Towards Defining Required Interval Management Performance (RIMP)

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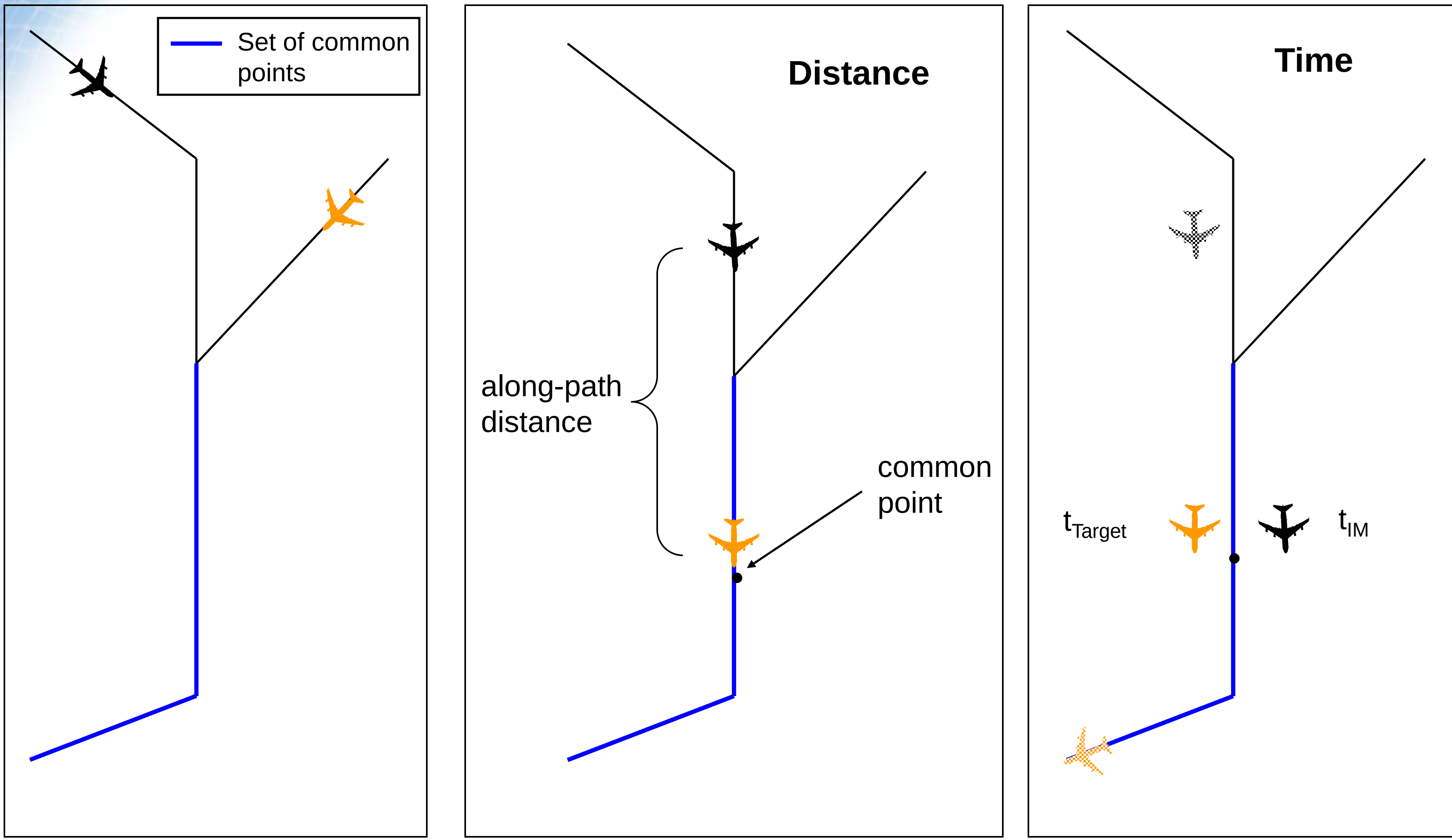
Introduction

- **Interval Management (IM) is an airspace concept, focused on the management of the spacing interval between two aircraft on merging or coincident routes.**
  - **Applicable in all phases of flight**
  - **Ground-based Interval Management (GIM)**
    - **Sequencer, scheduler, monitoring, speed advisories, set-up for FIM**
  - **Flight-deck based Interval Management (FIM)**
    - **Sequencing & Merging, Merging & Spacing, ASPA-FIM SPR, Louisville operations, NLR/Schipol**
  - **Non-coincident routes (e.g., parallel offset) are also being explored**
- **The spacing interval is the (true) horizontal along-path spacing between the IM and Target Aircraft.**
- **The measured spacing interval is determined by the IM Aircraft by using ADS-B surveillance on the Target Aircraft.**

Determining the Spacing Interval



Terminology

- **FIM Equipment – avionics onboard the IM Aircraft which provides speed and turn guidance**
  - **Speed/turn guidance permits the management of the spacing interval on the flight deck**
- **Measured Spacing Interval – the spacing interval as determined by the FIM Equipment**
- **Assigned Spacing Goal – desired spacing interval that should be achieved or maintained**
- **IM Tolerance – allowed deviation from the Assigned Spacing Goal which must be respected for 95% of the flight time over which it applies**

Problem Statement

- **Range of envisioned IM Operations leads to variations in requirements due to:**
  - **Phase of flight**
  - **Environment**
  - **Operational objectives**
- **For example, an arrival & approach spacing operation may require a tighter IM Tolerance than an en-route spacing operation.**
  - **Furthermore, even two IM Operations with the same IM Tolerance may have different requirements.**

Required Interval Management Performance (RIMP)

- **RIMP is a requirement on the along-path spacing accuracy**
  - **based both on what is required operationally and what spacing performance can be expected within a given airspace**
- **RIMP type is specified for an IM operation, and is designated by the IM Tolerance required to be met**
  - **RIMP type selected to meet operational requirements**
  - **a RIMP specification provides component functional, safety, and performance requirements, which are also associated with the type**
- **RIMP categorizes the top-down requirements for an IM operation**
  - **Paper focuses on the analysis utilized to establish the RIMP specification that meets the top-down requirements**

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RIMP Components

- **IM Tolerance**
  - **95% bounds on spacing performance based on minimum operational requirements**
  - **Designator for the RIMP type**
- **State data performance**
  - **Accuracy of Target Aircraft surveillance (e.g., ADS-B) and ownship state data affects the accuracy of the Measured Spacing Interval**
- **Speed control performance**
  - **Algorithm performance against the operational uncertainties inherent in the environment**
- **Additional functional capabilities**
  - **Types of intended flight paths that can be processed, use of final approach speeds, direct coupling to the auto-throttles, delegated-separation capable, etc**

Motivation for the RIMP Concept

- **Different IM Tolerance values are required for different phases of flight, environments, and operational goals**
- **There is a corresponding range of IM Tolerance values and associated RIMP specifications**
  - **A single specification would not be sufficient for some IM operations or would over-constrain others**
- **In light of these variations, RIMP provides consistency of use to:**
  - **airspace planners**
  - **FIM equipment manufacturers**
  - **controllers and pilots**
  - **certification authorities**

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IM Tolerance

- **Derived from the Operationally Required Tolerance (ORT) methodology**
  - **Two points on the nominal (i.e. Gaussian, fault-free) performance curve are specified:**
    - **Nominal Spacing Bounds (95% bounds meeting the operational goals)**
    - **Controller Intervention Threshold (> 99% bounds ensuring controller trust in the system)**
- **IM Tolerance value is derived through reconciling these two independent bounds**

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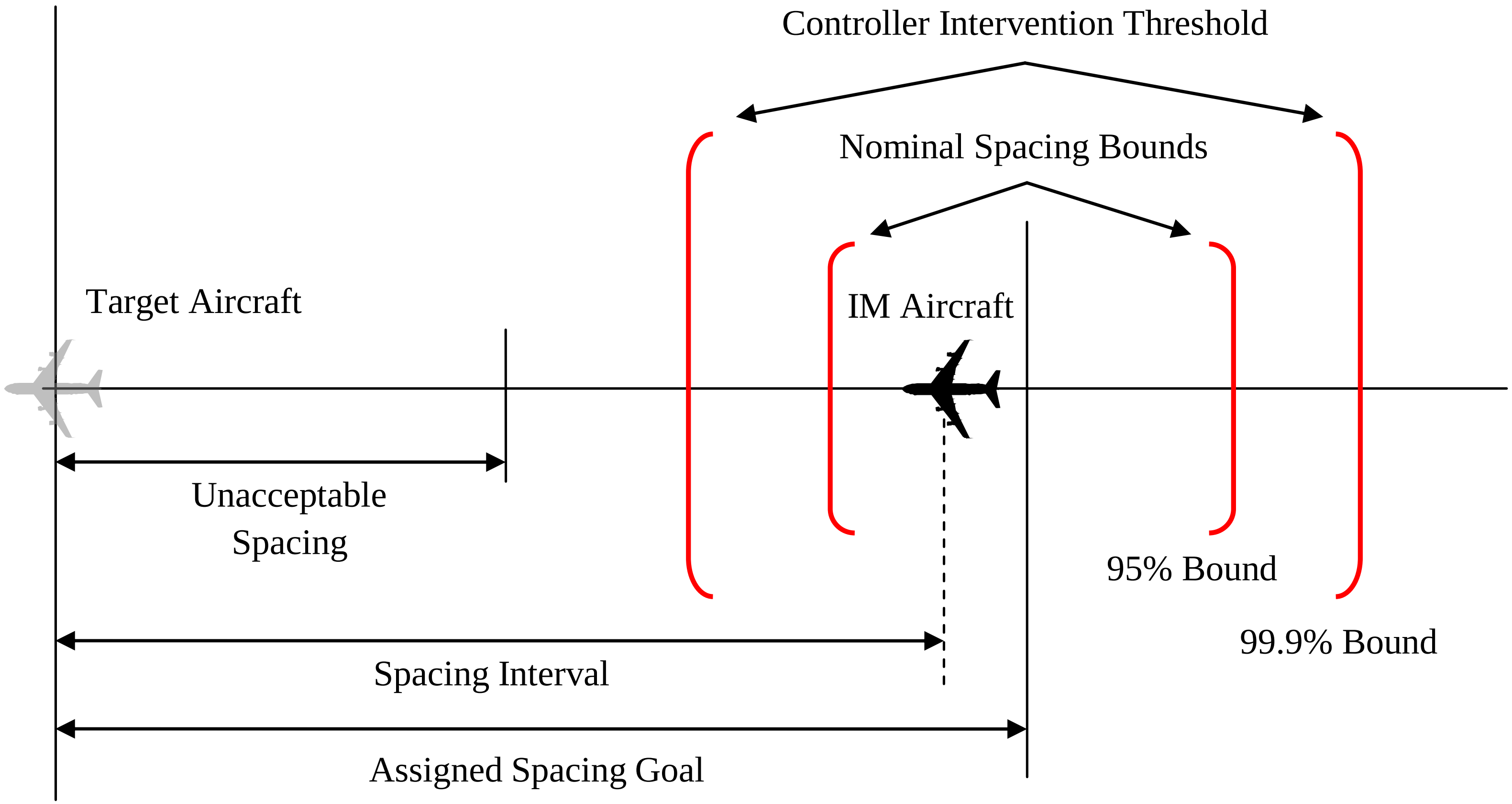
Operationally Required Tolerances



Allocation of the IM Tolerance

- IM Tolerance allocated to:
  - State data performance
  - Speed control performance in the assumed operating environment
- State data allocation based on budgeted uncertainty in the Measured Spacing Interval
- FIM Equipment Tolerance is the remaining allocation, within which the speed control algorithm is required to perform

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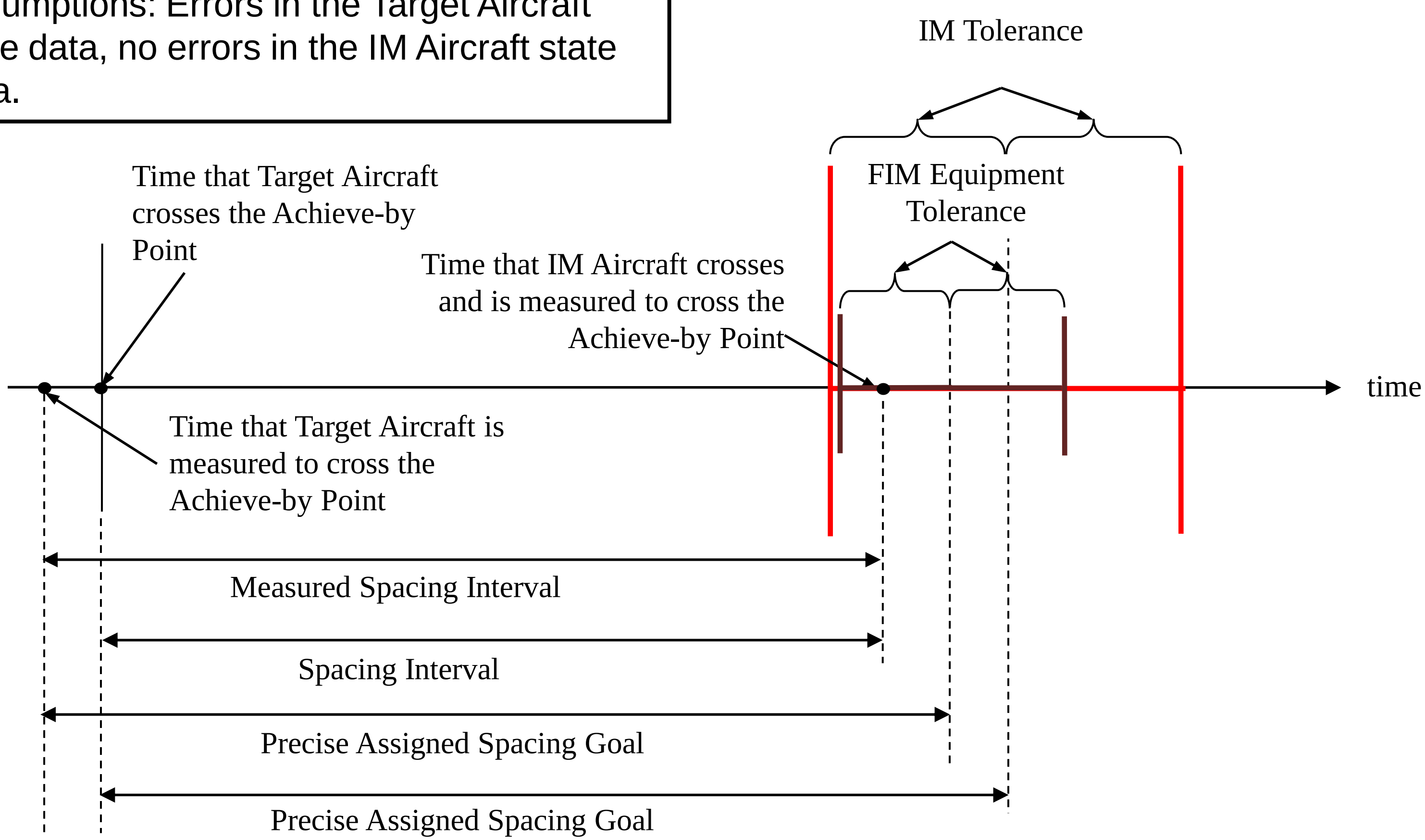
Measured Spacing Interval Uncertainty and FIM Equipment Tolerance

Assumptions: Errors in the Target Aircraft state data, no errors in the IM Aircraft state data.



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State Data Performance (1/2)

- For both IM and Target Aircraft state data, State Data Performance Level is defined to include:
  - horizontal position accuracy
  - horizontal velocity accuracy
  - latencies
  - update interval
  - horizontal position integrity
- Two discrete performance levels have emerged:
  - differ only in the horizontal position accuracy (0.3 NM and 0.1 NM) and horizontal position integrity (0.1 NM and 0.2 NM).
  - more levels may be identified, with variation in other parameters

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State Data Performance (2/2)

- **State data performance affects the accuracy of the Measured Spacing Interval**
- **Closed-form model relating performance parameters to Measured Spacing Interval uncertainty published in the ASPA-FIM SPR**
  - **can be used to determine an appropriate FIM Equipment Tolerance based on actual reported or measured state data performance**

Speed Performance in the Assumed Operating Environment (1/3)

- The speed performance in the environment specifies the ability to drive the Measured Spacing Interval to within the FIM Equipment Tolerance.
  - <u>In the design of an IM Operation</u>, the FIM Equipment Tolerance should be appropriate for the assumed operating environment.
  - <u>In the design of the Speed Control Algorithm</u>, the algorithm must be validated in the assumed operating environment to ensure that the FIM Equipment Tolerance can be met.

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Speed Performance in the Assumed Operating Environment (2/3)

- **There are two considerations in the design of a Speed Control Algorithm:**
  - **Ability to meet the FIM Equipment Tolerance**
  - **Provide good string performance (i.e., prevent the propagation of disturbances through a string of aircraft)**
- **Harder to characterize the ability of a Speed Control Algorithm to provide sufficient performance in the environment (i.e., no closed-form model yet developed)**
- **FIM Equipment implementations may be validated using fast-time simulations given a modeled environment (e.g., MOPS)**

Speed Performance in the Assumed Operating Environment (3/3)

- **Systematic means for validating the Speed Control Performance for an IM Operation is desirable**
  - Characterize the operational uncertainties in the operation,
  - Characterize the algorithm response to those uncertainties, and
  - Combine in the context of the operation to show top-down requirements are met
- **Expect that a set of discrete categories for Speed Performance will be identified**
  - May specify FIM Equipment Tolerance levels or Speed Control Algorithm levels

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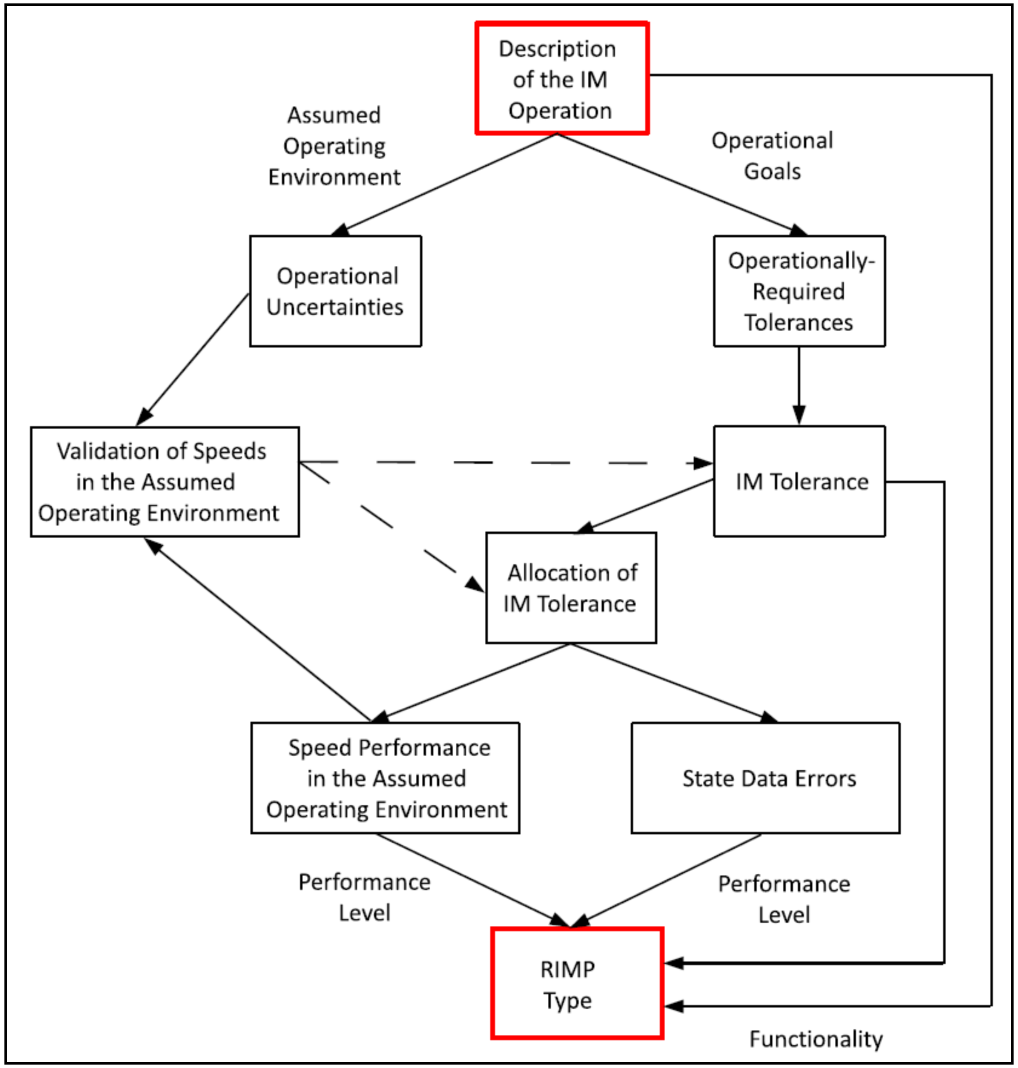
Establishing the RIMP Type

- **RIMP Specification is comprised of:**
  - **IM Tolerance**
  - **State Data Performance Level**
  - **Speed Performance Level**
  - **Additional Functionality**
- **Dashed lines indicate feedback to adjust the IM Tolerance and/or the allocations if FIM Equipment Tolerance cannot be met**



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RIMP Methodology Applied to Example IM Operation (1/4)

- **IM Operation is used to achieve the desired inter-aircraft spacing at the entry to the terminal area**
  - **Given a sequence and STAs, controller determines the Assigned Spacing Goal between aircraft**
  - **Operational goal is to limit schedule drift to within ±2 minutes, 95%, over one hour**
  - **Controller Intervention Threshold is modeled to be one-third of the desired spacing**

RIMP Methodology Applied to Example IM Operation (2/4)

- **Determining IM Tolerance**
  - **Nominal Spacing Bounds:** $$\sigma < \frac{120 \text{ seconds}}{1.96\sqrt{N}}$$
  - **Controller Intervention Threshold:** $$3.29\sigma < \frac{\Delta_i}{3}$$
  - **Assume Δ_i = 120 sec, N = 30, σ = 11.2 sec (driven by the NSB); therefore, <u>IM Tolerance = 22.0 sec</u>**
  - **Assume Δ_i = 90 sec, N = 40, σ = 9.7 sec (driven by the CIT); therefore, <u>IM Tolerance = 17.9 sec</u>**

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RIMP Methodology Applied to Example IM Operation (3/4)

- **IM Tolerance Allocation**
  - **IM Tolerance: 17.9 seconds**
  - **Initial conservative allocation to FIM Equipment Tolerance: 13.0 seconds**
  - **State Data Error Budget: 12.3 seconds**

$$\text{State Data Error Budget} = \sqrt{(\text{IM Tolerance})^2 - (\text{Speed Performance Budget})^2}$$

$$= \sqrt{(17.9 \text{ sec})^2 - (13.0 \text{ sec})^2} = 12.3 \text{ sec}$$

  - **State Data Performance Level 1 meets the budget. For a Target Aircraft equipped with ADS-R, the worst-case bound on the Measured Spacing Interval Uncertainty = 6.6 seconds**
  - **Re-allocation to FIM Equipment Tolerance = 16.6 seconds**

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RIMP Methodology Applied to Example IM Operation (4/4)

- RIMP type: RIMP 18
- RIMP specification for this IM Operation would include:
  - IM Tolerance of 18 seconds
  - State Data Performance Level 1
  - Appropriate Speed Performance Level (FIM Equipment Tolerance)
  - No additional functionality

Comparing PBN and RIMP (1/3)

- RIMP was developed without consideration for other Performance-Based concepts, but it can be compared to RNP to highlight similarities
- For example:
  - RIMP 10
    - ensures that the IM Aircraft has the capability to achieve and/or remain within 10 seconds of the Assigned Spacing Goal (95%), and within 20 seconds (99.991%)
    - provides performance monitoring and alerting
  - RNP 3
    - ensures that the aircraft has the capability to remain within 0.3 NM of the centerline (95%), and within 0.6 NM (99.999%)
    - includes performance monitoring and alerting requirements

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Comparing PBN and RIMP (2/3)

RNP	RIMP
Accuracy requirement on the Total System Error (TSE) (95%)	Accuracy requirement on the IM Tolerance (95%) (or Total System Performance)
Navigation System Error (NSE) related to the GNSS sensors and satellite state	Measured Spacing Interval Uncertainty related to the IM Aircraft and Target Aircraft data quality
Flight Technical Error (FTE) related to ability to follow path	FIM Equipment Tolerance related to ability to achieve or maintain the Assigned Spacing Goal
Path Definition Error (PDE) related to ability to accurately define the desired path. Generally assumed zero	Intended Flight Path for IM and Target Aircraft defined a priori and must be acquired by FIM Equipment. Errors generally assumed zero

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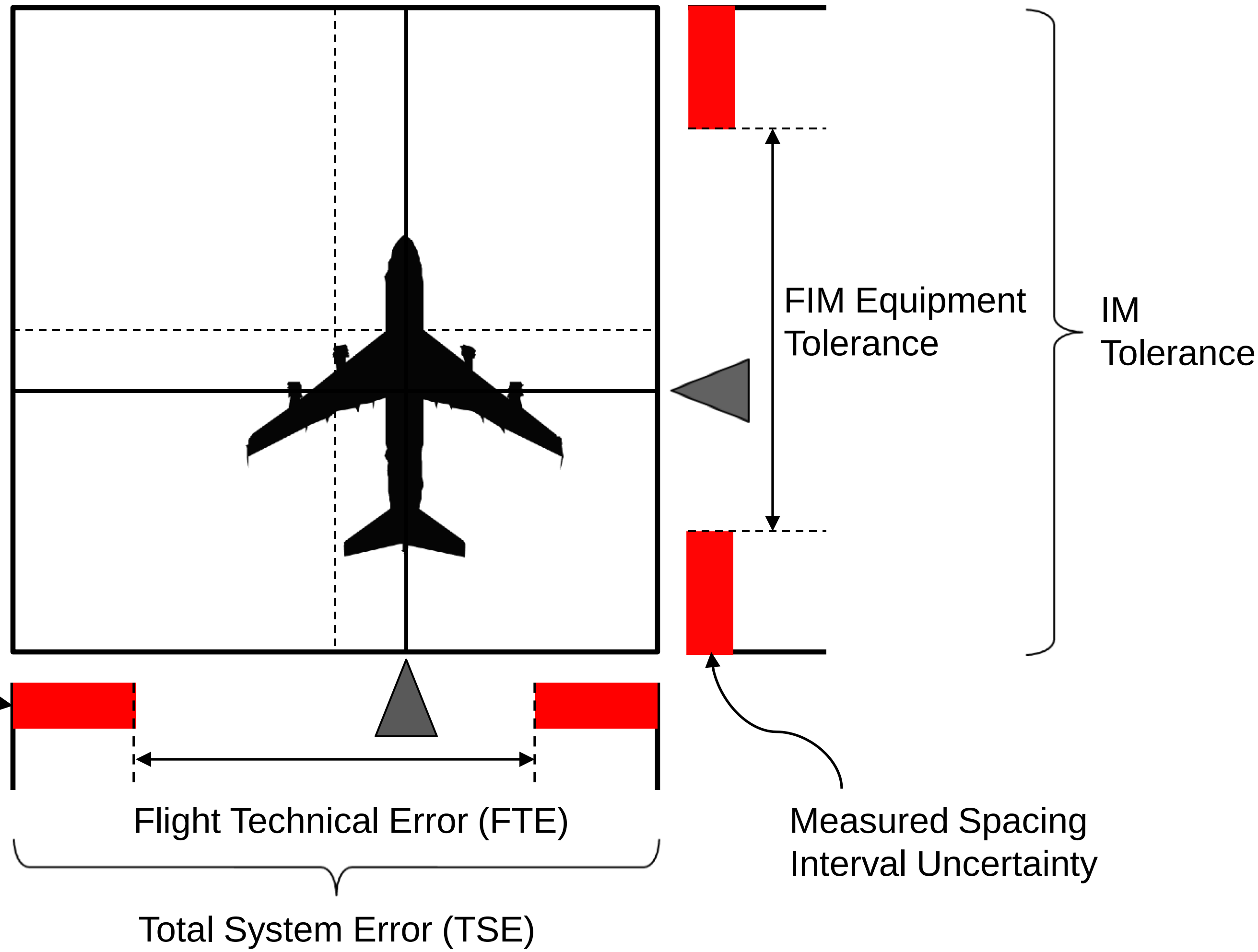
Comparing PBN and RIMP (3/3)

Example display shows:

- lateral position relative to path, and
- Measured Spacing Interval relative to Assigned Spacing Goal measured from Target Aircraft



Conclusions

- A performance-based approach to the Interval Management concept has been proposed and is under development
- RIMP specification includes requirements on the:
  - IM Tolerance (RIMP type)
  - State Data Performance Level
  - Speed Performance Level
  - Required Functionality
- A framework for analyzing an IM Operation and determining performance requirements to meet top-down operational constraints has been established and requires further development

Future Work

- Evaluate IM use cases to fully establish:
  - IM Tolerance values
  - State Data Performance Levels
  - Speed Performance Levels (FIM Equipment Tolerance)
  - Required Functionality
- Develop Minimum Operational Performance Standards (MOPS) for FIM Equipment; RIMP would be developed concurrently and may align well with the MOPS activity
- Work with experts within the community to refine the RIMP concept from a flight and ground operations perspective, as well as to benefit certification
- It is not expected that initial IM Operations will require the full and complete development of RIMP
- Further work on a methodology for validating the FIM Equipment Tolerance for a given IM Operation is needed

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Questions?