Evaluation on Ground Velocity Vector Field Formulations

Unified Path Following Guidance for hybrid VTOLs

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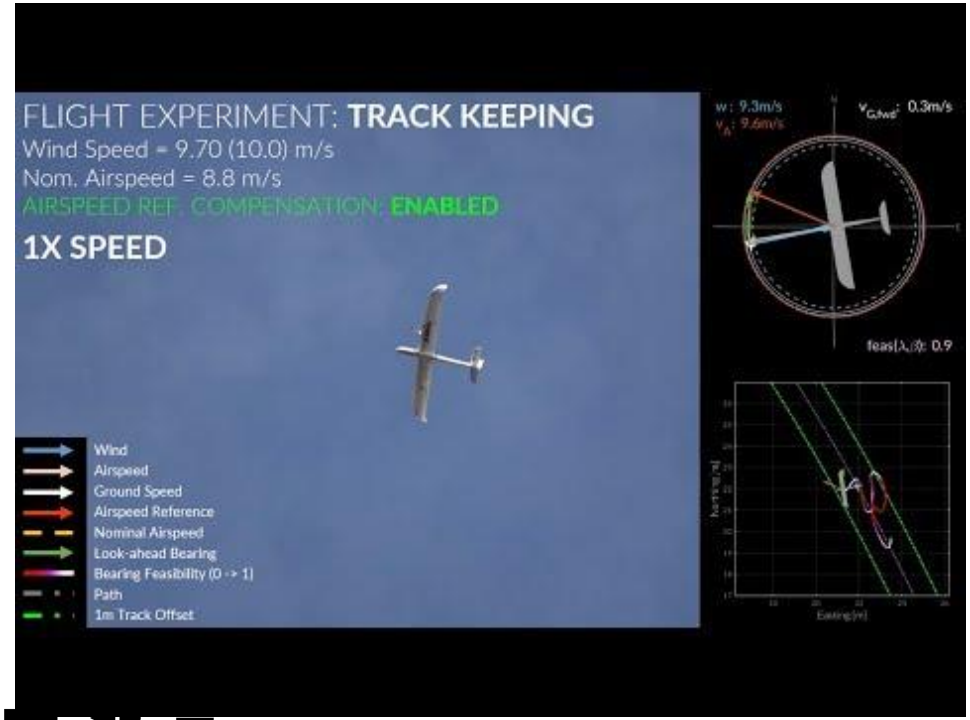
Goal of this Presentation

Evaluate the newly proposed Ground velocity VF generation methods against the pre-existing unicyclic motion based VF algorithm.

Thus, this will conclude the first step of the thesis: Finalizing ground velocity VF.

Existing solution: Unicyclic Path Following Guidance



Pros

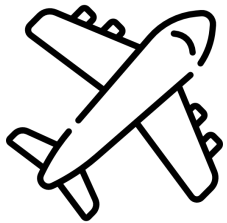
- Optimized for Fixed Wing guidance
- Provides simple geometric ‘look ahead angle’ based ground bearing reference point

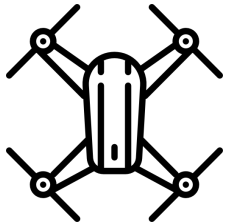
Cons

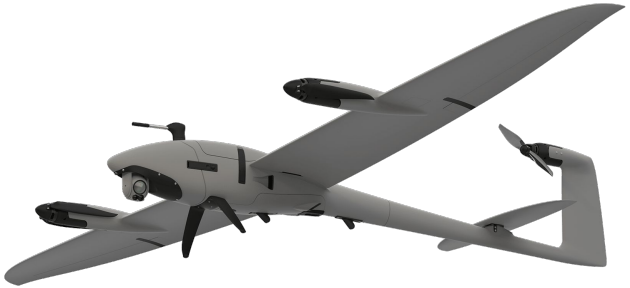
- **Bearing** setpoint doesn’t make sense when vehicle has 0 airspeed
- **Unicyclic** path following behavior (constant airspeed = nominal airspeed)

“On Flying Backwards: Preventing Run-away of Small, Low-speed, Fixed-wing UAVs in Strong Winds”

Now what about Multirotors? And Hybrid VTOLs?







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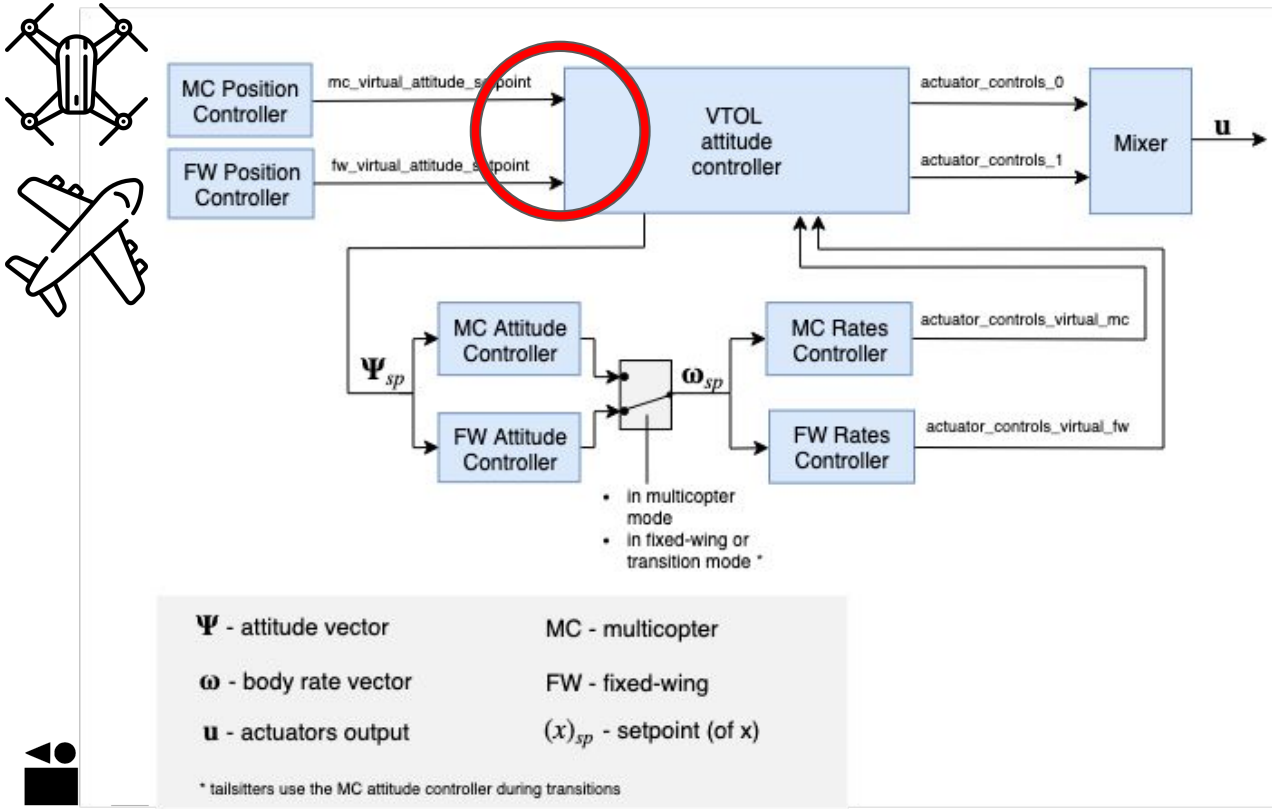
Current control algorithm for hybrid VTOLs



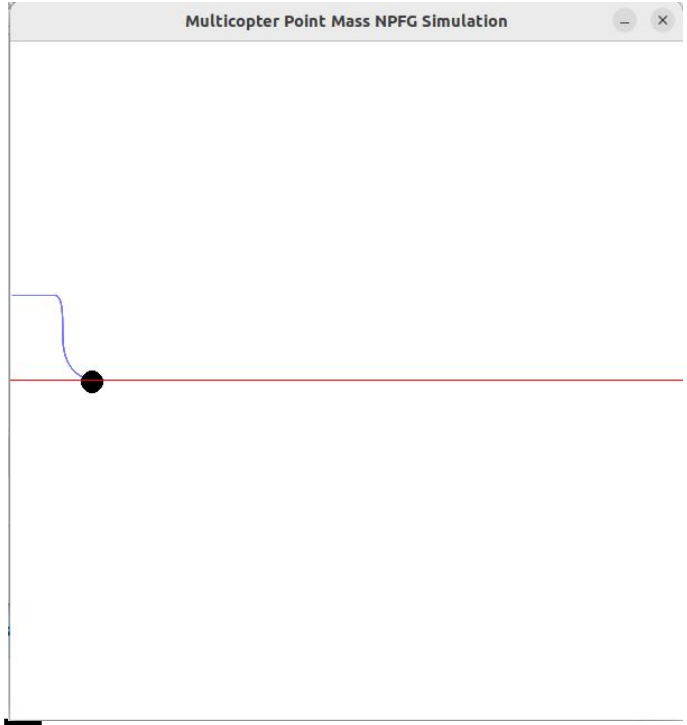
Includes **decoupled** 2 path following (position control) algorithm.

This creates **discrepancy between two control methods**.

Results in **discontinuous** actuator control & **hard-switching**

What happens when we try existing unicyclic Path Following controller on Multirotor?

Limitation of the unicyclic path following algorithm



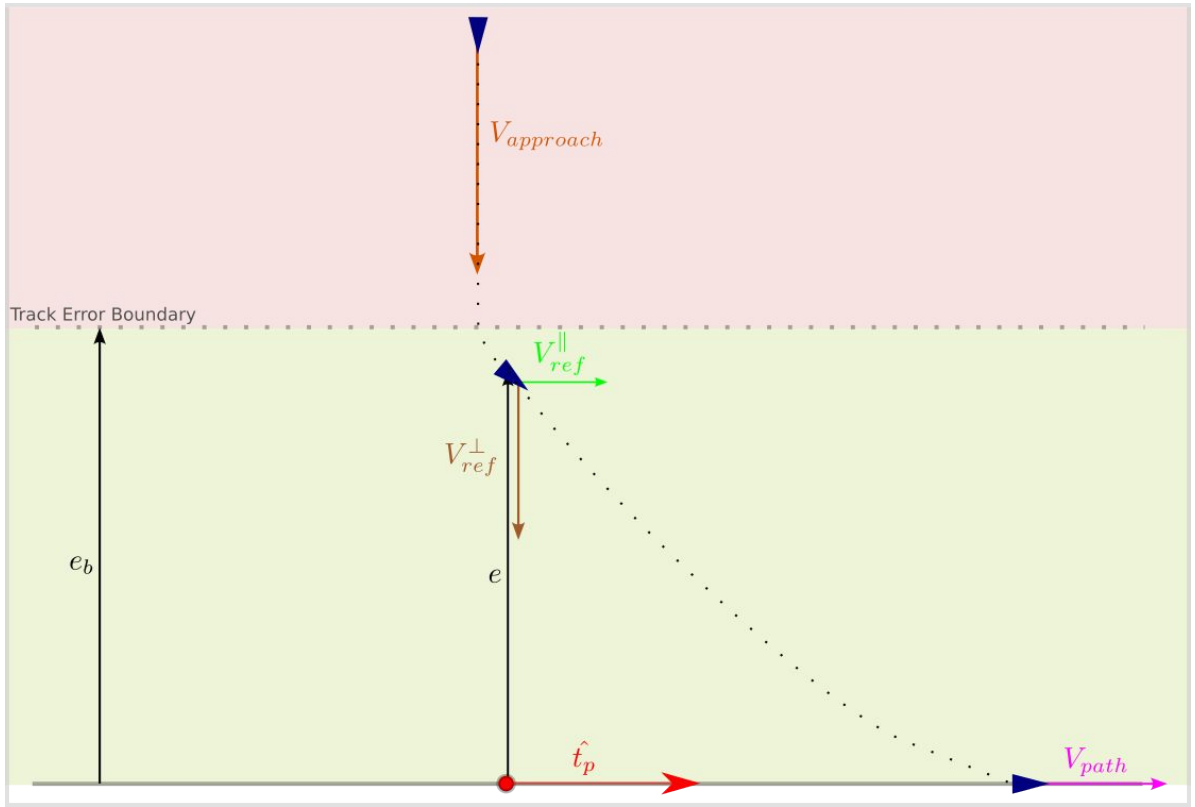
What do we do when we want to go **slower** on the path?

- Unicyclic Path Following assumes that vehicle maintains the ‘nominal airspeed’, so **it can never stop.**
- Reducing nominal airspeed produces **weird artifacts**

What about going **faster**?

- We can set nominal airspeed to a higher value, but it **alters the definition of ‘cruise speed’** (energy optimal speed)

Path following graphical overview



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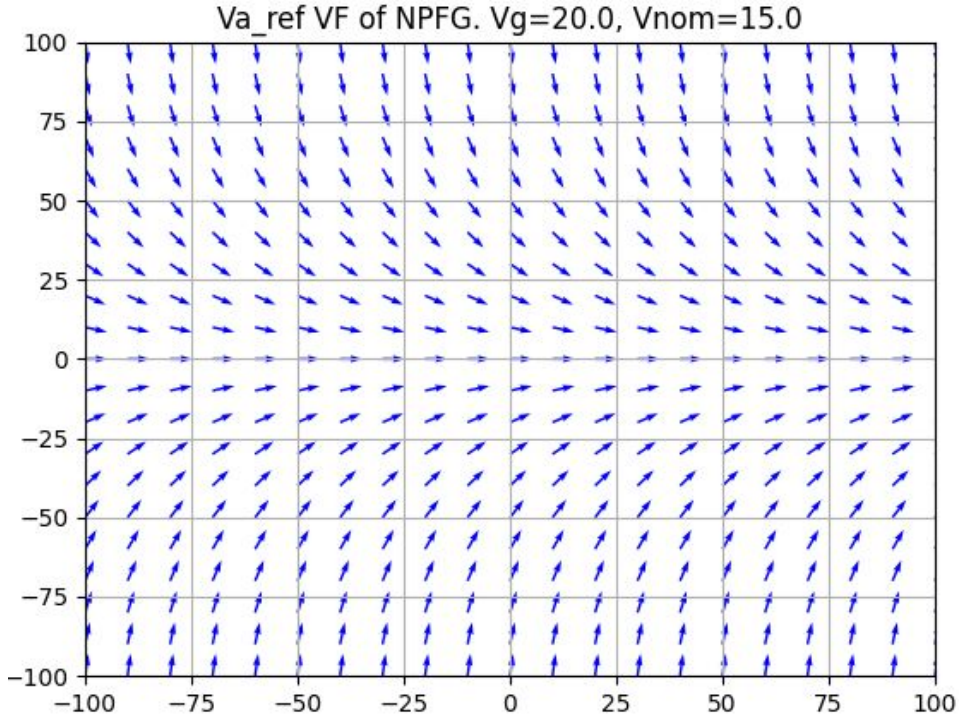
Quick note on Vector Field path following guidance



PF Algorithm must do 2 things:

1. **Define a ground velocity / course (direction of travel) vector field around the path**

2. *Formulate stable control strategy to follow the vector field*

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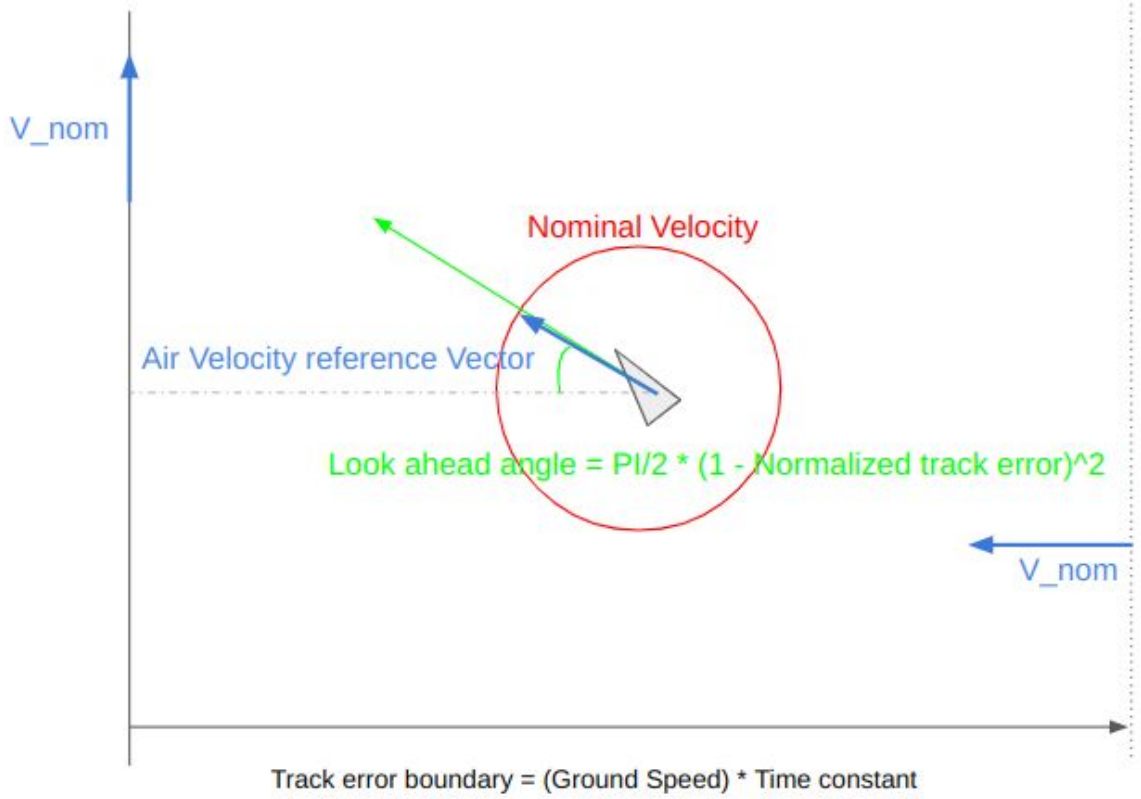
The Challenge: Formulate a new Vector Field that can handle different speed on path!

“**Unicyclic**” Path Following Algorithm breakdown



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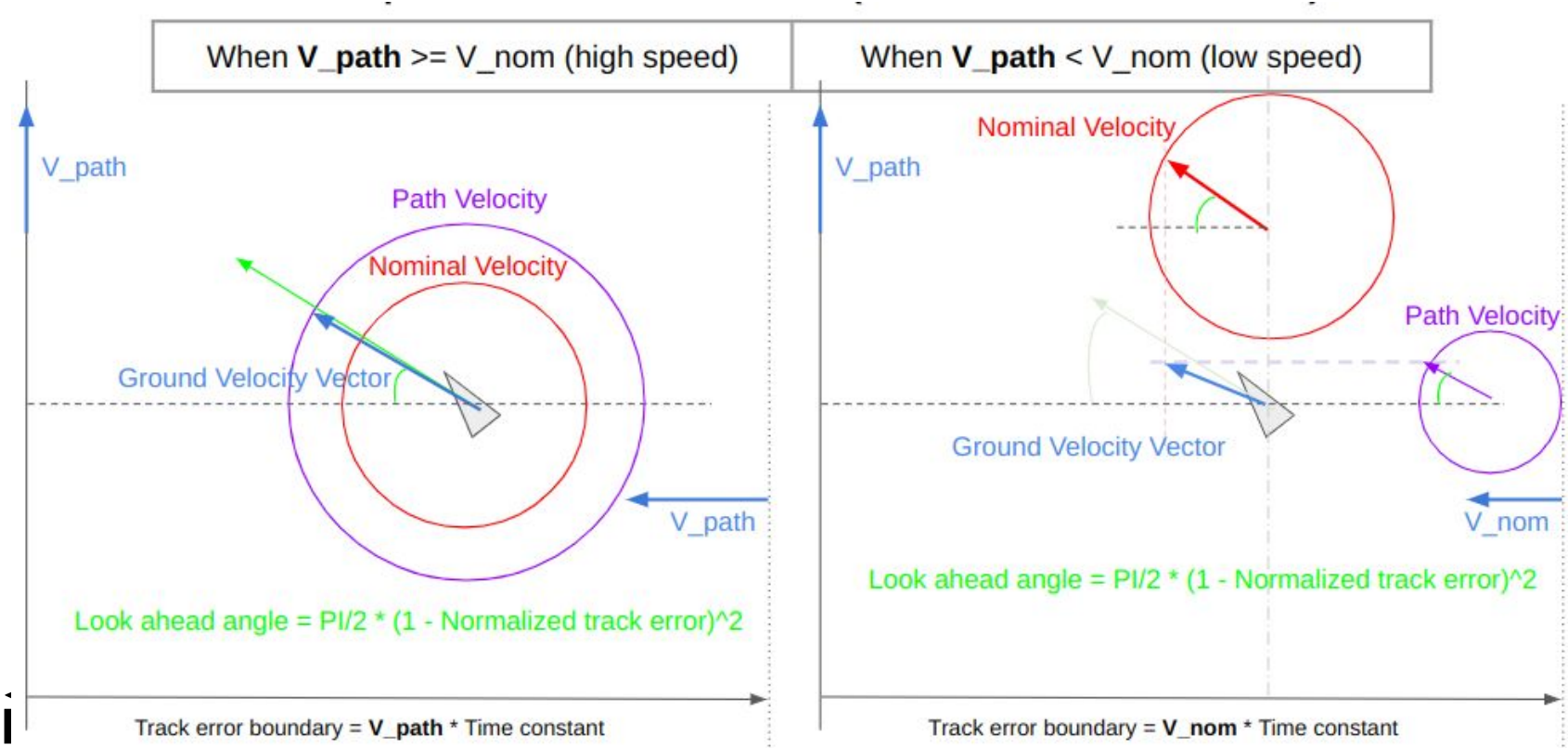
Newly proposed Formulation: **“Hybrid Unicyclic”**



Analysis on satisfying ‘speed on path’ requirement

	Path velocity **<** Nominal airspeed	Path velocity **>** Nominal airspeed
Original	Ground velocity on path: **Nominal airspeed**	Ground velocity on path: **Nominal airspeed**
Proposed	Ground velocity on path: **Path velocity**	Ground velocity on path: **Path velocity**

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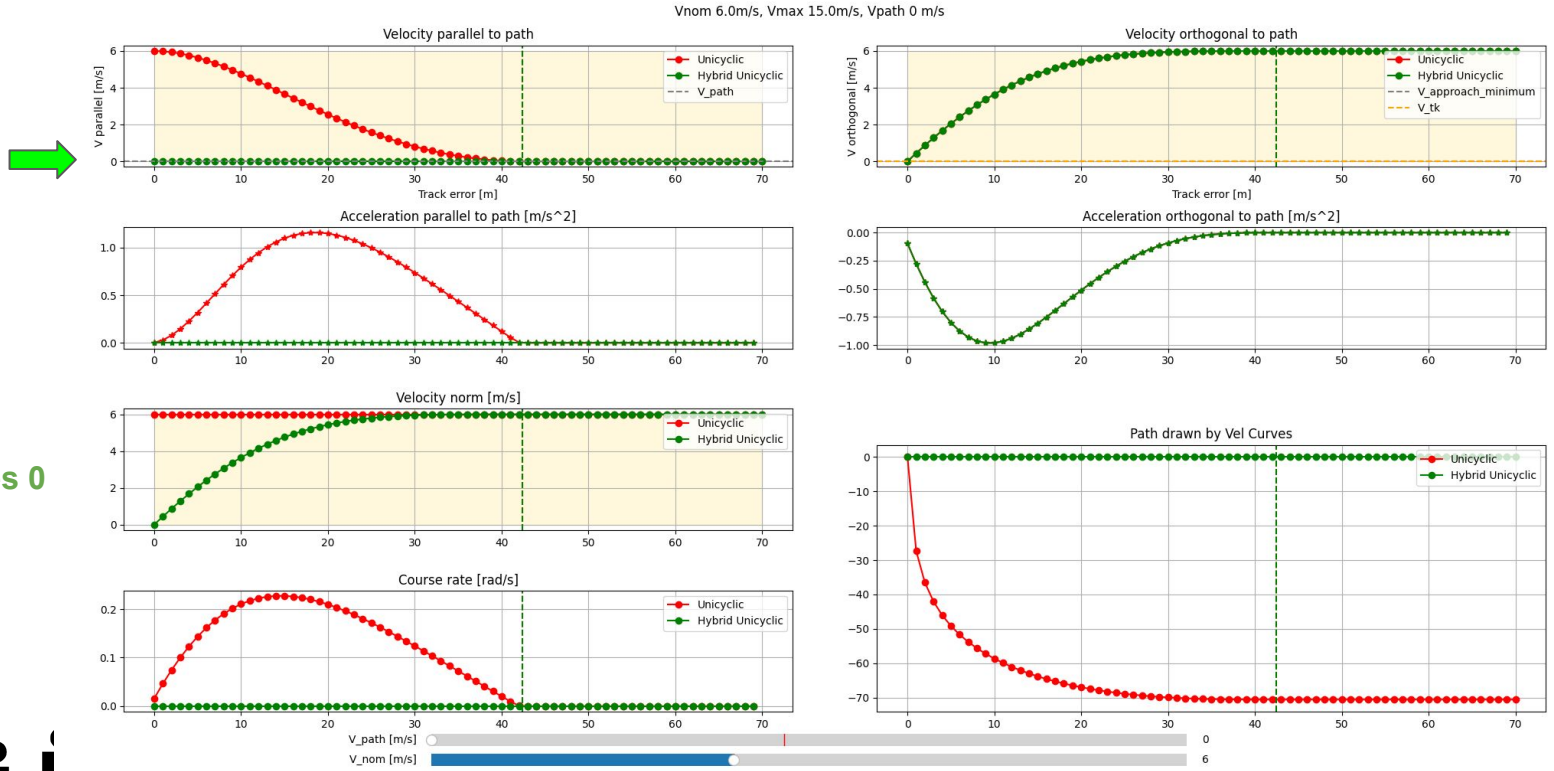
Case study: Zero speed on path



Speed reaches 0

Approaches the path orthogonal

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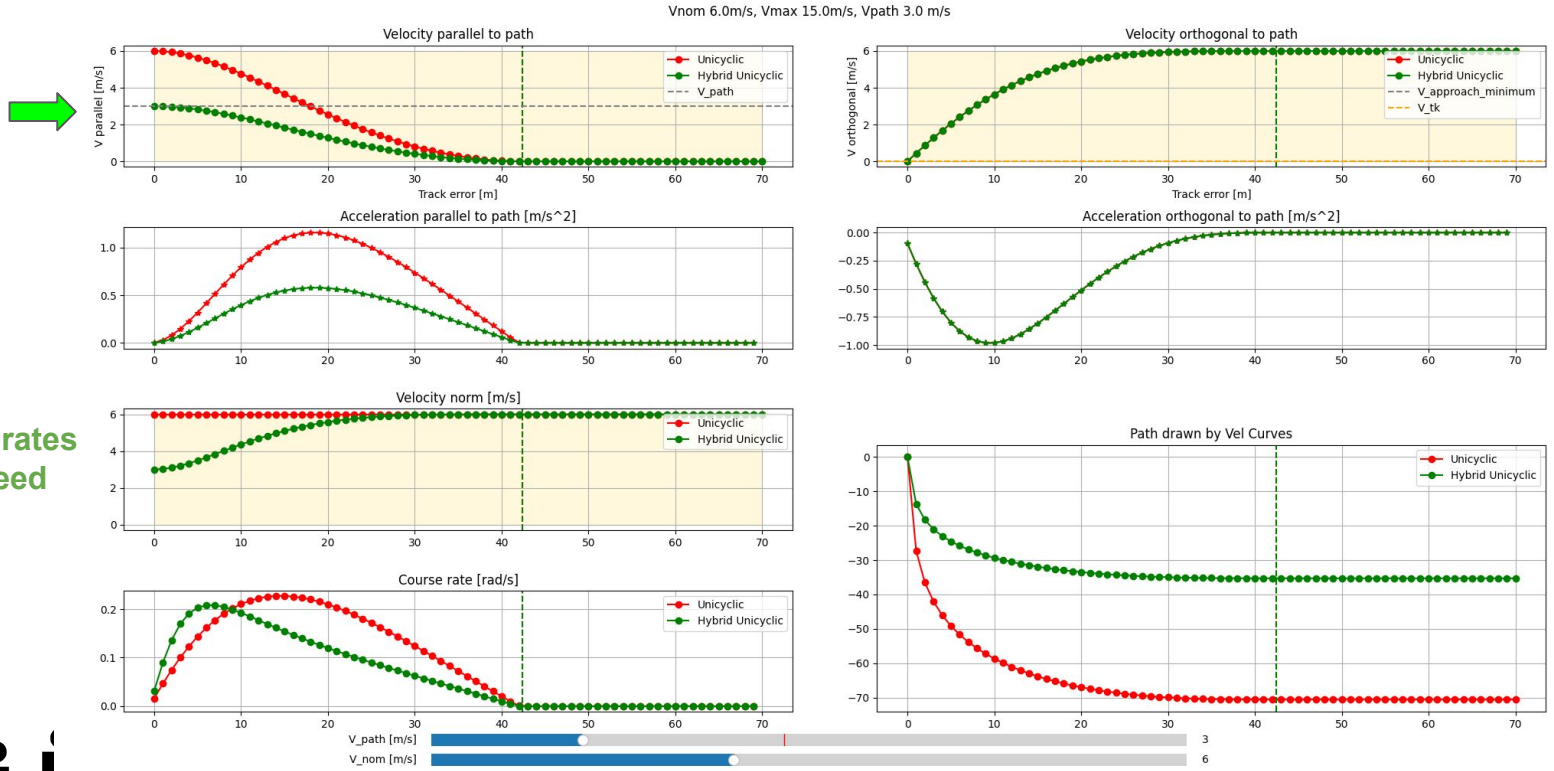
Case study: Low speed on path



Decelerates the speed

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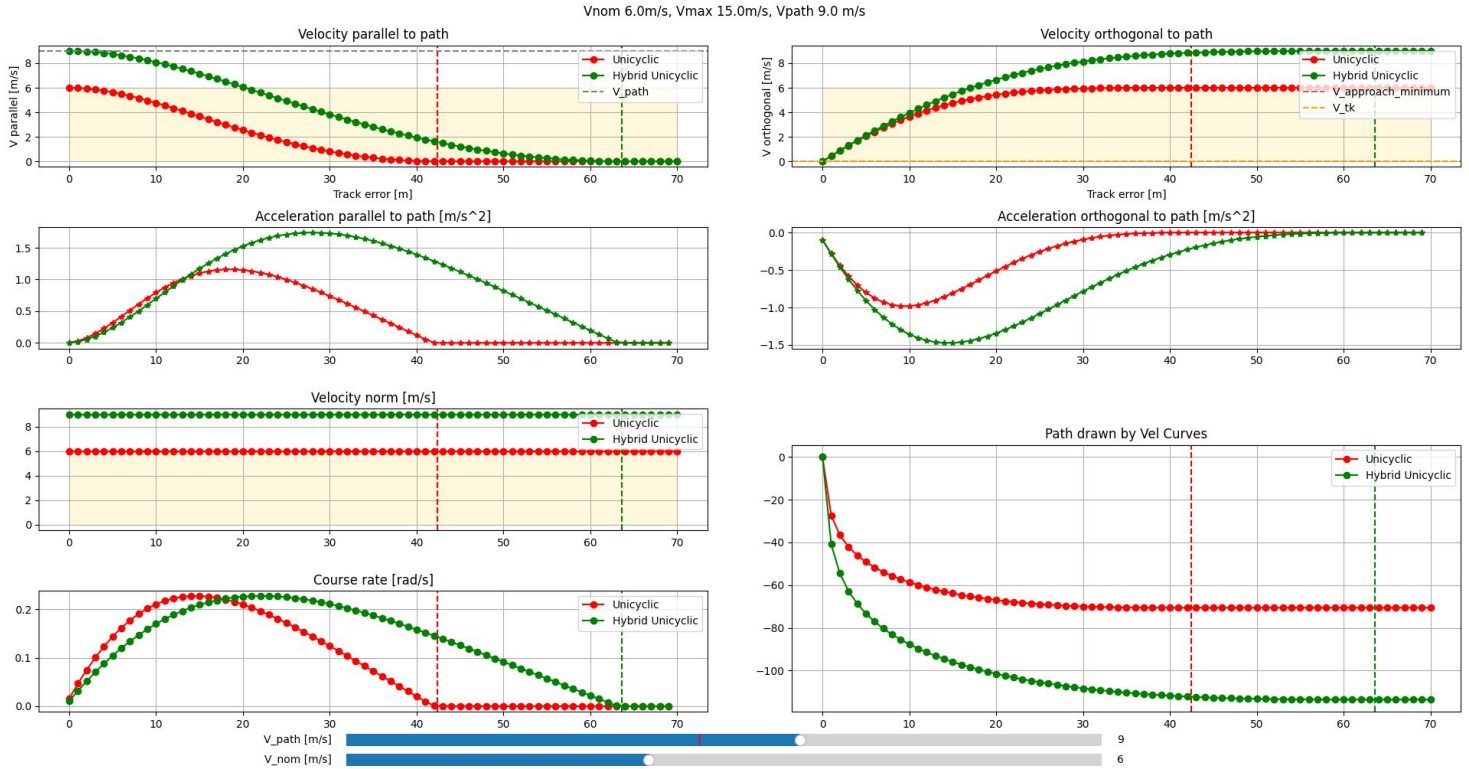
Case study: High speed on path



Approaches at higher speed

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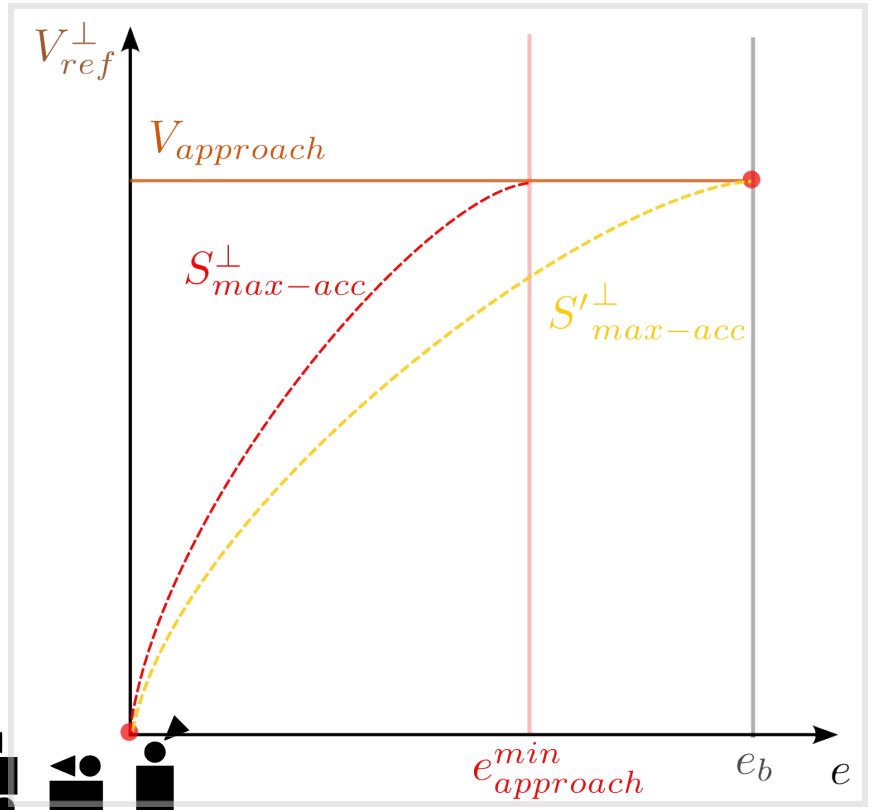
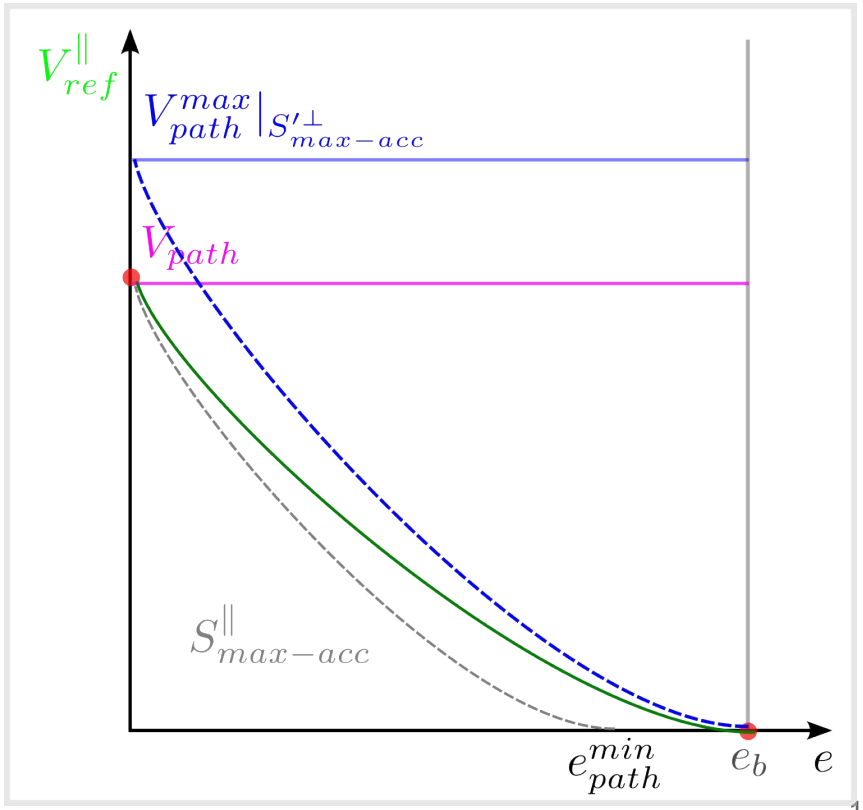
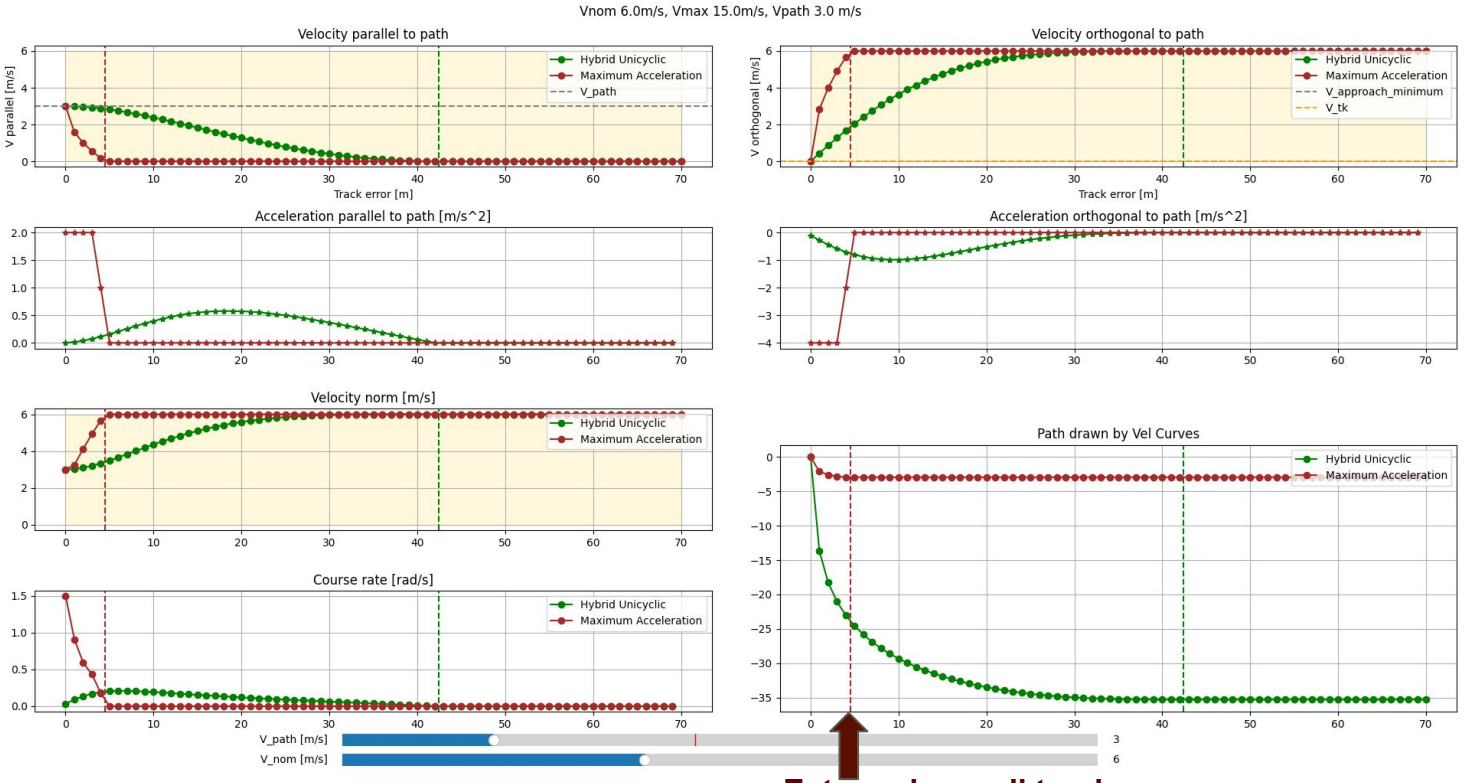
How about using maximum acceleration?

Maximum Acceleration Formulation





Case study: Low speed on path



Extremely small track error boundary

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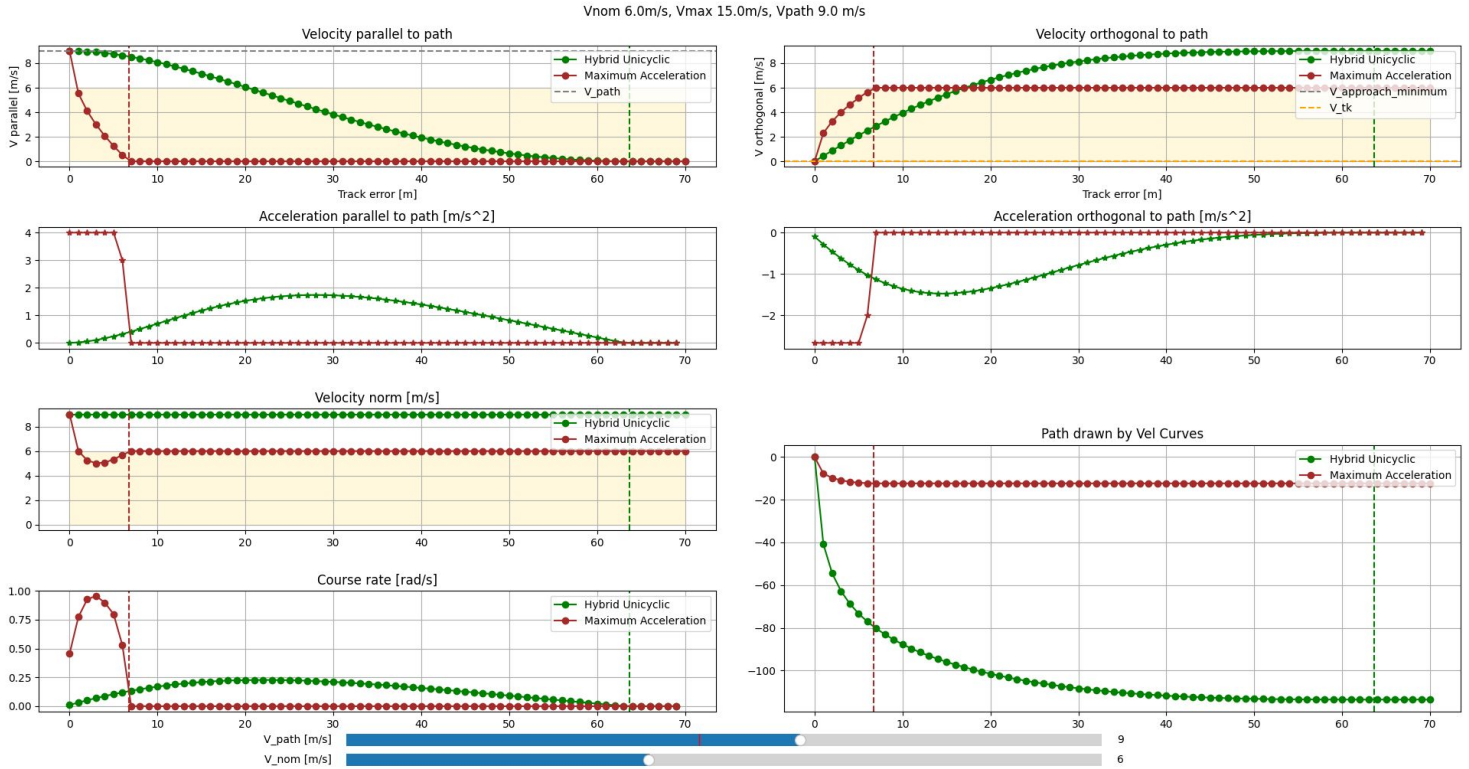
Case study: High speed on path



Monotonicity not satisfied

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How about Jerk limited trajectory?

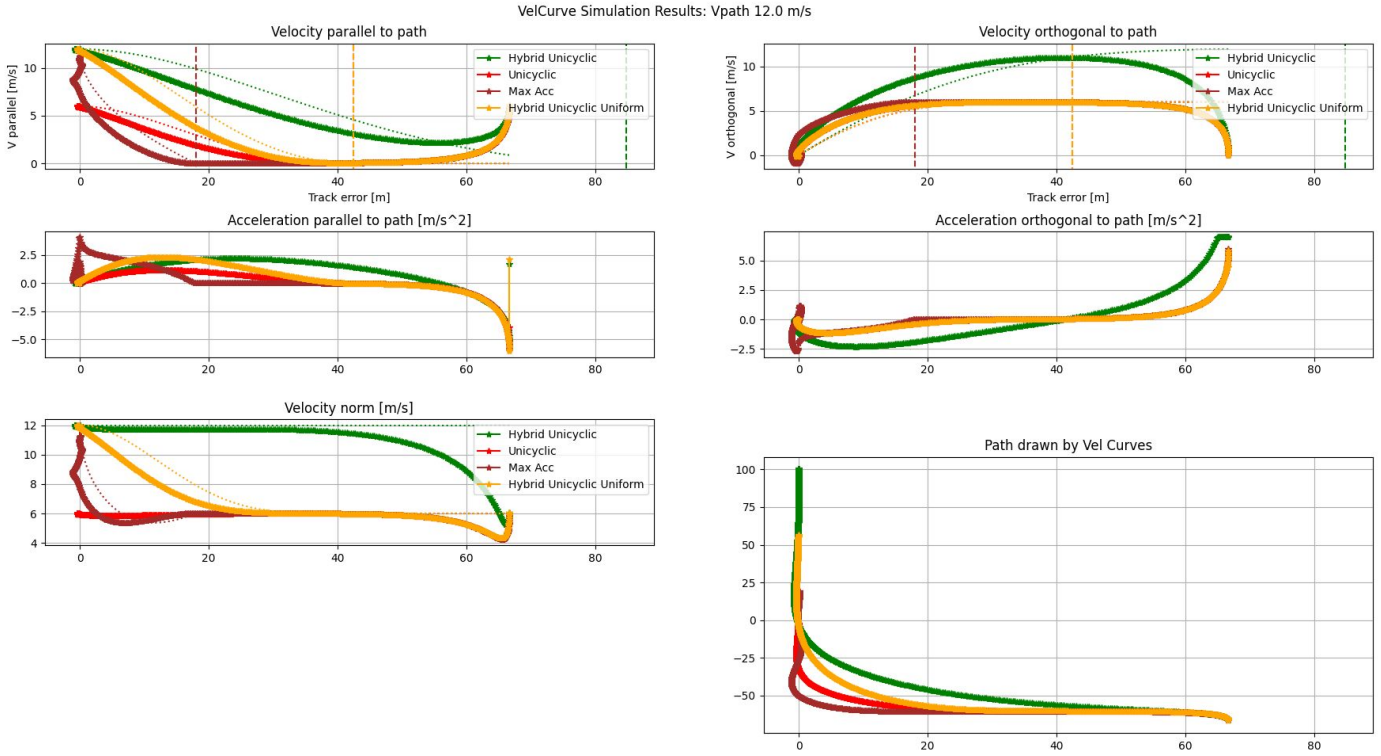
TODO

Simulation Results

Multicopter: High speed on Path

Note: Simulated environment is a point-mass multicopter model with only Velocity feedback control with P-controller.

Dotted lines show ground-truth reference velocity curves



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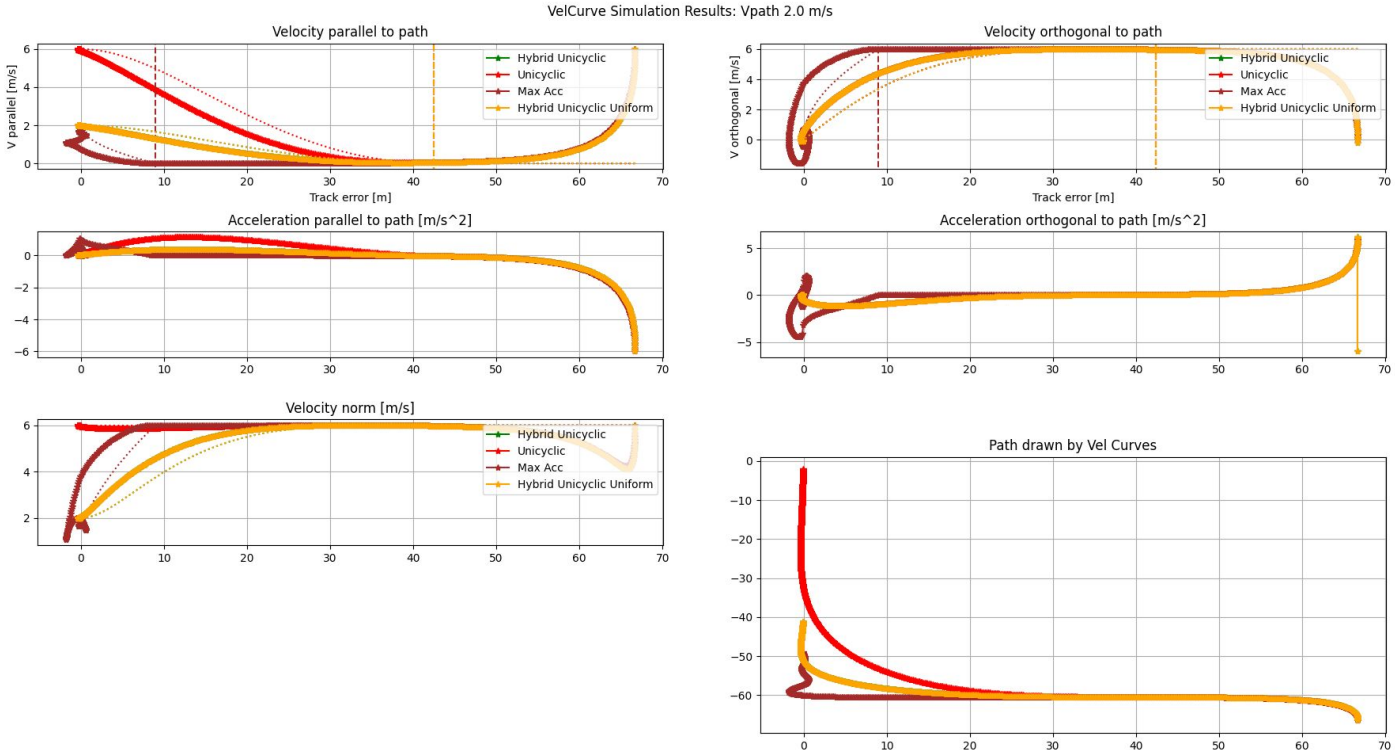
Multicopter: Low speed on Path

Dotted lines show ground-truth reference velocity curves



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