# iVEX

## Intelligent Vehicle Technology

Mario Torres, CEO

## Vision

Reduce # traffic victims to **zero** by 2030

## Mission

Make autonomous & semi-autonomous vehicles **Safe**

## Passion

Use our skills to save **lives**

## UN Goals:

# Leadership

**Mario Torres, CEO**
PhD Computer Science
Post-doctoral Robotics
KU Leuven

**Prof. Tom Holvoet, CTO**
100+ published papers
5000+ scientific citations

**Quentin De C., COO**
MSc. Vehicle Engineering
Entrepreneur

# Advisers

**Kurt Daniel**

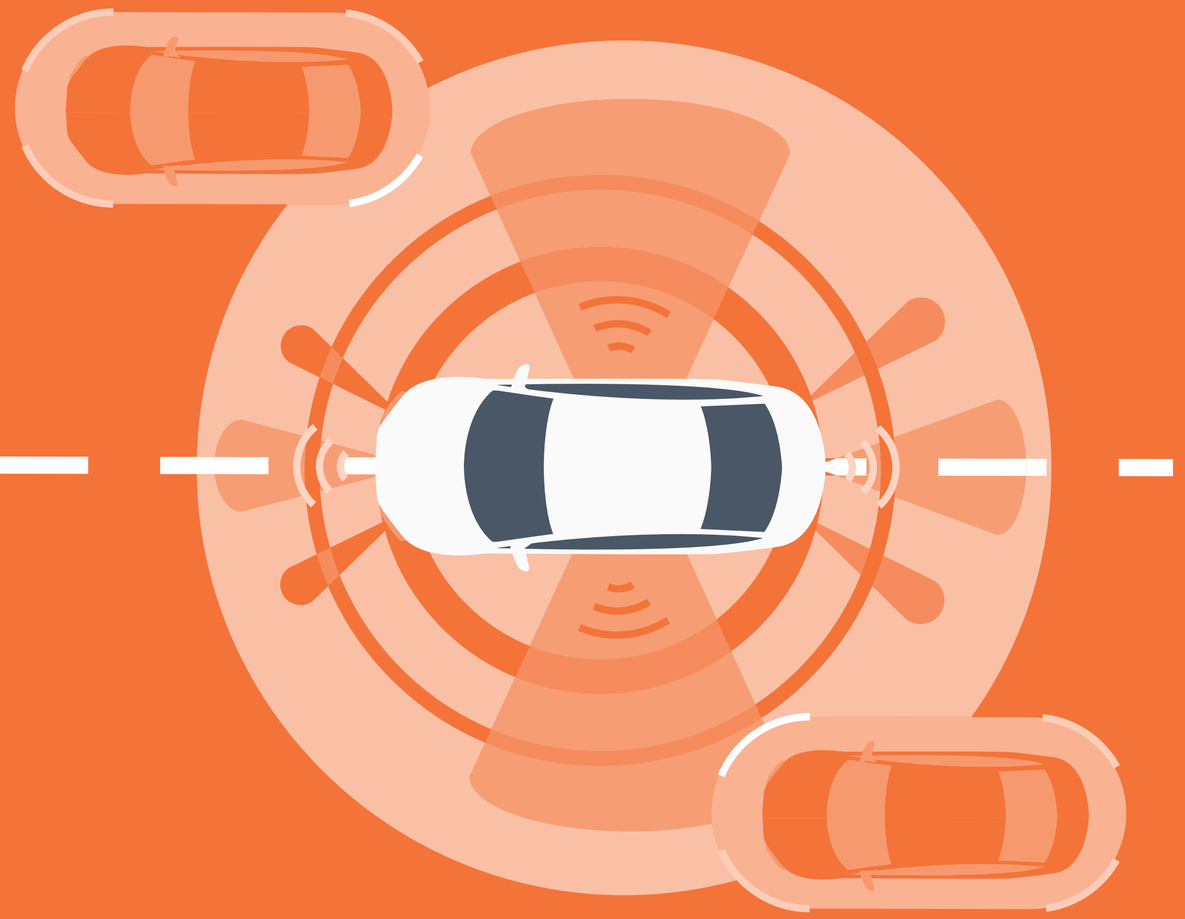
**Sari Depreeuw**

**Dr. Sven Fleck**

**Dr. Walter Buga**

# Customers

# Investors



# Automated cars can drive but they are not safe yet

Confirmed by Autonomous Driving experts of:

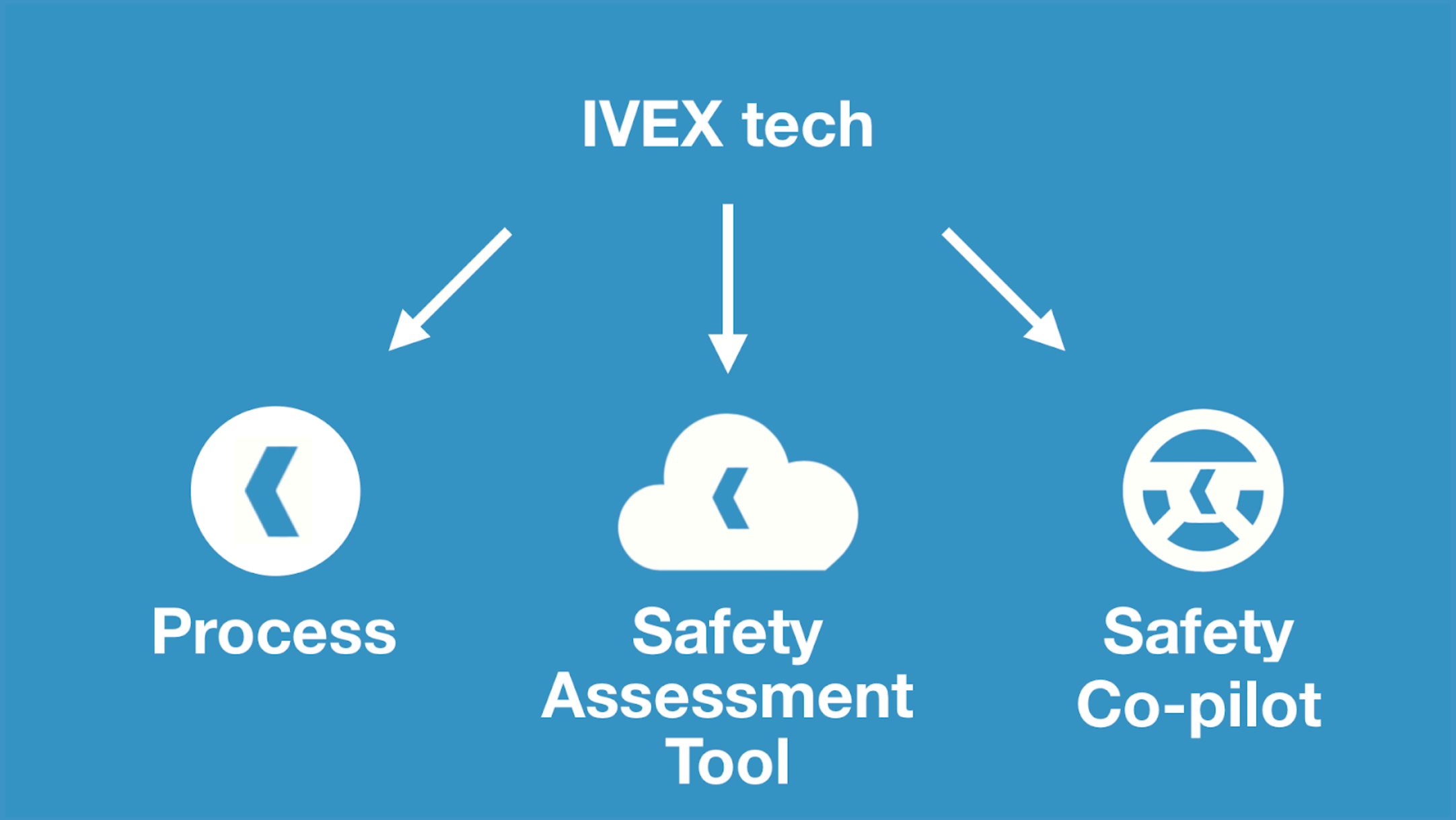
PSA GROUPE

BOSCH

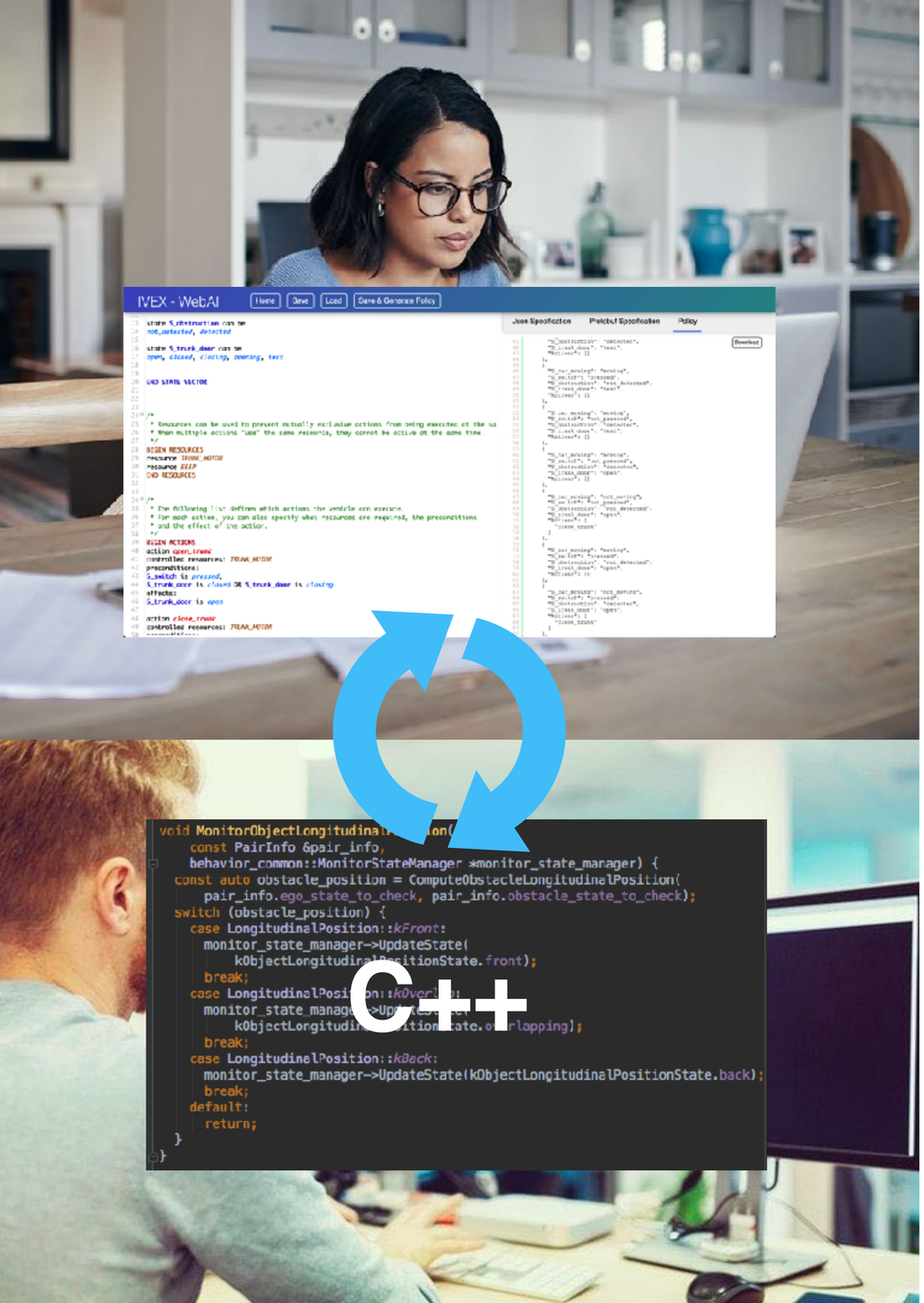
Ford

TOYOTA

RENAULT


IVEX tech
Process
Safety Assessment Tool
Safety Co-pilot

# IVEX PROCESS




- Automatically transforms safety policies into formally verified software
- Generates correct-by-construction software
- Highlights limitation of safety policies (Consistency and completeness checks)
- Shortens iteration cycles and reuses existing knowledge
- Supported by mature toolchain

# Safety Assessment Solutions

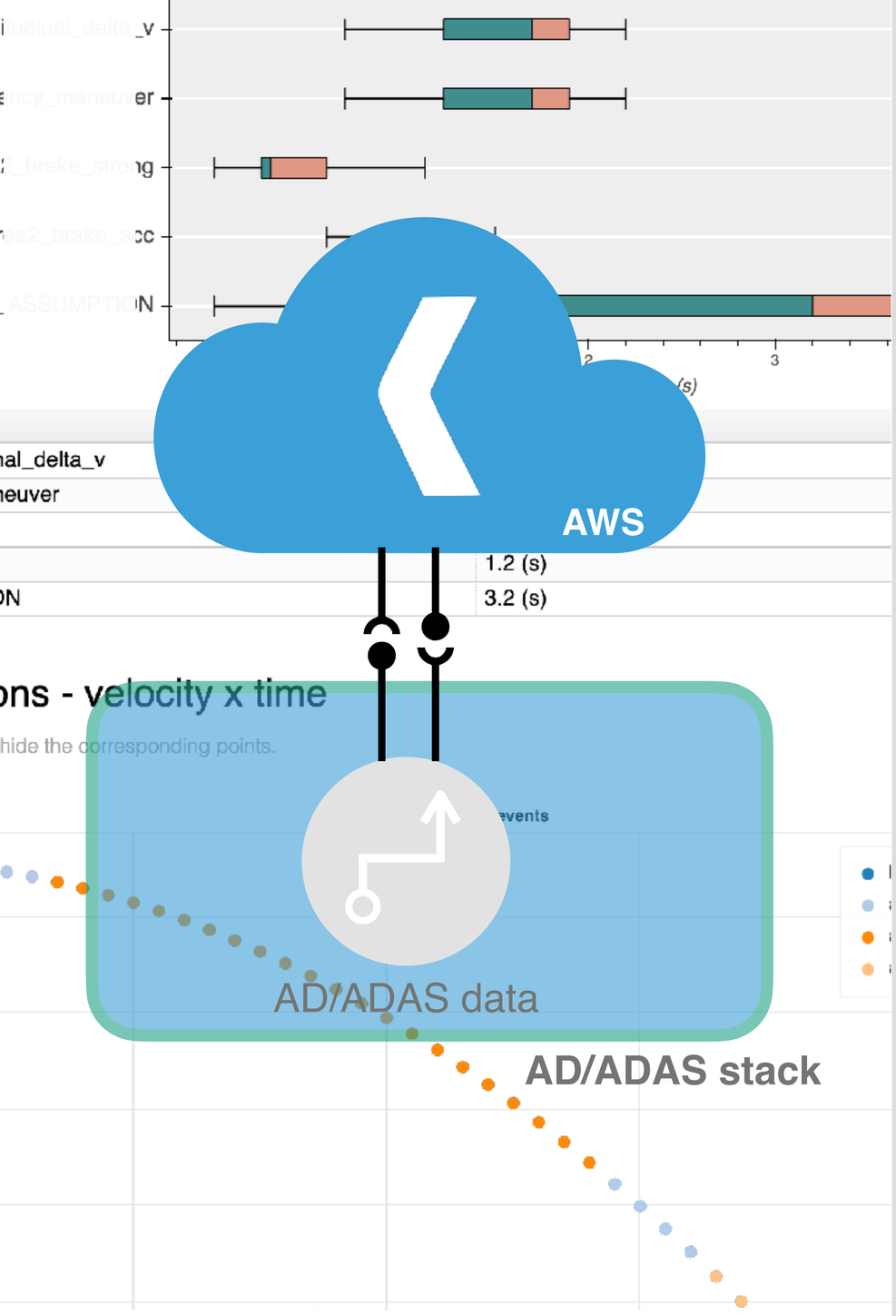
## Assessment tool

Cloud based safety assessment tool

## Safety Co-pilot

Embedded software for trajectory checking

# SAFETY ASSESSMENT TOOL




- Identifies safety critical situations in recorded data (simulation/real-road)
- Highlights perception system issues
- Safety metrics KPIs
- OEM safety policies can be easily and formally incorporated

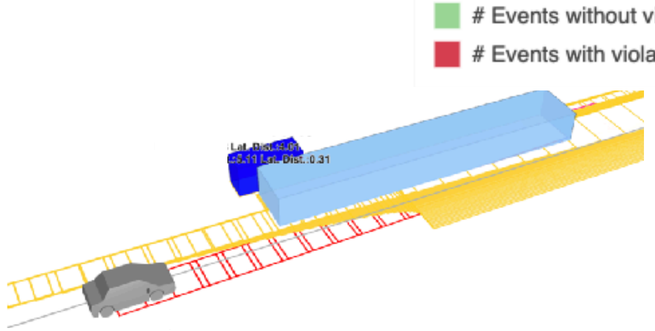
# SAFETY METRICS (KPIs)

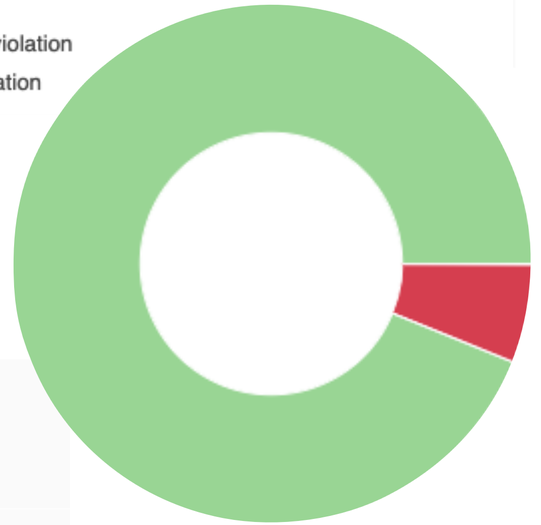
- **Violation Rate**
  The rate of safety violations of the ego_car related to the total duration of the scenario

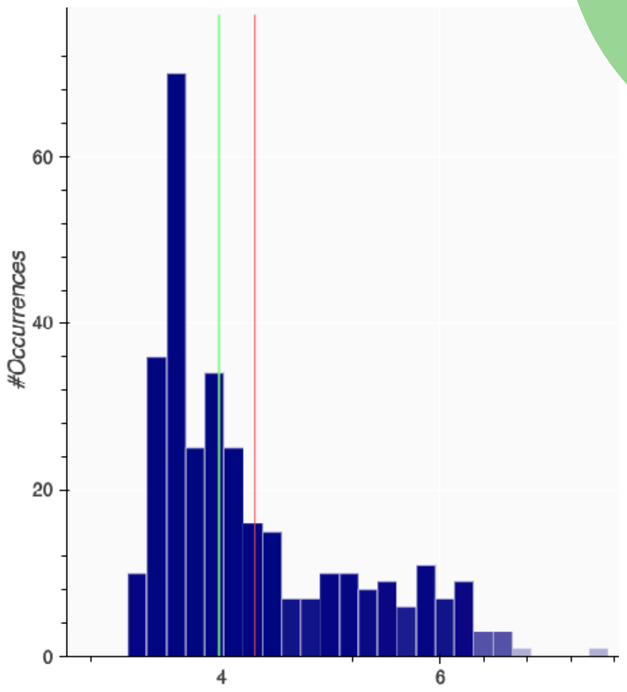
- **Delta Braking**
  How much more, compared to the current braking deceleration, should the ego_car be braking to avoid hitting the front_car, if the front_car would start braking with 4.5m/s²

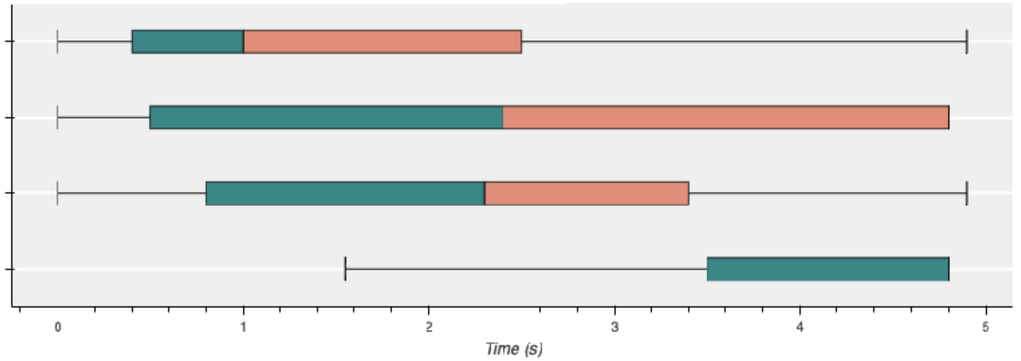
- **Time to Safety Violation**
  The extra time the ego_car has, before it would enter a safety violation.

-…





# Safety Assessment Solutions

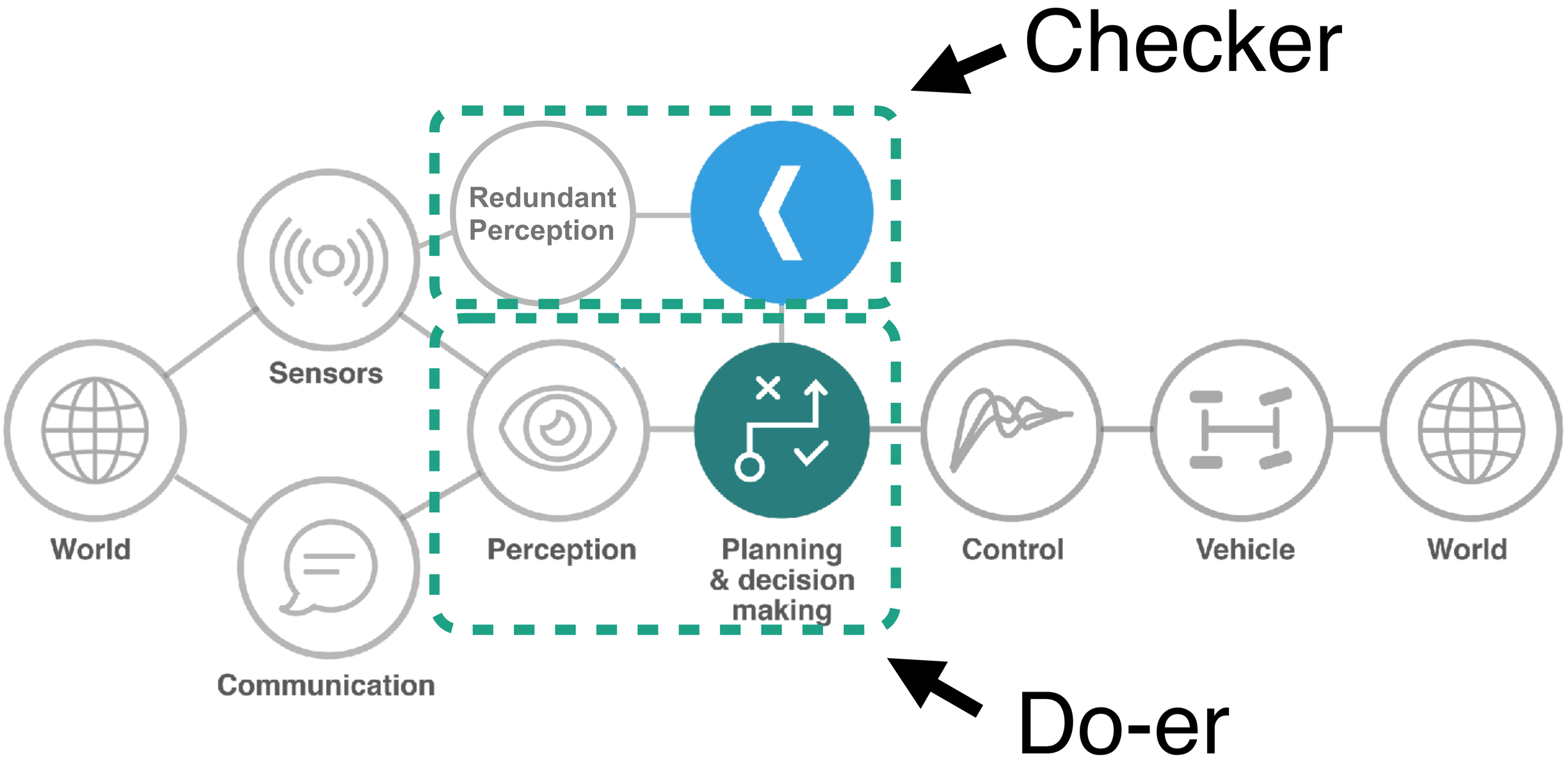
## Assessment tool

Cloud based
safety assessment
tool

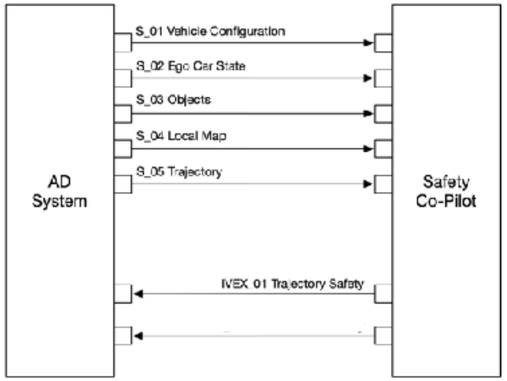
## Safety Co-pilot

**Embedded software
for trajectory checking**

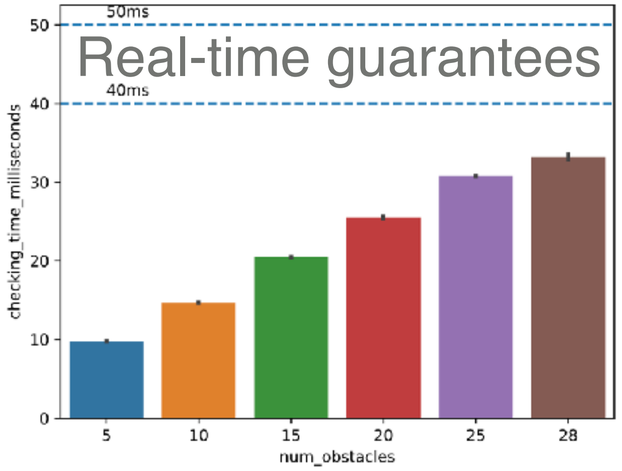

AD and ADAS
have to answer:
“Is it safe?”
iVEX
Check
Is the trajectory safe?
Advise
Tell AV which violated safety constraints


Checker
Redundant Perception
Sensors
World
Communication
Perception
Planning & decision making
Control
Vehicle
World
Do-er

# IVEX Safety Co-pilot





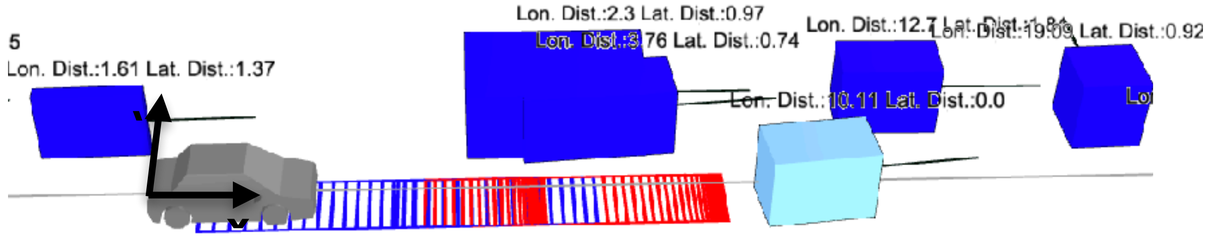




- Checks planned trajectory according to safety policies (OEM, IVEX, RSS,…)
- Correct-by-Construction software development
- Returns constraints to be respected by motion planner
- Incorporates safety rules from motion and ODD of the vehicle
- Embeddable software component optimized for real-time execution

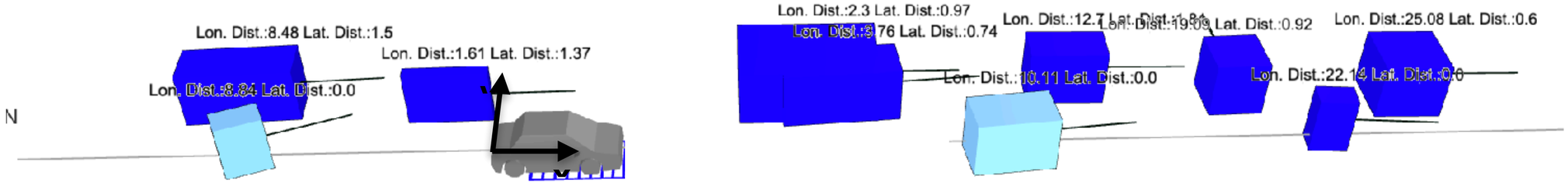
# Safety model for AD/ADAS

- **Internal point of view**
  - Monitors the quality of sensor information
  - Monitors quality of planned trajectories
  - Can use knowledge about the internals of the AD/ADAS software stack
  - Computes risk a-priori, to make decision

- **Observer point of view**
  - Sees the traffic information from an external point of view (birds-eye view)
  - Technology agnostic
  - Computes the risk a-posteriori using any external information available
    - Weather conditions
    - Traffic density, etc.




# Internal




# Observer

# Minimum information for Observer point of view

- Observer Data Input
  - Road entity
    - Classification (human, car, bike, etc)
    - Bounding boxes
    - Absolute position
    - Heading
    - Time

- Depending on the risk metric you also need a map

# Minimum information for Internal point of view

- Internal Data Input
  - **Ego car state**
    - Position
    - Velocity
    - Acceleration
    - Heading
    - Corresponding standard deviations
  - **Ego trajectory**
  - **Obstacle**
    - Position
    - Velocity
    - Acceleration
    - Heading
    - Classification
  - **Reference Line**
  - **Parameters**
    - E.g. maximum acceleration ego car
    - Maximum expected longitudinal/lateral acceleration obstacle
    - Maximum expected longitudinal/lateral braking deceleration obstacle

# Observer

## Assessment tool

Cloud based safety assessment tool

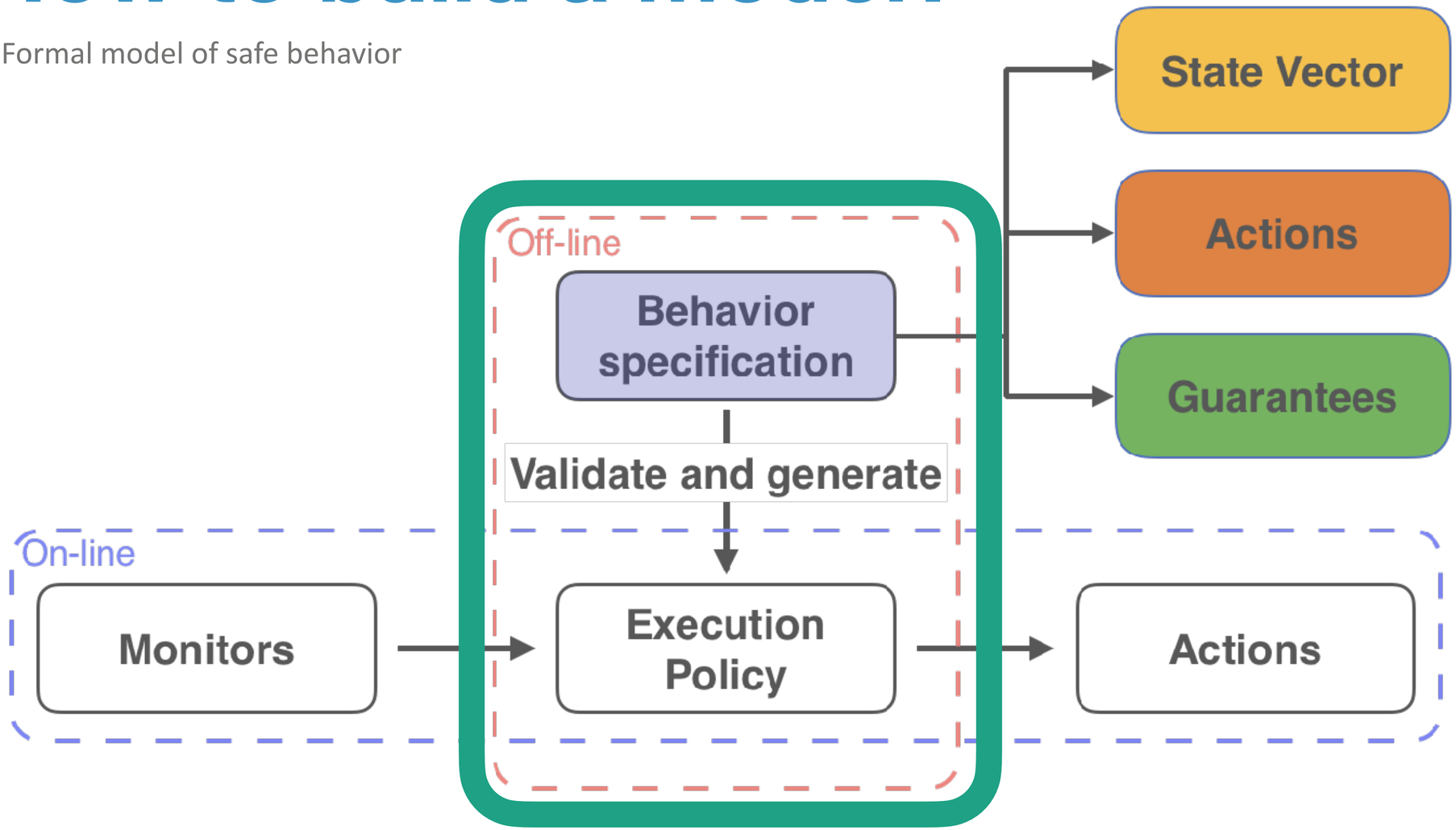
# Internal

## Safety Co-pilot

Embedded software for trajectory checking

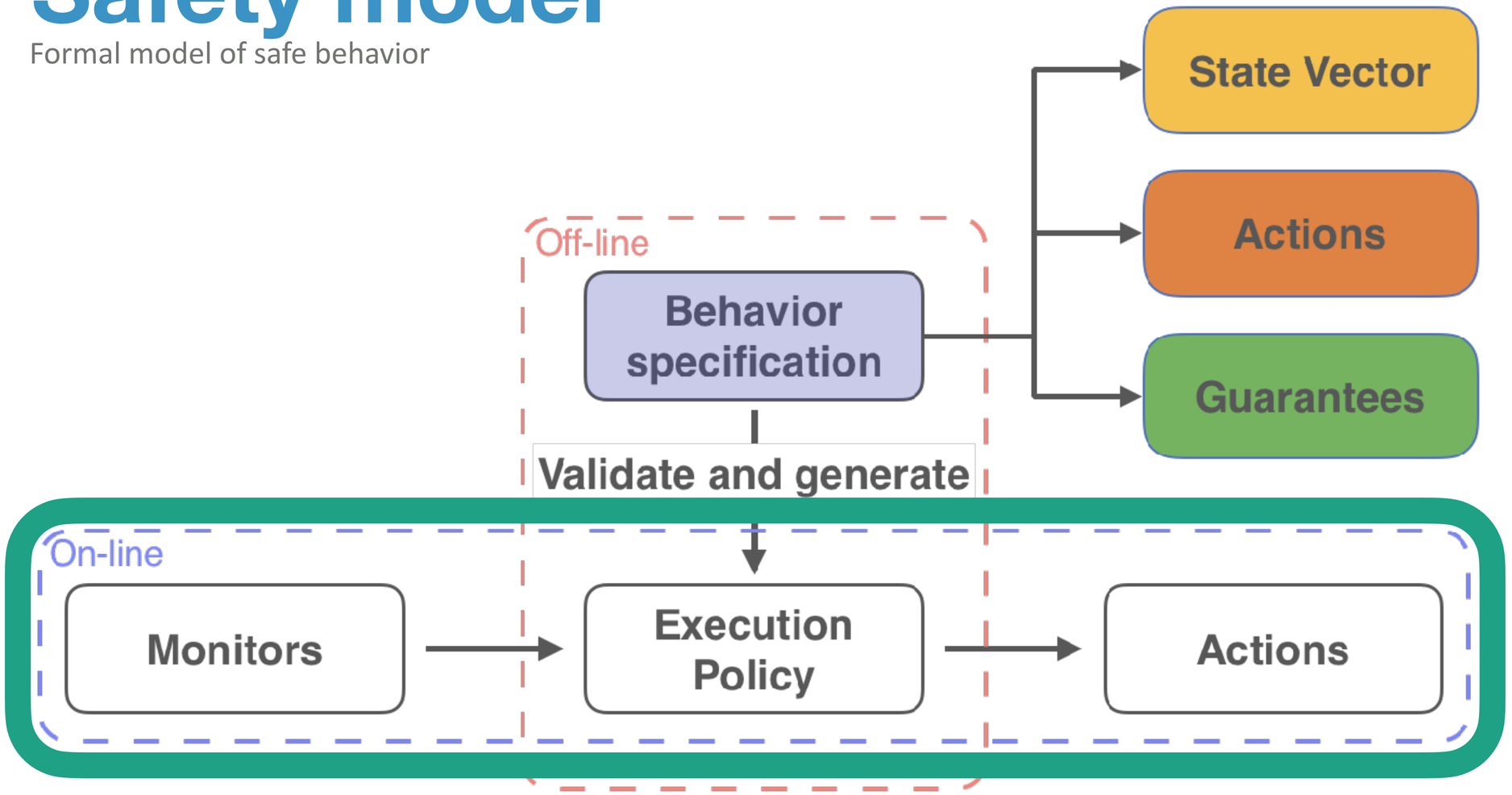
# How to build a model?

Formal model of safe behavior



# Safety model

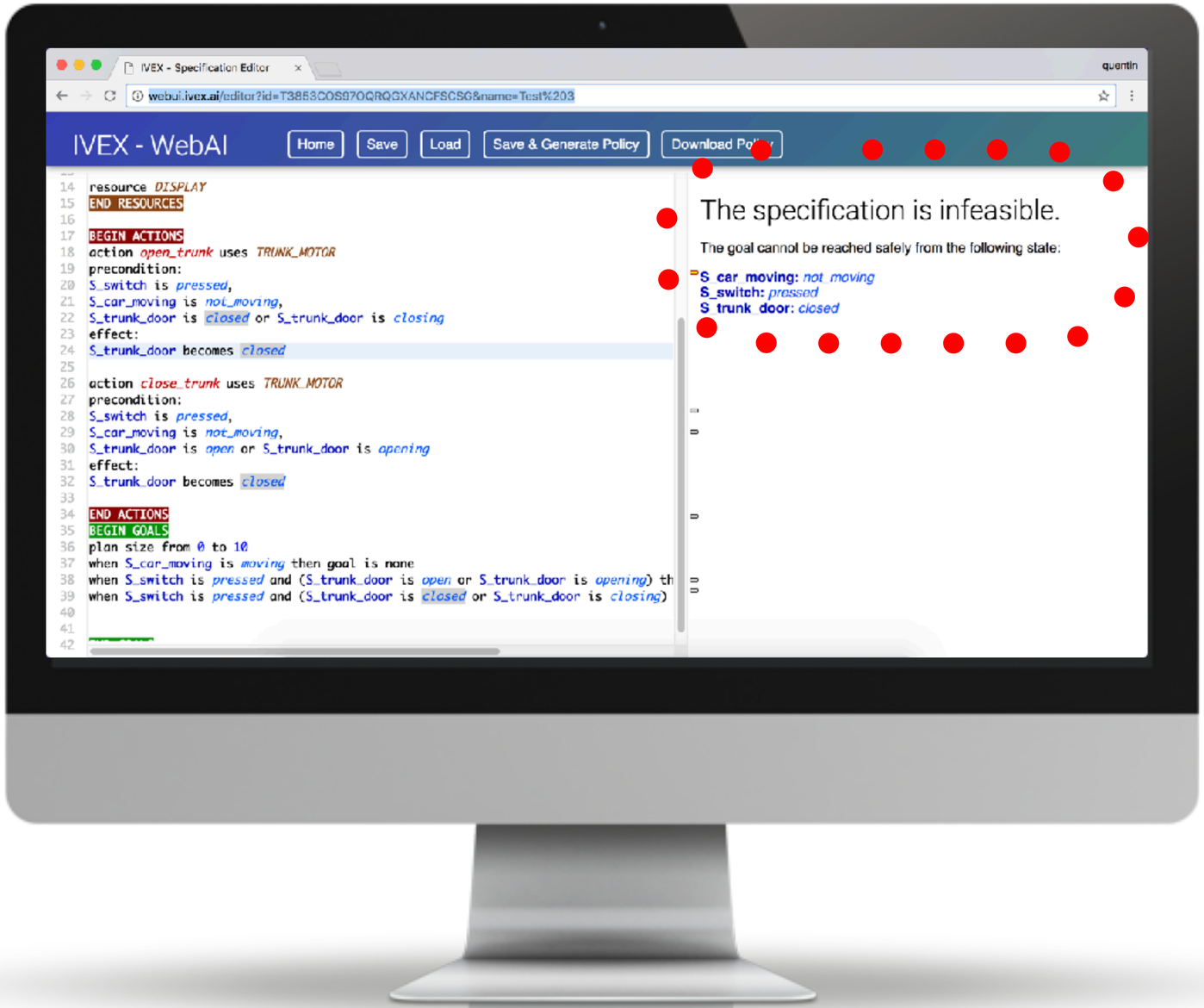
Formal model of safe behavior



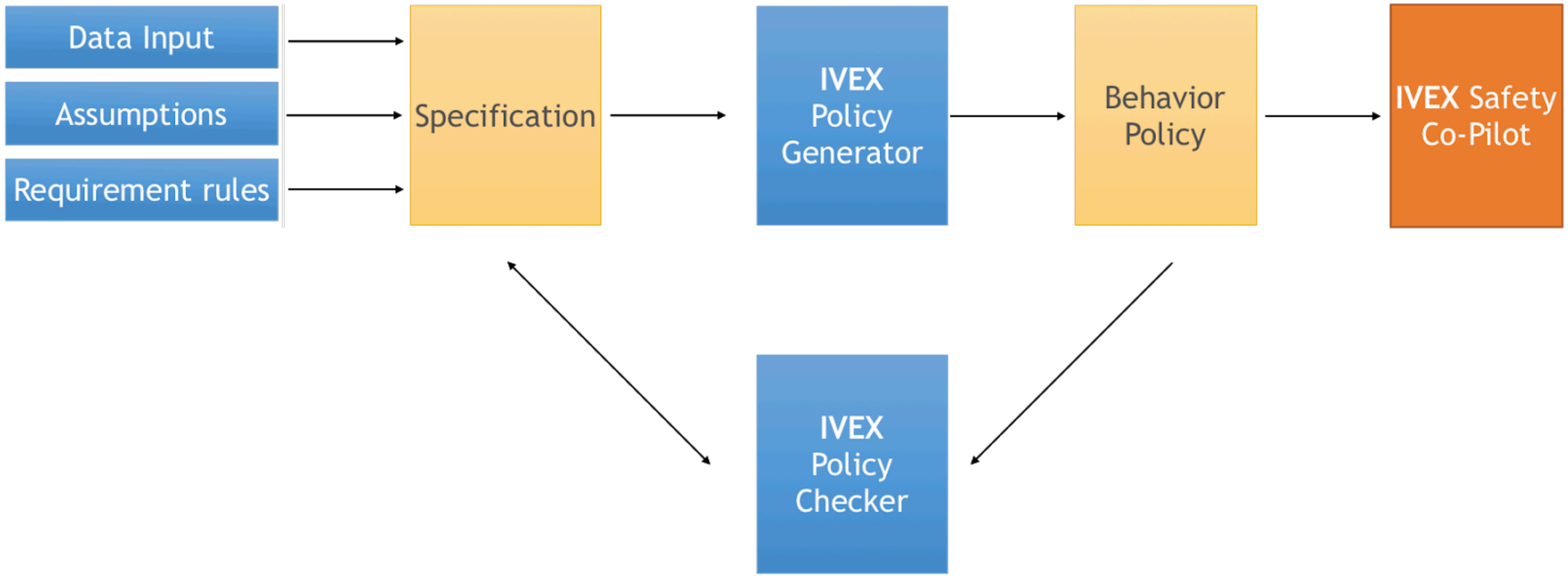
# VALIDATE AND GENERATE

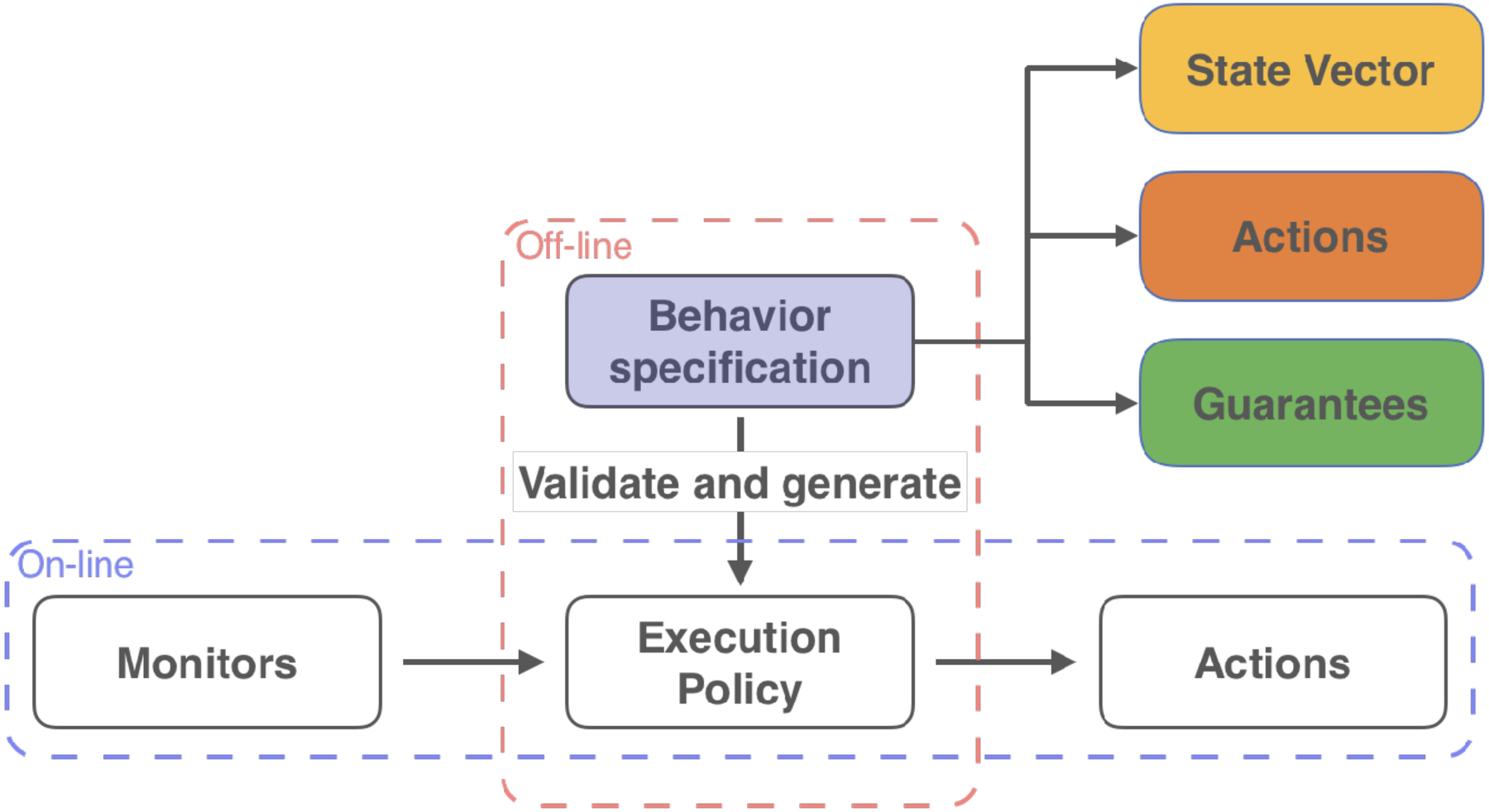
DETECT INCONSISTENCIES

ANALYSIS OF COMPLETENESS OF MODEL



# Adding rules




State Vector
Actions
Guarantees
Off-line
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Monitors
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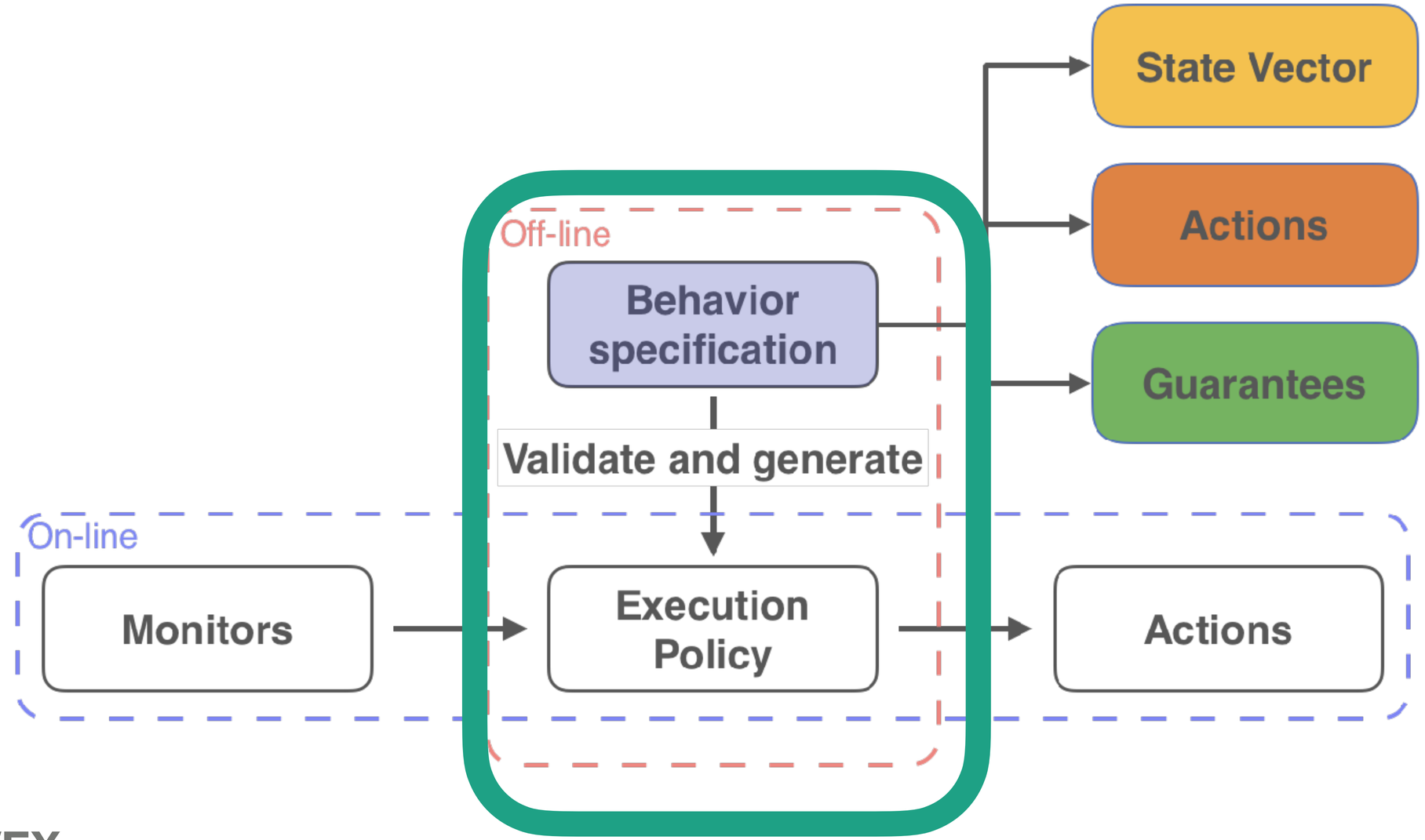
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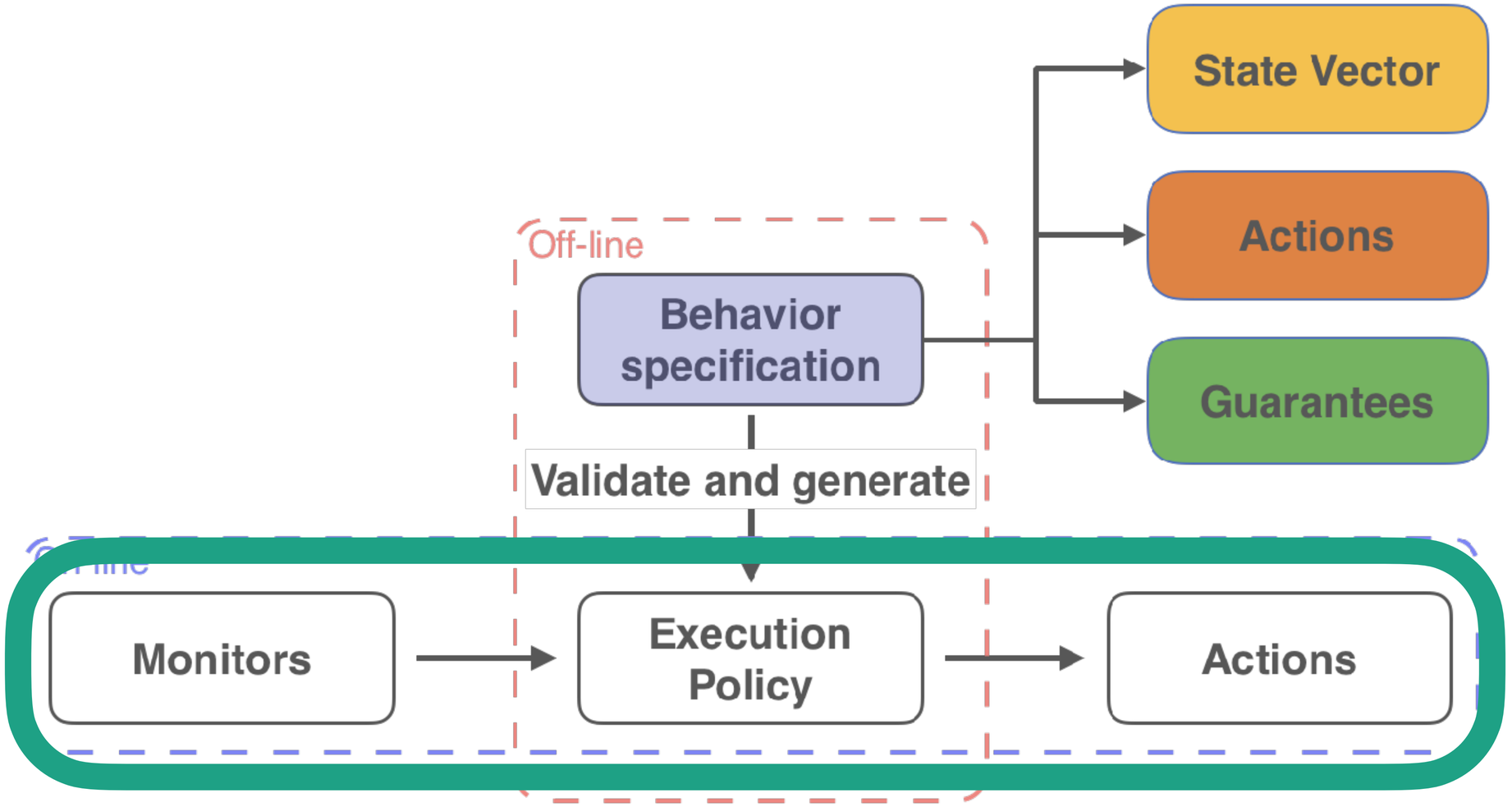
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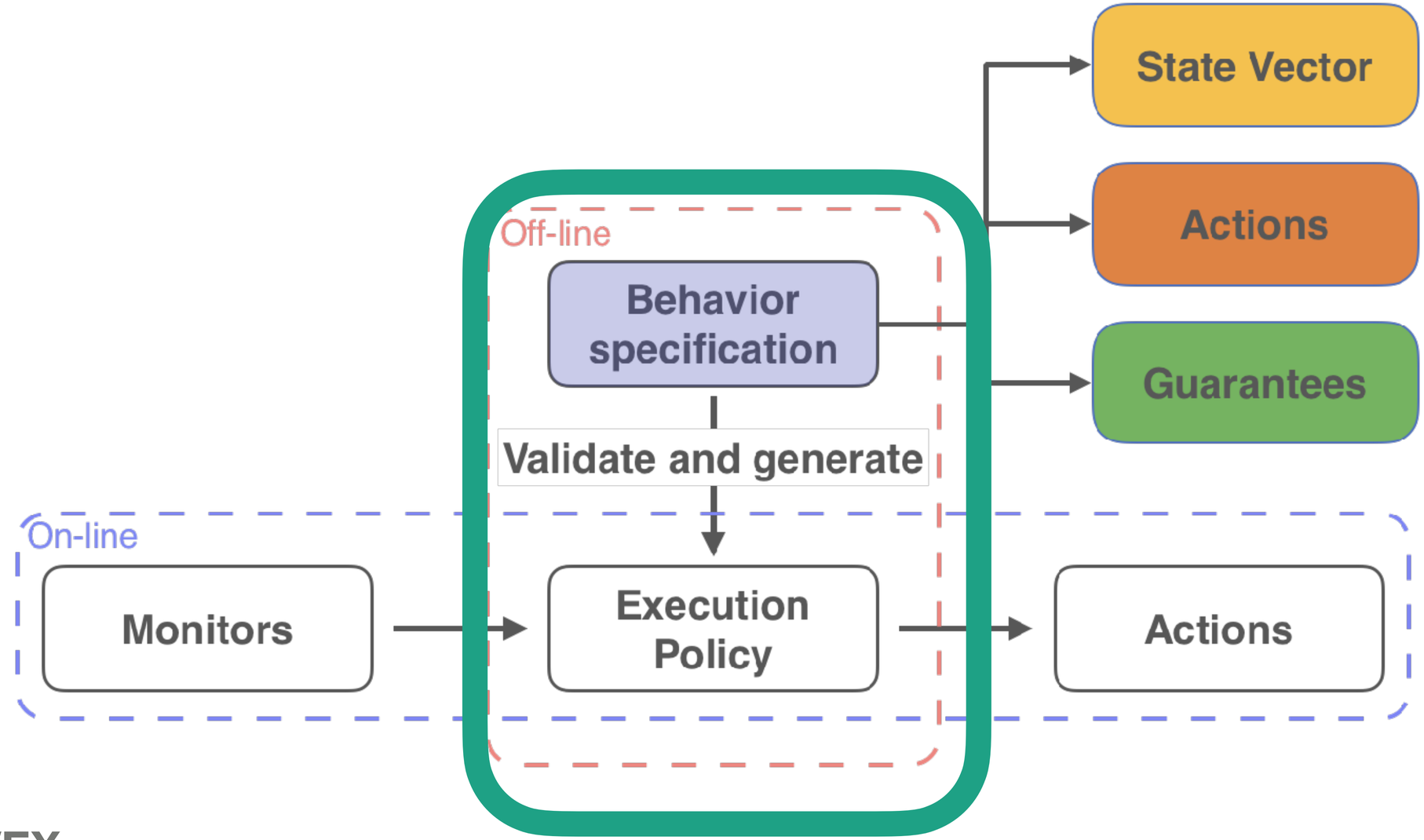
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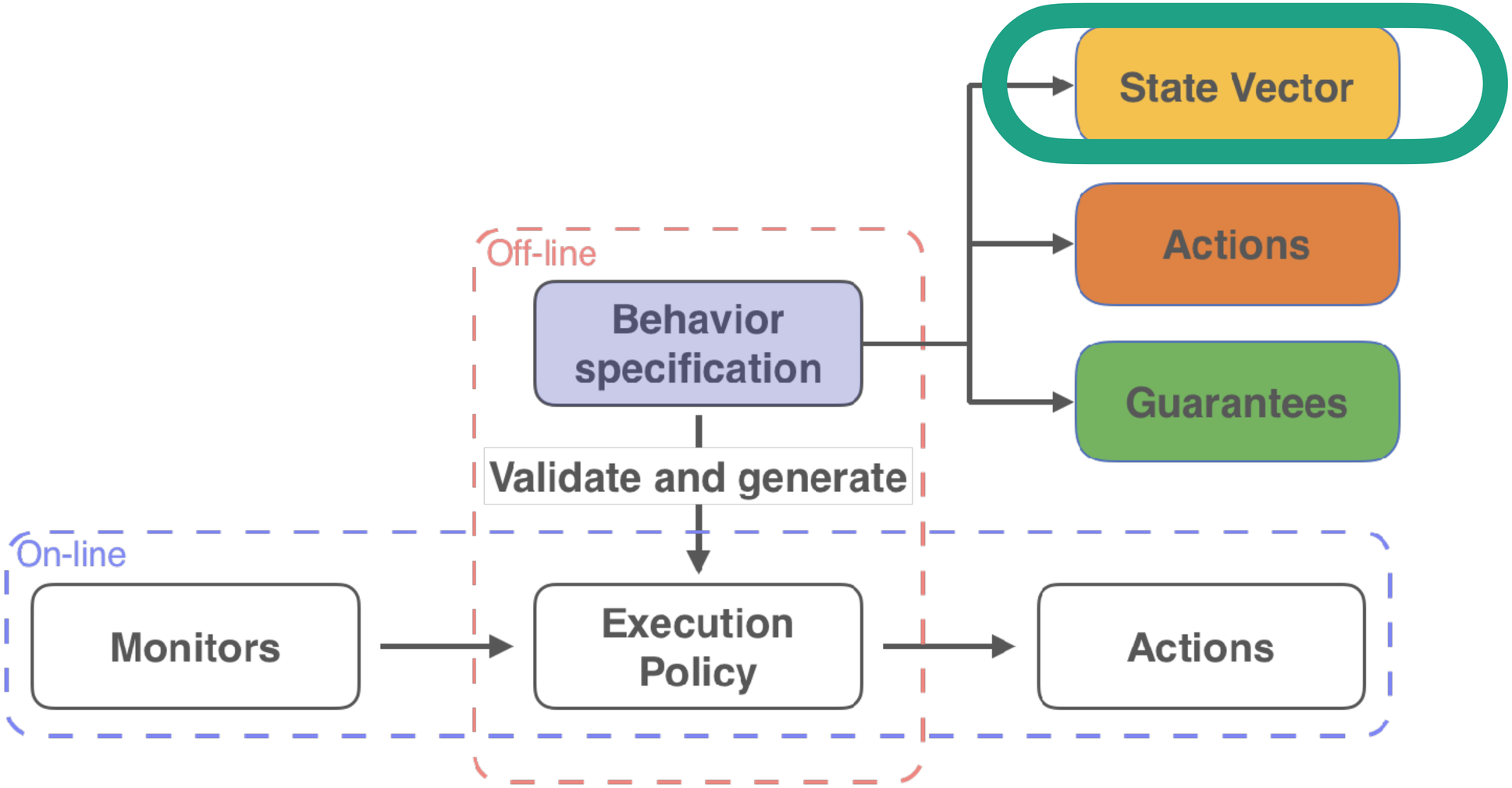
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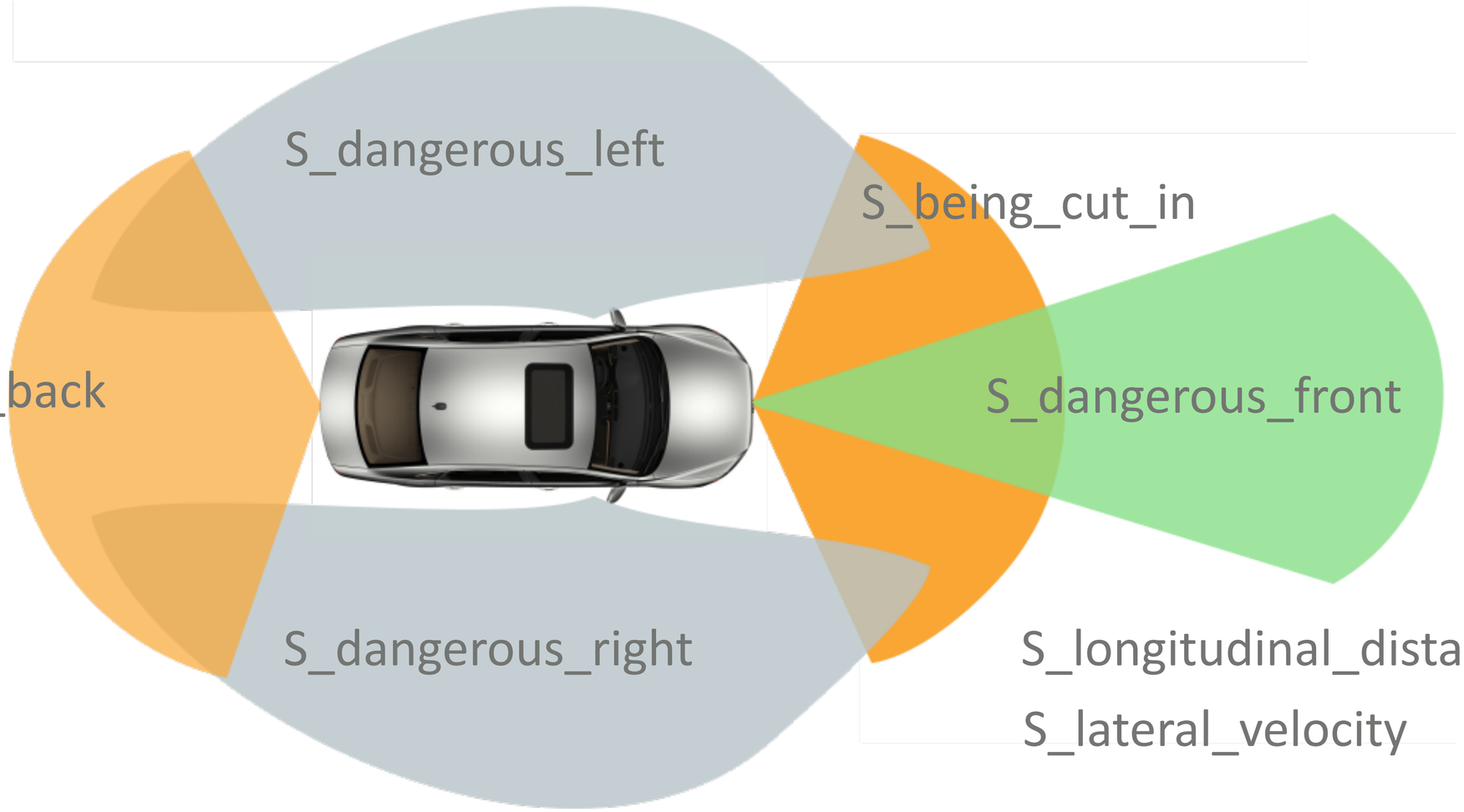
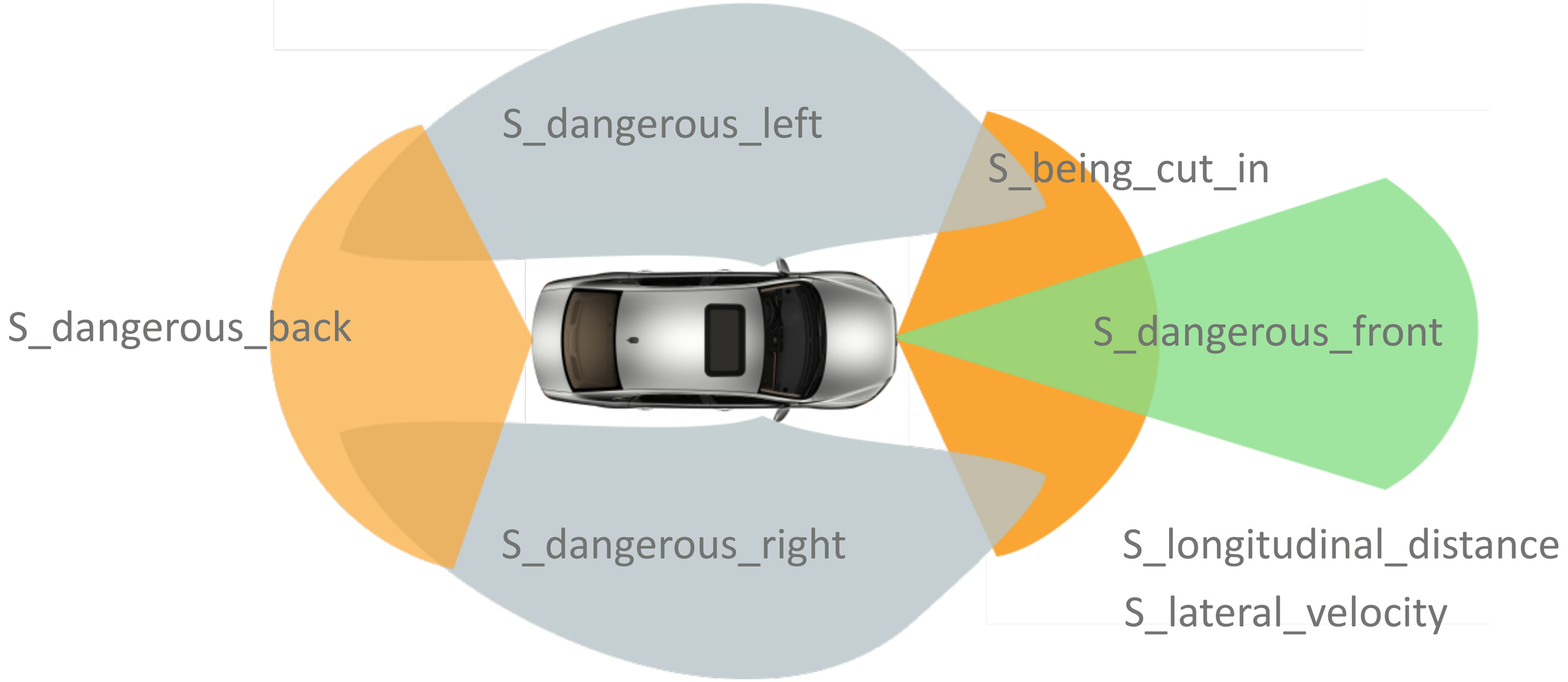
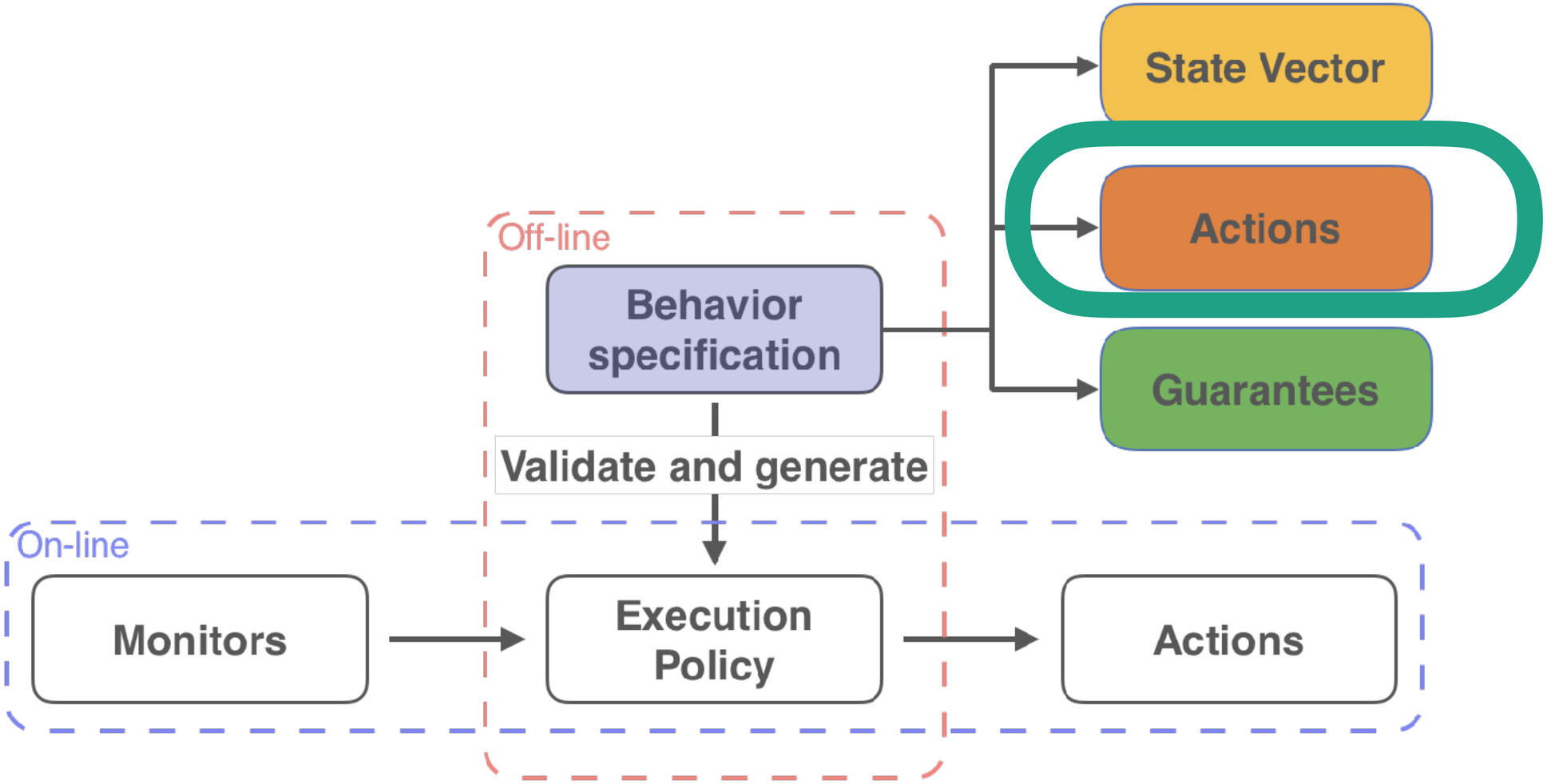

S_dangerous_left
S_being_cut_in
S_dangerous_back
S_dangerous_front
S_dangerous_right
S_longitudinal_distance
S_lateral_velocity

# state **S_longitudinal_distance** can be dangerous, not_dangerous

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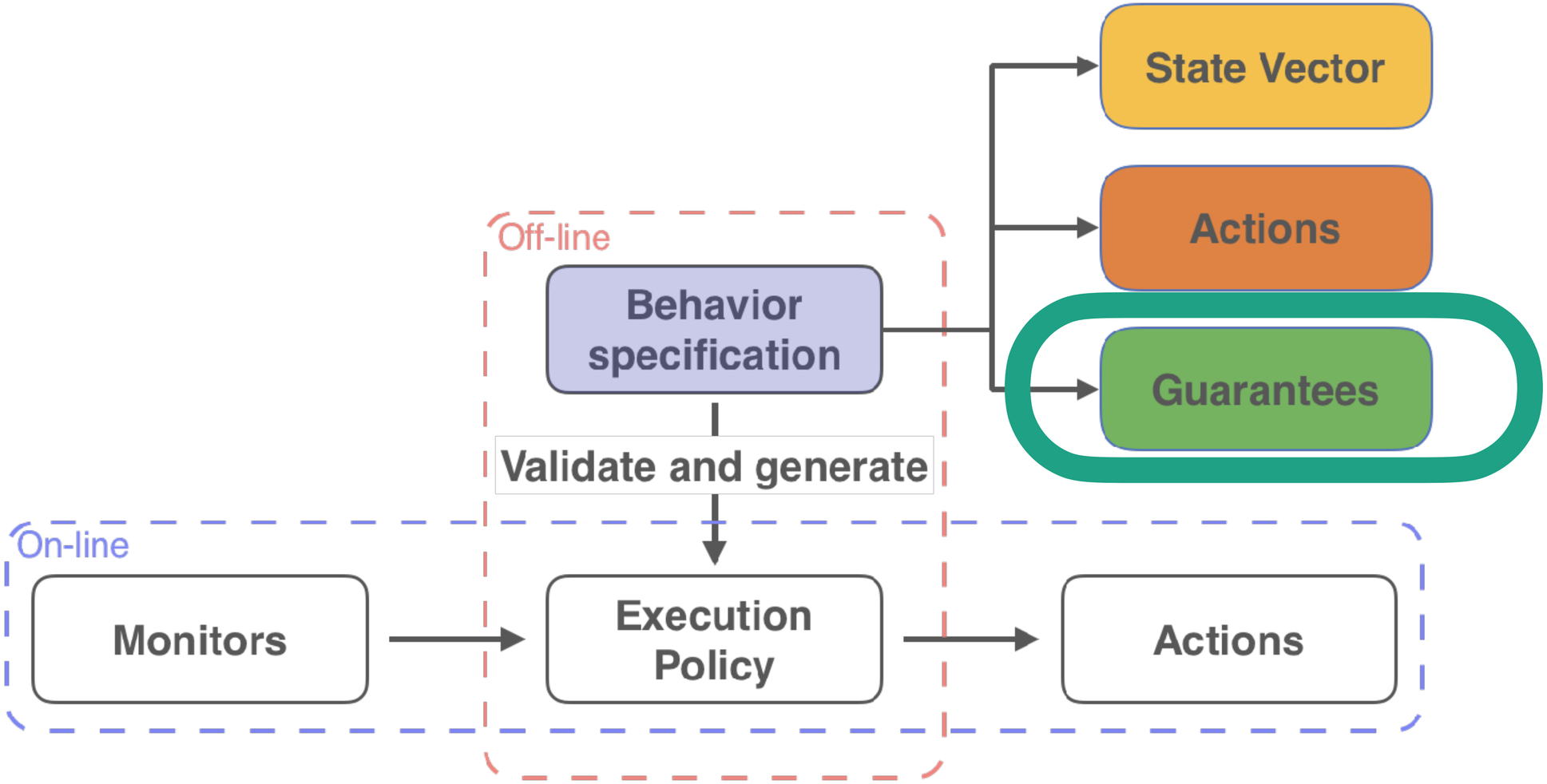
# SPECIFICATION simplified example

We create a mathematical model of the sensors and actions that the car can take


"A_longitudinal_brake",
"A_longitudinal_evasive_brake",
"A_lateral_brake",
"A_lateral_evasive_brake",
"A_longitudinal_accel_leq_0",
"A_lateral_accel_leq_0",
"A_lateral_accel_geq_0"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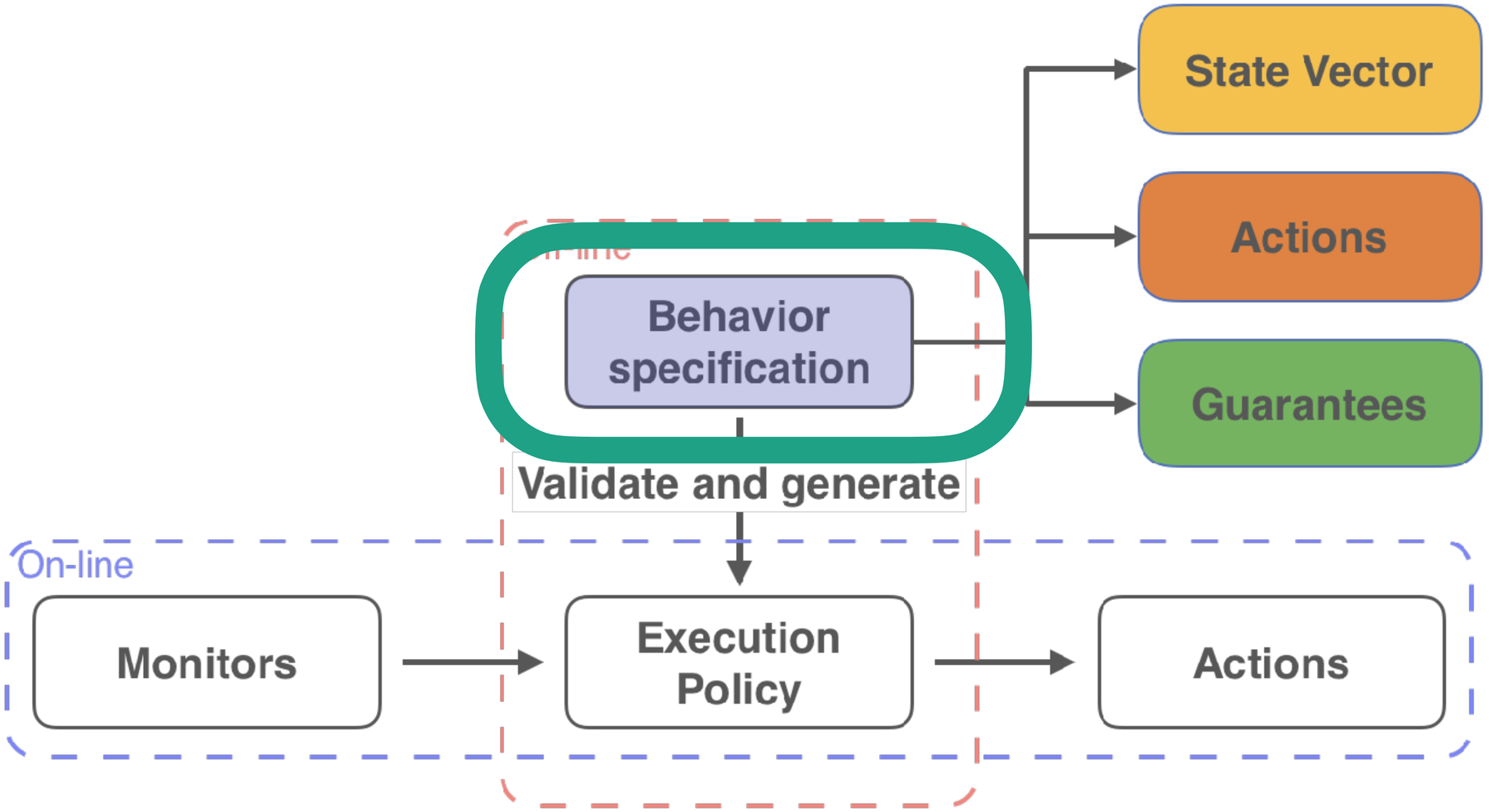
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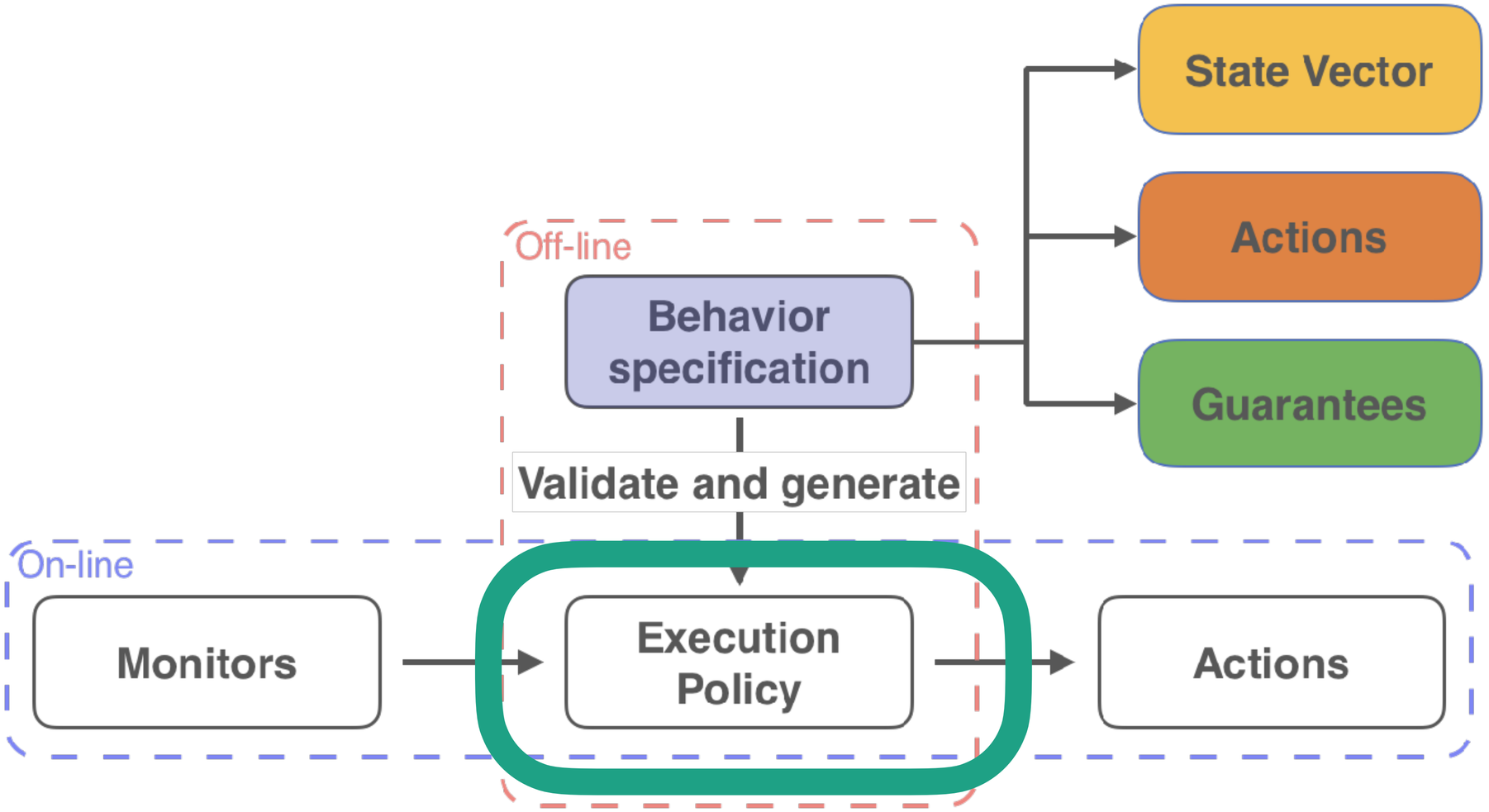
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# VALIDATE AND GENERATE

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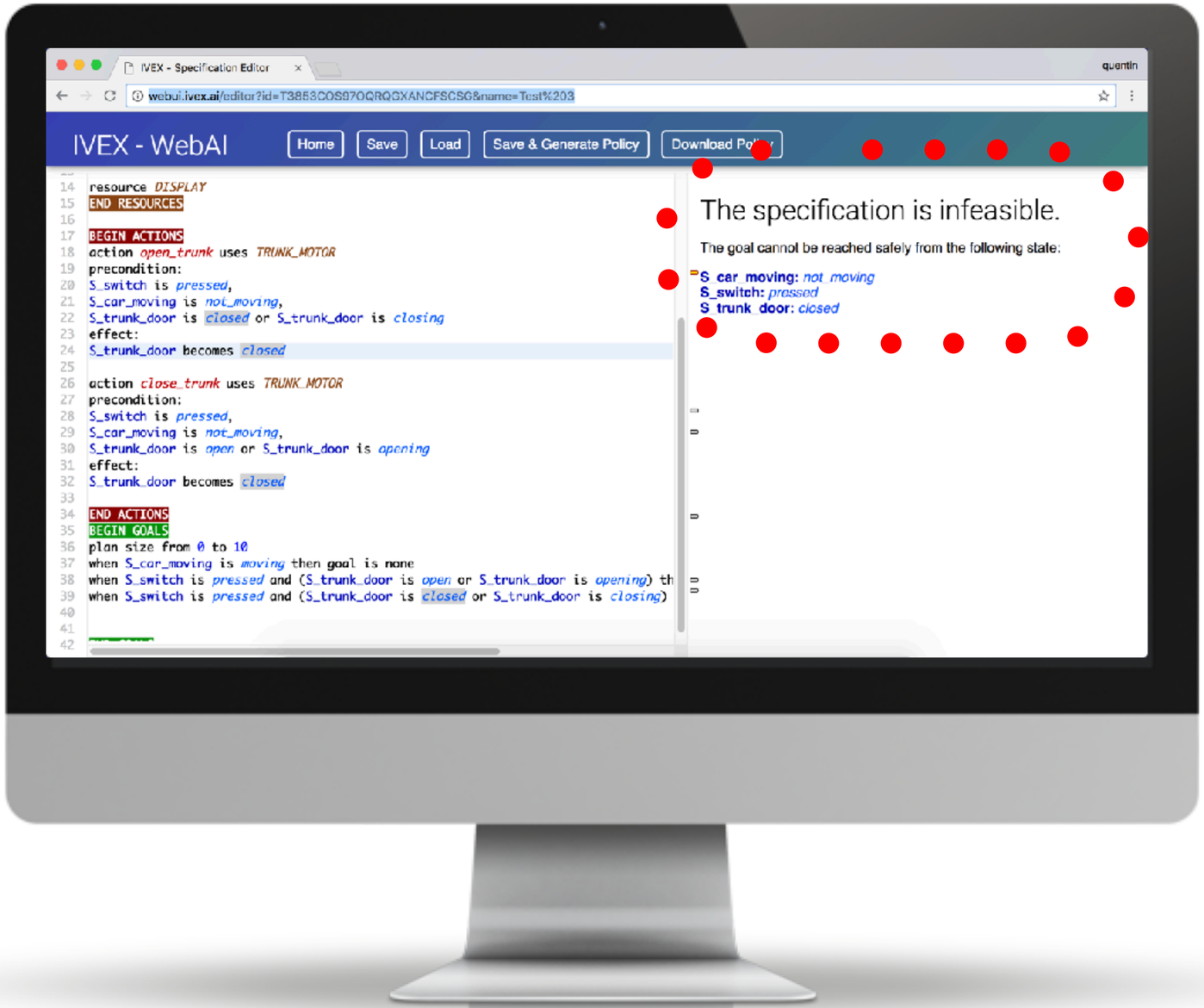


# EXECUTION POLICY

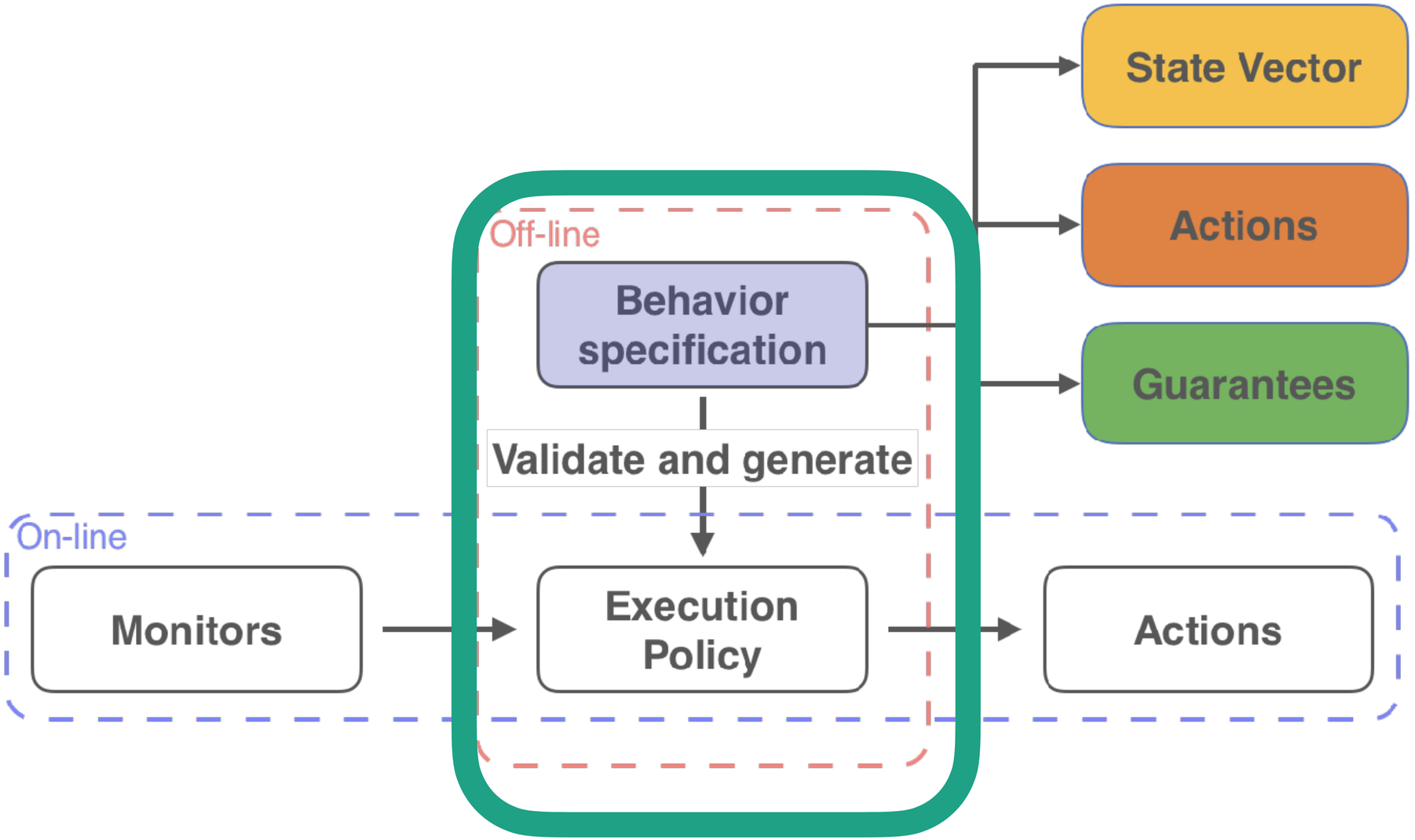
## Example Discrete Scenario

```
    {
      "S_longitudinal_distance": "dangerous",
      "S_lateral_distance": "dangerous",
      "S_object_lateral_position": "left",
      "S_dangerous_threshold_time": "equal_to_lat_time",
      "S_ego_lateral_velocity": "positive",
      "Actions": [
        "lat_accel_leq_minus_a_lat_min_brake"
      ]
    },
```

# EXECUTION POLICY

## Example Discrete Scenario

```
{
      "S_longitudinal_distance": "dangerous",
      "S_lateral_distance": "dangerous",
      "S_object_lateral_position": "left",
      "S_dangerous_threshold_time": "equal_to_both_time",
      "S_ego_lateral_velocity": "positive",
      "S_longitudinal_direction": "same_direction",
      "S_has_passed_by": "not_yet_passed_by",
      "Actions": [
        "lon_accel_leq_minus_a_lon_min_brake",
        "lat_accel_leq_minus_a_lat_min_brake"
      ]
    }
```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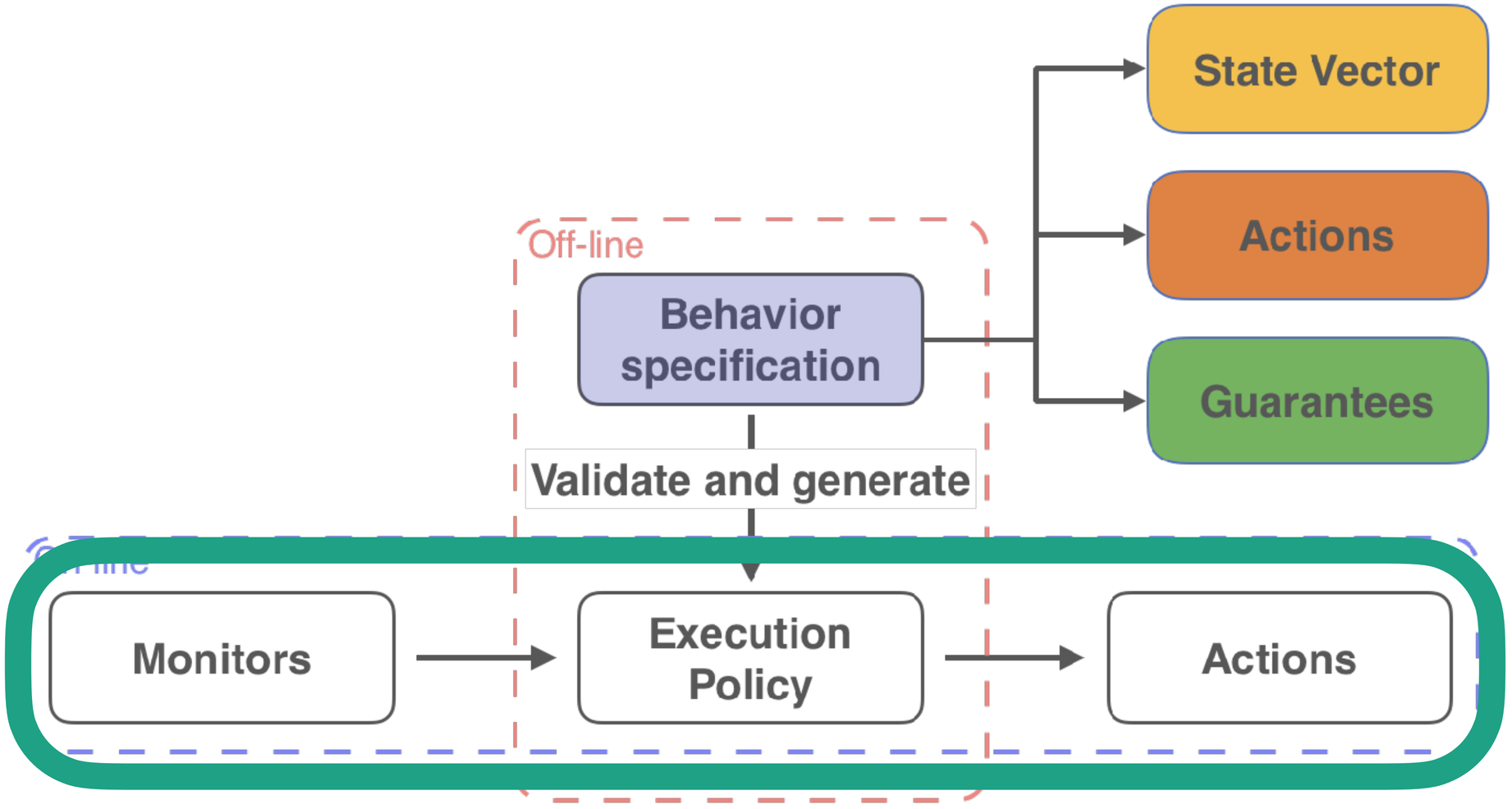
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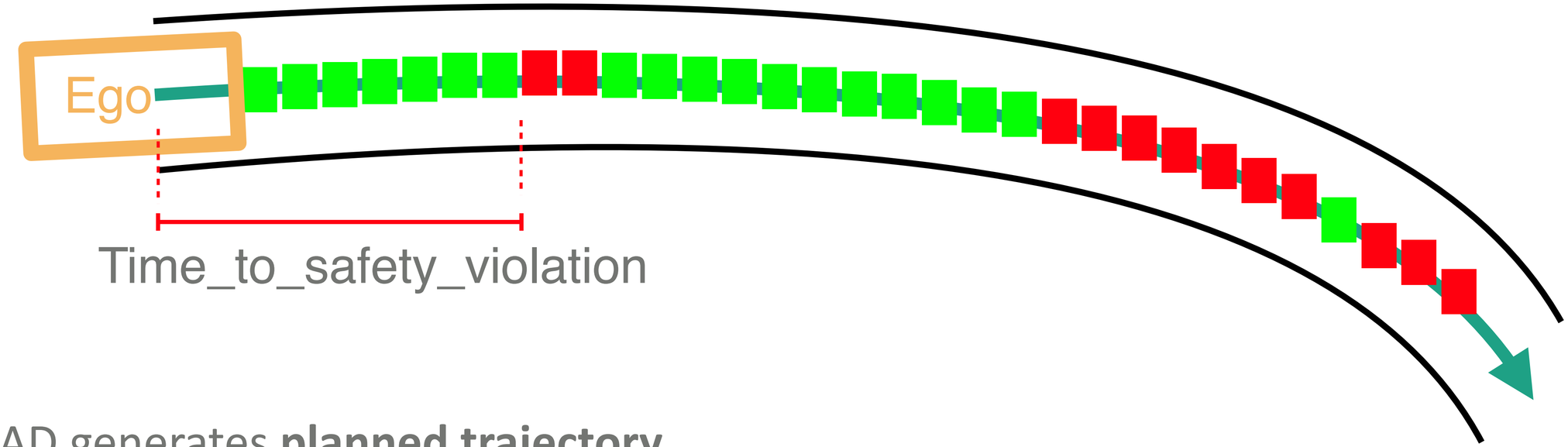
# OUTPUTS - SAFETY CO-PILOT - Internal model




AD generates **planned trajectory**

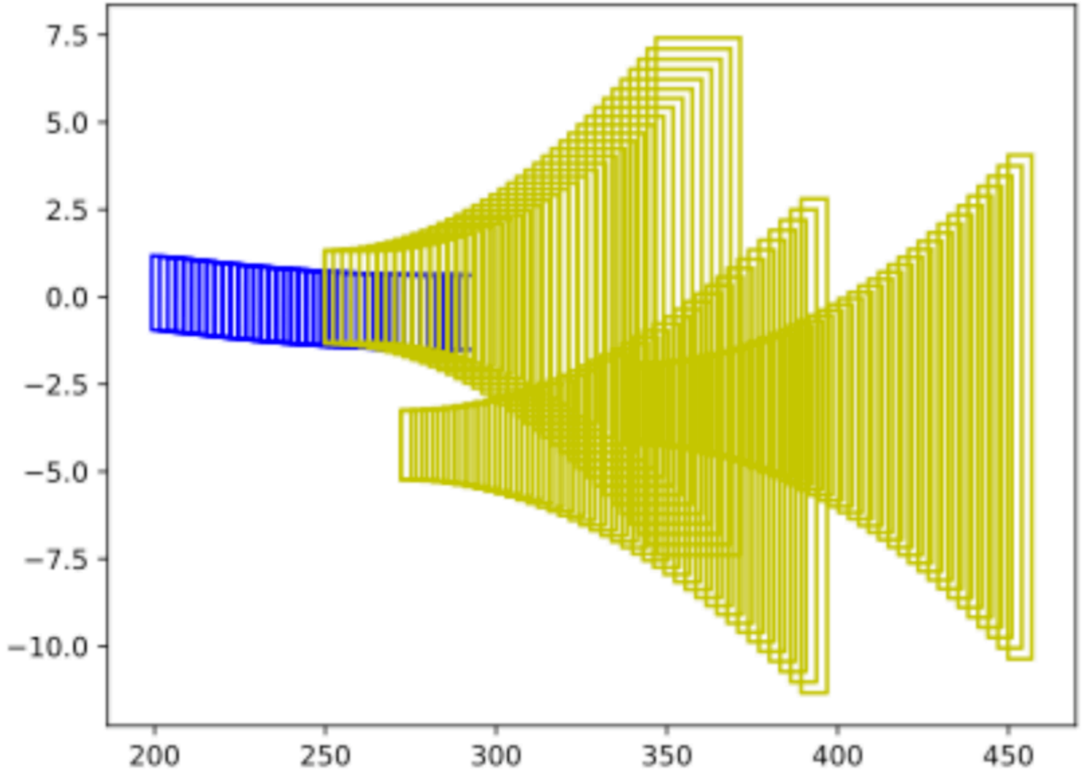
Trajectory

IVEX Checker - **checks** safety of planned trajectory

No Safety Violation

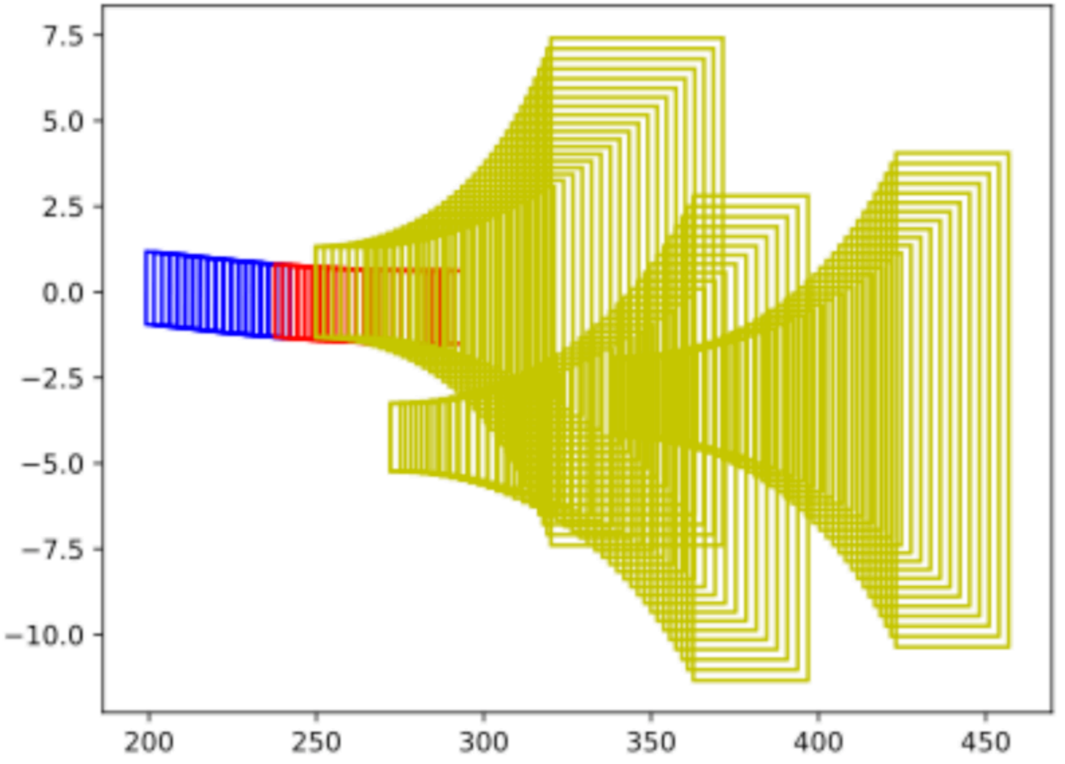
Safety Violation

## No braking




No violation

## Reasonable braking




Violation at t = 1.70 s


# Thank you

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