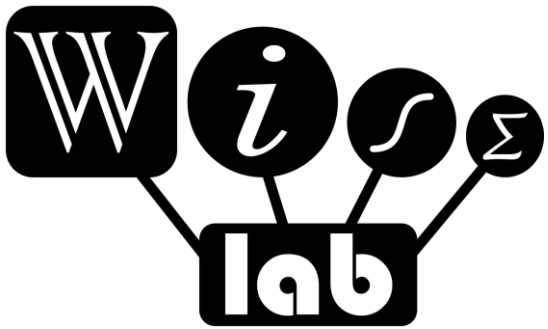
Towards a Framework to Manage Perceptual Uncertainty for Safe Automated Driving

Krzysztof Czarnecki & Rick Salay
Waterloo Intelligent Systems Engineering Lab
Electrical and Computer Engineering Department



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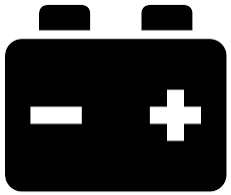
ADS Hazard Sources

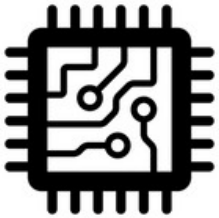
Mature best practices

Mechanical faults

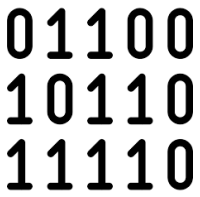


Electrical faults

ISO 26262



Computer HW faults



Computer SW faults

(ISO / PAS 21448)

Sensor noise & limitations

Machine learning errors

Inadequate driving behavior

DDT fallback failures

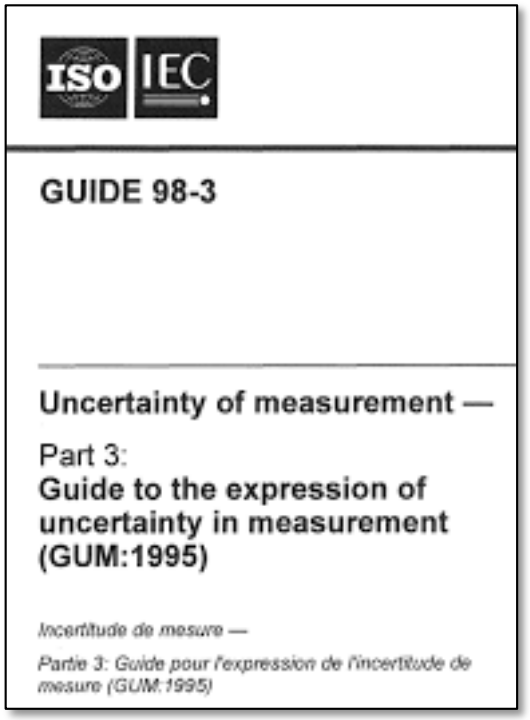
SAE J3061

Cyber attacks

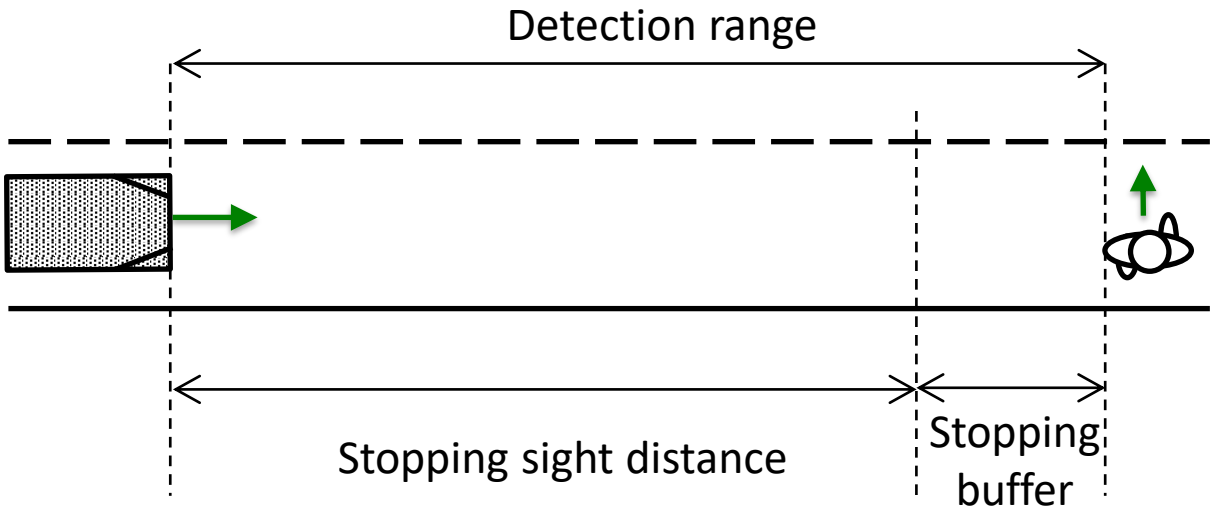
Perception (measuring world state)

Guide to the Expression of Uncertainty in Measurement (GUM)

- True accuracy unknowable
  - Accuracy in ML wrt. test set only
- Must estimate uncertainty

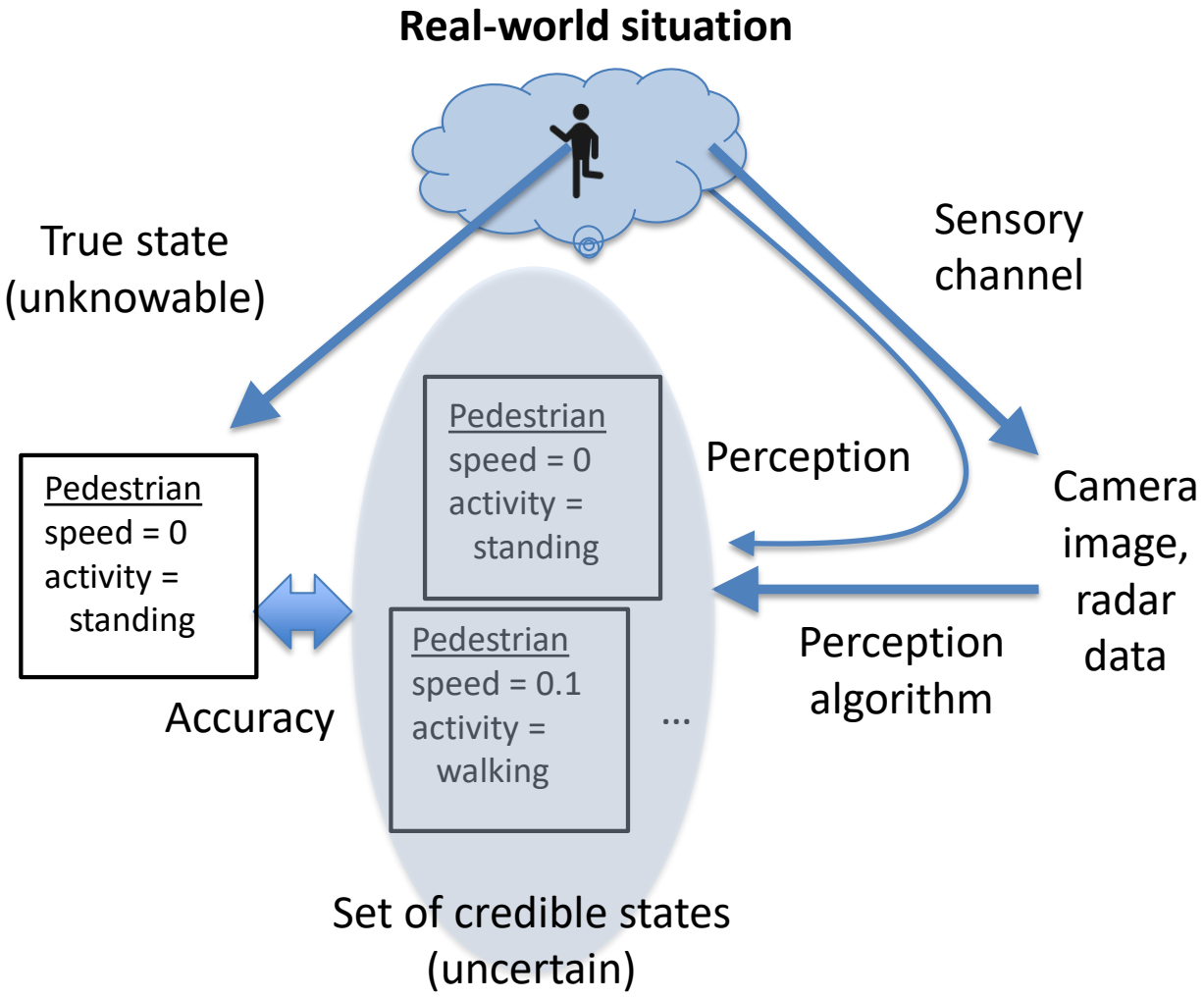


Sample Scenario-Dependent Perception-Performance Safety-Requirement Spec

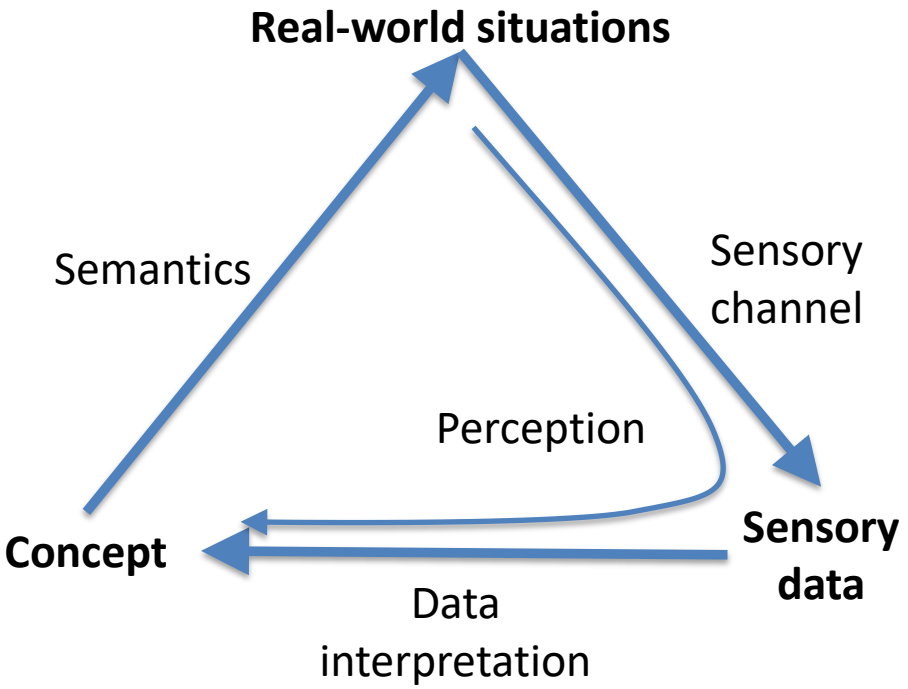


Detect pedestrians on the roadway
within range 10 m and with maximum perception-reaction delay of 0.5 s
with missed detection **probability** of 10^{-9} or less
with localization **uncertainty** of ± 0.5 m or better
within ODD conditions

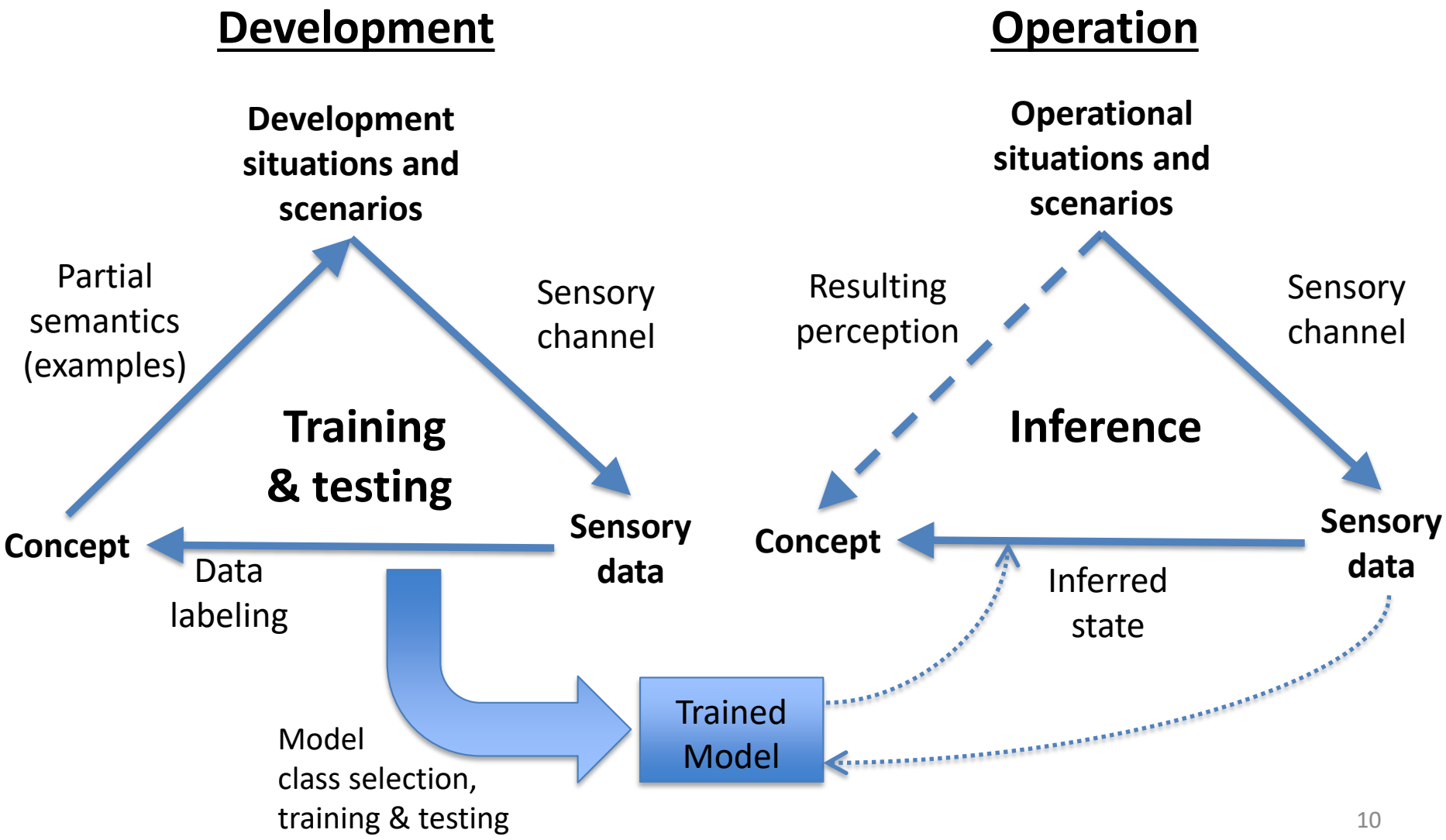
Perception Triangle (Instance level)



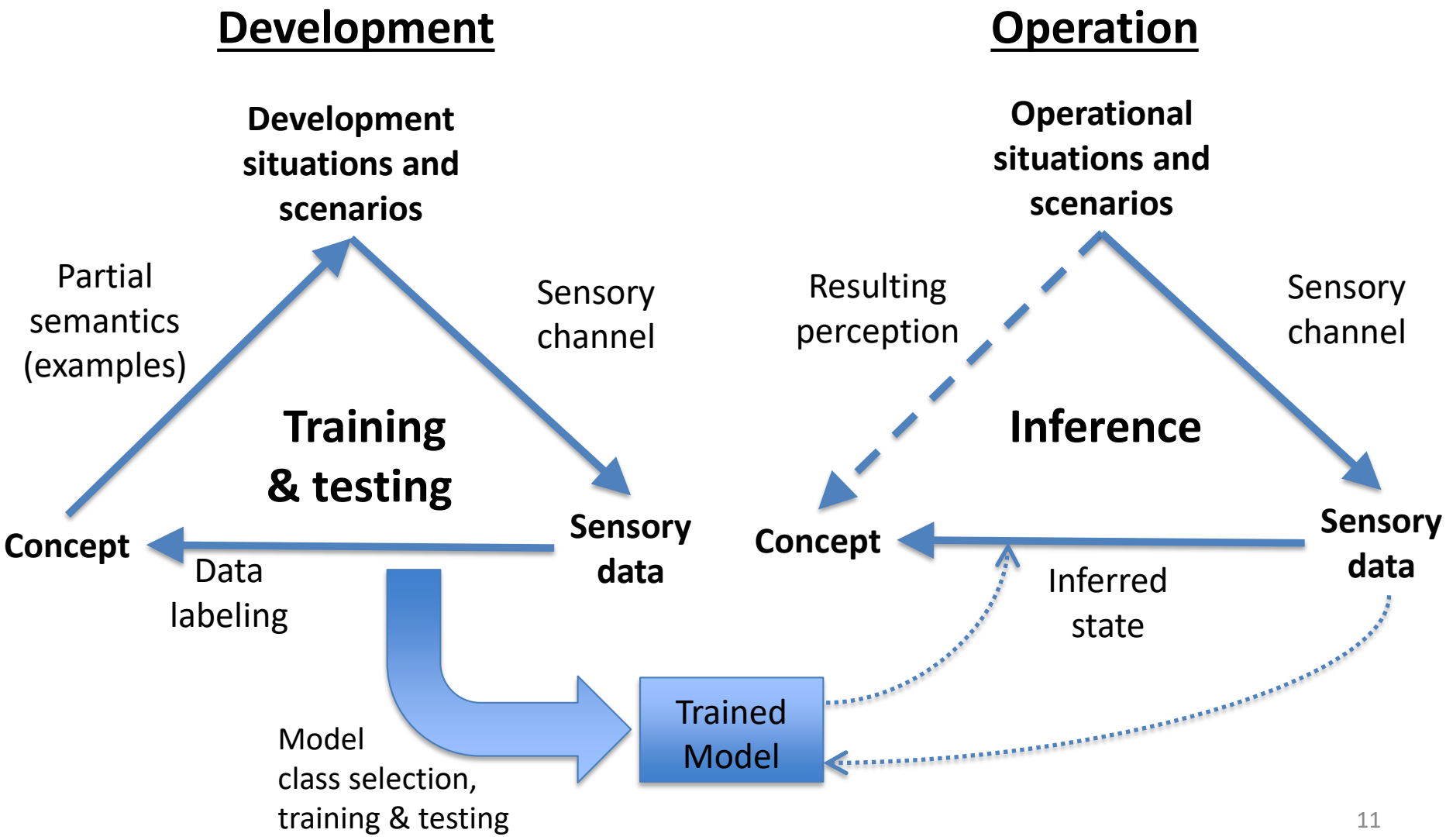
Perceptual Triangle (Domain level)



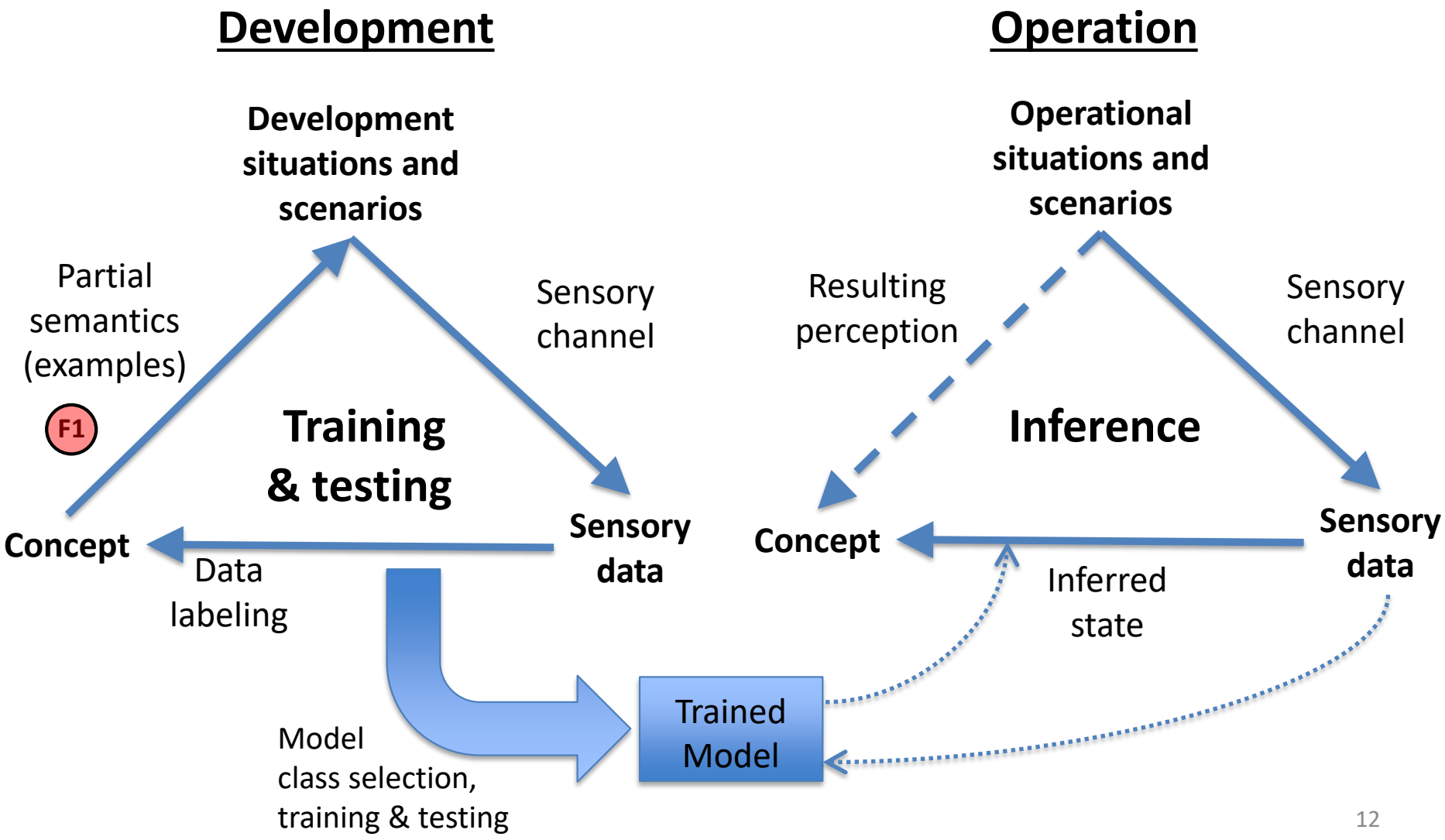
Perceptual Triangle When Using Supervised ML



Factors Influencing Uncertainty

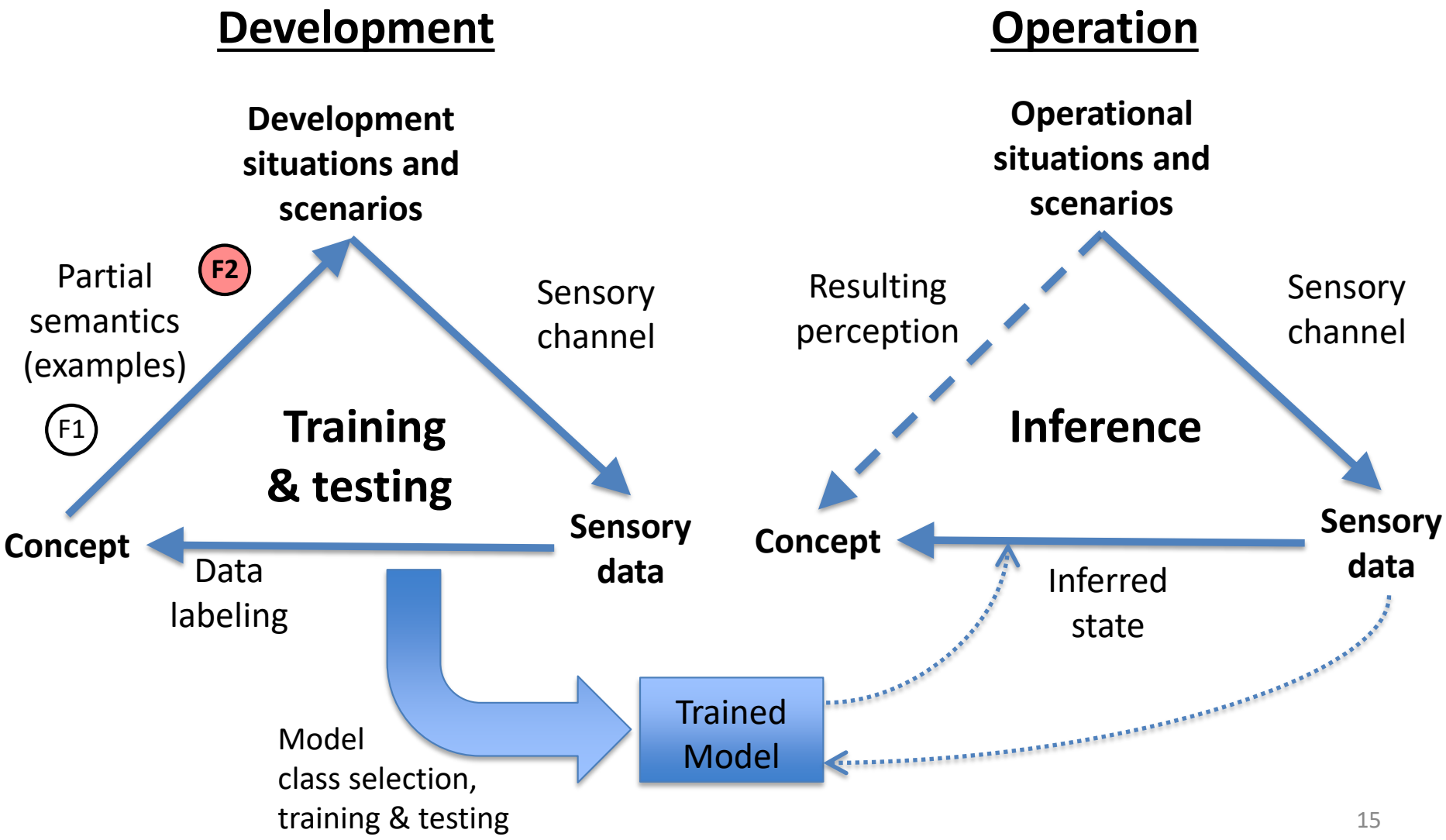


F1: Conceptual Uncertainty

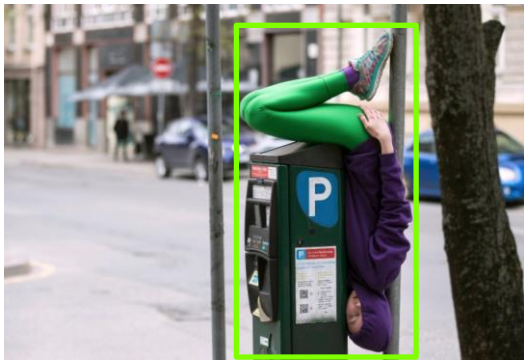


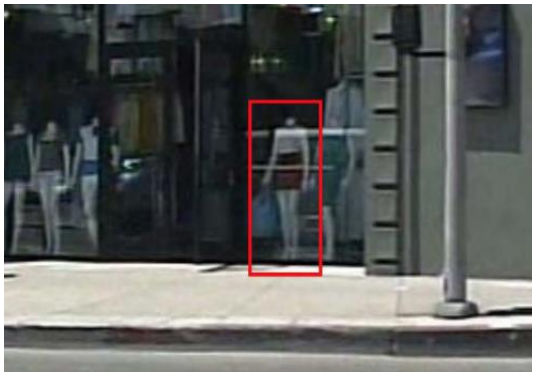
F1: Conceptual Uncertainty
Pedestrian or Cyclist?

F2: Development Scenario Coverage

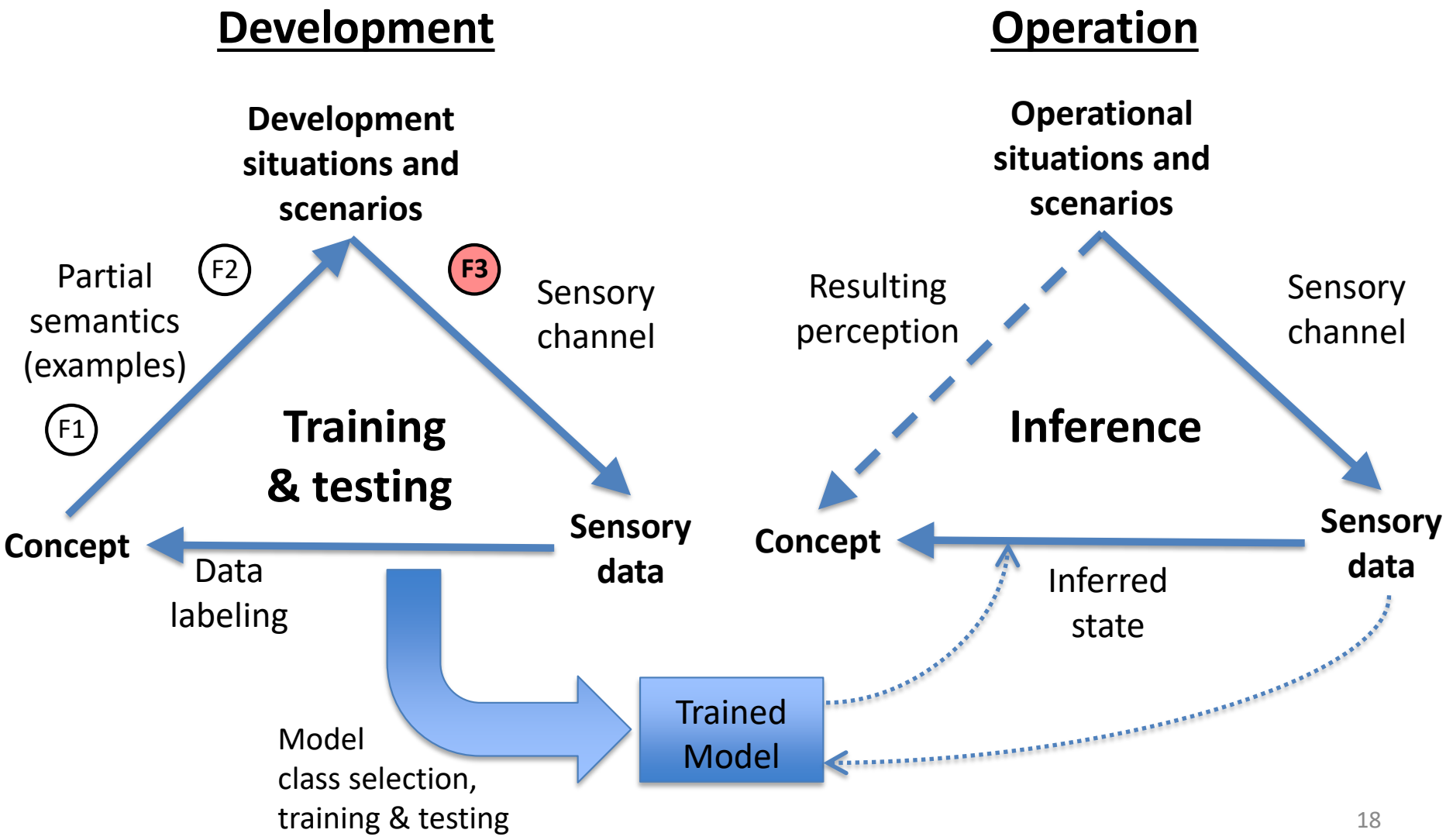


F2: Development Scenario Coverage



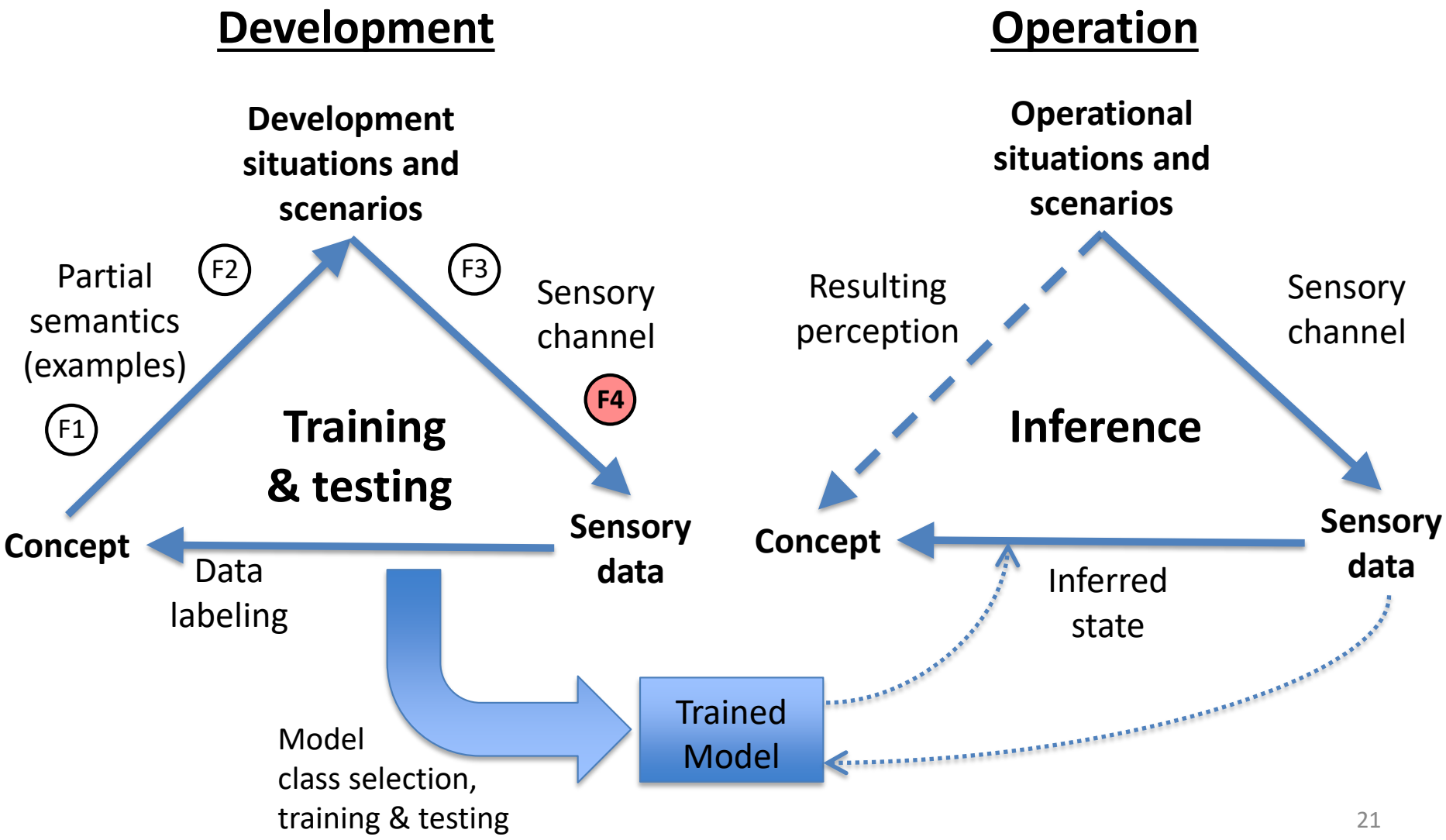


F3: Scene Uncertainty

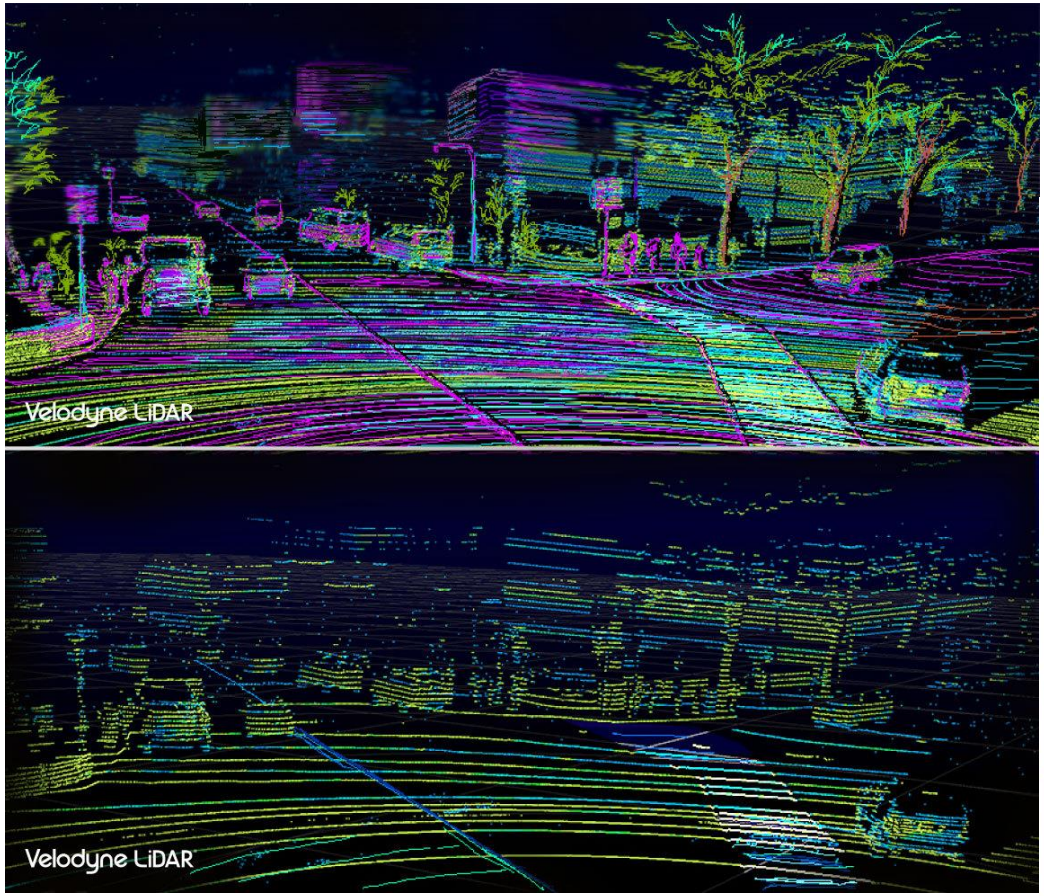


F3: Scene Uncertainty

F4: Sensor Properties



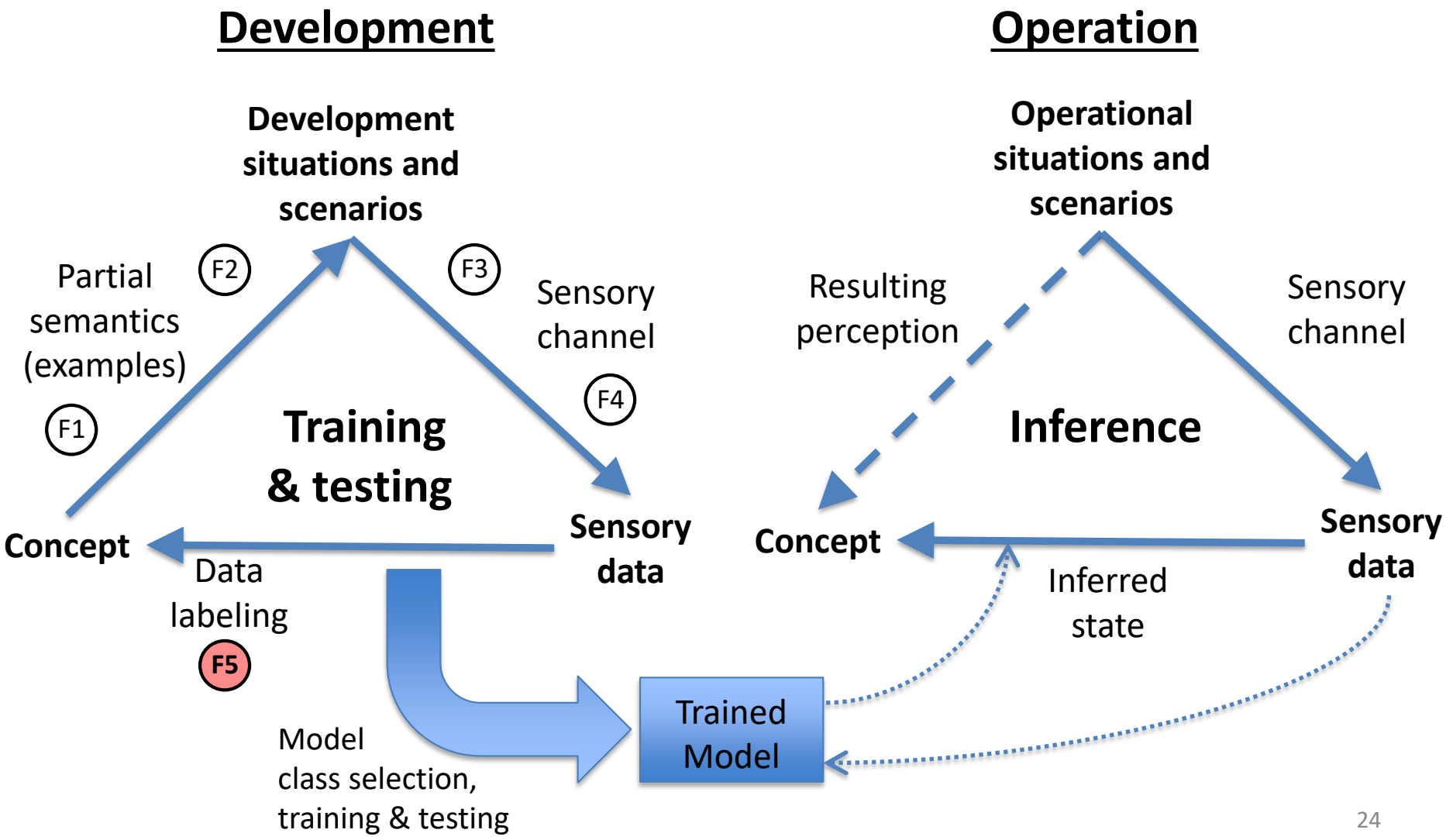
F4: Sensor Properties



Daylight White Balance | Cloudy White Balance

Shade White Balance | Tungsten White Balance

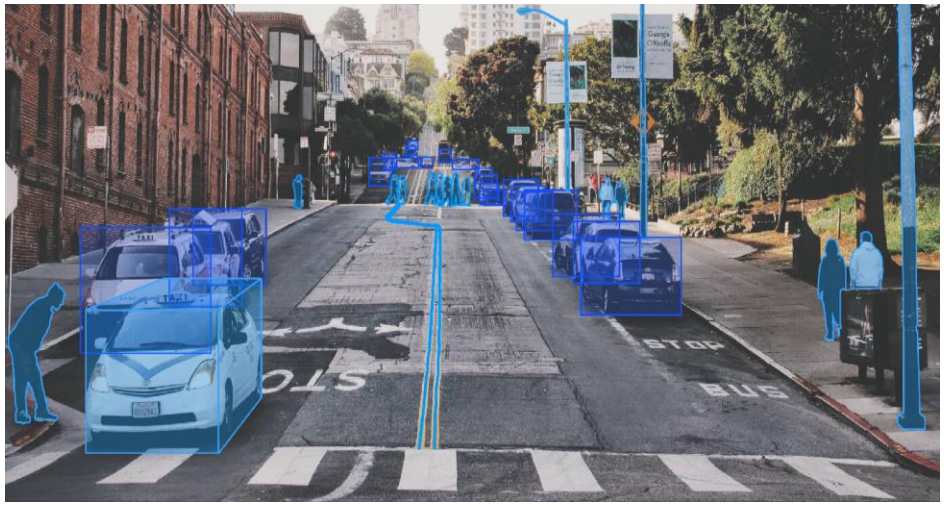
F5: Label Uncertainty



F5: Label Uncertainty

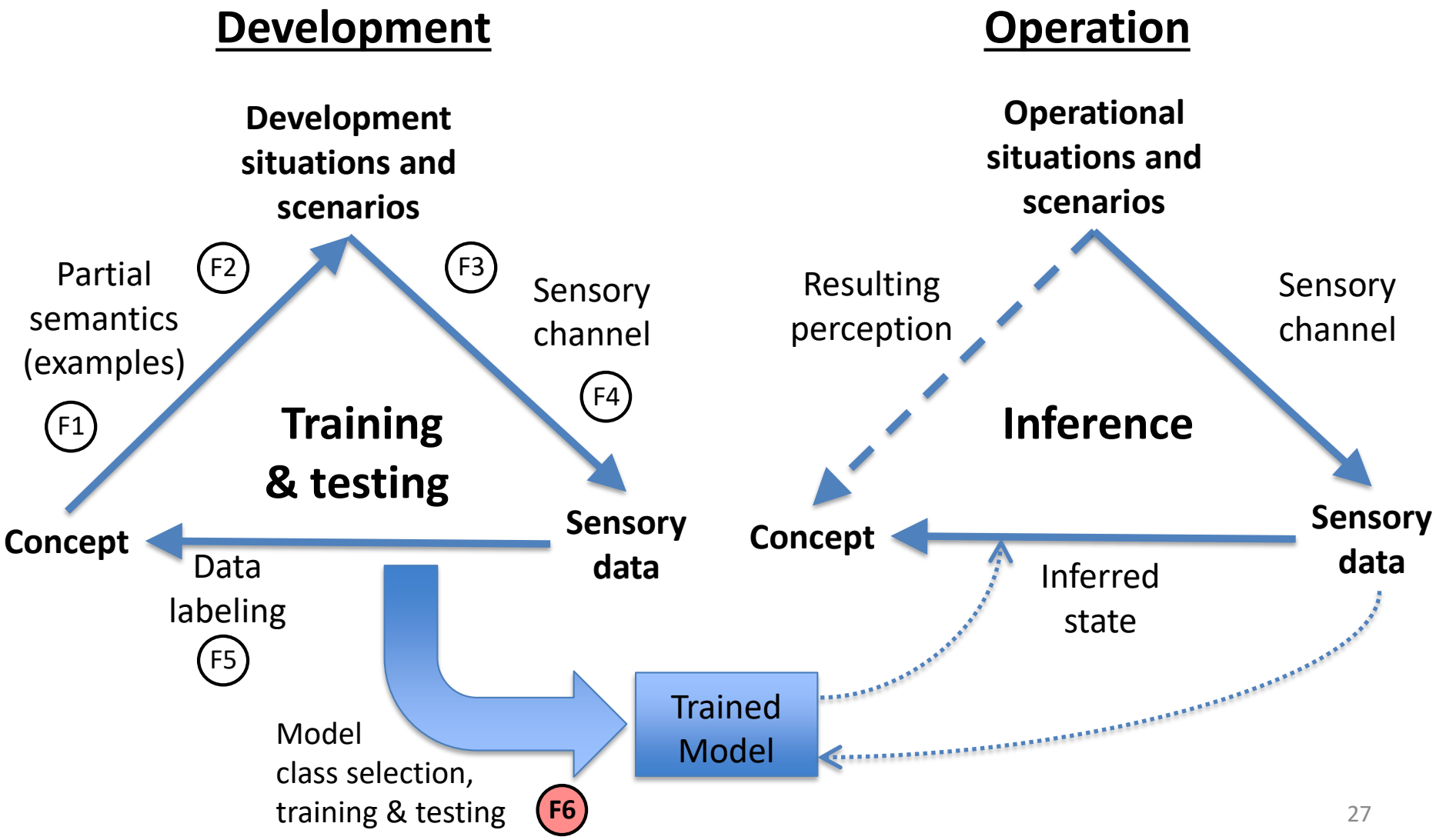
Class: cyclist vs. pedestrian

Bounding box placement uncertainty

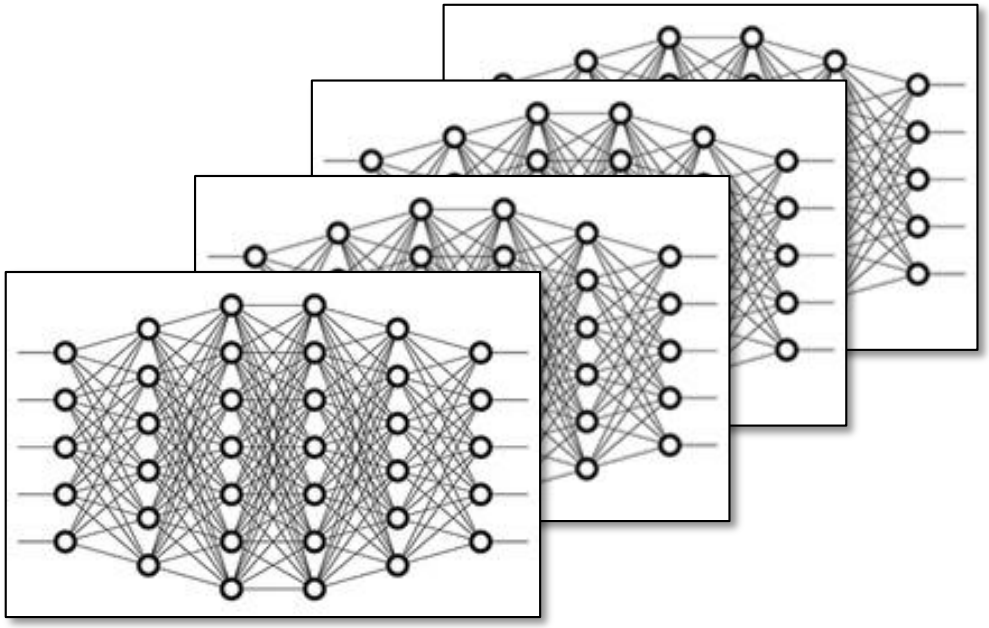


3D bounding box placement is challenging

F6: Model Uncertainty

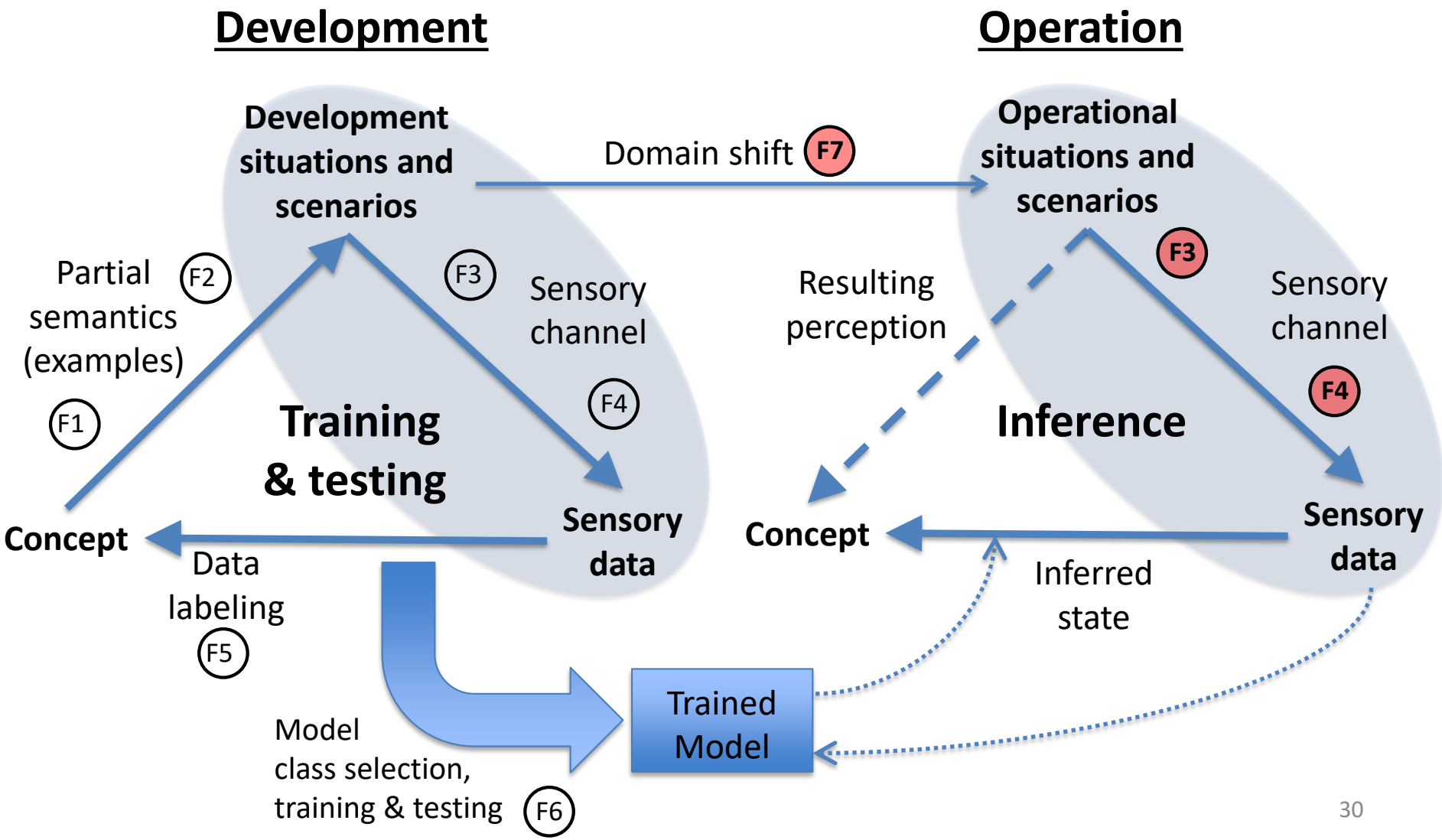


F6: Model Uncertainty

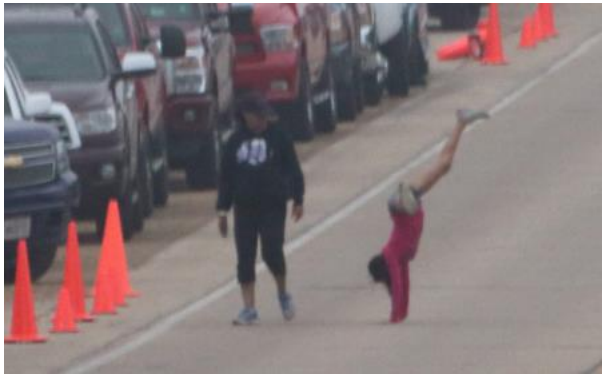


What model was learned in training?
What decisions will it make in operation?

F7: Operational Domain Uncertainty



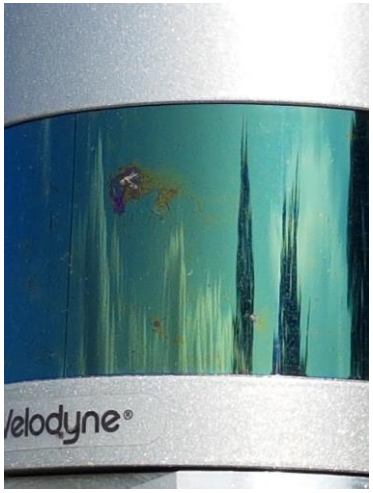
F7: Operational Domain Uncertainty



New pedestrian pose

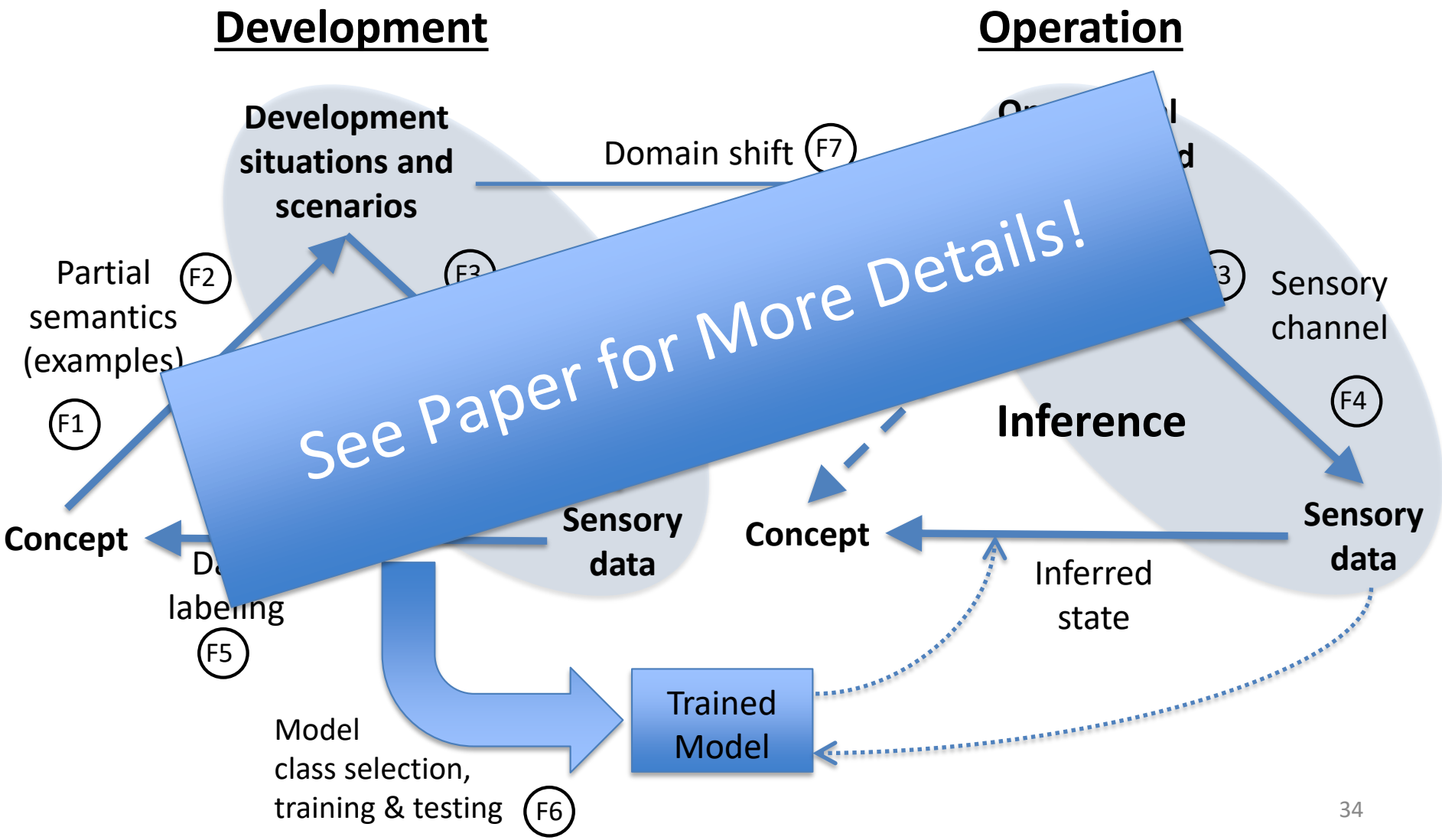
Camera miscalibration

New type of car shape



Fly splatters on LIDAR

Factors Influencing Uncertainty



Conclusion and Next Steps

1. Perceptual uncertainty is a key performance measure in safety requirements
2. Introduced perceptual triangle and identified seven influence factors for perceptual uncertainty when using supervised ML
3. Future: methods to control the influence factors and use them in safety arguments

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THANK YOU