

Accuracy Required for Staging Arrival Spacing

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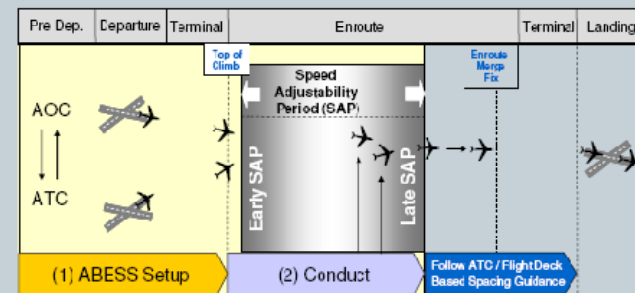
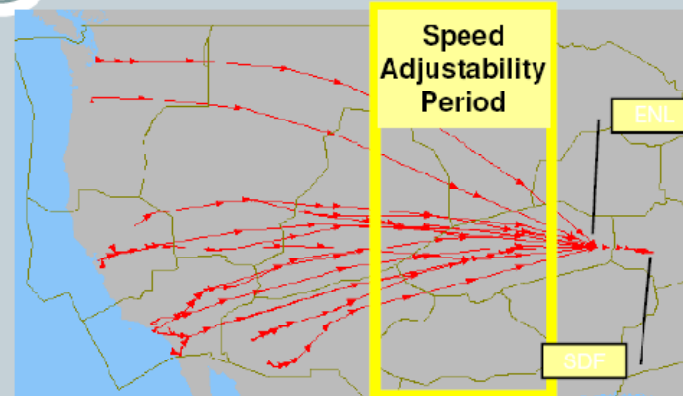
2009 Integrated Communications Navigation and Surveillance (ICNS) Conference

Presentation Outline

- Airline Based En Route Sequencing and Spacing (ABESS)
- Comparison of En Route Control Modes
- Cruise Speed Advisory Generation Algorithm
- Prediction Accuracy and Error Sources
- Modeling of Accuracy Requirements

Airline Based En Route Sequencing and Spacing

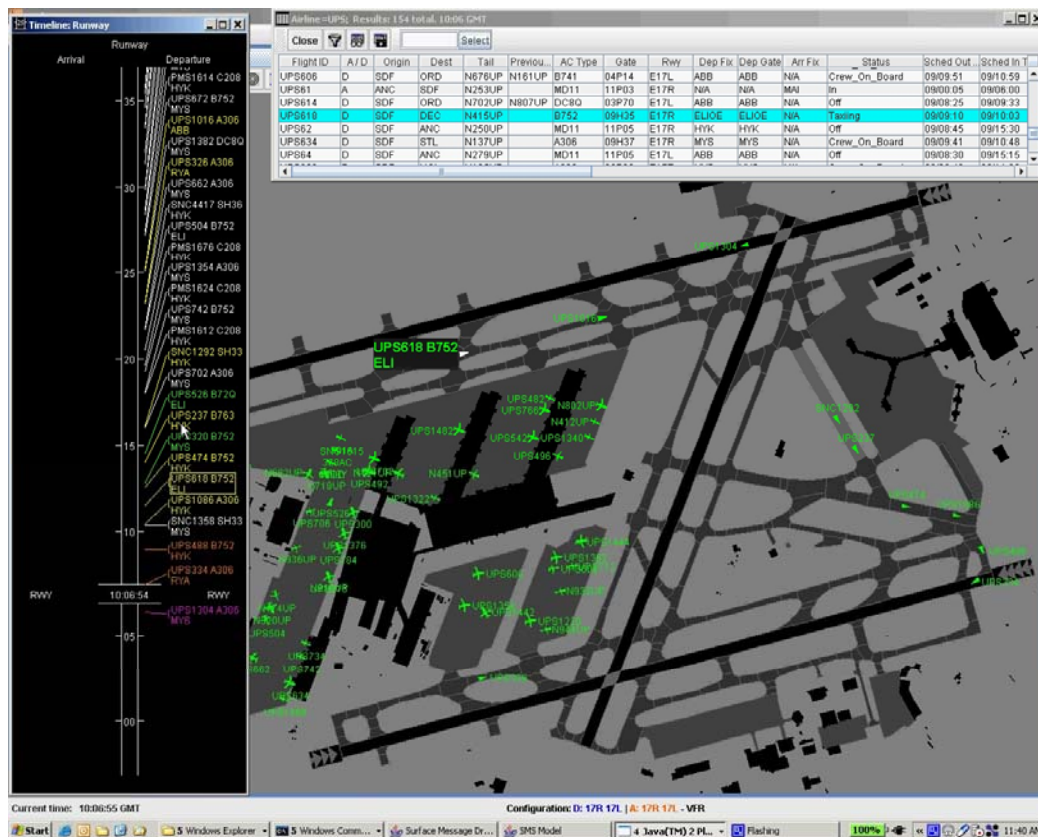
- ABESS is a concept of operations for the Airline Operations Center (AOC)
- Goal is to adjust the spacing of arrival aircraft at an enroute merge fix
 - by uplinking speed advisories
 - during the enroute phase of flight for
 - single merge stream
- The concept has been developed by the ABESS working group since spring 2005



Source: Mitre/CAASD and ABESS Working Group

Background

- How did Mosaic ATM get involved in the ABESS effort?
 - Through previous and current FAA-contracted effort, Mosaic ATM developed and deployed the Surface Management System (SMS) for operational use by UPS

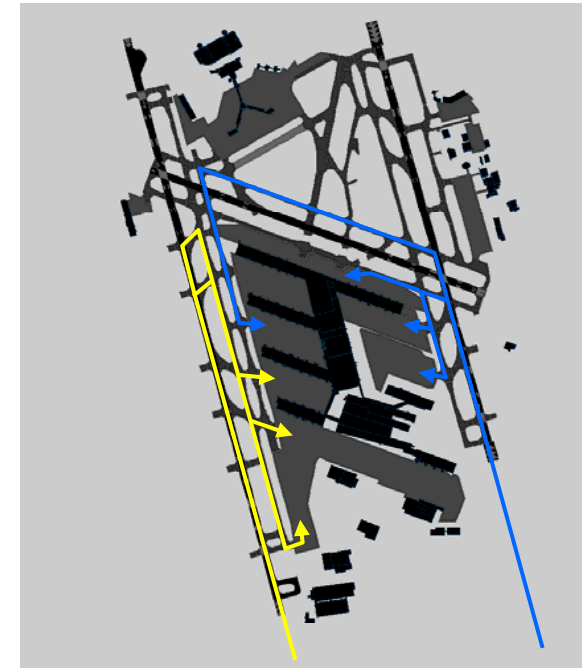
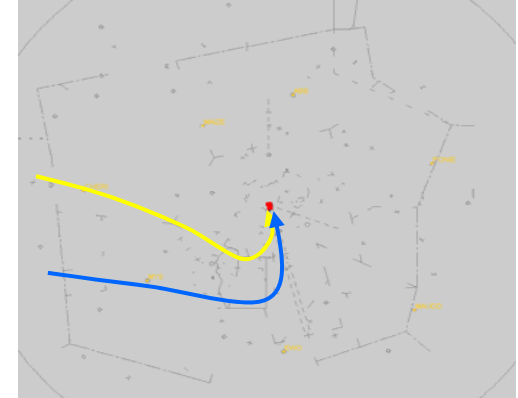


- UPS now has approximately 200 workstations configured and over 50 users trained for use of SMS in Louisville
- UPS uses SMS for ramp management and dispatch operations 24x7
- Mosaic ATM continues to provide support for SMS to UPS



SMS Role in ABESS Program

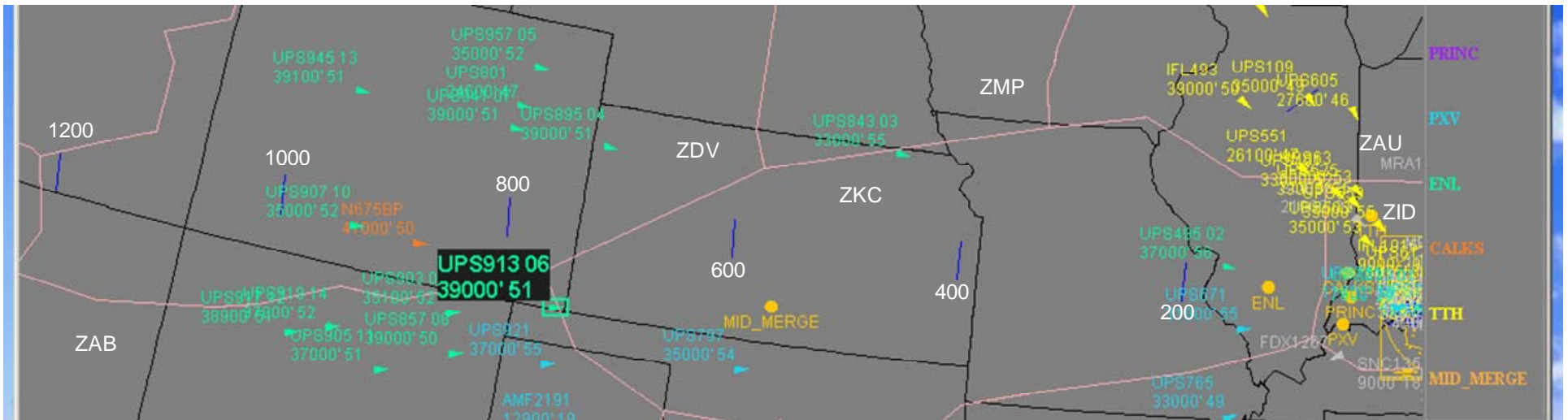
- The AOC Needs an Interface for Computing and Assigning Cruise Speed for Flights
 - UPS Dispatchers Already Familiar with SMS
 - Required Data Sources Available (or Easily Added)
 - Desire to Reduce Number of Different Systems/Displays in AOC
- Additional Benefits/Opportunities:
 - Using the Surface Data Available in SMS, Better Strategic Decisions can be Made
 - Ideal Procedure:
 - CDAs are Paired with Runway – Each CDA Feeds One Runway
 - Assign Flights to Continuous Descent Approach (CDA) Procedure
 - Choose Flight and CDA Based on Runway Utilization and Parking Gate Location
 - Maximize Use of Runway Capacity, and
 - Minimize Airport Surface Taxi Times and Surface Congestion



Objectives

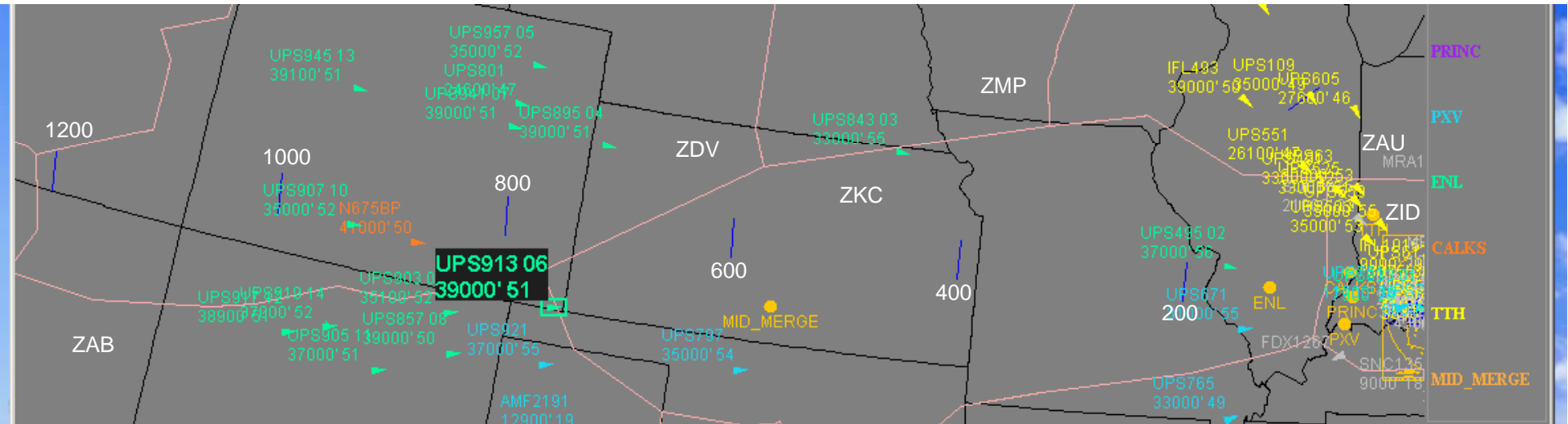
- Objectives of ABESS Procedures
 - Sequence and Stage Arrival Flights for Flight Deck Merging and Spacing (FDMS) Procedures
- Objectives of the ABESS Project
 - Evaluate and Identify the Performance Requirements for the ABESS Function
 - Perform Operational Evaluation of the ABESS and FDMS Concepts
 - Obtain Benefits Data from Operational Trials of ABESS and FDMS

Nominal Process Flow



- Identify flights of interest (merge fix-specific flight list)
 - Look for “bunching” of flights (spatially) with “close” ETAs at merge fix
 - Try to send speeds as early as feasible (after Top of Climb)
- Define nominal sequence based on:
 - ETA at merge fix
 - Current relative position and route
- Manually tweak sequence as desired
- Generate cruise speed constraint advisories w.r.t. separation constraint
- Enter “desired” Mach number(s) into table
- Send “desired” Mach number(s) to individual aircraft

ABESS Tool Overview



Current time: 05:04:46 GMT

Configuration: D: 35L 35R | A: 35L 35R - VFR

ABESS Tool Results: 14 total, 5:04 GMT

Close **1** Generate New Cruise Speed Adjust Sequence Required Time Separation (seconds): 150 Select

A...	Flight ID	Origin	Tail	AC Type	Status	ABESS Fix	ArrFix Time	Altitude	Mach	ABESS Req	Assigned	ABESS Pre...	ABESS Pr...	ABESS ...	ABESS TM...	ABESS TM...	ABESS TM...	Al
11	UPS801	DEN	N142UP	A306	En_Route	E21/06:23	E21/06:44	24600'	M0.76			0	0	876	ZDV	05:04:35	-6768	2
12	UPS495	OMA	N409UP	B752	En_Route	E21/05:07	E21/05:20	37000'	M0.79					36	ZKC	05:05:03	-432	2
13	UPS843	SLC	N131UP	A306	En_Route	E21/05:40	E21/05:54	33000'	M0.80			1920	367	341	ZKC	05:05:03	-3414	2
14	UPS895	RNO	N450UP	B752	En_Route	E21/06:12	E21/06:28	39000'	M0.81			1920	344	591	ZDV	05:04:35	-5261	2
15	UPS957	MHR	N173UP	A306	En_Route	E21/06:19	E21/06:49	35000'	M0.80			450	82	668	ZDV	05:04:35	-4718	2
16	UPS913	SNA	N402UP	B752	En_Route	E21/06:16	E21/06:30	39000'	M0.80			-110	-20	630	ZKC	05:05:03	6681	2
17	UPS941	SJC	N313UP	B763	En_Route	E21/06:21	E21/06:37	39000'	M0.79			610	108	676	ZDV	05:04:35	-4959	2
18	UPS857	PHX	N319UP	B763	En_Route	E21/06:31						610	107	721	ZAB	05:04:24	-6105	2
19	UPS903	LAX	N320UP	B763	En_Route	E21/06:31	E21/06:41	35100'	M0.79			110	20	721	ZAB	05:04:24	-6121	2
20	UPS907	BUR	N172UP	A306	En_Route	E21/06:36	E21/06:49	35000'				250	45	806	ZDV	05:04:35	-7323	2
21	UPS905	LGB	N328UP	B763	En_Route	E21/06:39	E21/06:50	37000'	M0.82			100	19	789	ZAB	05:04:24	-6682	2
22	UPS917	ONT	N401UP	B752	En_Route	E21/06:56	E21/06:57	38900'	M0.81			600	108	864	ZAB	05:04:24	-8453	2
23	UPS945	OAK	N315UP	B763	En_Route	E21/06:37	E21/06:53	39100'	M0.80			-1120	-200	816	ZDV	05:04:35	-5884	2
24	UPS919	ONT	N814UP	DC87	En_Route	E21/06:57	E21/06:53	37000'				1220	220	928	ZAB	05:04:24	-10064	2

ABESS Sequence #

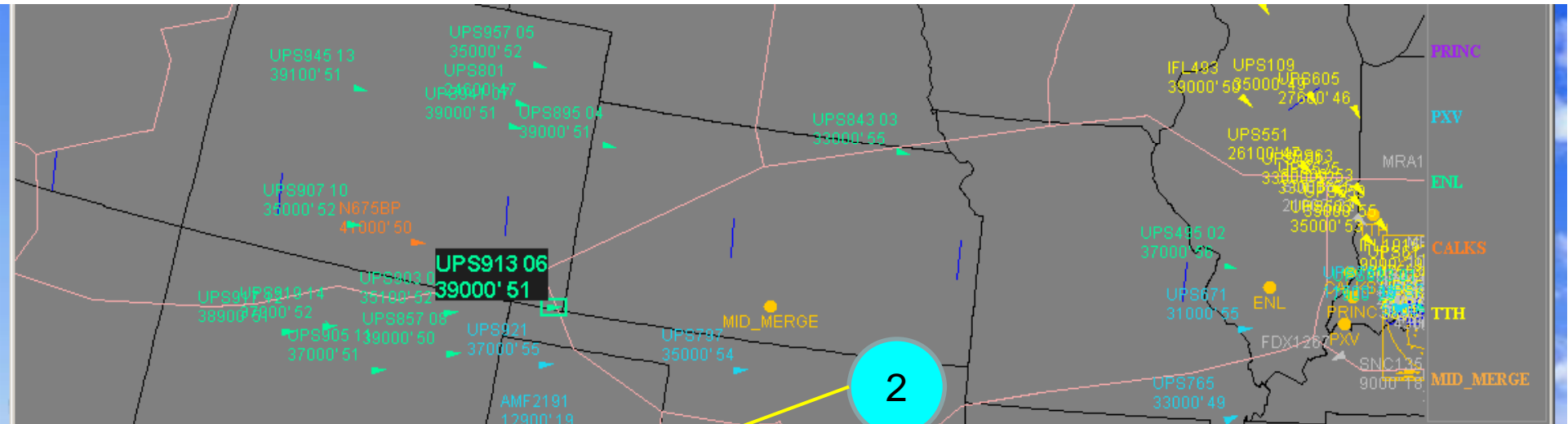
ETA @ MergeFix (TMA)

8

Prediction separation time (secs) and dist (nmi)



ABESS Tool Overview



Current time: 05:04:46 GMT

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ABESS Table: ENL Results: 14 total, 5:04 GMT

A...	Flight ID	Origin	Tail	AC Type	Status	ABESS Fix ...	ArrFix Time	Altitude	Mach	ABESS Req ...	Assigned	ABESS Pre...	ABESS Pr...	ABESS ...	ABESS TM...	ABESS TM...	ABESS TM...	AI
NA	UPS801	DEN	N142UP	A306	En_Route	E21/06:23	E21/06:44	24600'	M0.76			0	0	676	ZDV	05:04:35	-6768	2
02	UPS495	OMA	N409UP	B752	En_Route	E21/05:07	E21/05:20	37000'	M0.79			1920	367	341	ZKC	05:05:03	-3414	2
03	UPS843	SLC	N131UP	A306	En_Route	E21/05:40	E21/05:54	33000'	M0.80			1920	344	591	ZDV	05:04:35	-5261	2
04	UPS895	RNO	N450UP	B752	En_Route	E21/06:12	E21/06:28	39000'	M0.81			450	82	668	ZDV	05:04:35	-4718	2
05	UPS957	MHR	N173UP	A306	En_Route	E21/06:19	E21/06:49	35000'	M0.80	NFT M0.04								
06	UPS913	SNA	N402UP	B752	En_Route	E21/06:16	E21/06:30	39000'	M0.80	NFT M0.02	M0.80	-110	-20	630	ZKC	05:05:03	6681	2
07	UPS941	SJC	N313UP	B763	En_Route	E21/06:21	E21/06:37	39000'	M0.79	ST M0.03	M0.77	610	108	676	ZDV	05:04:35	-4959	2
08	UPS857	PHX	N319UP	B763	En_Route	E21/06:31	E21/06:43	39000'	M0.79	NFT M0.08	M0.79	610	107	721	ZAB	05:04:24	-6105	2
09	UPS903	LAX	N320UP	B763	En_Route	E21/06:31	E21/06:41	35100'	M0.79	ST M0.02	M0.77	110	20	721	ZAB	05:04:24	-6121	2
10	UPS907	BUR	N172UP	A306	En_Route	E21/06:36	E21/06:49	35000'	M0.79	ST M0.00	M0.77	250	45	806	ZDV	05:04:35	-7323	2
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13	UPS945	OAK	N315UP	B763	En_Route	E21/06:37	E21/06:53	39100'	M0.80	ST M0.12		-1120	-200	316	ZDV	05:04:35	-5884	2
14	UPS919	ONT	N814UP	DC87	En_Route	E21/06:57	E21/06:53	37000'	M0.80	NFT M0.03		1220	220	328	ZAB	05:04:24	-10064	2

Relative speed advisory

"Assigned" Mach



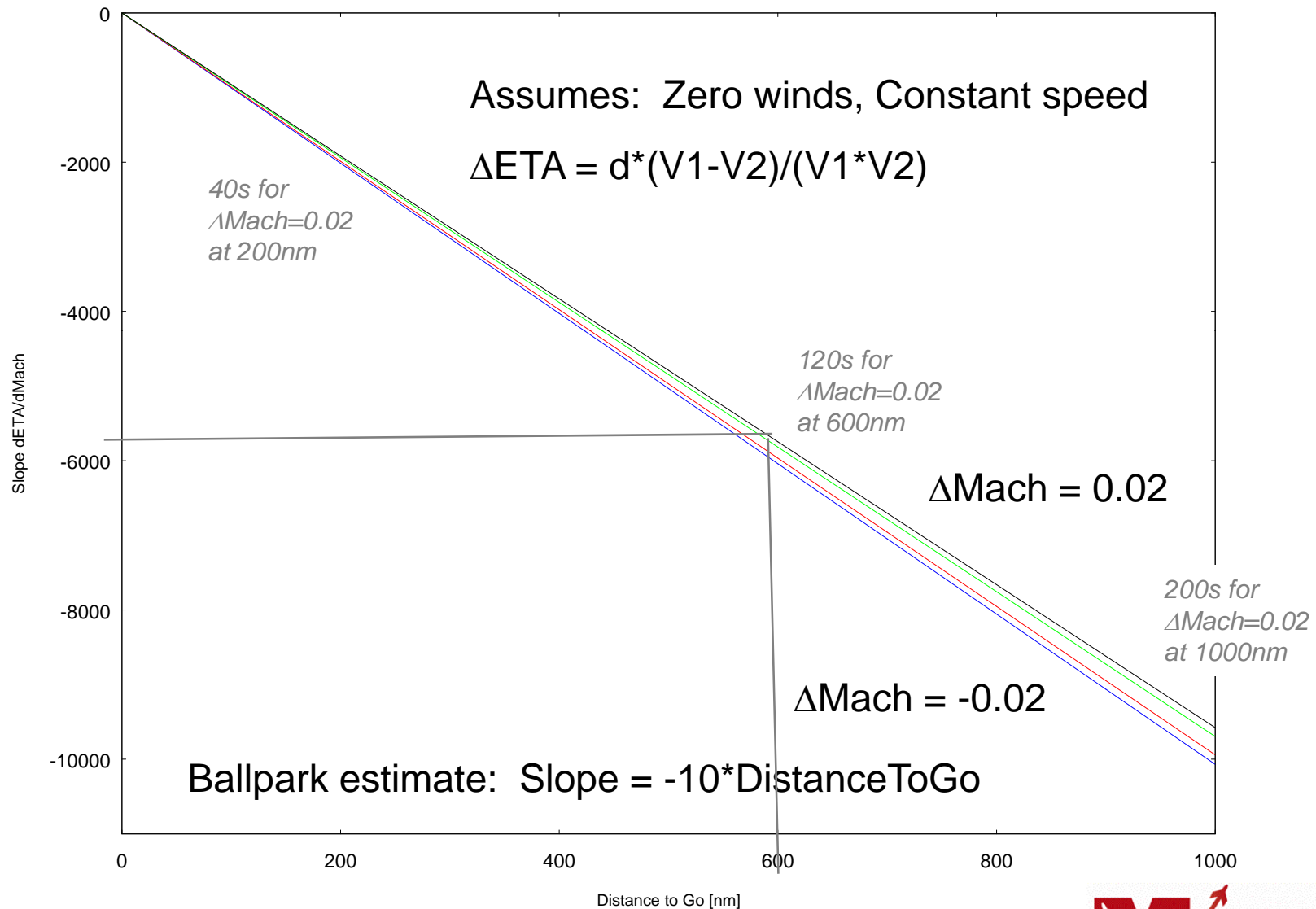
Comparison of En Route Control Modes

- Two En Route Control Modes:
 - Required Time of Arrival Assigned at Downstream Fix (RTA)
 - An Absolute Time Assigned as the RTA
 - Relative Spacing or Relative Speed Assigned (Relative)
 - Computed to Meet Required Spacing at Downstream Location
- RTA Control Mode:
 - Flights Can be Controlled Independently to Meet RTAs
 - With Sufficient Compliance Accuracy, Required Spacing is Met
 - Disadvantage: RTAs May Contain Unnecessary Delay due to Prediction Errors
- Relative Control Mode:
 - Spacing is Achieved, but Assigned Arrival Time is Flexible
 - Flights can Speed Up to Achieve Earlier Arrival Time
 - Disadvantage: Dependence on Relative Control can Cause Negative Feedback and Divergence

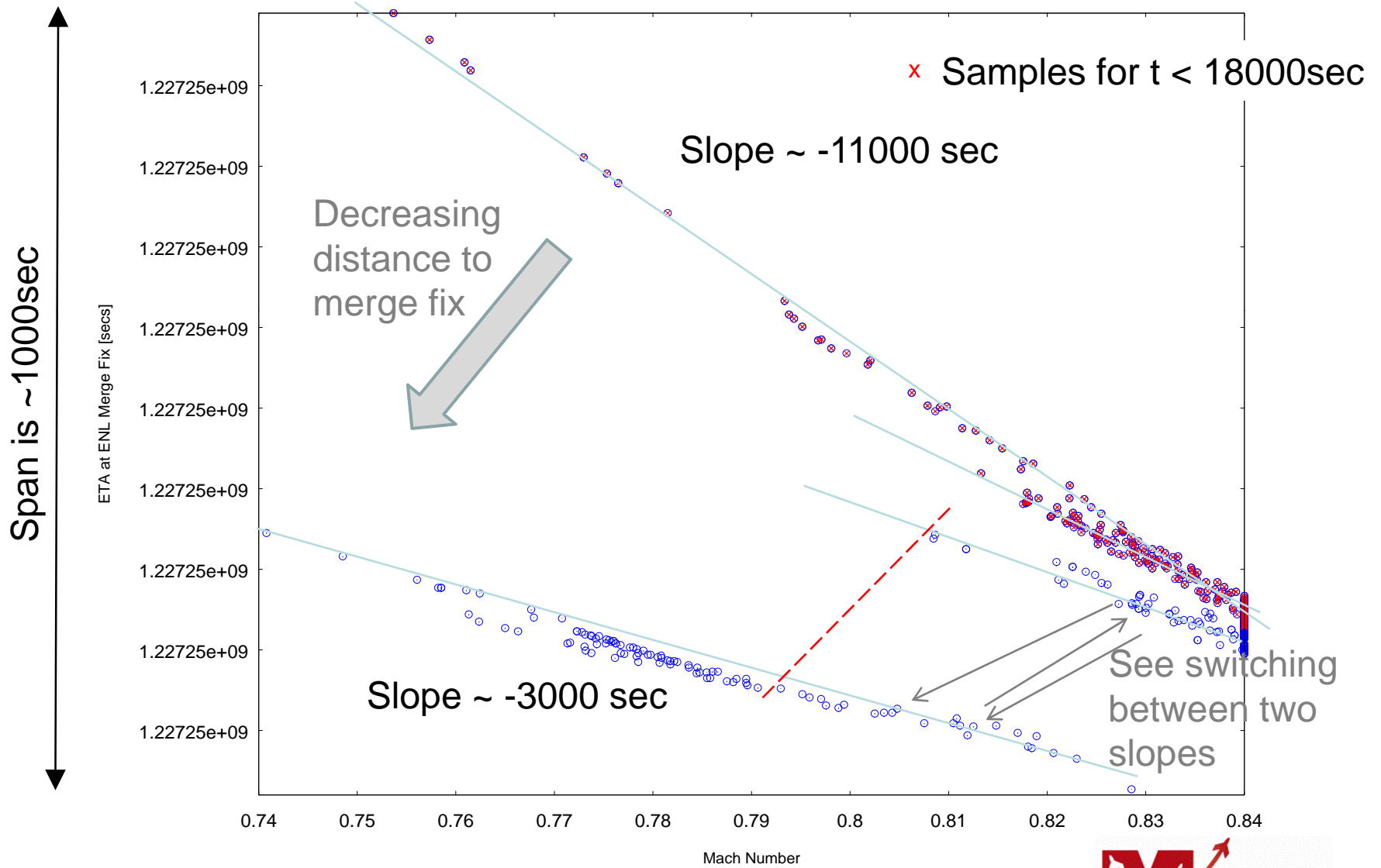
ABESS Tool – Core Modeling

- Based on “noise” or natural variation of ETA as a function of Mach number propagated by TMA
 - Each update, TMA estimates airspeed (based on radar update)
 - TMA propagates airspeed to create future trajectory and time of arrival at downstream points along flight plan
- Periodically query TMA database to get trajectory updates
- Create a polynomial fit to a set of $ETA = f(Mach)$ measurements
 - Only add point if “sufficient” Mach variation
 - Estimate slope: $dETA/dMach$
 - Weighted to favor most recent samples
- Utilize $dETA/dMach$:
 - as means for extrapolating effect of cruise speed changes on predicted separation, and
 - to remove ETA instability due to noisy cruise speed estimation

Ideal Variation in Slope as f(Dist)



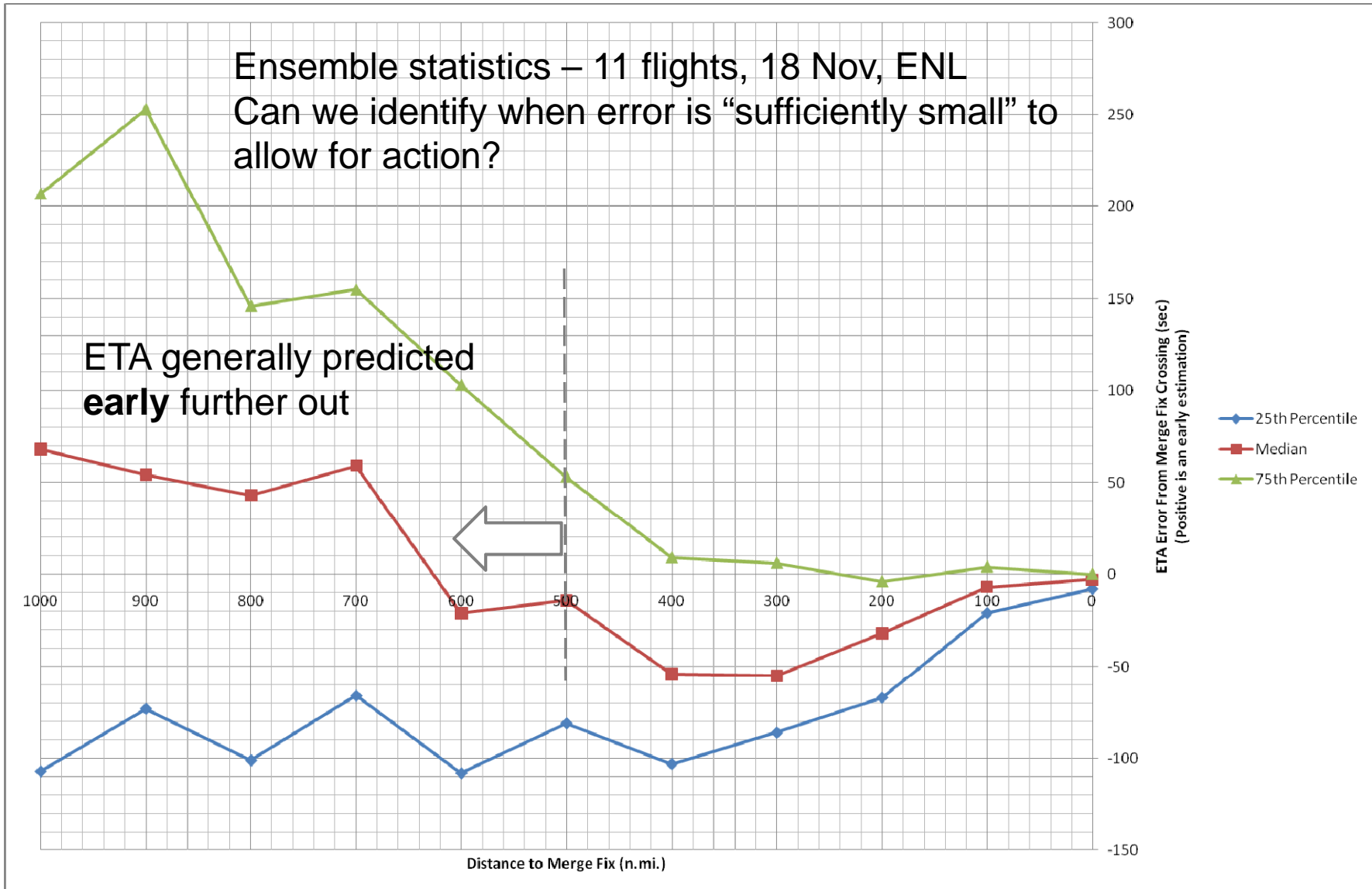
Time History – Slope vs. Mach (UPS895)



Cruise Speed Advisory Generation Algorithm

- Assume Target Spacing at Merge Fix Provided: e.g. 150 seconds
- Assume ABESS Operator Assigns Cruise Speed for Leading Flight
- Algorithm:
 - For Each Subsequent Flight in Sequence
 - Find Target Merge Fix Crossing Time
 - Previous Flight Target Time + Target Spacing
 - Use Current dETA/dMach Line to Find Necessary Mach Speed to Meet Target Merge Fix Crossing Time

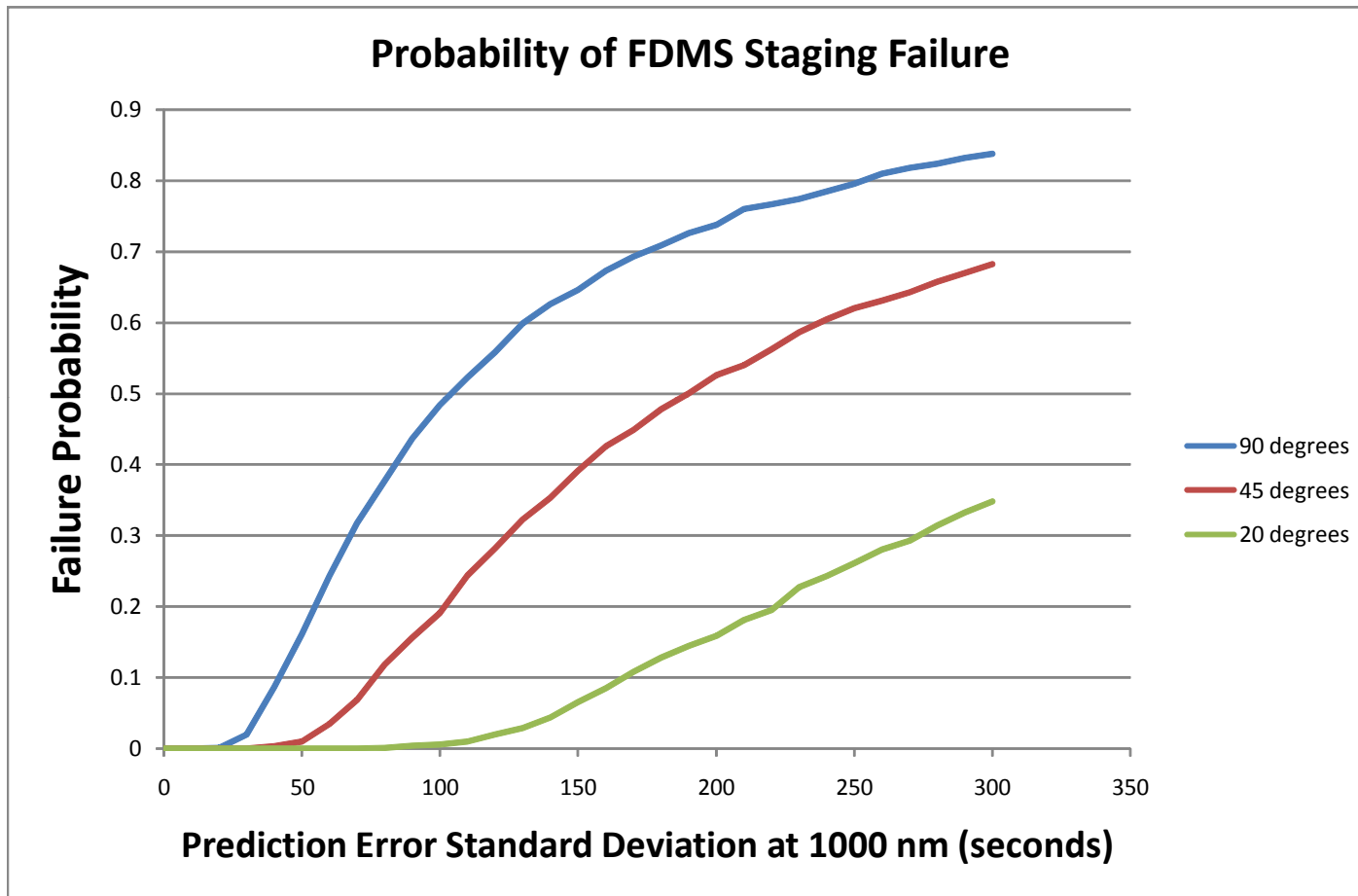
Examine ETA prediction error = f(dist)



Trajectory Prediction Error Sources

- Open Loop Prediction
 - No Ability to Control the Flight – just Predicting its Arrival
 - Error Sources
 - Surveillance Error
 - Route and Altitude Error
 - Wind Error
 - Flight Speed Error
- Closed Loop Prediction
 - Speed Control Available to Control Arrival Time
 - Error Sources
 - Surveillance Error
 - Route and Altitude Error
 - Wind Error
 - Flight Speed Adherence Error

Accuracy Requirements Analysis – 2 Flights

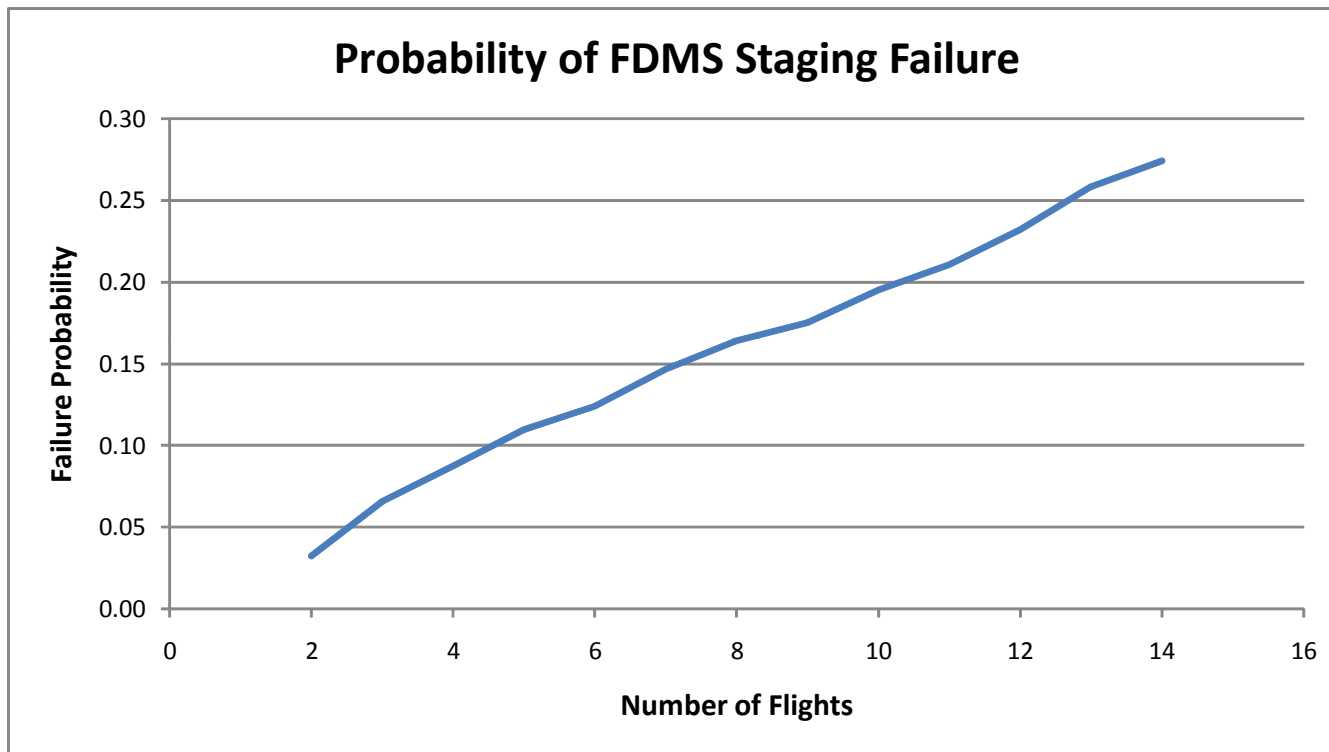


Assumptions:

- Two Speed Control Opportunities; 1st at 1000 nm from merge fix, 2nd at 500 nm
- Allowable Speed Adjustment Range is 0.08 Mach
- Prediction Error Standard Deviation at 500 nm is 50% of the Standard Deviation at 1000 nm
- Prediction Errors are Uncorrelated



Accuracy Requirements Analysis – Multiple Flights



Assumptions:

- Two Speed Control Opportunities, 1st at 1000 nm from merge fix, 2nd at 500 nm
- Prediction Error Standard Deviation at 1000 nm is 60 seconds
- Prediction Error Standard Deviation at 500 nm is 30 seconds
- FDMS Convergence Angle is 45 degrees

Conclusions and Next Steps

- Based on the Current Assumptions, FDMS Staging Failure is Likely for Multiple Flights
 - Assumptions Need to be Reviewed and Validated
 - Additional Modeling Recommended with Revised Assumptions
- Can 'Hedging' of Cruise Speed Advisories Improve Performance?
 - Probabilistic Selection of Smaller Cruise Speed Adjustment Earlier in Flight