

Intelligent Contingency Management for Urban Air Mobility

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Outline



- Describe the Urban Air Mobility vision
- Outline high level challenges that need to be addressed to enable UAM
- Focus on one of the enabling technologies – intelligent contingency management
- Discuss high level architecture and what role dynamic data plays
- Summary



Where are we heading in Aeronautics?

Third Aviation Revolution

- Urban Air Mobility
  - Part of **Anyone**, **Anywhere, Anytime**
  - Largely enabled by electrification and automation
  - **Autonomous flight** to fully realize the market potential
  - **Urban Air Mobility** is the most challenging subset
  - Operation in complex environment and densely populated areas
- Driving Factors
  - Cost
  - Reliability
  - Flexibility
  - Trustworthiness for safety-critical systems
- Dynamic data driven approaches play an integral part in enabling this emerging market



Challenges to Enable Urban Air Mobility



- Develop assured autonomous functions that enable safe and efficient operations in increasingly complex environments
- Driver is off-nominal conditions requiring robust contingency management and graceful degradation to unforeseen events
- Fundamental research challenges in adaptive mission management, robust autonomous decision making, explanatory intelligent systems, intelligent contingency management, and graceful performance degradation in the unique domain of aviation safety-critical systems
- External degraded information and communications
- High level of assurance and safety
- Systems designed to include understanding of human collaborators and own capabilities and limitations



Urban Air Mobility – Technical Challenges

Air traffic management system

Vehicle mission management system

- Resilient vehicle contingency management system, highly autonomous even at early maturity levels
- Hierarchical fault tolerance & graceful degradation
  - mission level
  - vehicle
  - subsystem
- Fail-operational stability
  - If physically capable, must maintain flight
- Real-time vehicle noise management
- Real-time mission planning & trajectory generation













UAM Mission Under Study

Vehicle mission: target final phase of autonomous flight

- safely fly from pt. A to pt. B following a nominal trajectory

Environmental and operational constraints:

- under all vehicle-allowable weather conditions,
- in a high-density airspace and complex urban environment,

React appropriately to off-nominal situations and contingencies without direct human control

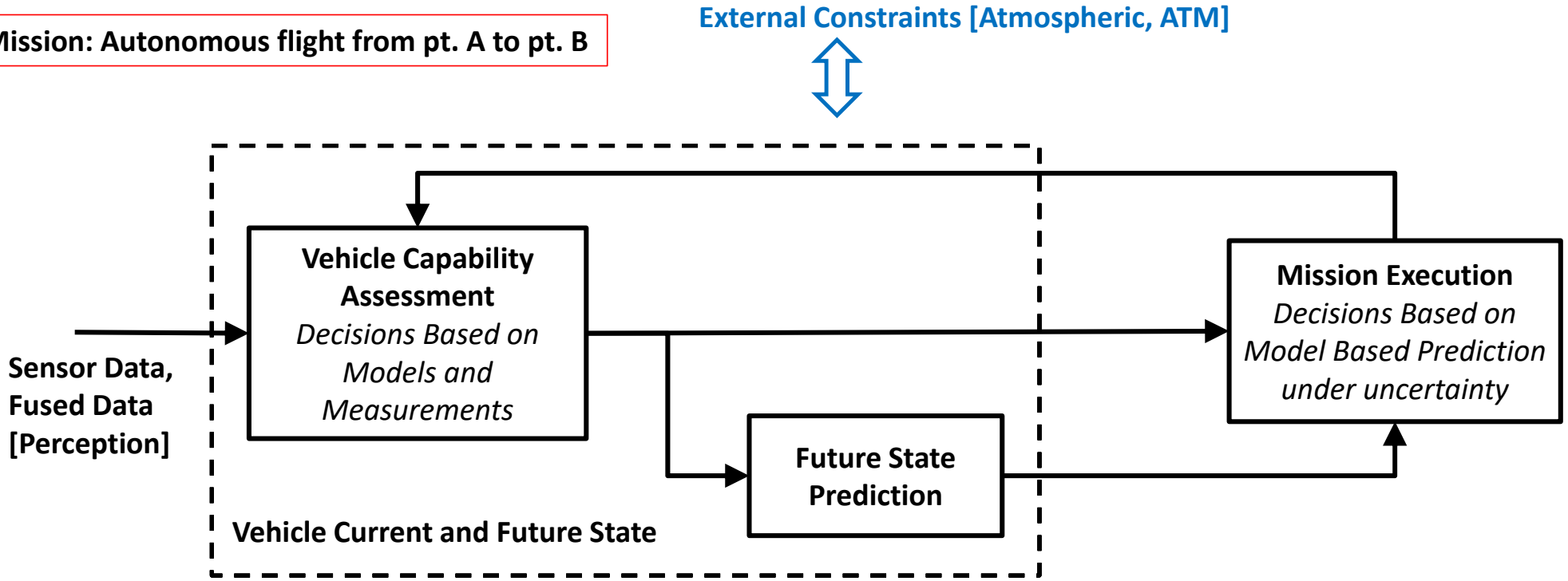
- Currently contingency management is a highly prescribed, rule-based approach.

- We are interested in exploring intelligent contingency management that can appropriately handle unanticipated situations.



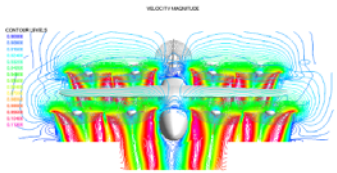
Intelligent Contingency Management – Architecture & Integrated Tools

Mission: Autonomous flight from pt. A to pt. B



- How can machine agents handle unforeseen contingency events?
- How can machines intelligently make decisions in the presence of uncertain, unreliable, and incomplete information?
- How can we assure learning ICM algorithms?

Intelligent Contingency Management – Architecture



Vehicle Model
- Model development (Automated **CFD/Wind tunnel data**)
- Onboard actual model identification (**feedback loop with sensor data**)

External Constraints (Weather & ATM)

Sensor data
External constraints

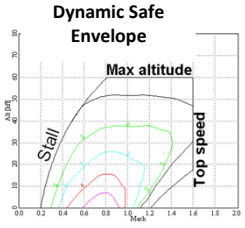
Sensor Data, Fused Data

Vehicle Capability Assessment
Decisions Based on Models and Measurements

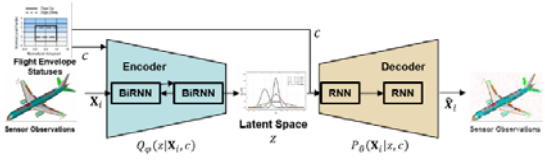
Future State Prediction

Mission Execution
Decisions Based on Model Based Prediction under uncertainty

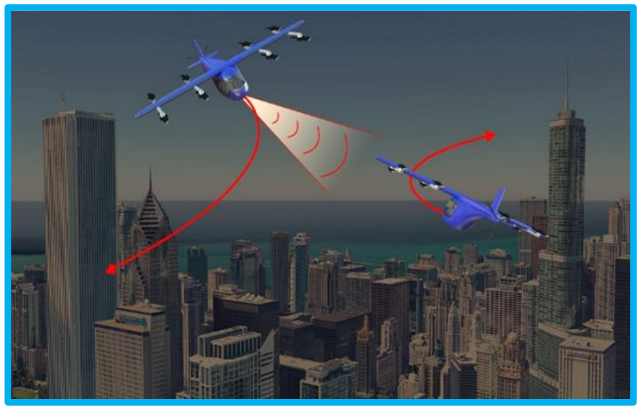
Vehicle Current and Future State

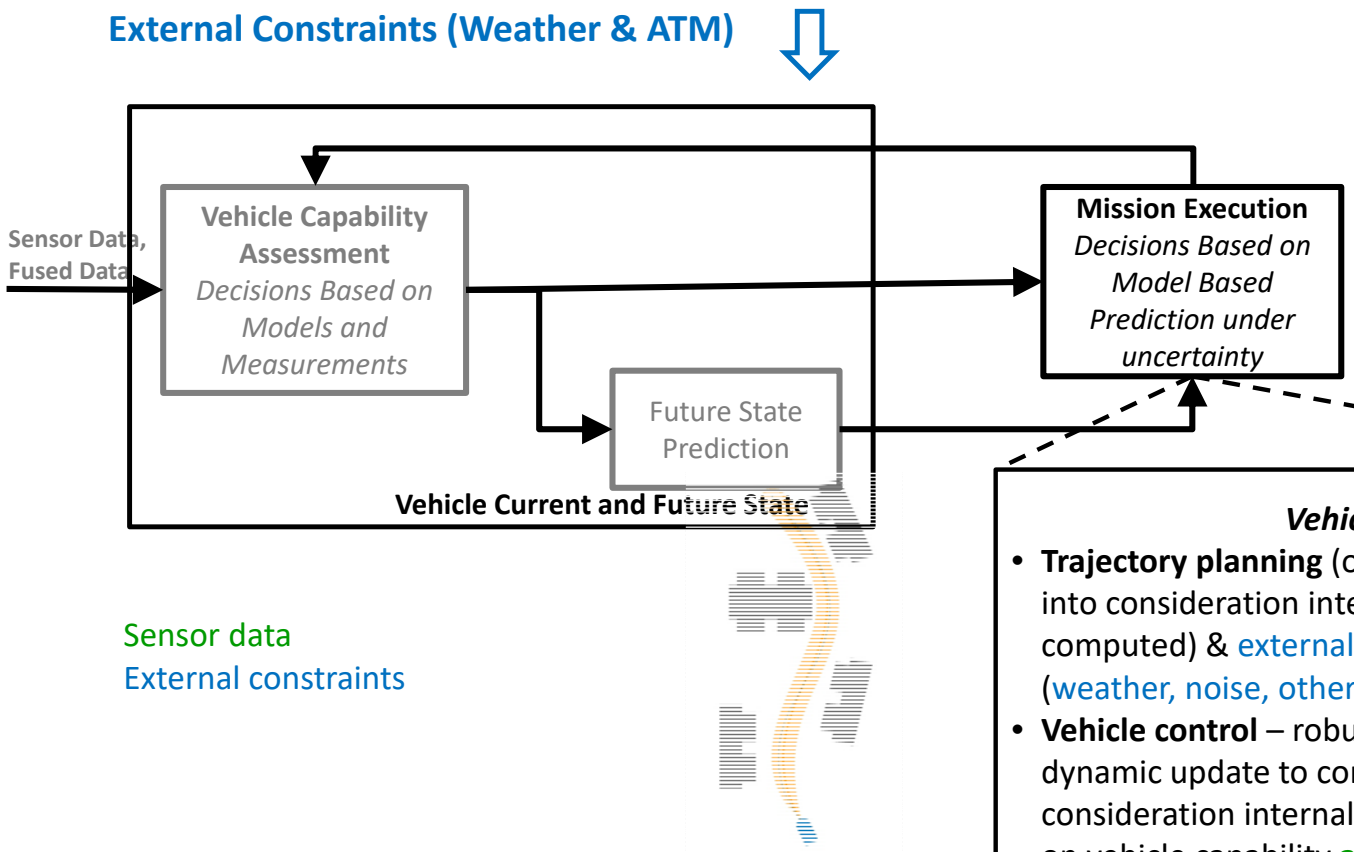


Vehicle Safety
- Safe dynamic envelope – based on actual **identified model and sensor data**
- Assured containment & Detect And Participate – external constraints and **environment data**



Intelligent Contingency Management – Architecture

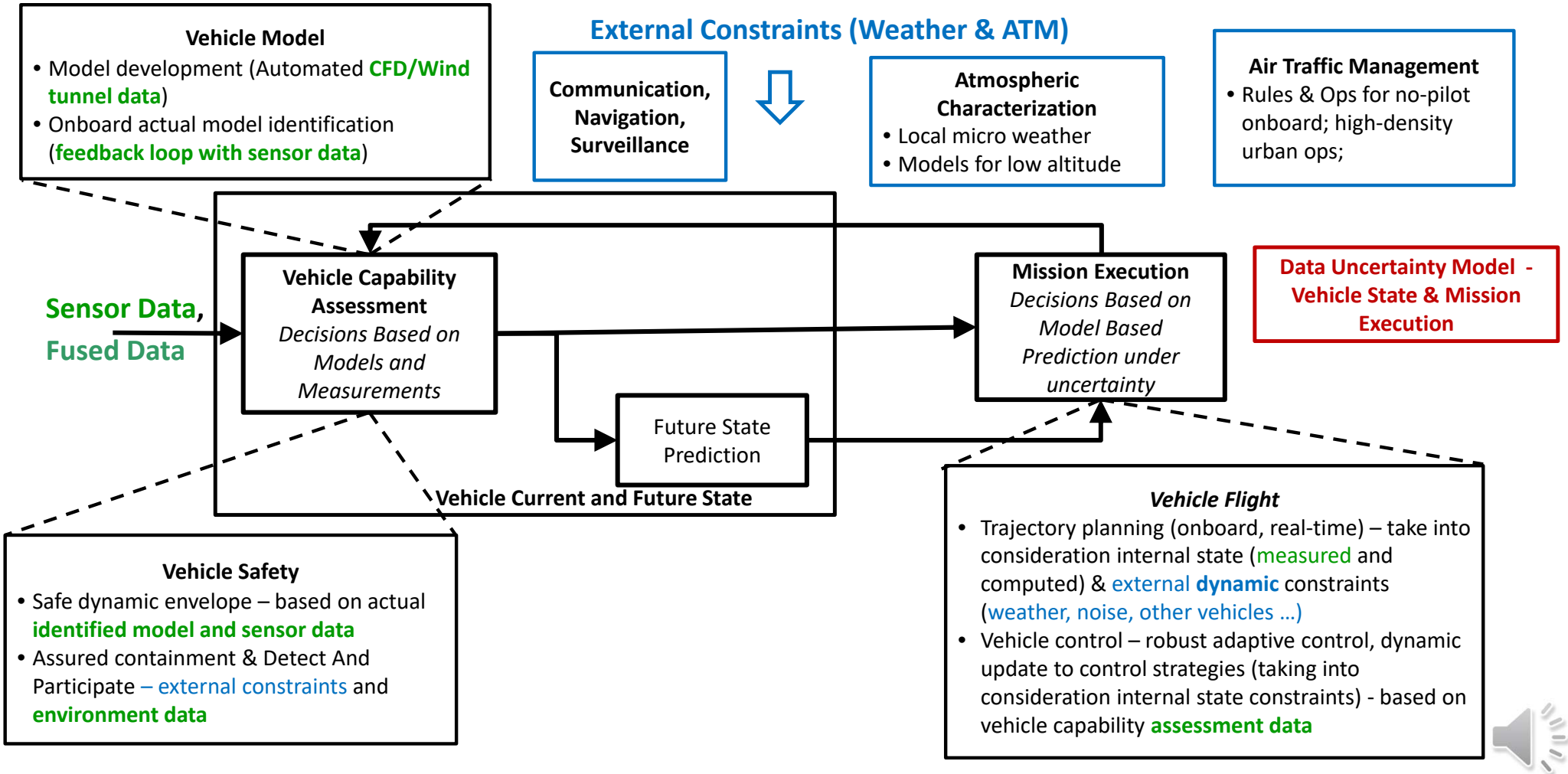




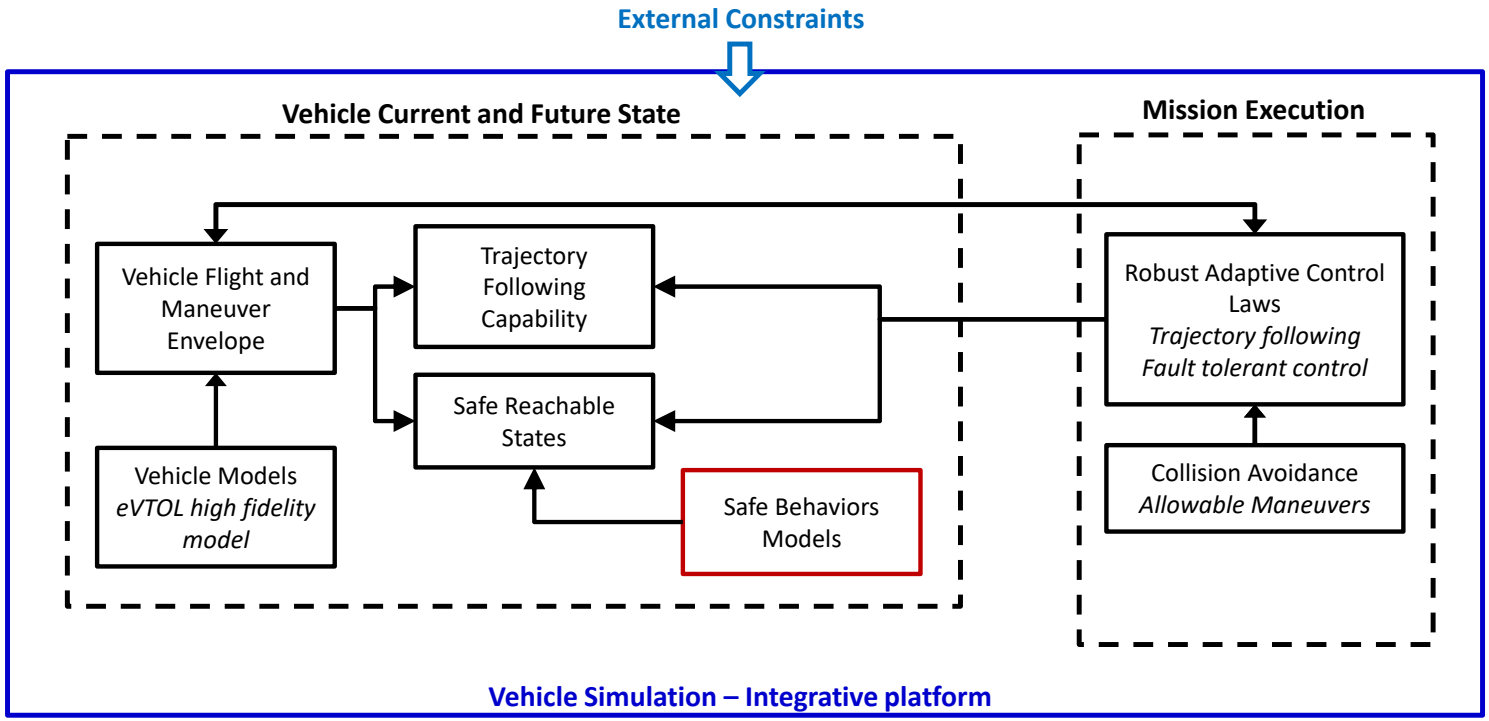
Vehicle Flight

- **Trajectory planning** (onboard, real-time) – take into consideration internal state (measured and computed) & external **dynamic** constraints (weather, noise, other vehicles …)
- **Vehicle control** – robust adaptive control, dynamic update to control strategies (taking into consideration internal state constraints) - based on vehicle capability **assessment data**

Intelligent Contingency Management – Architecture



Intelligent Contingency Management – Architecture & Integrated Tools



Summary



- Urban Air Mobility for the masses is a major component of user-driven, immediate and flexible air travel
- Autonomous flight for full market potential
- One of the primary challenges is responding to off-nominal events, both common and unforeseen
- Intelligent contingency management (ICM) is one of the enabling technologies
- Basic premise of vehicle ICM:
  - Vehicle aware of its internal state and external environment at all times
  - Ascertains its capability
  - Makes decisions about mission completion or modification
- Require data to model and assess the environment, and take actions based on these models
- Dealing with safety-critical systems → generate sufficient data and minimize uncertainty to enable practical decision making
- Propose overall architecture incorporating deterministic and learning algorithm to
  - Assess vehicle capabilities
  - Project these into the future
  - Make decision on mission management level
- Layered approach to allow mature technologies to be incorporated into early phases of UAM




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