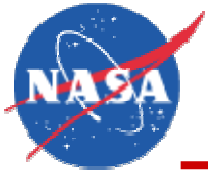




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Terminal Area ATM Research Branch
Moffett Field, California*

Fast-Time Simulation Evaluation of a Conflict Resolution Algorithm Under High Air Traffic Demand

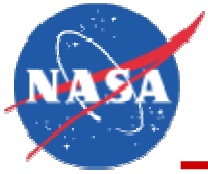
*Todd Farley
Heinz Erzberger*



Two topics

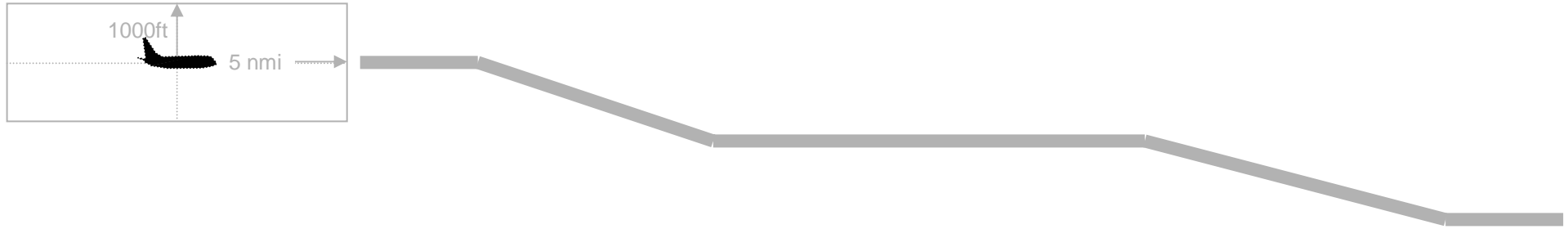
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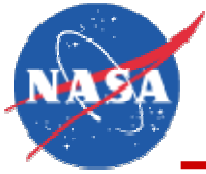
- Update: conflict resolution element of the automated airspace concept (AAC)
 - Approach
 - Example
- Report: benchmarking the algorithm's performance
 - Safety
 - Efficiency



AAC separation assurance strategy

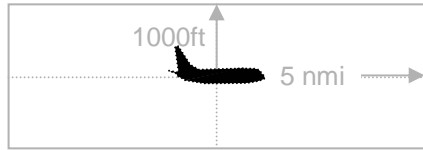
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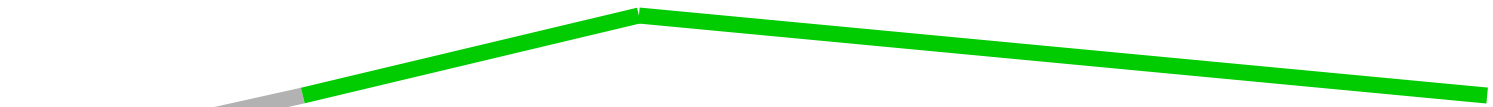
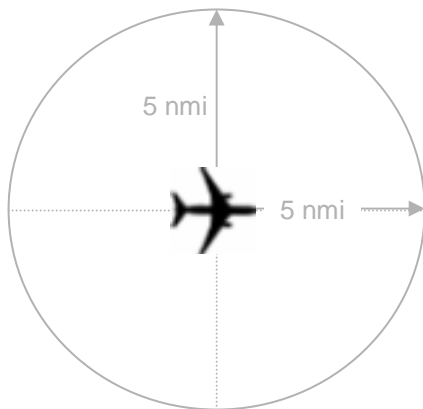


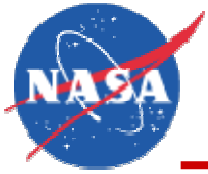
AAC separation assurance strategy

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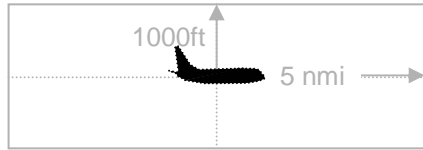
Conflict resolution
(2-20 min time horizon)





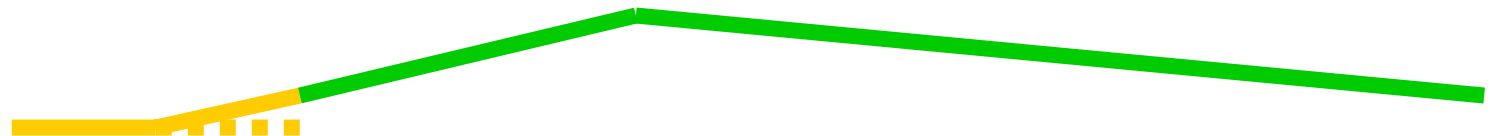
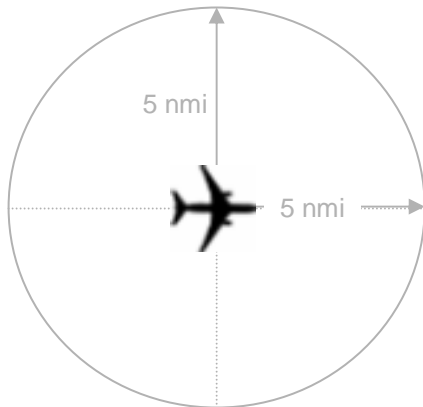
AAC separation assurance strategy

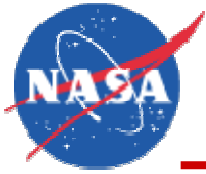
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Conflict avoidance
(0-2 min)

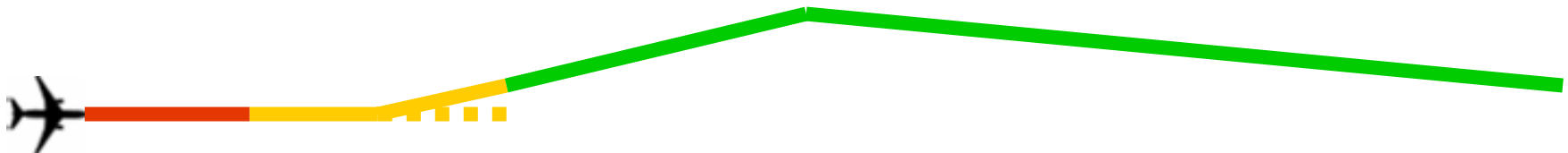
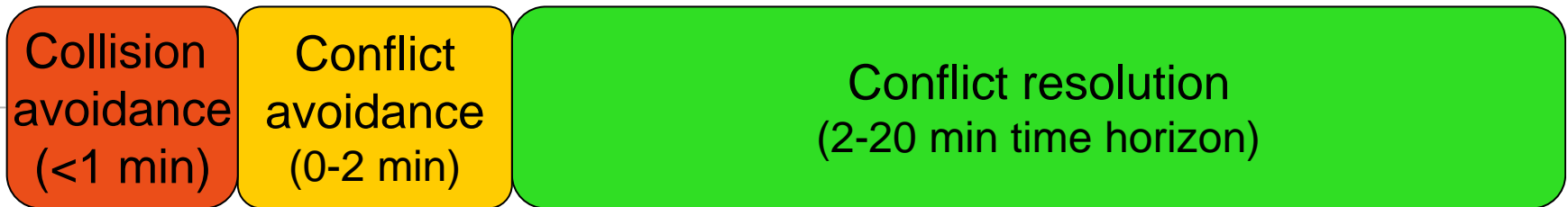
Conflict resolution
(2-20 min time horizon)

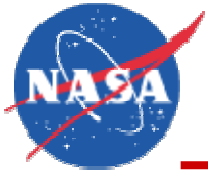




AAC separation assurance strategy

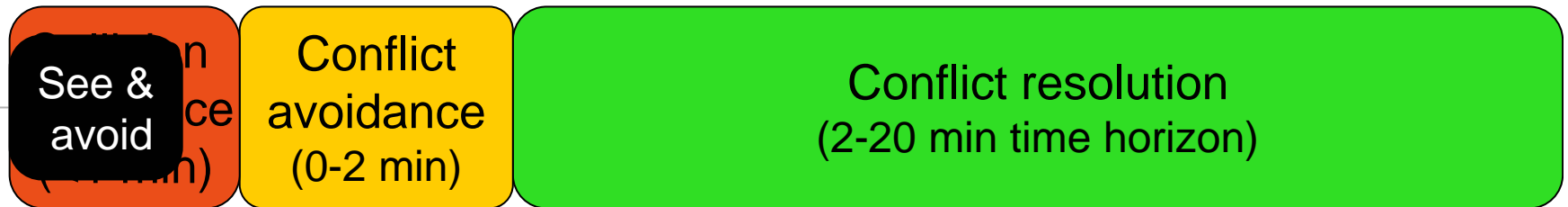
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AAC separation assurance strategy

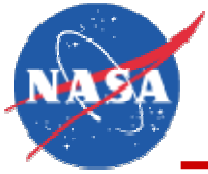
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See & avoid
(0-2 min)

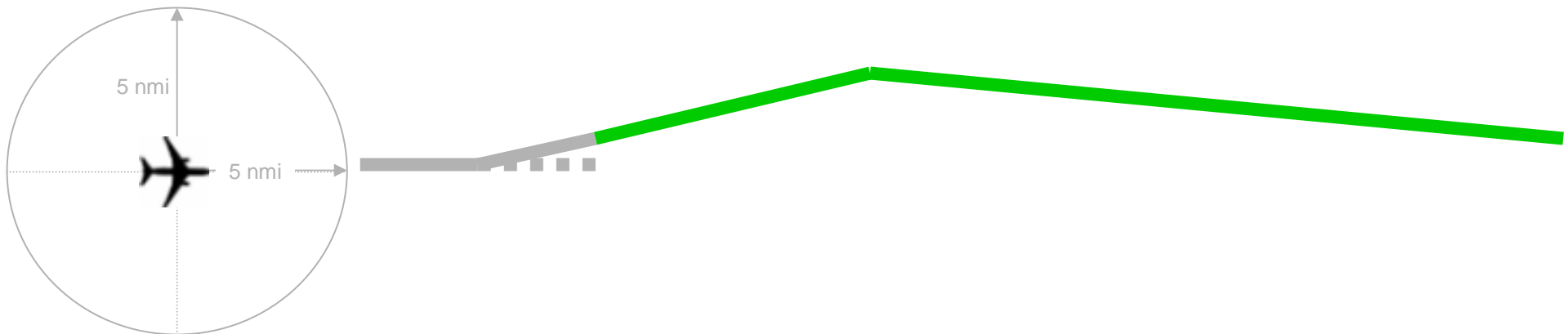
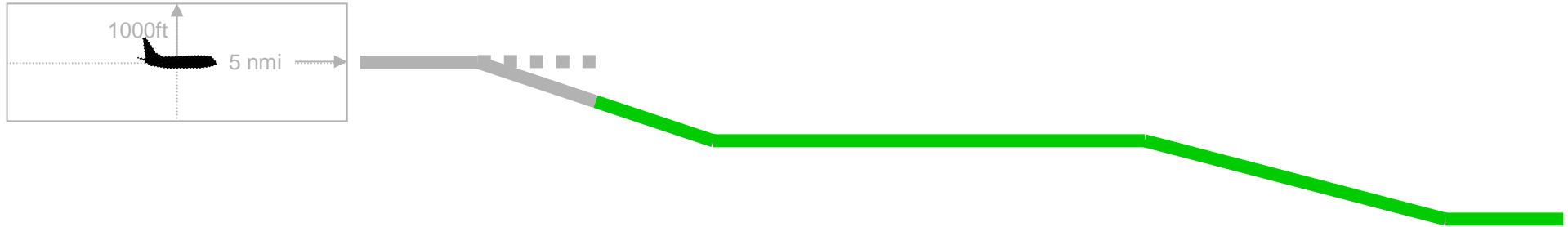
Conflict avoidance
(0-2 min)

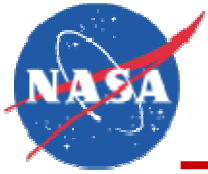
Conflict resolution
(2-20 min time horizon)



AAC separation assurance strategy

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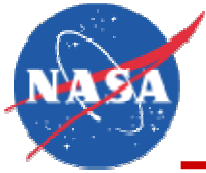


AAC conflict resolution algorithm

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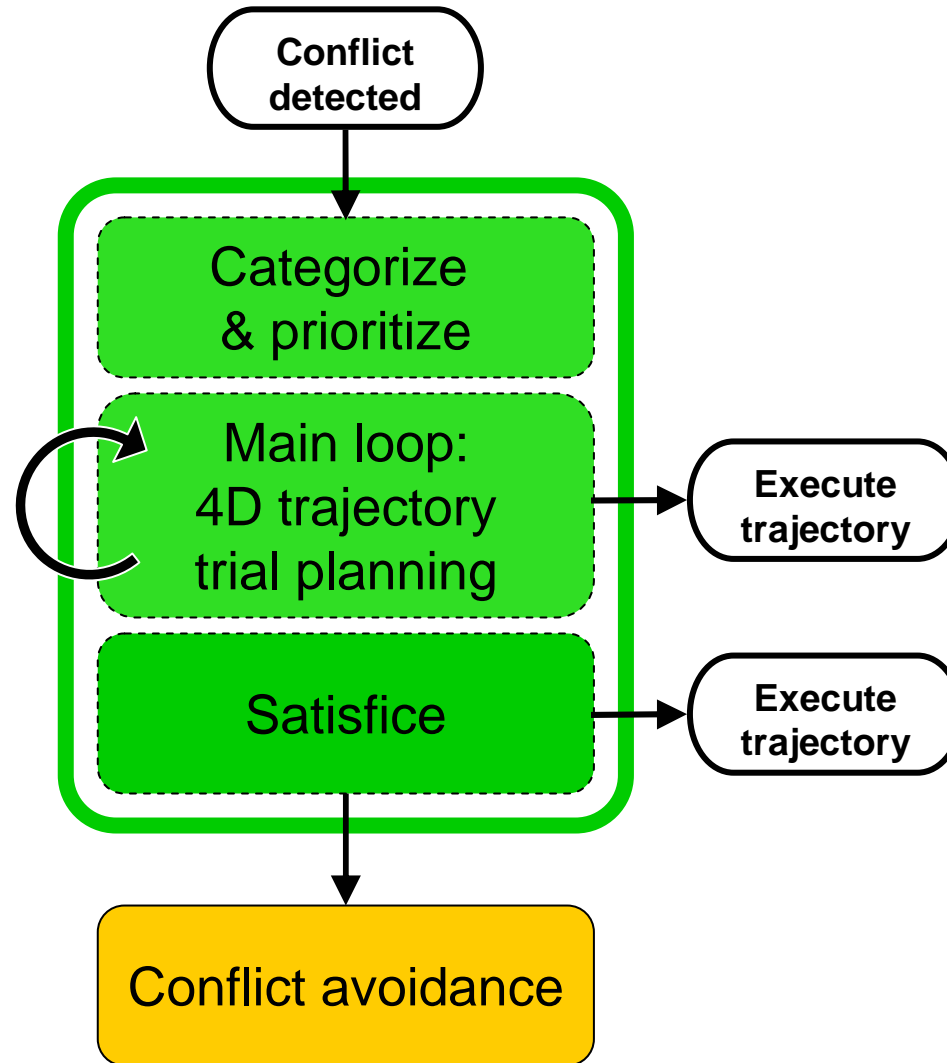
- Operational characteristics
 - All flight regimes
 - 2- to 20-minute time horizon

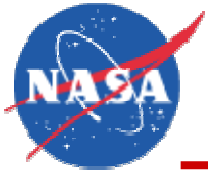
- Design characteristics
 - Pairwise
 - Maneuvers
 - ✧ Turns (path stretch), vertical maneuvers, speed changes
 - ✧ Either aircraft, not both
 - Optimized with respect to delay



AAC conflict resolution algorithm

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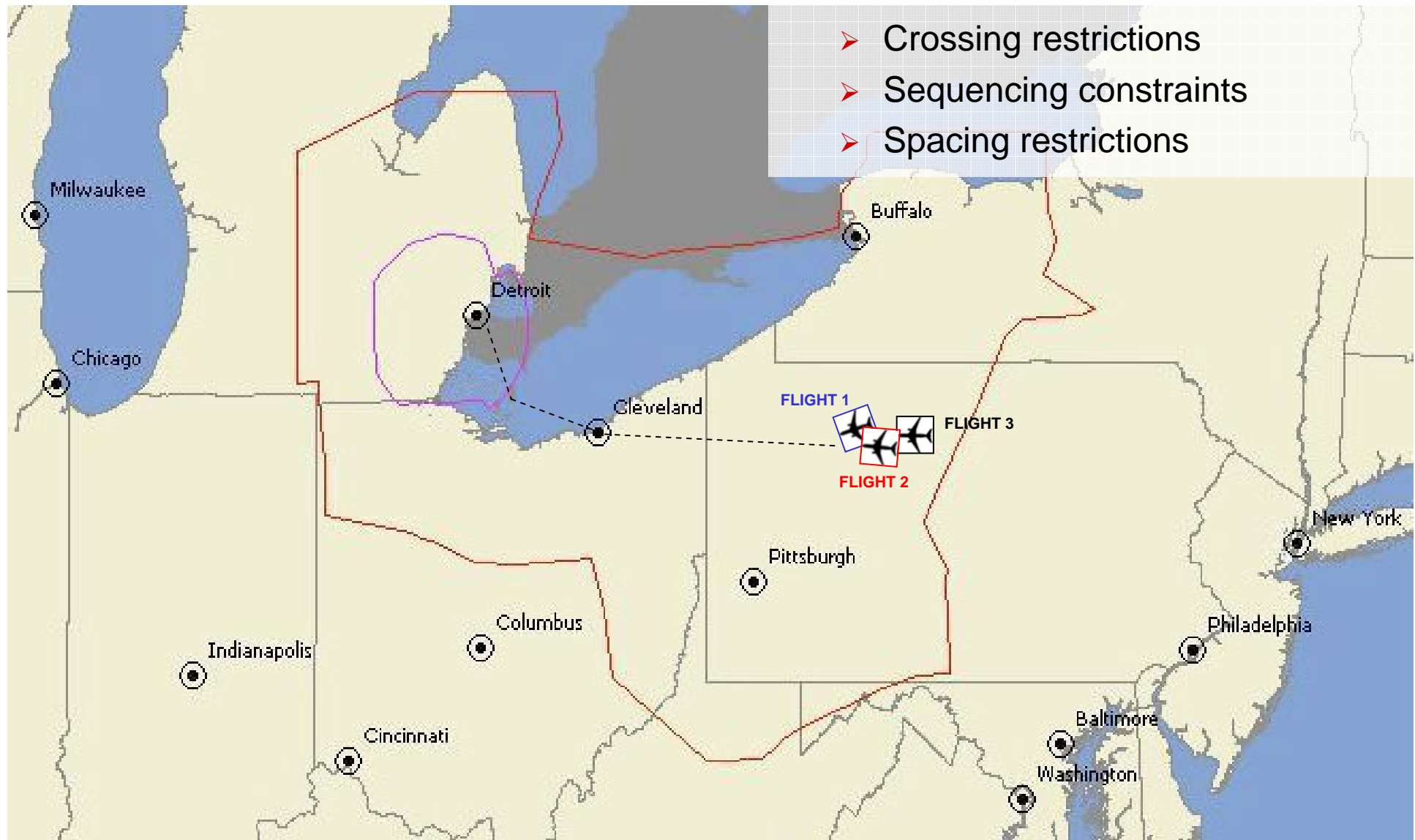


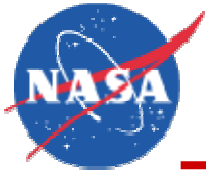
Example

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- In-trail conflict on arrival to Detroit

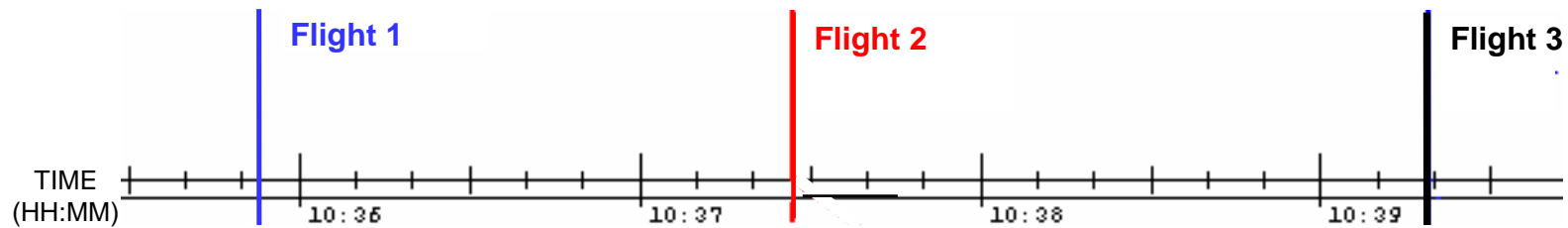
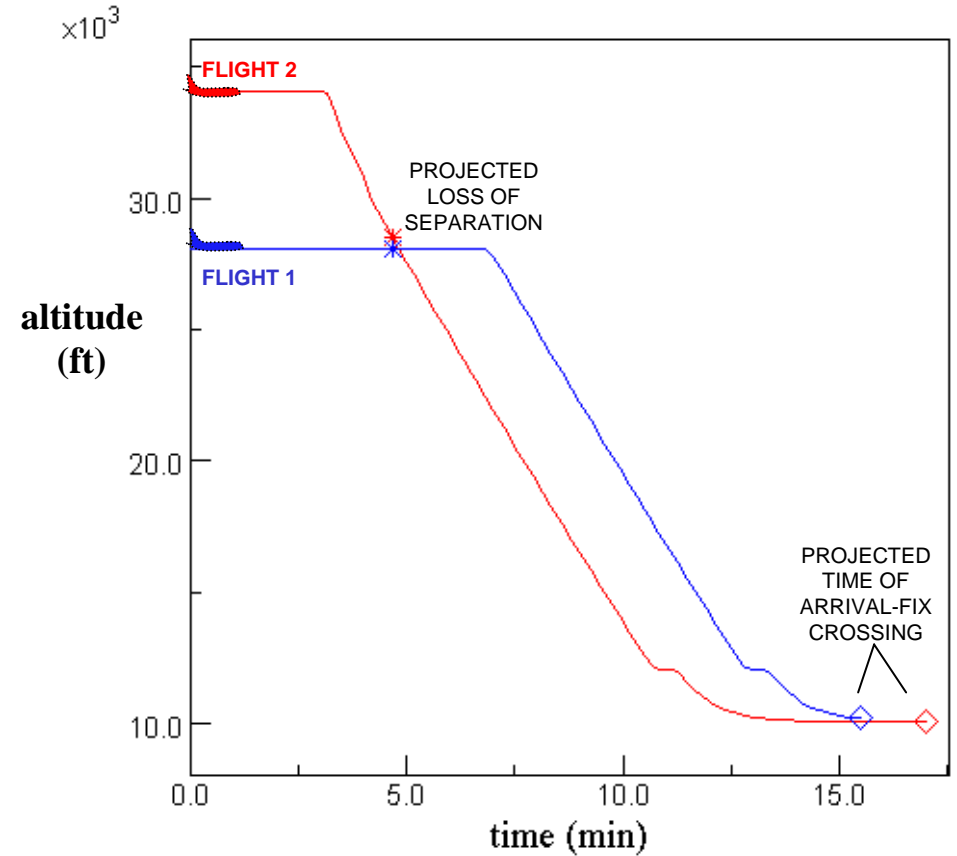
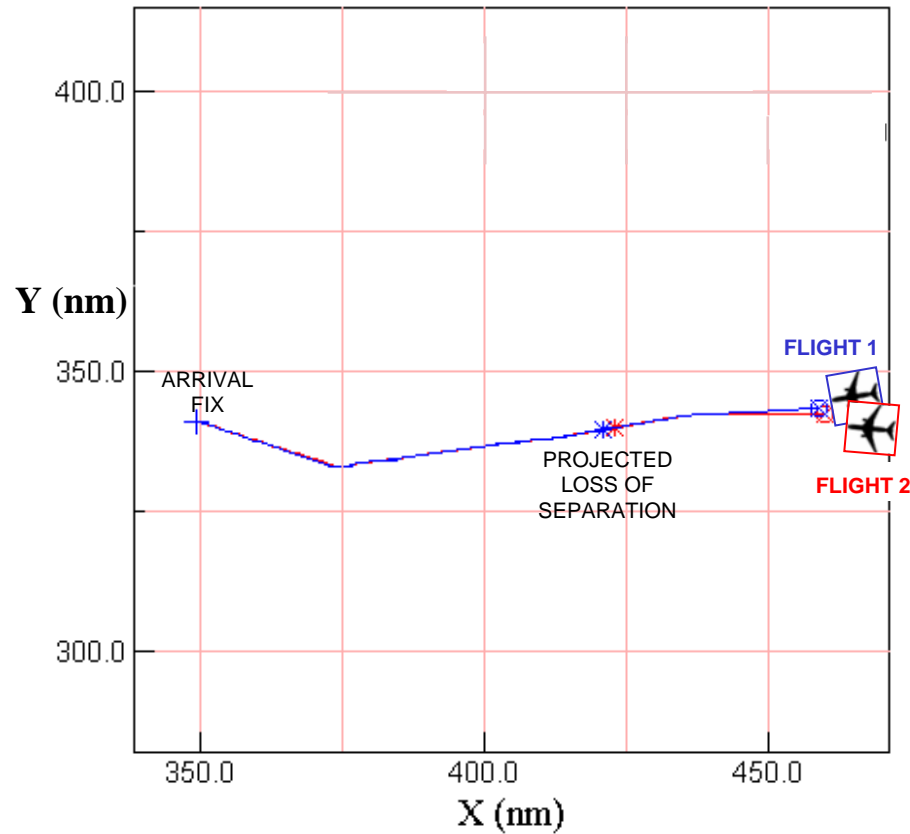
- Crossing restrictions
- Sequencing constraints
- Spacing restrictions

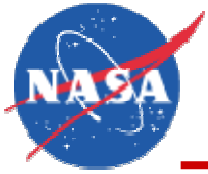




Example: arrival sequencing & spacing

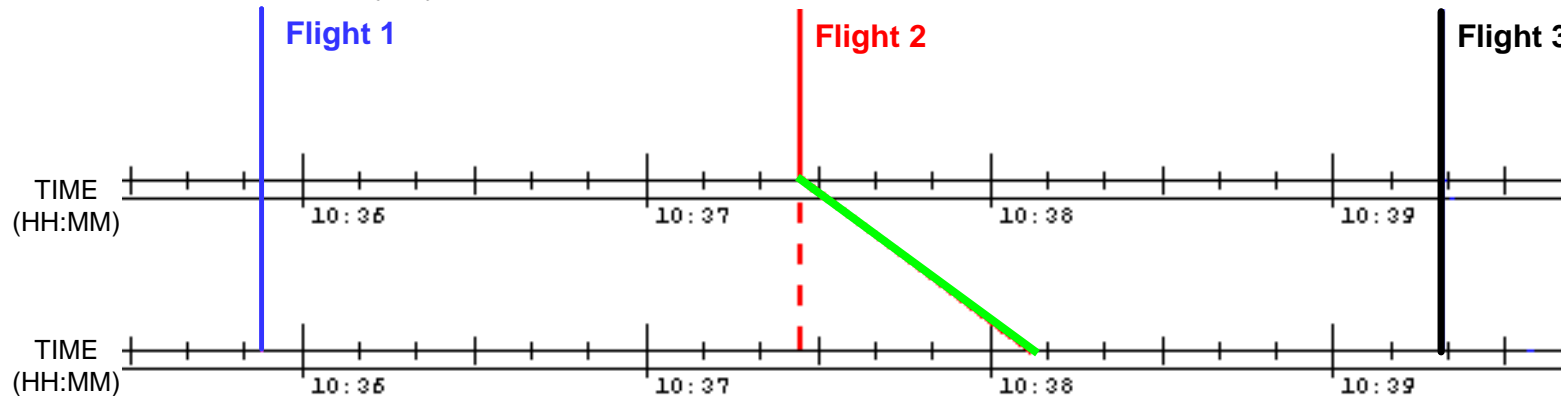
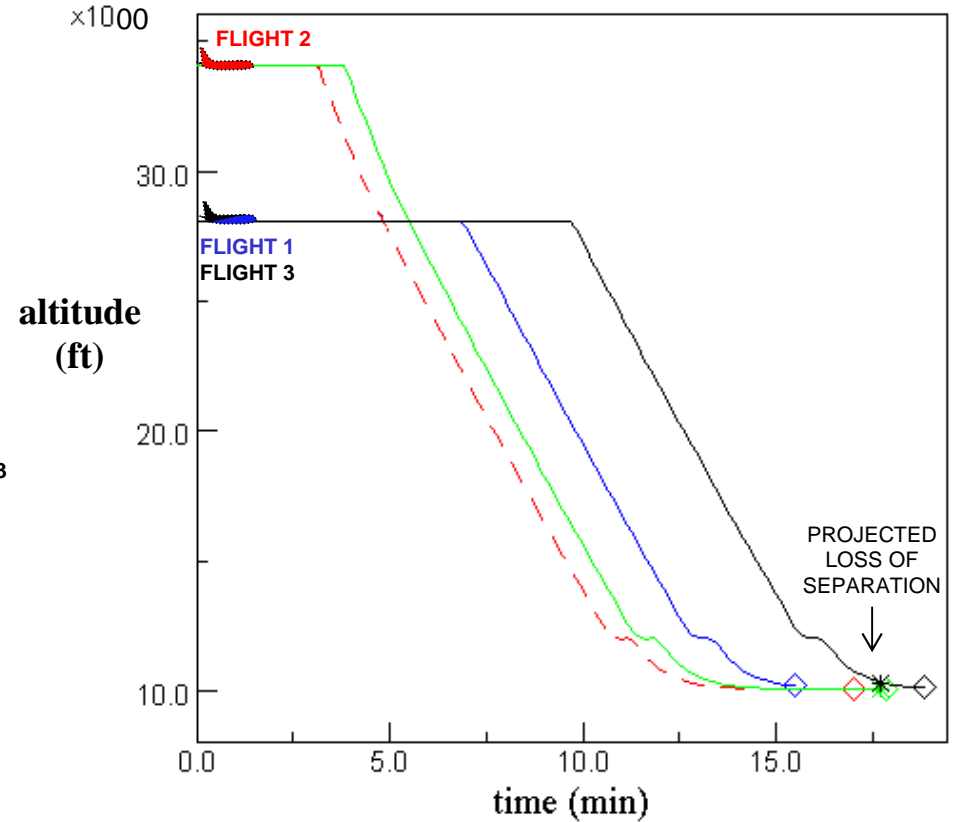
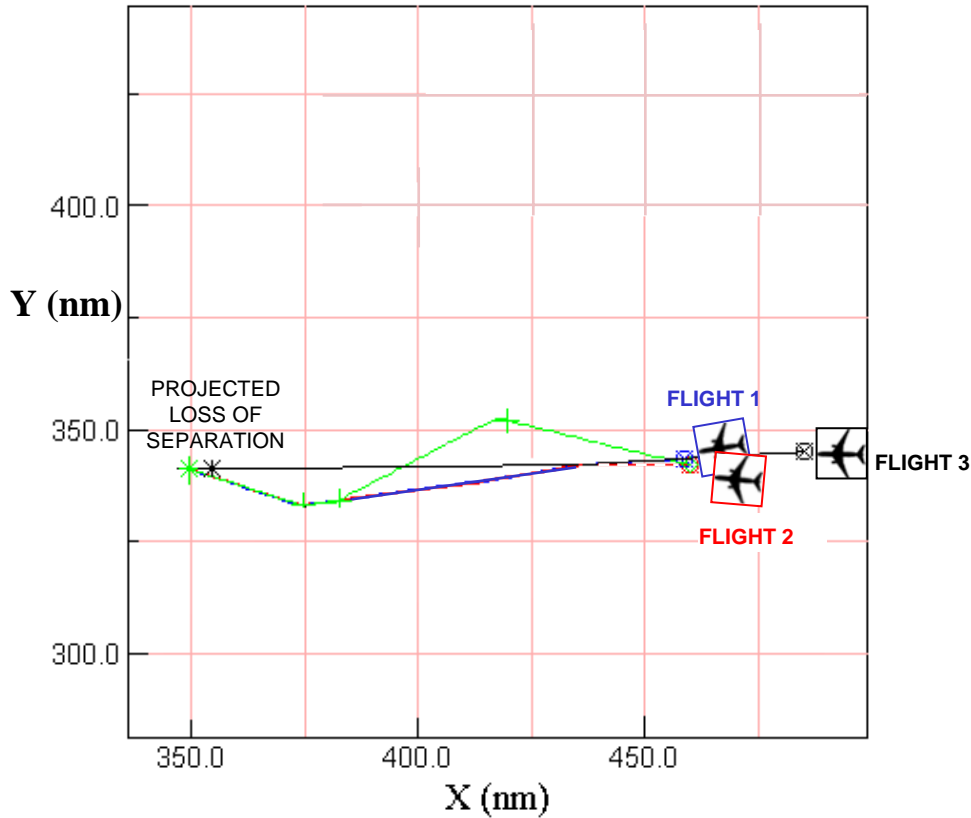
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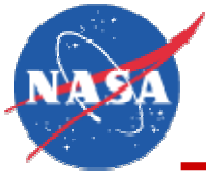




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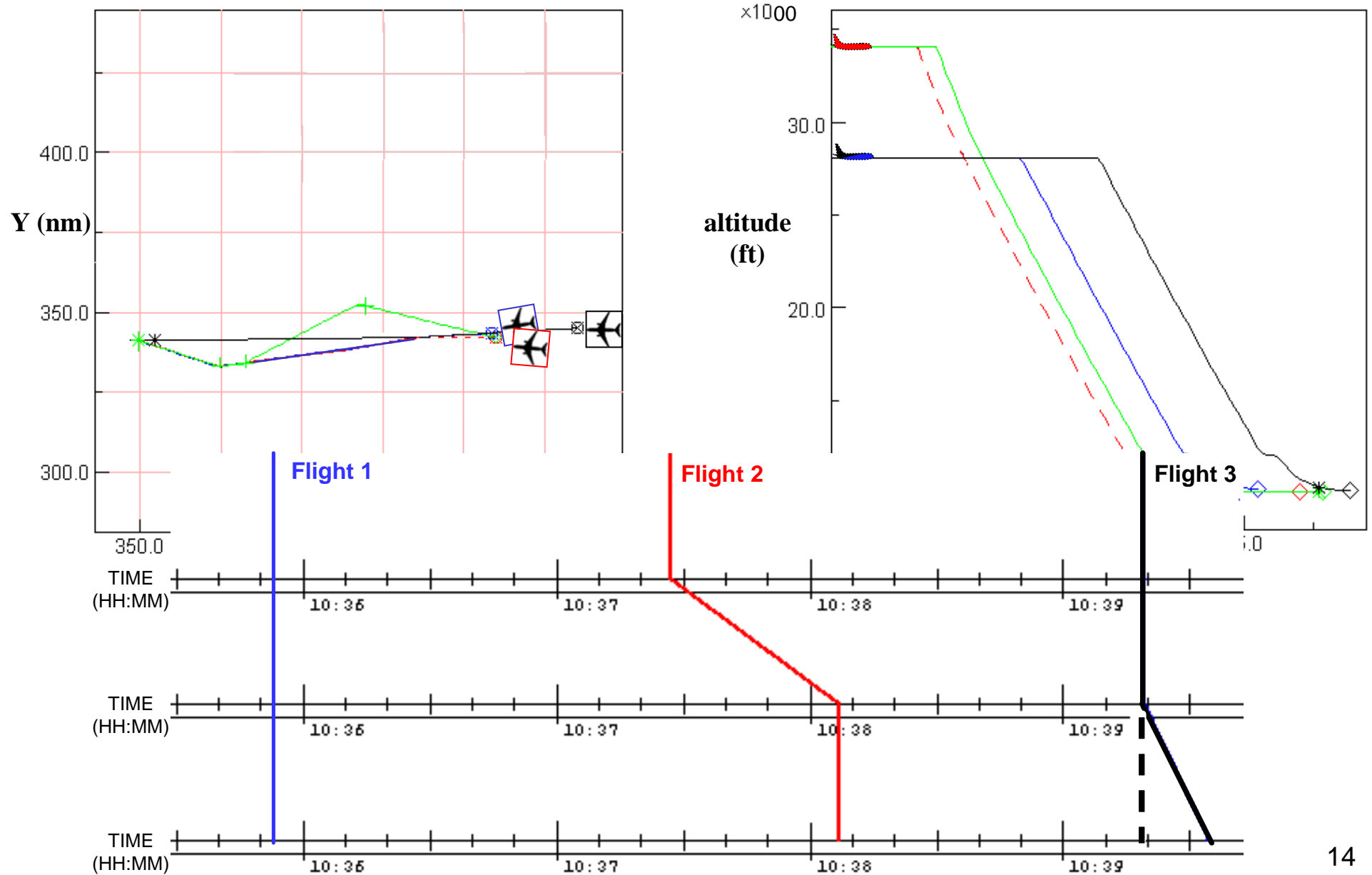
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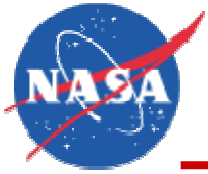




Example: arrival sequencing & spacing

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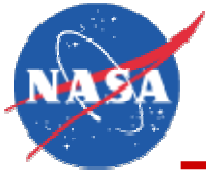




Motivation for the study

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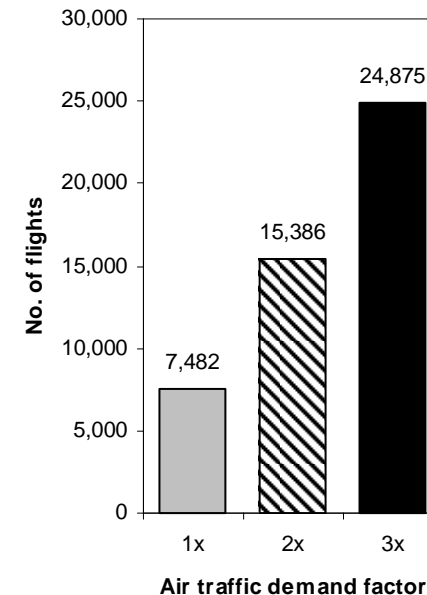
- Ample theoretical work
 - Pair-wise resolution strategies
 - Geometric studies
 - Genetic algorithms
- Need realistic performance assessments of candidate algorithms
 - Performance assessments need to include the **breadth and variety of conflict situations** that come with real-world operations
 - Need to develop a set of **accepted benchmarks** that place the results in context with those of other candidate conflict resolution algorithms

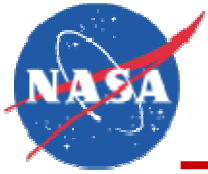


Research approach

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- Simulation study
 - Simulation test bed: Airspace Concept Evaluation System (ACES)
 - Fast-time; no human in the loop
- Representative, **unscripted** traffic
 - Cleveland en-route airspace
 - All flight regimes
 - Source data from April 21, 2005 (24 hrs)
 - ◇ Nominal traffic (“1x”): 7,482 flights
 - ◇ Double traffic (“2x”): 15,386 flights
 - ◇ Treble traffic (“3x”): 24,875 flights

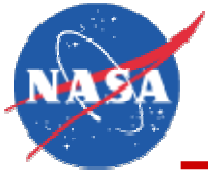




Modeling assumptions & simplifications

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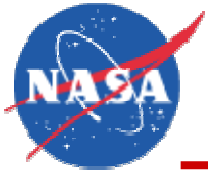
- No trajectory uncertainty
- No delay for trajectory exchange; no negotiation
- Arrival-fix conflicts not benchmarked in this study



Safety benchmarks

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	1x	2x	3x
Conflicts detected	490	1324	2380
Resolved in 4D trial planning loop	489 (99.8%)	1323 (99.9%)	2373 (99.7%)
Satisfice	1	1	2
Delegated	0	0	5
Not resolved	0	0	0

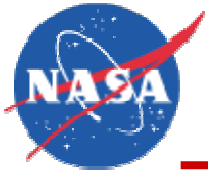


Safety benchmarks

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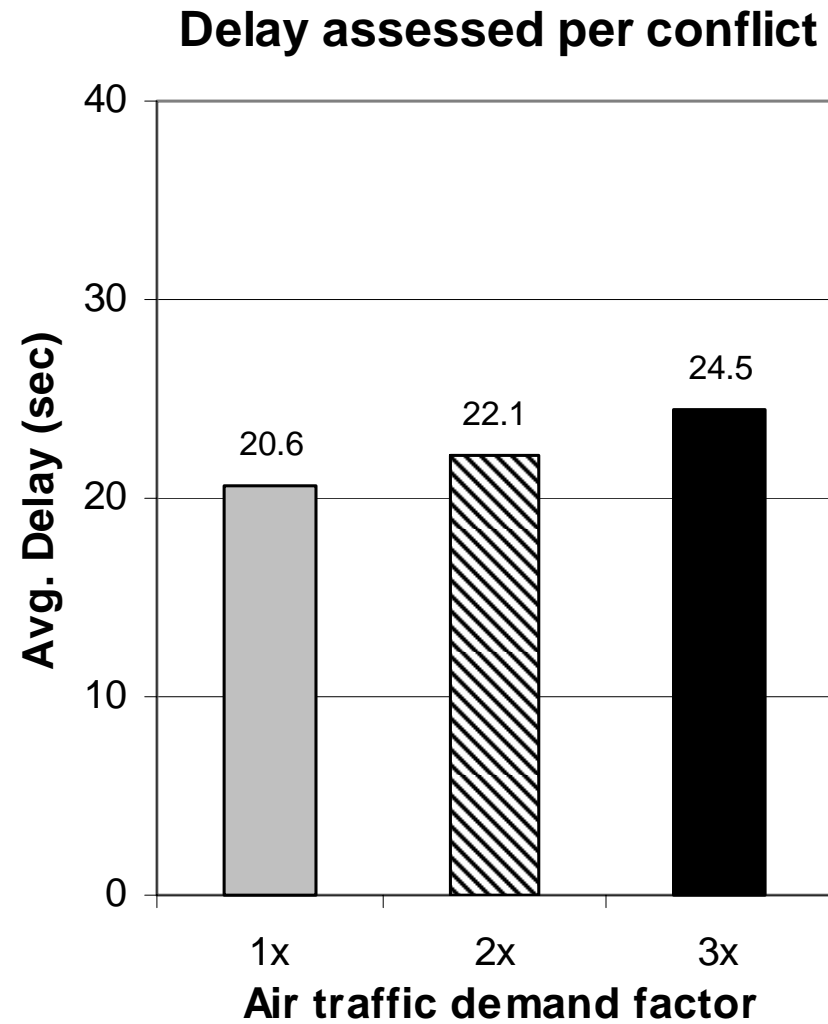
- ↻ Main loop
- Satisfice
- Conflict avoidance

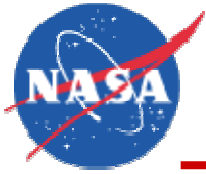
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Efficiency benchmarks

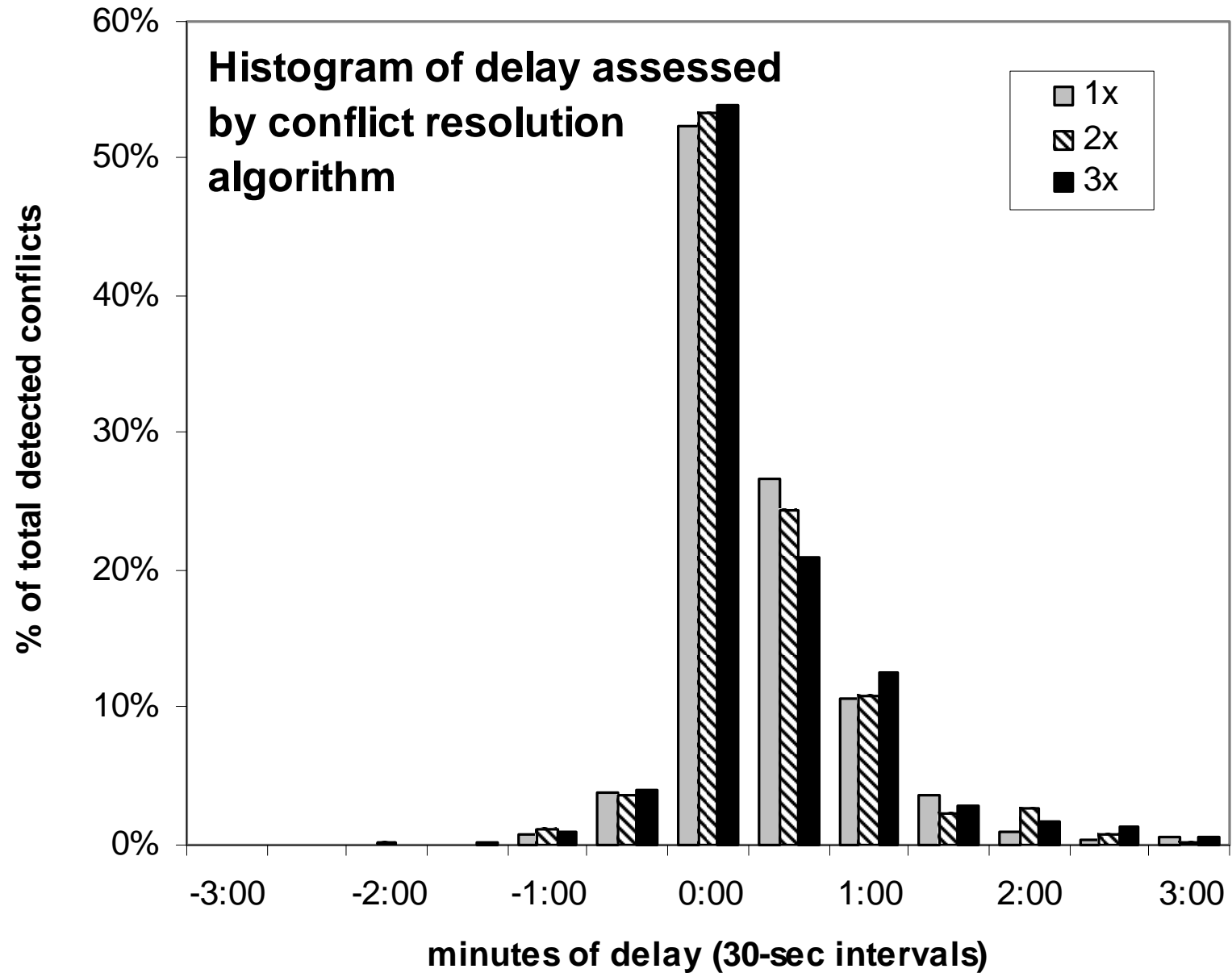
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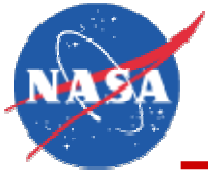




Efficiency benchmarks

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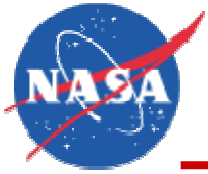


Summary

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- Conflict resolution algorithms maturing
 - Need realistic performance assessments
 - Need to adopt benchmarks that will put assessment results in context for the research community

- Contribution
 - Assessment protocol
 - Nominal set of benchmarks
 - Data point: AAC conflict resolution algorithm
 - ✧ Safety
 - 99.7% resolution rate at 3x traffic at today's busiest Center (exclusive of arrival-fix conflicts, and with no trajectory uncertainty)
 - 100% when supported with the AAC conflict avoidance function
 - ✧ Efficiency
 - <25 sec avg delay per resolution at 3x traffic
 - Delay distribution "Poisson-like"



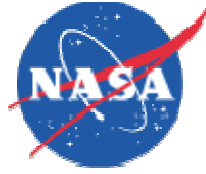
Future work

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- Simulation & modeling
 - Uncertainty models
 - Traffic management models

- Benchmarking
 - Arrival-fix conflicts
 - Develop benchmarks (insightful yet still generally applicable)

- Sensitivity studies
 - Traffic management initiatives
 - Airspace regions
 - Internal parameters (e.g., time horizons)
 - External parameters (e.g., uncertainties, lag times)



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