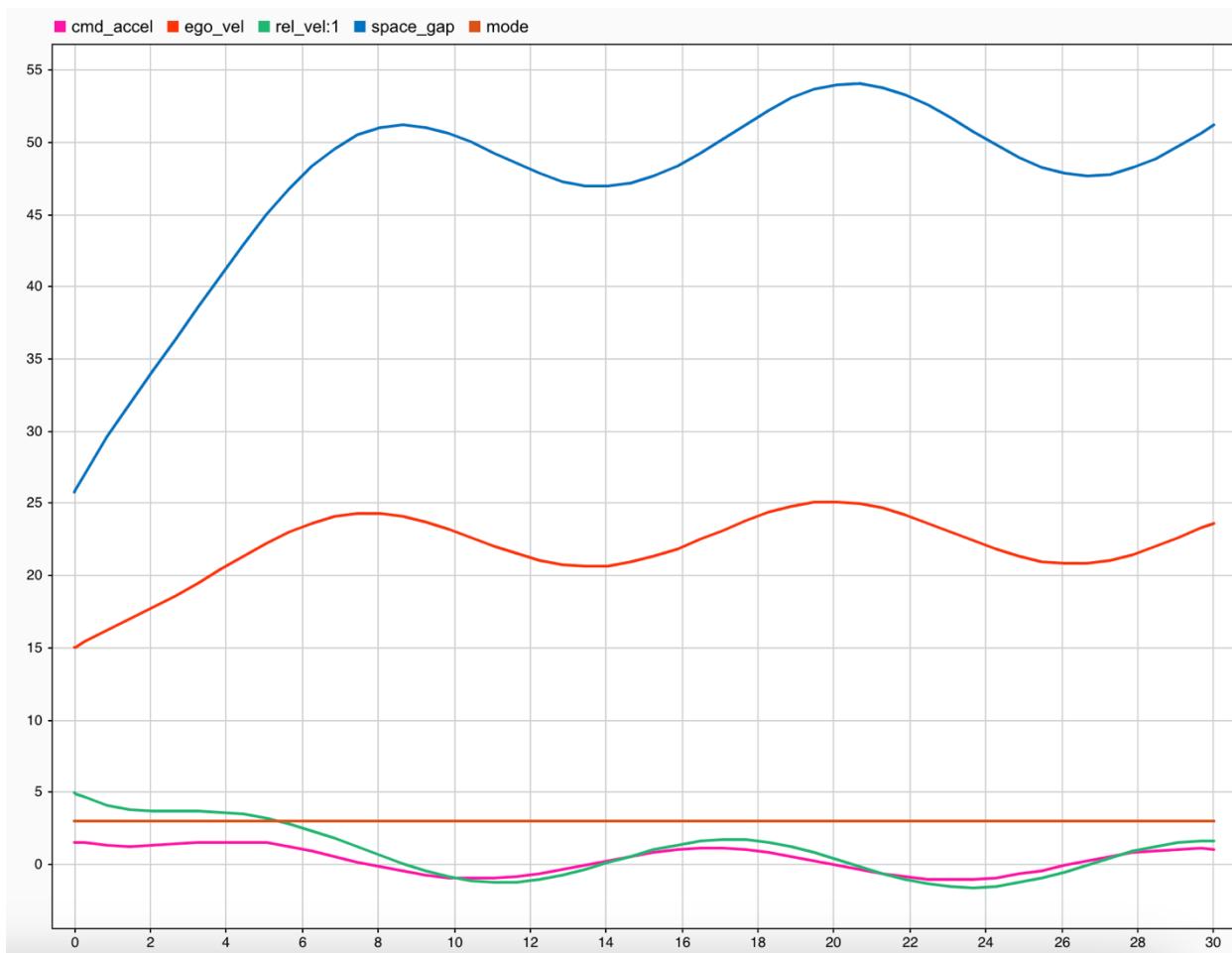
Mode 1 and 2 Behavior:



Mode 3 Behavior:



Mode 4 Behavior:



Safety and Sanity Checks:

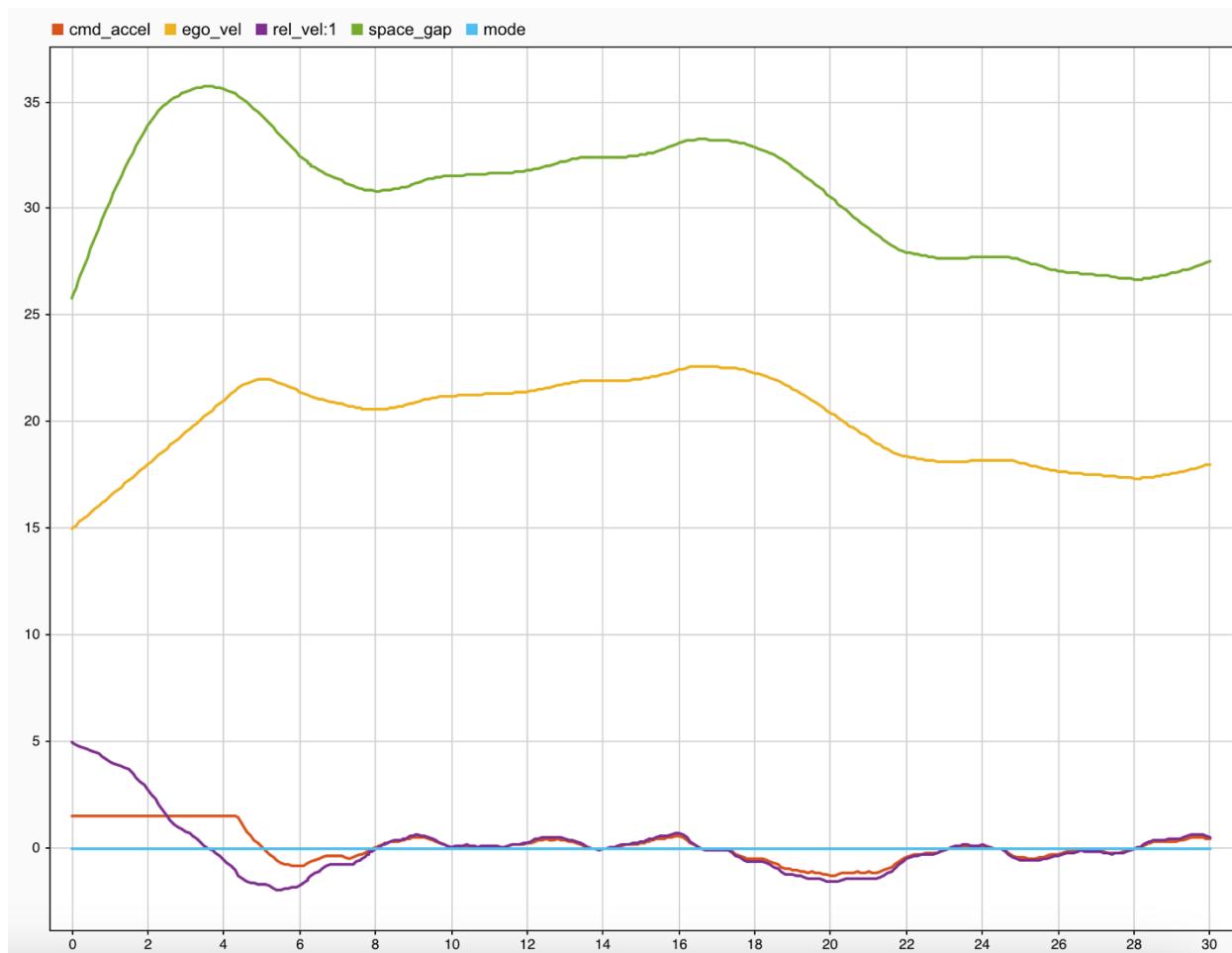
- ✓ Acceleration remains within safe range
- ✓ Space gap stays positive (no collision)
- ✓ Relative velocity tries to get to 0
- ✓ Ego velocity is never negative (doesn't go backwards)

Random Leader Behavior:

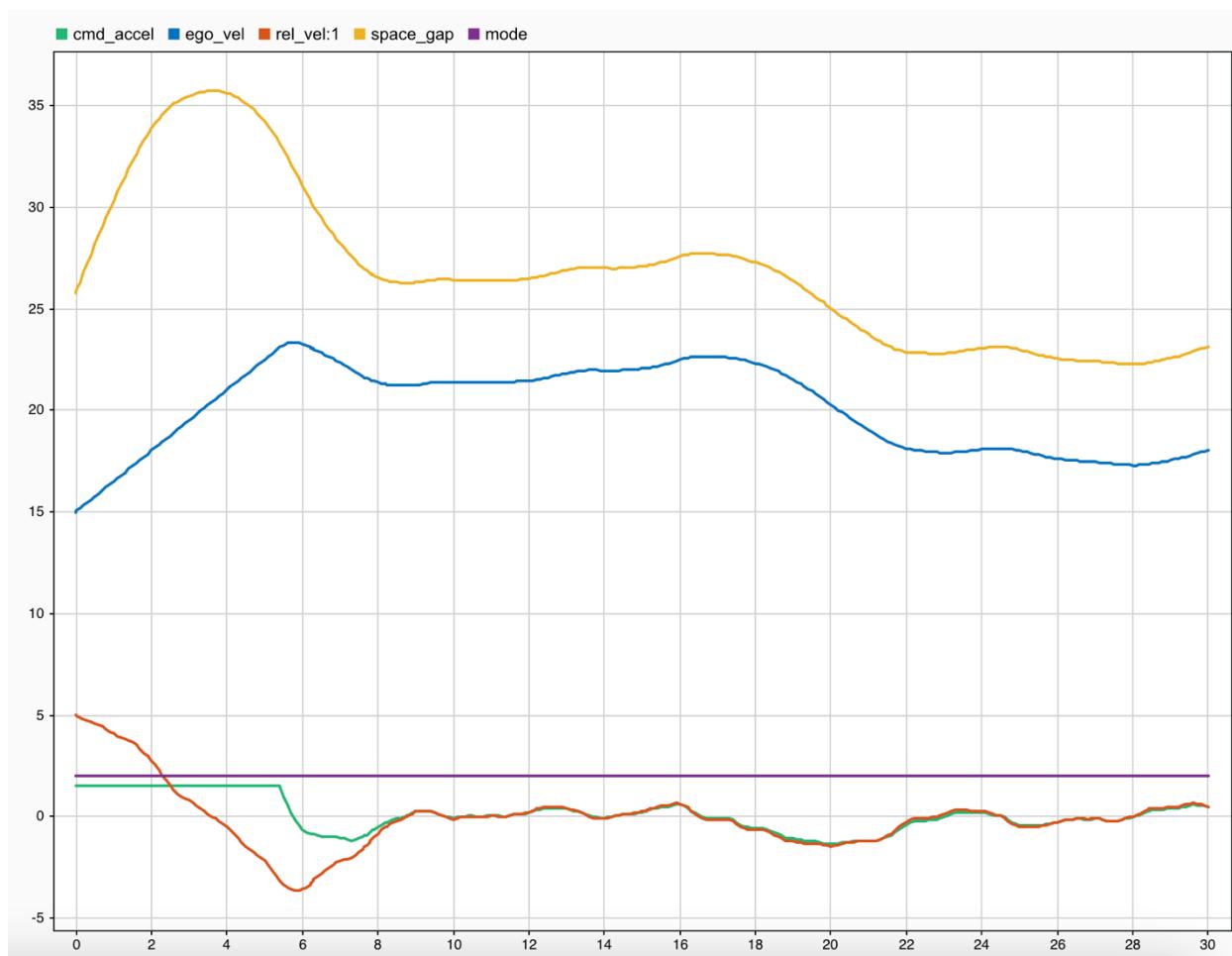
Leader: $a_0=\text{band-limited white noise}$ (with transfer function and saturation), $v_0=20$, $x_0=30$

Ego: $v_0=15$, $x_0=0$

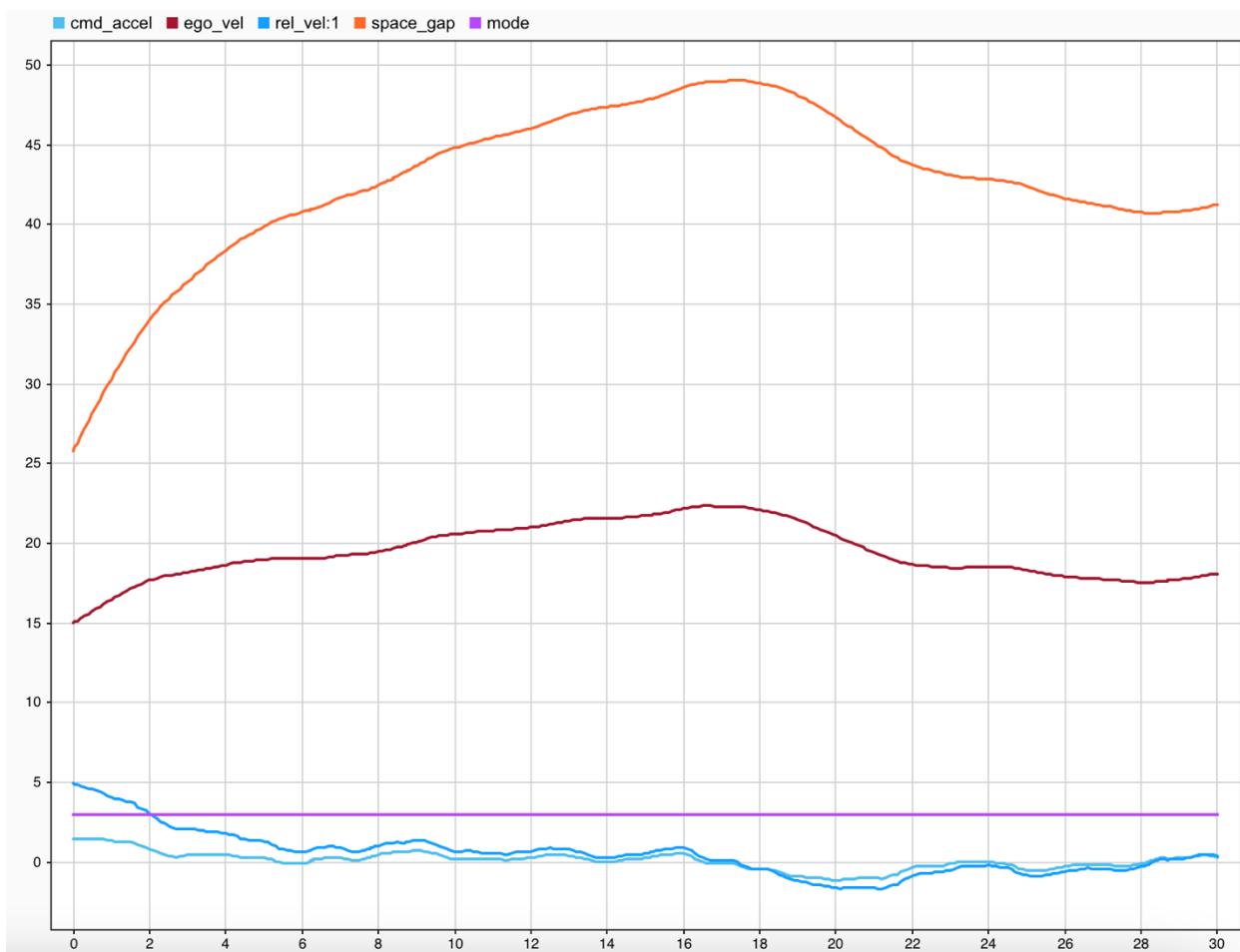
Mode 1 and 2 Behavior:



Mode 3 Behavior:



Mode 4 Behavior:



Safety and Sanity Checks:

- ✓ Acceleration remains within safe range
- ✓ Space gap stays positive (no collision)
- ✓ Relative velocity tries to get to 0
- ✓ Ego velocity is never negative (doesn't go backwards)

Leader Entering:

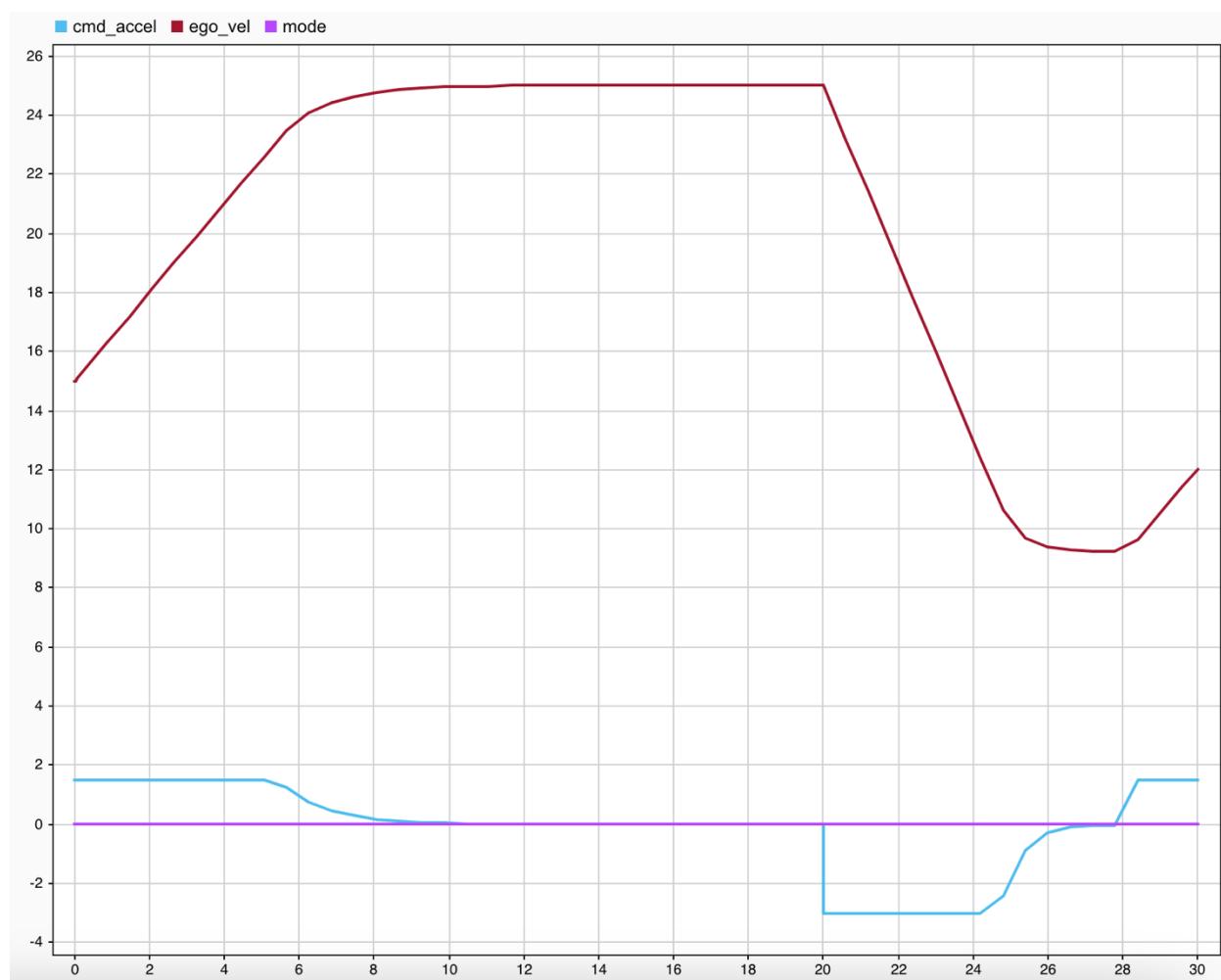
Leader: $a_0=0, v_0=20, x_0=1000$ and switches to 30

Ego: $v_0=15, x_0=0$

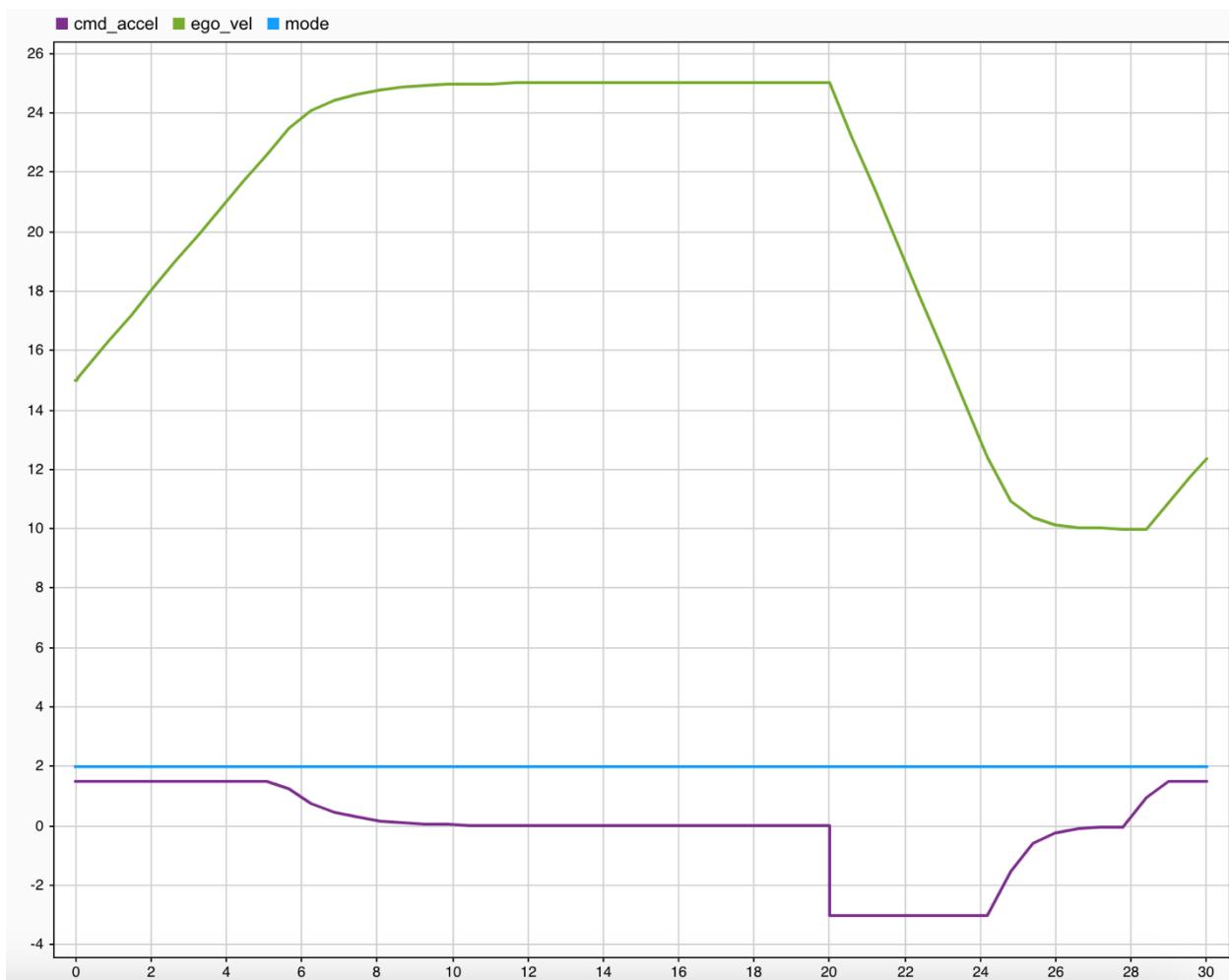
Space Gap for reference:



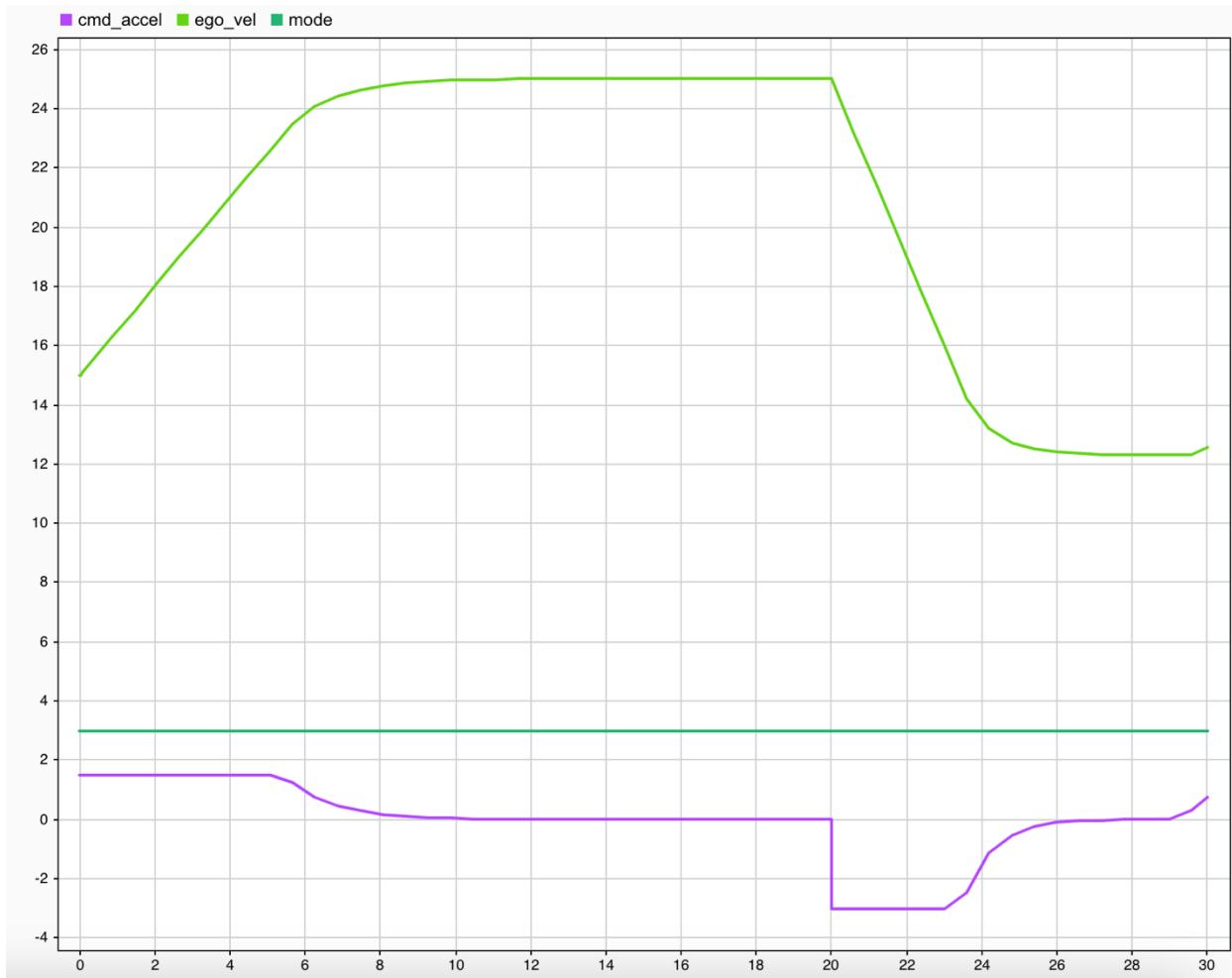
Mode 1 and 2 Behavior:



Mode 3 Behavior:



Mode 4 Behavior:



Safety and Sanity Checks:

- ✓ Acceleration remains within safe range
- ✓ Space gap stays positive (no collision)
- ✓ Leader entering does not throw off ego behavior
- ✓ Relative velocity tries to get to 0
- ✓ Ego velocity is never negative (doesn't go backwards)

Concern:

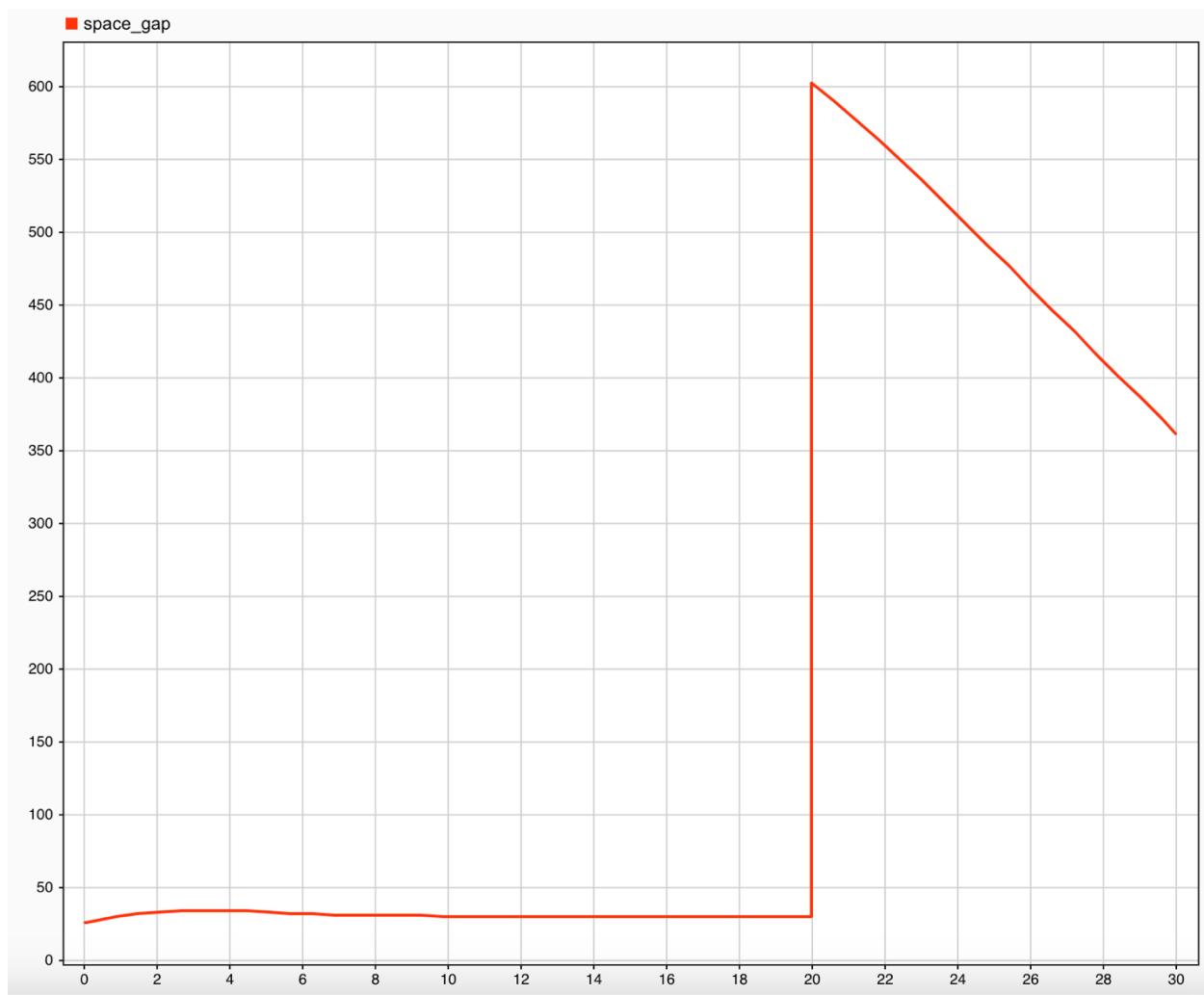
- ✗ The cmd_accel makes an instantaneous jump at 20 seconds, which may be unwanted and unfeasible

Leader Exiting:

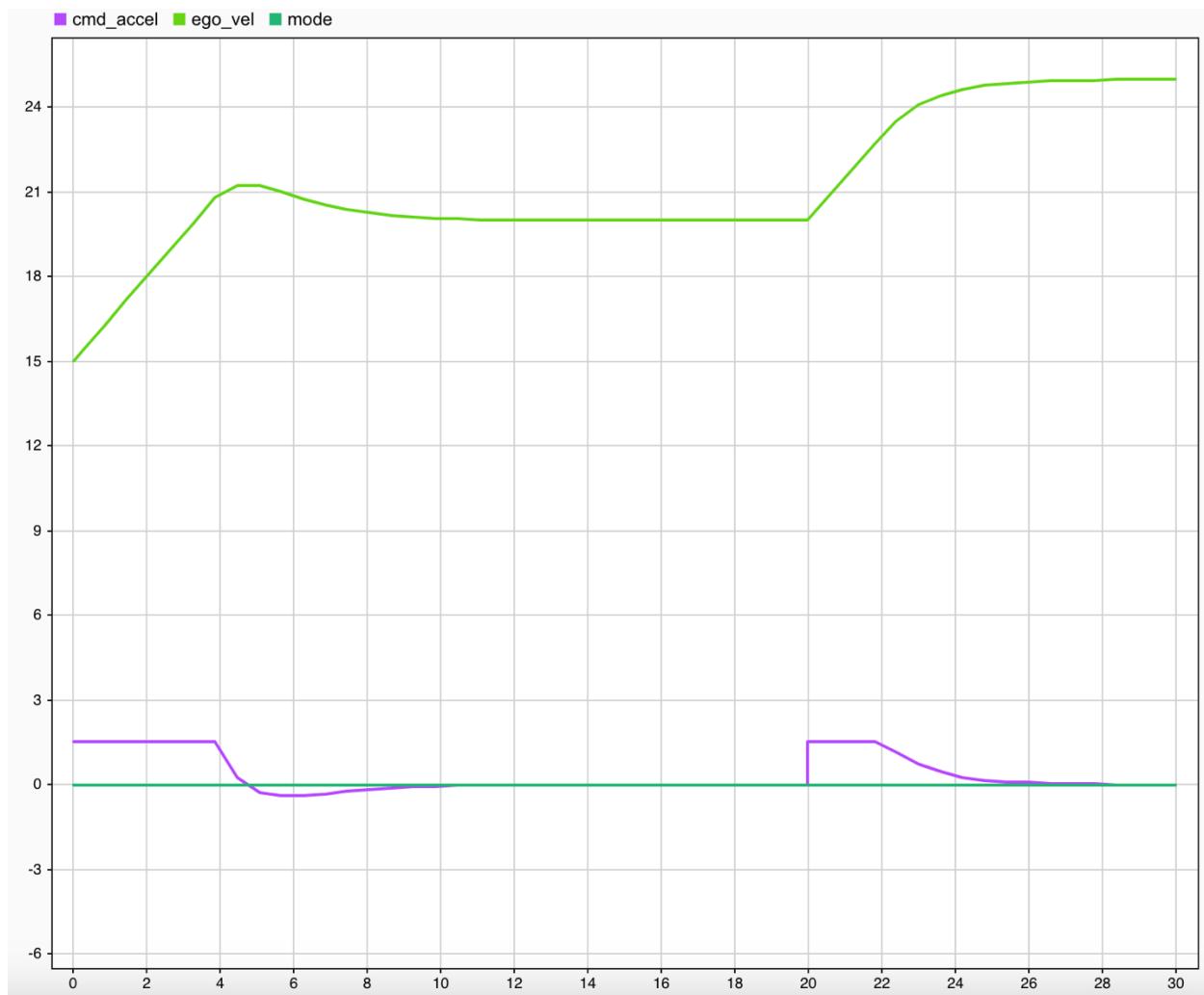
Leader: $a_0=0, v_0=20, x_0=30$ and switches to 1000

Ego: $v_0=15, x_0=0$

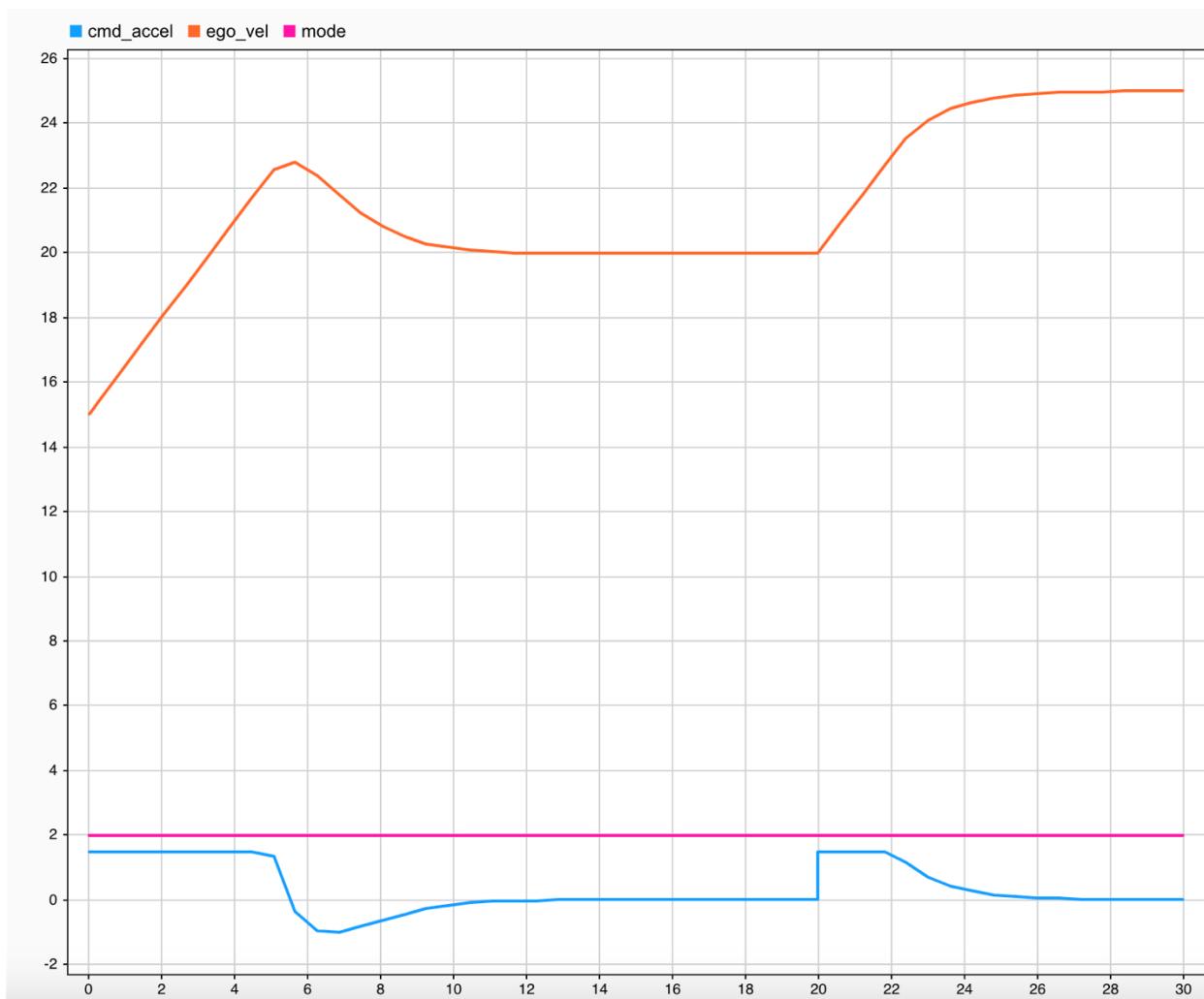
Space gap for reference:



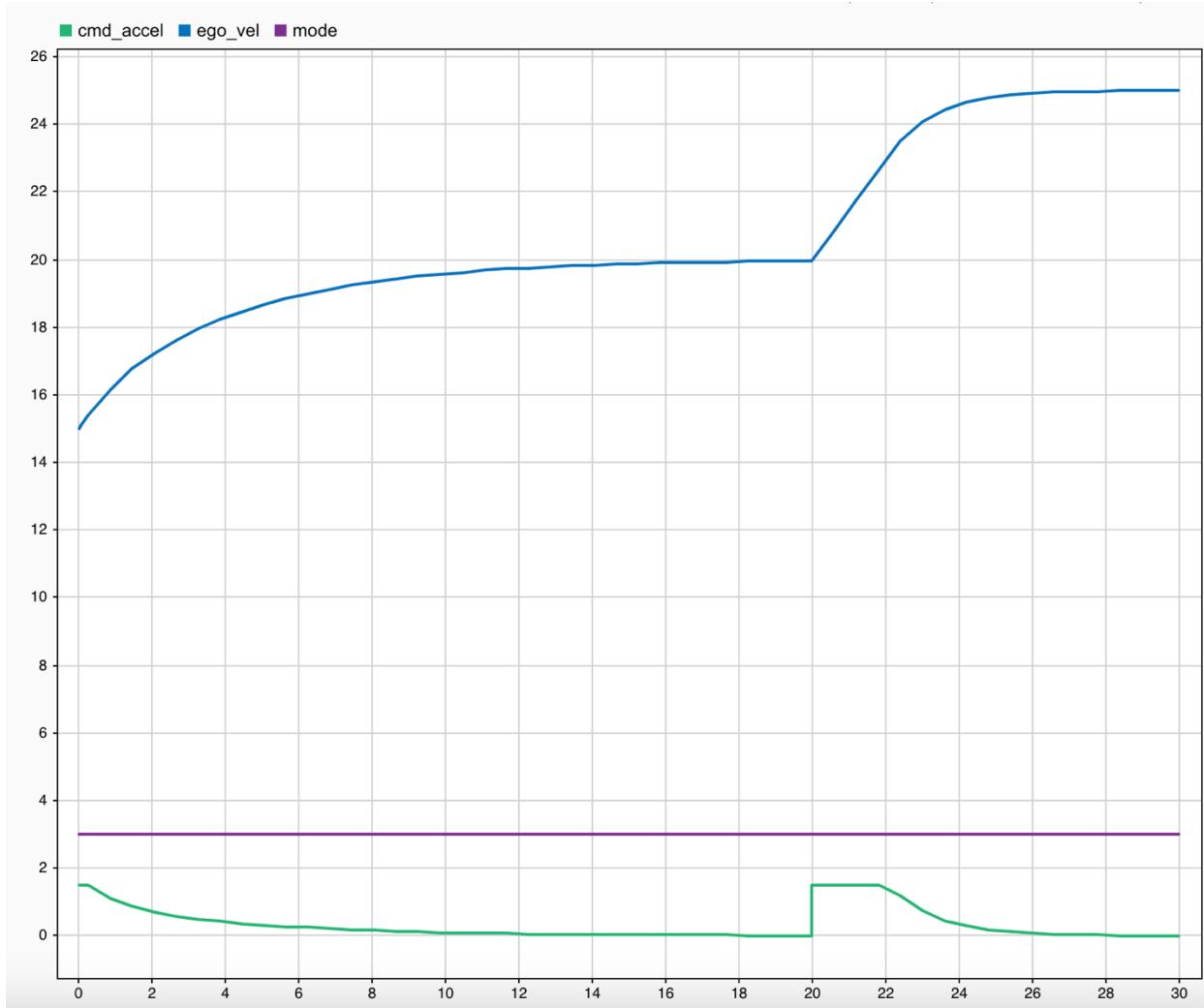
Mode 1 and 2 Behavior:



Mode 3 Behavior:



Mode 4 Behavior:



Safety and Sanity Checks:

- ✓ Acceleration remains within safe range
- ✓ Space gap stays positive (no collision)
- ✓ Leader leaving does not throw off ego behavior
- ✓ Leader entering does not throw off ego behavior
- ✓ Relative velocity tries to get to 0
- ✓ Ego velocity is never negative (doesn't go backwards)

Concern:

- ✗ The cmd_accel makes an instantaneous jump at 20 seconds, which may be unwanted and unfeasible

Overview of Next Steps for ROS Implementation

1. Finalize all input/output topics and message types (/lead_dist, /rel_vel, etc.) and all alpha/tau values for each mode
2. Convert Simulink controller into ROS node using ROS-compatible codegen
3. Implement mode logic & safety bounds by integrating mode-switching, warmup detection, alpha/tau lookups, and acceleration and velocity bounds
4. Build a launch file that runs node and plays recorded rosbag, visualize results
5. Run and log all tests created
6. Tune and validate parameters alpha and tau across mode to enhance benefits across oscillation dampening and road capacity

Link to Youtube Tutorial:

<https://youtu.be/yVXCvlsKKuM>