Metron Aviation R&D Activities

Outline

- Introduction
- Overview of Select Projects
- Recent Findings

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TFM R&D Program Elements

- Enhanced Data Exchange
- Enhanced Arrival/Departure Management
- Congestion Management
- Performance Assessment
- System Impact Assessment

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Metron Aviation Major Efforts

Work Item	Enhanced Data Exchange	Enhanced Arrival & Departure	Congestion Management	Performance Assessment	System Impact Assessment
FSM	X	X			X
FSA				X	
ADC/DDP	X	X			
* RMT			X		
* POET				X	
* Cflow				X	X
* Complexity and En route Throughput Analysis					X
* Demand Uncertainty & Congestion Prediction		X	X		X
* CR Resource Allocation Methods & Evaluation			X		X
* GDPE/FSM Research & Arrival/Departure Throughput R&D		X			X
CIDB Infrastructure				X	X
CDM Analysis		X		X	
Surface Mgmt Technology Integration	X	X			

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RMT R&D

- New Tables
  - National Playbook (CR Workshop)
  - Advanced Navigation Routes (CR Workshop)
  - Special Events Routes (ATCSCC)
  - ACES data - PARs, PDRs, PDARs (RAT Team)
  - Additional NFDC tables – Fixes, STARS, Airways, Navaids
- New Capabilities
  - Global Modifications/Error Reporting Capabilities
  - Search by Centers that a Route Goes Through (ATCSCC, CR Workshop)
  - Comment Capability for all users (CR Short Term Meeting)
  - New Reporting Capabilities
  - Export CDRs to a STEREO File (CR Workshop)
  - Weather - Overlay weather (CCFP) on RMT Map

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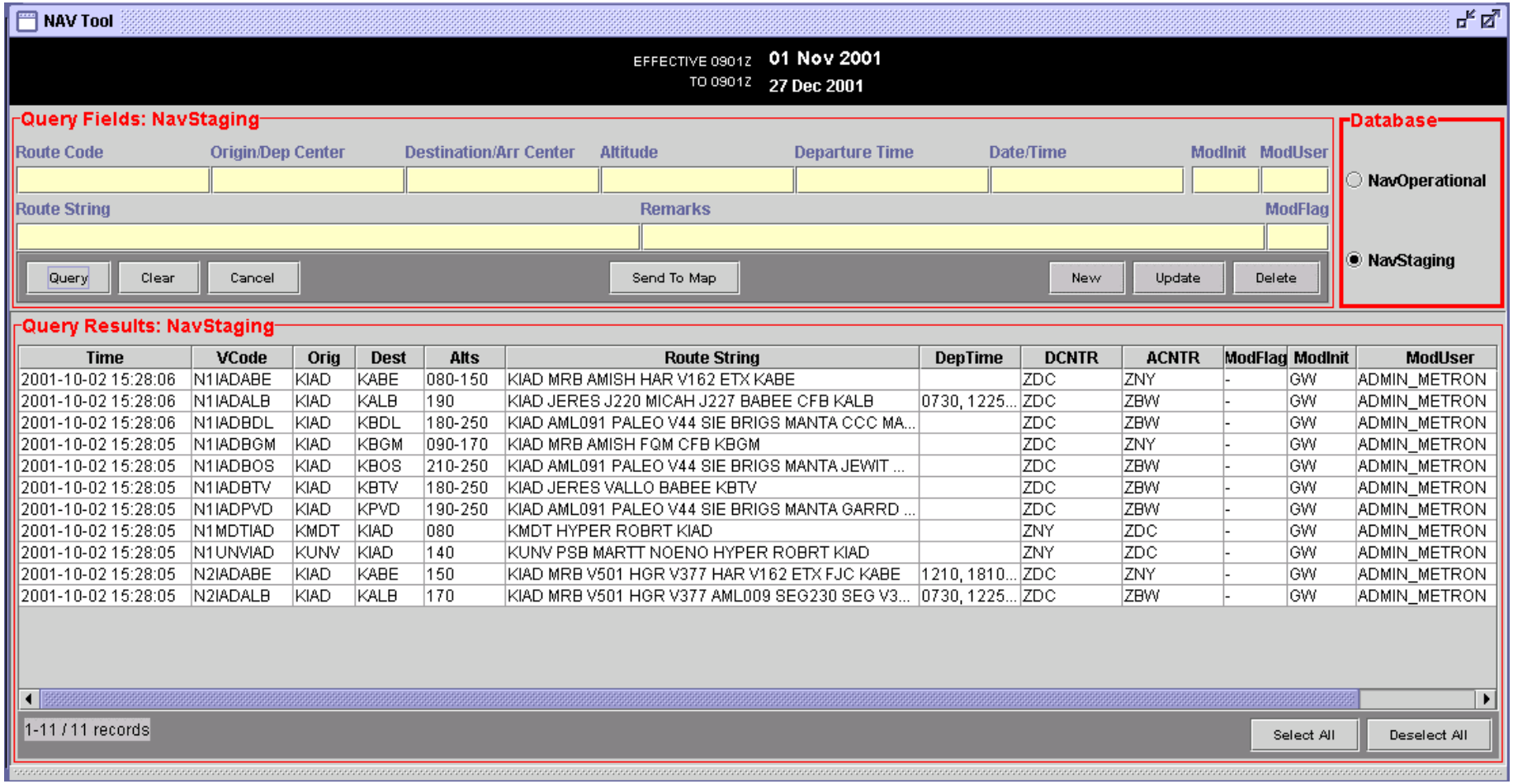
RMT 1.2 preview

New “Nav Tool” showing advanced Nav routes



Time	VCode	Orig	Dest	Alts	Route String	DepTime	DCNTR	ACNTR	ModFlag	ModInit	ModUser
2001-10-02 15:28:06	N1IADABE	KIAD	KABE	080-150	KIAD MRB AMISH HAR V162 ETX KABE		ZDC	ZNY	-	GW	ADMIN_METRON
2001-10-02 15:28:06	N1IADALB	KIAD	KALB	190	KIAD JERES J220 MICAH J227 BABEE CFB KALB	0730, 1225...	ZDC	ZBW	-	GW	ADMIN_METRON
2001-10-02 15:28:06	N1IADBDL	KIAD	KBDL	180-250	KIAD AML091 PALEO V44 SIE BRIGS MANTA CCC MA...		ZDC	ZBW	-	GW	ADMIN_METRON
2001-10-02 15:28:05	N1IADBGM	KIAD	KBGM	090-170	KIAD MRB AMISH FQM CFB KBGM		ZDC	ZNY	-	GW	ADMIN_METRON
2001-10-02 15:28:05	N1IADBOS	KIAD	KBOS	210-250	KIAD AML091 PALEO V44 SIE BRIGS MANTA JEWIT ...		ZDC	ZBW	-	GW	ADMIN_METRON
2001-10-02 15:28:05	N1IADBTV	KIAD	KBTV	180-250	KIAD JERES VALLO BABEE KBTV		ZDC	ZBW	-	GW	ADMIN_METRON
2001-10-02 15:28:05	N1IADPVD	KIAD	KPVD	190-250	KIAD AML091 PALEO V44 SIE BRIGS MANTA GARRD ...		ZDC	ZBW	-	GW	ADMIN_METRON
2001-10-02 15:28:05	N1MDTIAD	KMDT	KIAD	080	KMDT HYPER ROBRT KIAD		ZNY	ZDC	-	GW	ADMIN_METRON
2001-10-02 15:28:05	N1UNVIAD	KUNV	KIAD	140	KUNV PSB MARTT NOENO HYPER ROBRT KIAD		ZNY	ZDC	-	GW	ADMIN_METRON
2001-10-02 15:28:05	N2IADABE	KIAD	KABE	150	KIAD MRB V501 HGR V377 HAR V162 ETX FJC KABE	1210, 1810...	ZDC	ZNY	-	GW	ADMIN_METRON
2001-10-02 15:28:05	N2IADALB	KIAD	KALB	170	KIAD MRB V501 HGR V377 AML009 SEG230 SEG V3...	0730, 1225...	ZDC	ZBW	-	GW	ADMIN_METRON

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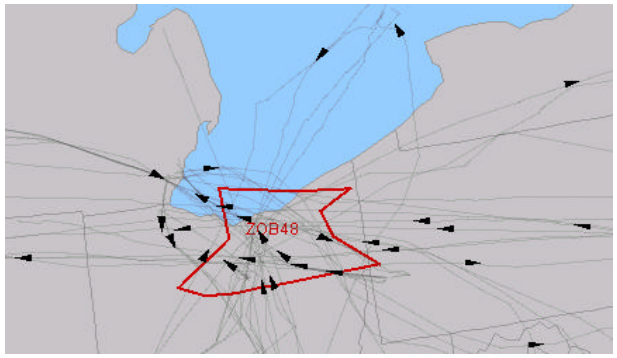
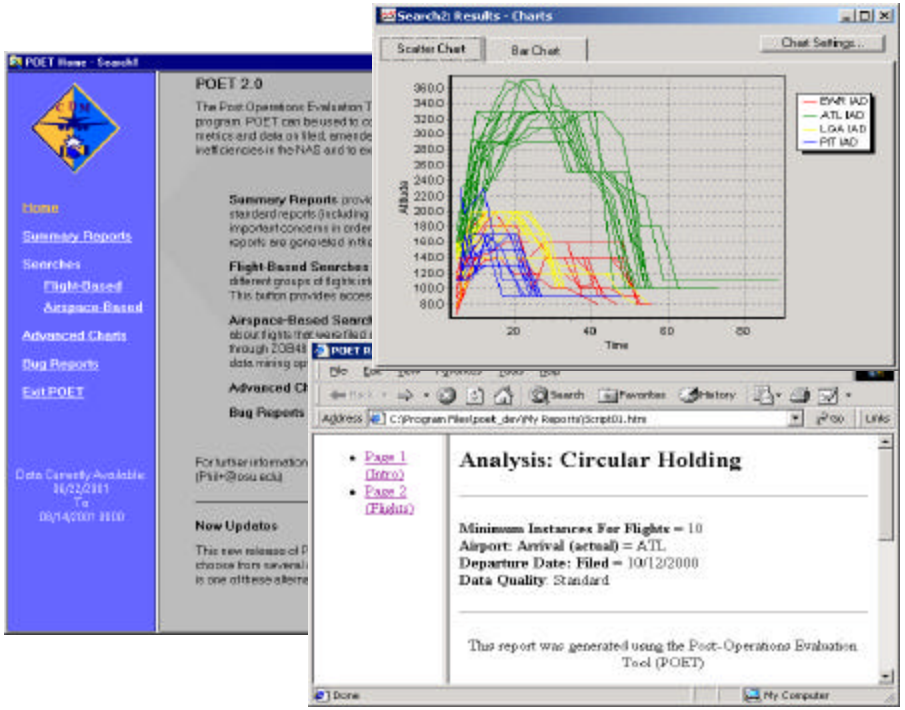
POET Status



- POET v1.5 released in April
  - Event Replay functionality
  - New performance metrics
  - GUI enhancements



- POET v2.0 released in July
  - Canned Summary Reports (analysis scripts)
  - Advanced charting (e.g., altitude profiles, traffic flow (delivery) graphs—over fixes, thru sectors, into airports)
  - New data mining algorithms & “plug-in” architecture
  - Reorganized search builder

- NRT data access (~1 hr late)
  - Released - Oct 2

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POET R&D

- Additional and improved automatic summary reports.
- Additional advanced charts
- NRT data access via CDMnet
- Add the capability to capture the map replay of events as a movie file (e.g., avi file) to add to reports and presentations
- Integrate ORNL TFM visualization tools.
- Develop user connection/query services manger to better manage/accommodate the increasing number of users accessing the system.
- Port the non-Java parts of the POET client to Java to create a more cross-platform capable tool (possible).
- Migrate to Oracle RDMS (possible).

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POET R&D (cont.)

- Identify missing or data accuracy problems in the existing ETMS data feed, and as feasible implement software algorithms to correct these data problems.
- Improve the flight threading capabilities of the data preprocessor. Flight threading is the process on insuring that all data for a particular flight is correctly associated with that flight.
- Add new data sources (potential list).
  - FCAs
  - Data from the National Logs program (including TFM restrictions in place)
  - Data from the airlines (including planned/actual OOOI information)
  - ASPM data
  - Weather data
- Explore data import feature

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Demand Uncertainty & Congestion Prediction

- Identify sources of uncertainty and data quality problems that contribute to poor demand predictions
- Conduct systematic analyses to understand the magnitude and operational impact of identified sources of uncertainty
- Categorize identified sources of uncertainty
  - Potential deterministic solutions (e.g., improve data quality, early intent)
  - Potential stochastic solutions (e.g., better prediction of dynamic events with inherent uncertainty using stochastic methods)
- Select and evaluate potential improvements that will most likely result in improved demand/congestion prediction

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C-Flow: En-Route TFM Issues

- What Problems are we Trying to Solve?
  - Sector Congestion
  - System Predictability and Results of Prediction Errors
  - Flight Route Coordination
  - Equitable Allocation of Resources

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Approach

- NAS-Wide System Impact Assessment Tools are Needed
  - What Impact Does an En-Route Constraint have on the Airport Operation (Arrival, Departure, Surface)?
  - What about Surface Constraints on the En-Route Operation?
  - These Impacts are Significant and Affect System Performance
  - TFM Constraints Impact Equity
    - Equity May Be Increased or Decreased by a TFM Constraint
- A Prototype System Impact Assessment Tool is Currently Being Developed
  - As an Extension of GCDR and MIT Monitor
- The Prototype will be Validated
  - Through Quantitative Analysis
  - Through Human-in-the-Loop Simulation

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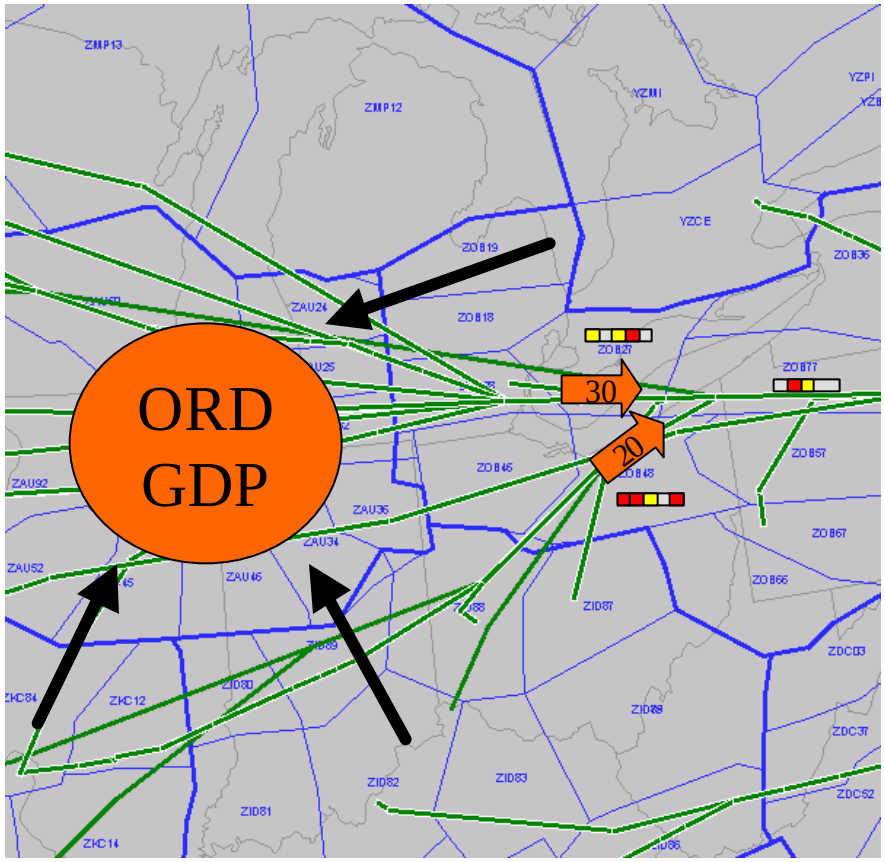
C-Flow Concept



- C-Flow Provides Common Visualization of Flow Restrictions and Impacts
  - Resultant Airport Flows
  - Sector Counts
  - Airborne Delay in Sectors
- C-Flow Dynamically Updates Impact Predictions
- ATC Specialists Can Evaluate the Need for Restrictions
  - Can a Restrictions be Dropped?
  - Are New Restrictions Needed?
- New Restrictions can be Planned by Evaluating the Predicted Impact on Flow Rates, Delays and Equity

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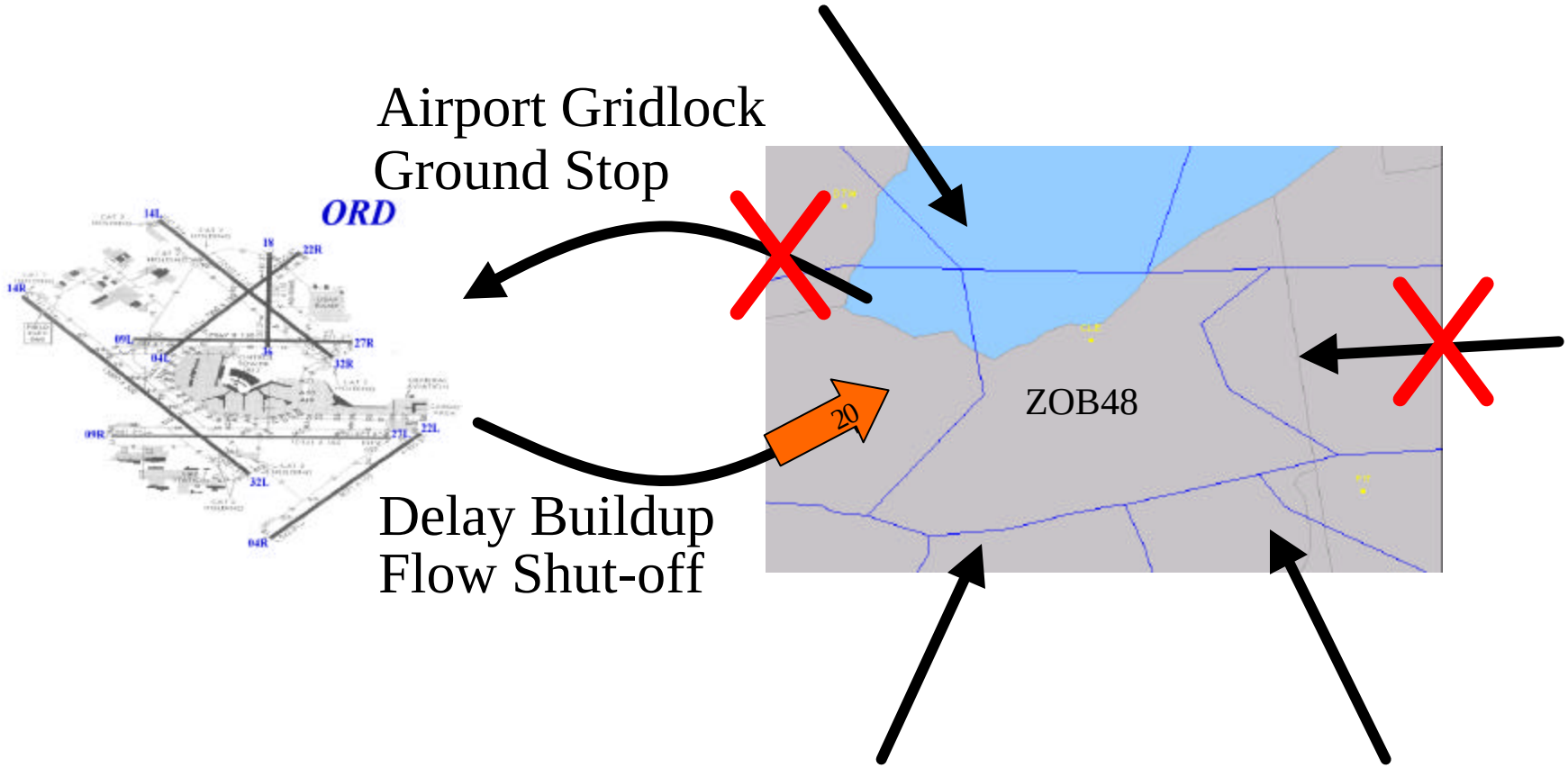
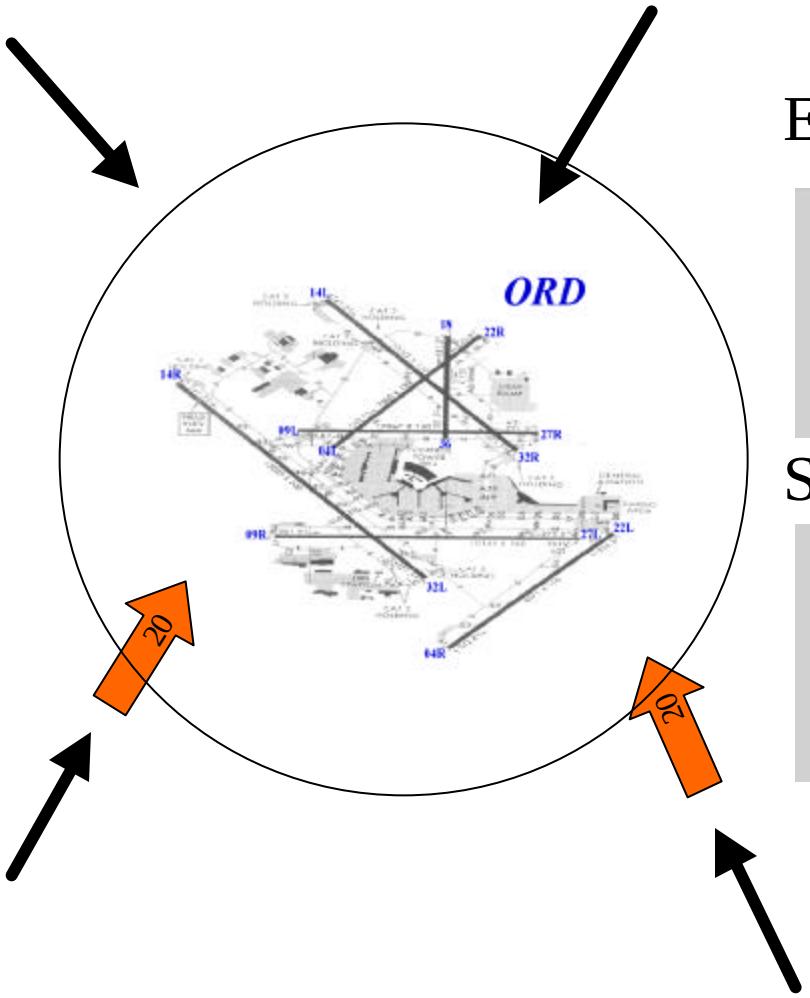
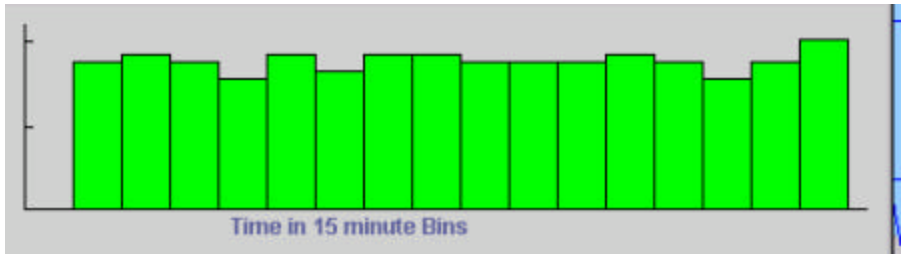
Upstream Effects of Traffic Management Restrictions



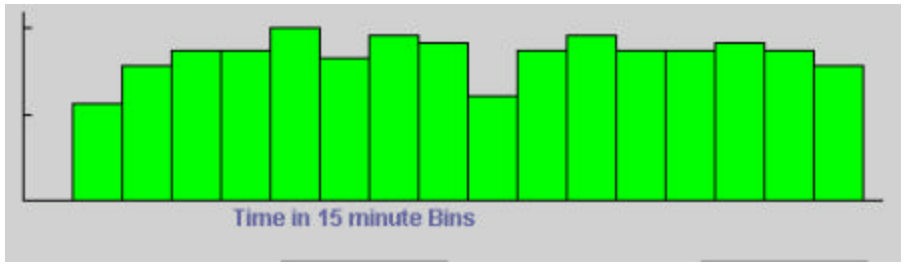
Cumulative Effects of Traffic Management Restrictions



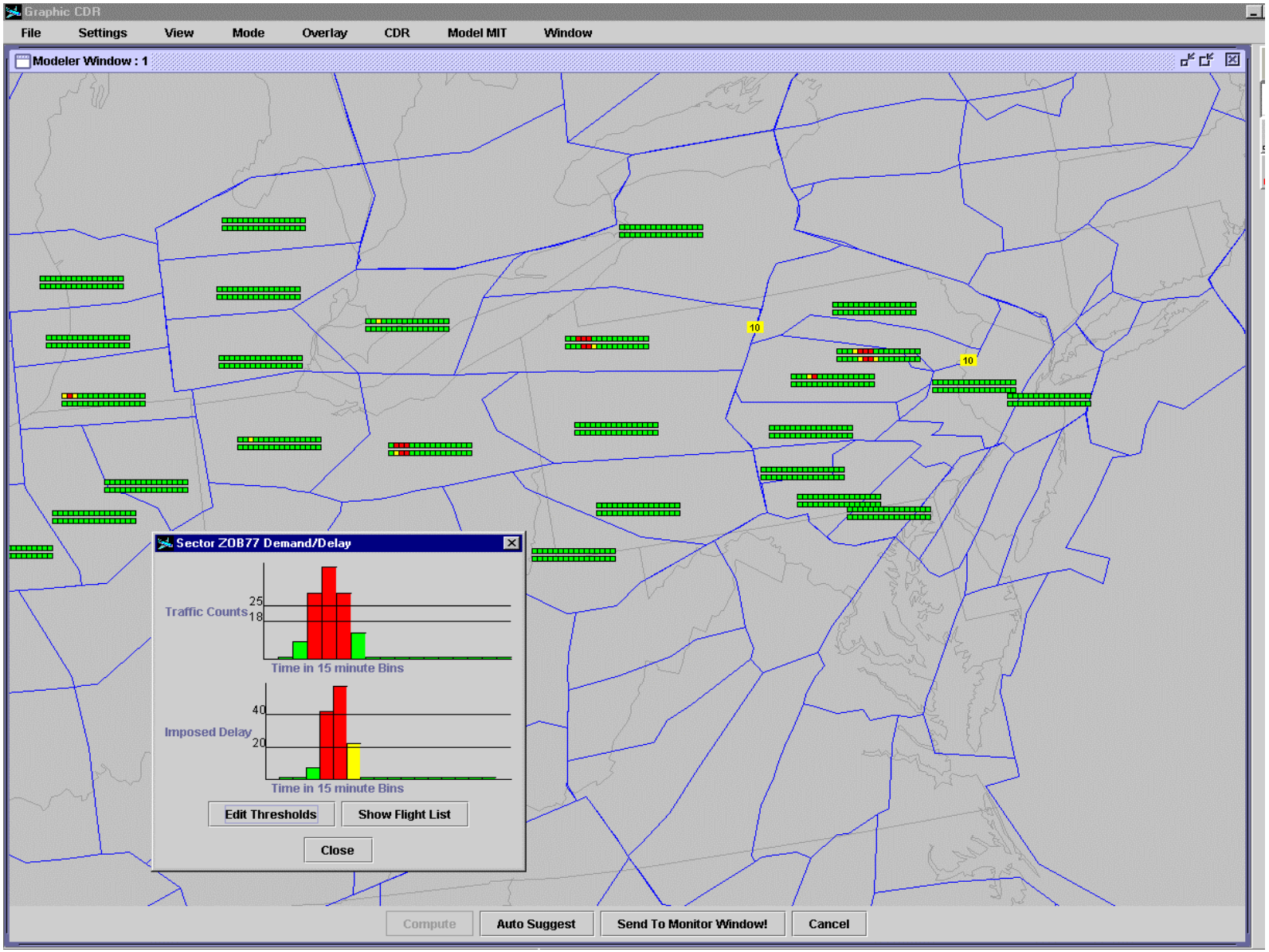
Even Arrival Flow with GDP



Slots Lost with MITs



C-Flow GUI Display



System Impact Analysis

- Using C-Flow, Analyzed LAX Traffic Management Program on May 1, 2001
  - Ground Delay Program
    - Initiated after Host Computer Problems at ZLA
  - ARTCCs Adjacent to ZLA Also Added Miles-in-Trail Restrictions
  - ZLA Also Assigned Release Times for Internal Departures
  - Significant Delays Result
    - But Some Delay Was Unnecessary
    - Excess Unused Capacity at LAX

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System Impact Analysis

- C-Flow Modeled Four Major TFM Elements:
  - Ground Delay Program
  - Miles-in-Trail Restrictions
  - Internal Departure Release Times
  - Sequencing and Separation of Flights
- The Results Showed Good Correlation with Actual Operations
  - An Operational C-Flow Could Help Avoid the Under-delivery Problem

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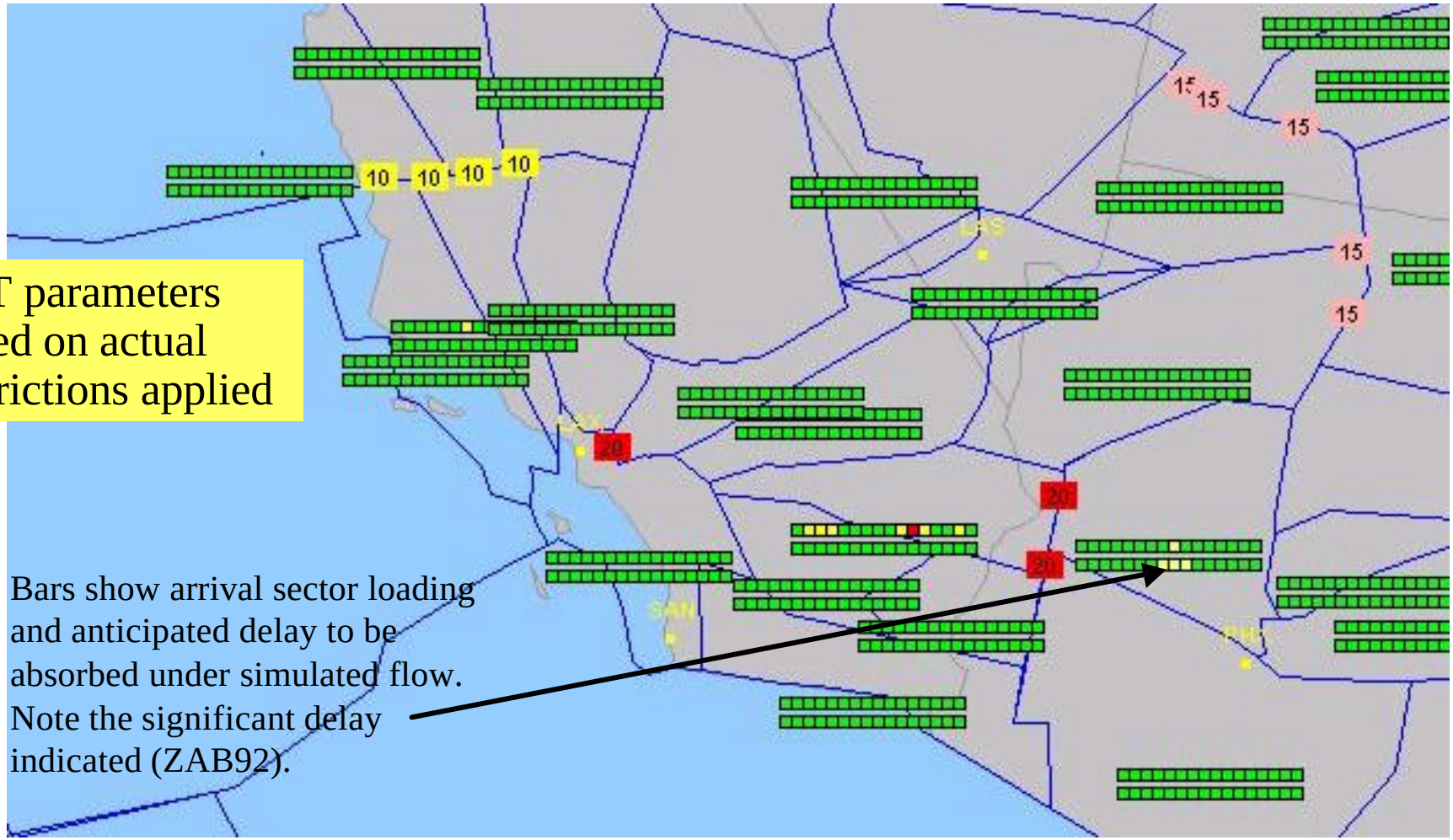
C-Flow Simulation of LAX Event 5/1/2001

Program 1630Z to 2359Z, LAX at 60/64 Arrivals per Hour

MIT parameters based on actual restrictions applied



Bars show arrival sector loading and anticipated delay to be absorbed under simulated flow. Note the significant delay indicated (ZAB92).

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C-Flow Simulation of LAX Event 5/1/2001

Time	Arrivals - URS 60		Arrivals - MIT 60	
1400	10		10	
	2		2	
	13		12	
	11	35	11	35
1500	15		13	
	13		7	
	15		15	
	15	58	13	48
1600	15		13	
	15		8	
	15		11	
	13	58	8	40
1700	17		10	
	15		9	
	15		9	
	15	62	13	41

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Development Phases

- Phase 1
  - Predict and Display Traffic Flow that Results from Miles-in-Trail Restrictions obtained from National Log Program
    - In Downstream Sectors and to Airports
    - Assist ATC Specialists to Determine if MIT Restrictions are Necessary
- Phase 2
  - Over/Under Constrained Decision Support Due to MIT and Possibly GDP Restrictions
    - Provide Automated Alert if MIT Restrictions
      - are not enough to avoid excess demand downstream
      - are more than necessary to avoid excess demand downstream

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Development Phases (cont.)

- System Impact Assessment Tool
  - Assist ATC Specialists in Selecting between Strategies:
    - Re-routes
    - Ground stops
    - GDPs
    - Sector GDPs
    - Miles-in-Trail
    - others?
  - Predict and Display Flow and Equity of Each Strategy or a Combination of Strategies

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Evaluation Phases

- Shadow Operations and Evaluation
  - Analytical Evaluations to Assess Sector Demand Prediction Accuracy
  - Demonstrations to Users to Obtain Subject Matter Expert Feedback
- War-Game
  - Human-in-the-Loop Simulation of ATCSCC, TMU and AOC
  - Simulated Evaluation of Use of C-Flow for
    - What-If Evaluations of Traffic Management Strategies
    - Communication of Predicted Congestion and Delays to Airlines
- Purpose/Goal of War-Game
  - Validation of Tool Capabilities
  - Identification of Missing Capabilities
  - Validation/Improvement of User Interface
  - Development of Procedures for Use of Tool
  - Identification of Methods for Collaborative Decision Making

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C-Flow Status

- Real-Time Infrastructure Under Development
  - Real-Time Database (POET)
    - Allow trajectory predictions to be stored in database
    - Allow access to these predictions for sector load metrics
- Trajectory Prediction (non-developmental item)
  - Collect and archive RUC2 wind data from NOAA
- Graphical User Interface (developed as variant of GCDR)

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Complexity Application in TFM - Possible Utility

- **Complexity, in some form, measures enroute workload, or demand for enroute services.**
  - **This workload/demand is the correlate of airport arrival demand, and must be balanced against workload capacity.**
- **To the degree that TFM actions are taken to control workload, then better prediction of workload might lead to better prediction of possible TFM restrictions (e.g., 20 MIT due to volume).**
- **Just as in TFM applied to arrival demand, early and accurate prediction of enroute TFM actions can be used to advise users, obtain revised user intentions, smooth demand, and, if necessary, to ration capacity.**

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Complexity Application in TFM - Basic Questions

- **What are the elements of complexity metrics, and can they be calculated in realtime from available TFM data?**
- **Do the complexity metrics correlate with enroute TFM actions?**
- **Is there sufficient correlation to predict TFM actions at a level of practical utility? How complex is the correlation, if any? Are there simple thresholds that could be used as indicators?**
- **How sensitive is the correlation, if any, to the available flight-plan data? How will traffic without timely flight plans be included in the complexity metric?**
- **What if complexity does not appear to correlate with these actions? Are there patterns in complexity that can be used to devise better TFM strategies?**

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Complexity Metrics - Data Issues

- **Dynamic density elements can be calculated from FS, FZ, or TZ information.**
  - **FS- and FZ-based processing requires the use of a trajectory predictor to convert route information into 4-D trajectory points.**
- **Accuracy and completeness of input data are important for all complexity elements.**
  - **Conflict and minimum-distance elements are especially sensitive due to comparison to two flight tracks.**
- **Further improvements in early and accurate filing of intent may be necessary to achieve practical utility of complexity metrics in TFM.**

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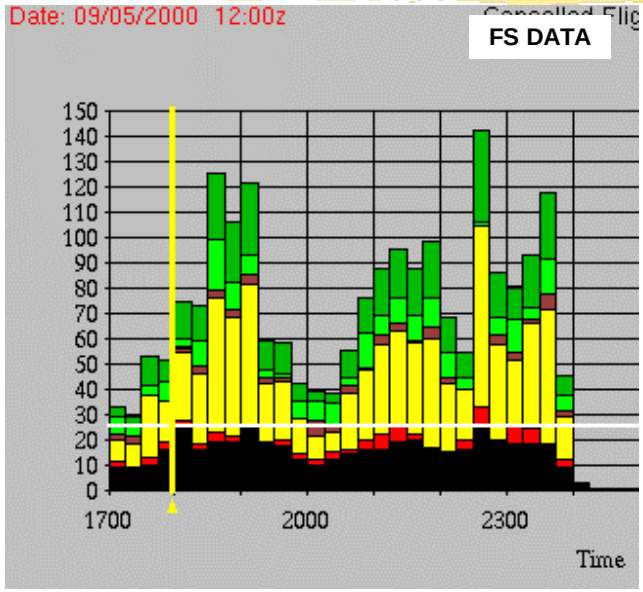
ZOB48/49 5 Sep 00/17-24 GMT (FS, FZ, TZ Data)



CHARACTERISTIC	FS	FZ	TZ
Flights	670	683	647
Aircraft-minutes	6840	7395	6660
Heading changes	81	124	82
Conflicts	841	777	181
Speed changes	65	80	317
Altitude changes	223	236	325
Density counts	421	390	91

415 of 670 FS flights are in TZ
232 other TZ flights are:

62 from "major" carriers
96 from GA
74 others.

464 of 683 FZ flights are in TZ
183 other TZ flights are:

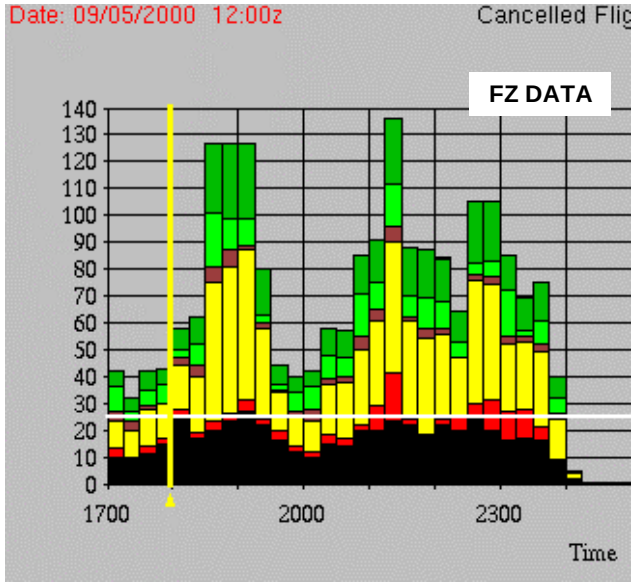
33 from "major" carriers
95 from GA
55 others.

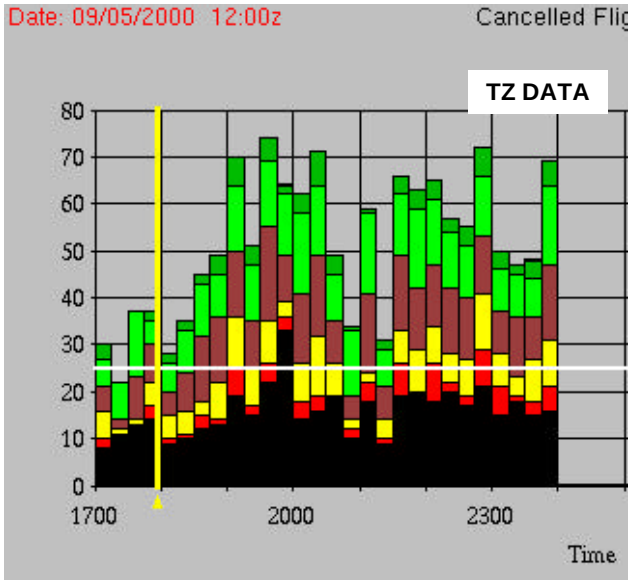
531 of 670 FS flights are in FZ
152 other FZ flights are:

61 from "major" carriers
1 from GA
90 others.

Large disparity may be due to speed estimation in TP algorithm.

Disparity may be due to anomalies in TZ altitude data and due to smooth profiles in TP output.





1. VERTICAL AXES MAY DIFFER FROM BETWEEN GRAPHS.
2. TYPE-2 WEIGHTS:

   COUNT - TIME IN SECTOR
   DENSITY - 0.5
   ALL OTHERS - 1.0

3. ALTITUDE FILTER OFF.

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Exploratory Data Analysis: FS/FZ Time Distributions for 5 Sep 2000

- **Time of route message receipt must be considered in development of data feed for complexity analysis.**

FS Messages by Hour

Day	Hour	Messages	Percentage
4	8	79	1.76932
4	9	199	6.2262
4	10	149	9.56327
4	11	129	12.4524
4	12	37	13.2811
4	13	19	13.7066
4	14	33	14.4457
4	15	24	14.9832
4	16	24	15.5207
4	17	33	16.2598
4	18	60	17.6036
4	19	265	23.5386
4	20	290	30.0336
4	21	269	36.0582
4	22	339	43.6506
4	23	229	48.7794
5	0	292	55.3191
5	1	279	61.5677
5	2	224	66.5845
5	3	293	73.1467
5	4	301	79.888
5	5	272	85.9798
5	6	365	94.1545
5	7	261	100
	Total	4465	

FZ Messages by Hour

Day	Hour	Messages	Percentage
4	13	1	0.0194553
4	15	2	0.0583658
4	16	2	0.0972763
4	17	2	0.136187
4	18	2	0.175097
4	19	10	0.36965
4	20	45	1.24514
4	21	49	2.19844
4	22	140	4.92218
4	23	233	9.45525
5	0	186	13.0739
5	1	110	15.214
5	2	59	16.3619
5	3	42	17.179
5	4	47	18.0934
5	5	41	18.8911
5	6	67	20.1946
5	7	75	21.6537
5	8	137	24.3191
5	9	317	30.4864
5	10	266	35.6615
5	11	231	40.1556
5	12	320	46.3813
5	13	241	51.07
5	14	336	57.607
5	15	255	62.5681
5	16	284	68.0934
5	17	311	74.144
5	18	317	80.3113
5	19	255	85.2724
5	20	362	92.3152
5	21	220	96.5953
5	22	168	99.8638
5	23	7	100
	Total	5140	

100 % OF FS AVAILABLE 10 HOURS IN ADVANCE OF PERIOD OF CONCERN, BUT ONLY 22 % OF FZ AVAILABLE

68 % OF FZ AVAILABLE ONE HOUR IN ADVANCE OF PERIOD OF CONCERN

- **Hybrid of FS and FZ data will probably be required for complexity monitoring.**

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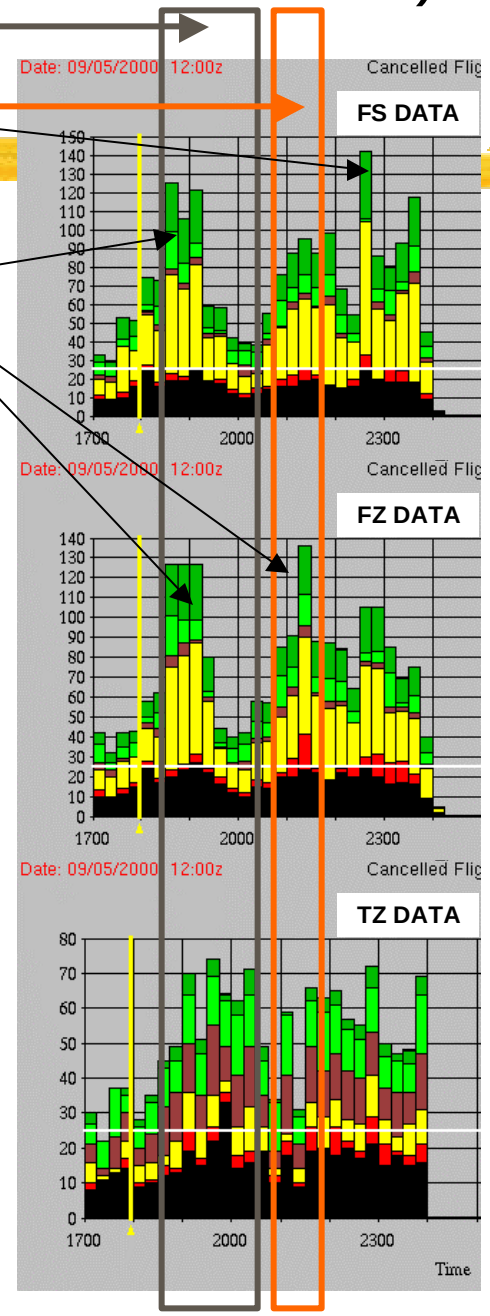
ZOB48/49 5 Sep 00/17-24 GMT (Restrictions)

Dynamic Restriction
1830 - 2030
ZOB to ZAU: 20 MIT
Posted 1603
Reason = Volume in ZOB48/66

MISSING CORRELATION?

POSSIBLE CORRELATIONS



Historically Validated Restrictions From ZOB

FROM	TO	START	STOP	STREAMS	RESTRICTION	VIA_FIX,_JETWAY,_NAVAID	ARPT/SCTR	REASON
ZOB	ZAU	1645	1730		20_MIT	VIA_WAKEM	CLE	VOLUME
ZOB	ZID	1645	1730		20_MIT	VIA_WAKEM	CLE	VOLUME
ZOB	DTW	1745	1845		20_MIT	VIA_ACO/CXR_AS_ONE	DTWD	VOLUME
ZOB	ZAU	1800	2015		10_MIT		JFK	VOLUME
ZOB	ZAU	1800	2015		20_MIT		EWR	VOLUME
ZOB	ZAU	1830	2030		20_MIT	VIA_GERBS(BWI,DCA,PHL,LGA)	ORDD	VOLUME
ZOB	ZAU	1845	2000		20_MIT	VIA_MIZAR	DTW	VOLUME
ZOB	ZID	1845	2000		20_MIT	VIA_MIZAR	DTW	VOLUME
ZOB	ZID	1845	2015		20_MIT	AS_ONE_DCA/BWI		VOLUME
ZOB	ZID	1900	2000		20_MIT	VIA_FFO	CVGD	VOLUME
ZOB	ZID	1900	2000		20_MIT	VIA_REDSS	CVGD	VOLUME
ZOB	ZID	1930	2130		30_MIT	VIA_J152	PHL	VOLUME
ZOB	ZBW	2015	2100		20_MIT	VIA_SPICA	DTW	VOLUME
ZOB	ZNY	2015	2100		20_MIT	VIA_SPICA	DTW	VOLUME
ZOB	ZDC	2030	2115		20_MIT	VIA_J109/211	DTW	VOLUME
ZOB	ZID	2045	2130		20_MIT	VIA_J85	DTW	VOLUME
ZOB	ZAU	2245	2345		20_MIT	VIA_MIZAR	DTW	VOLUME
ZOB	ZID	2245	2345		20_MIT	VIA_MIZAR	DTW	VOLUME
ZOB	ZAU	2330	30		20_MIT	VIA_WAKEM	CLE	VOLUME
ZOB	ZID	2330	30		20_MIT	VIA_WAKEM	CLE	VOLUME

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Exploratory Data Analysis - Initial Conclusions

- **Complexity generally follows traffic count, but differences are amplified.**
- **Weighting scheme may not be a major concern in TFM applications.**
- **FS and/or FZ route data can be used to calculate complexity in a reasonable fashion.**
  - **Disparity between filed and flown tracks is apparent, but useful general trends in complexity may still be discernable.**
- **TZ-based complexity levels may be of use in setting thresholds for gauging the complexity seen in FS-based or FZ-based complexity.**
- **There appears to be some possible correlation of restrictions and complexity.**

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CR Resource Allocation (CRRA)

- Objective: Assess the feasibility and effectiveness of the various enroute rationing concepts that have been proposed in the CR long-term workgroup.

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CRRA : Project Status

- Schema have been proposed for rationing (earlier work with CR long-term group)
- Architecture design (rough) has been laid out for testbed
- Building has begun of test bed or demo for exploring the various schema (NEXTOR, UMD, MITRE)

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CRRA : Technical Approach

- Bundle air traffic by traffic classes
  - e.g., LGA arrivals, southbound
- Set aggregate flow levels for air routes
  - flights per hour
  - balance the flow (equity)
- Assign end-to-end routes and departure times for individual flights, honoring carrier preferences

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CRRA : Technical Issues

- Identification of FCA capacity-demand imbalance
- Provide incentive for early filing
- What constitutes OAG time enroute?
- Provide airline control over resources
- Must fit in with long-range view of CR

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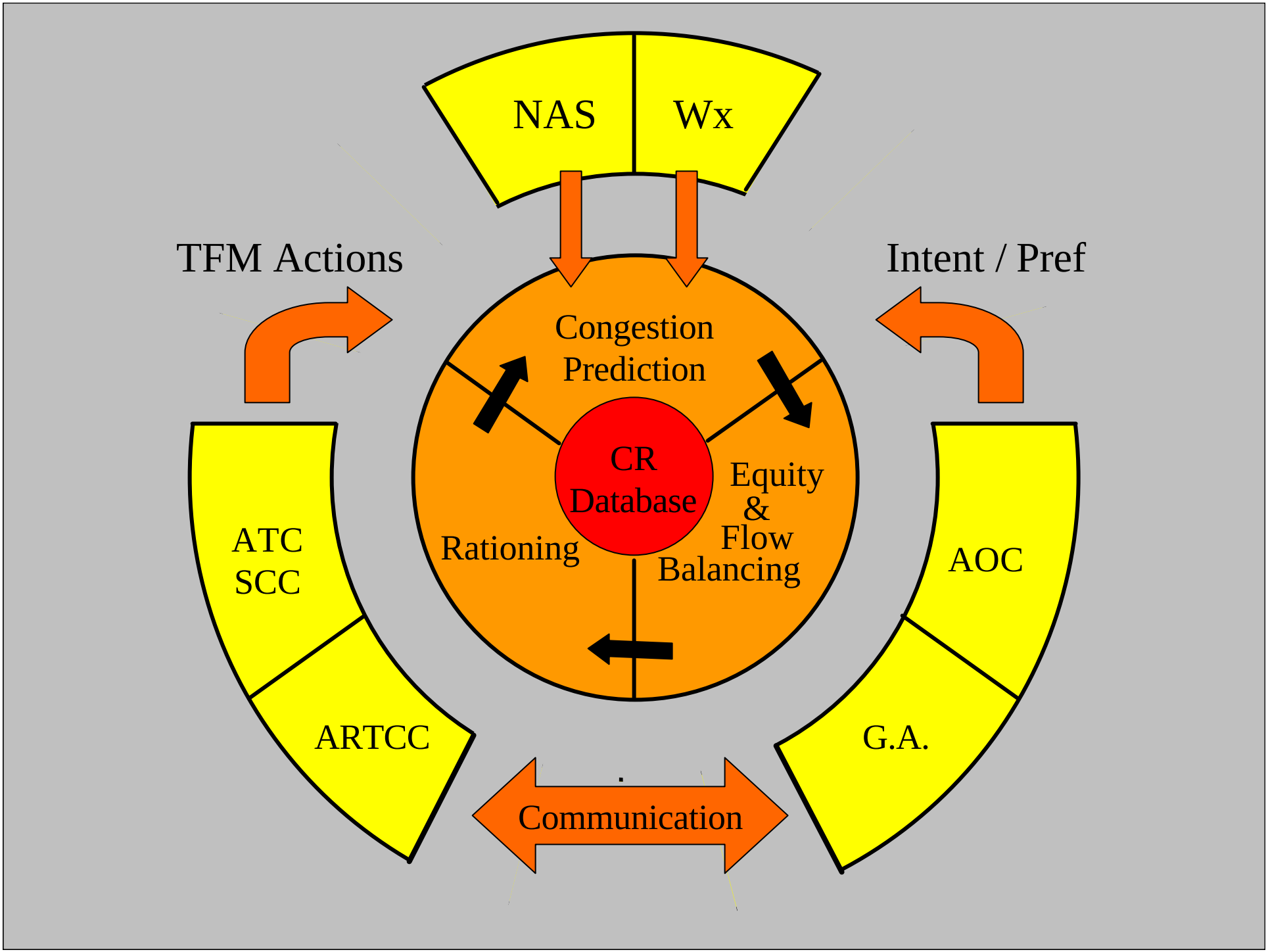
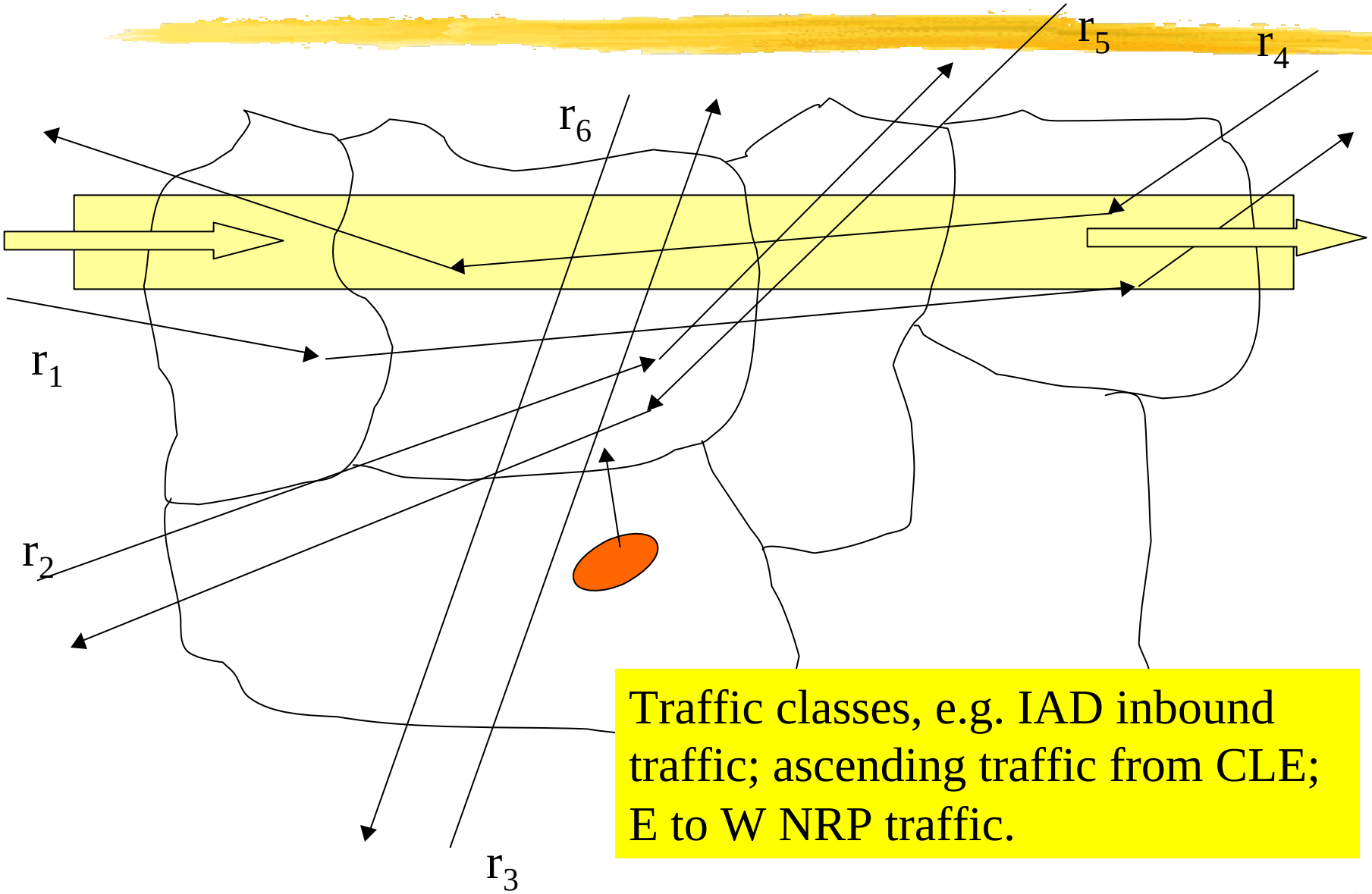

NAS
Wx
TFM Actions
Intent / Pref
Congestion
Prediction
CR
Database
Equity
&
Flow
Balancing
Rationing
ATC
SCC
ARTCC
AOC
G.A.
Communication

Aggregate Flow: Traffic Classes



Traffic classes, e.g. IAD inbound traffic; ascending traffic from CLE; E to W NRP traffic.

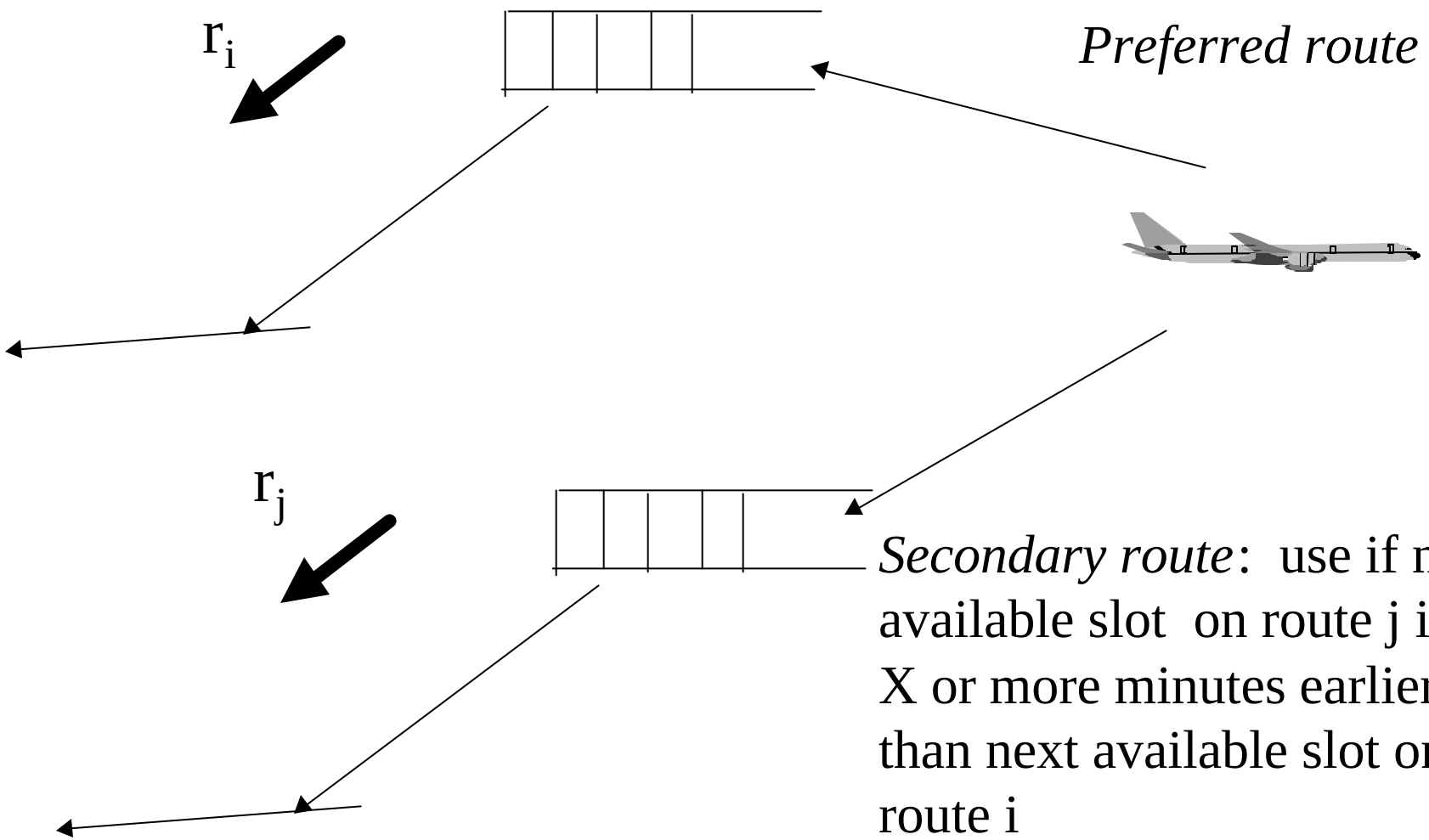
METRON AVIATION

Multiple Allocation Concepts

- Priority based on combination of file time and OAG time
- Priority based on overall delay
- Multiple queues:
  - queue1 for early filers, queue2 for later filers, ...
  - each queue ordered by OAG time
  - select 1st from queue1, then queue2, etc.

METRON AVIATION

Trading Off Multiple Routes Options



Secondary route: use if next available slot on route j is X or more minutes earlier than next available slot on route i

Main Thrusts of GDPE/FSM Research

- Distance-Bases GDPs
- Multi-fix, multi-airport GDPs

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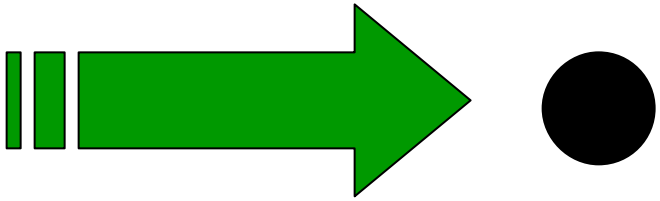
Multi-fix GDPs

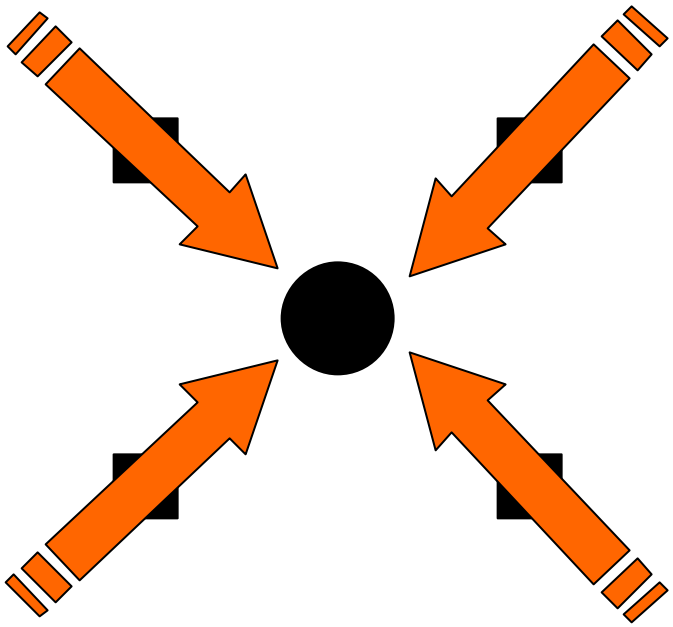
- Current model of flow into airport (during GDP) is a single queue



METRON AVIATION

Multi-fix GDPs

- In reality, flow into an airport is multiple queues over fixes.



METRON AVIATION

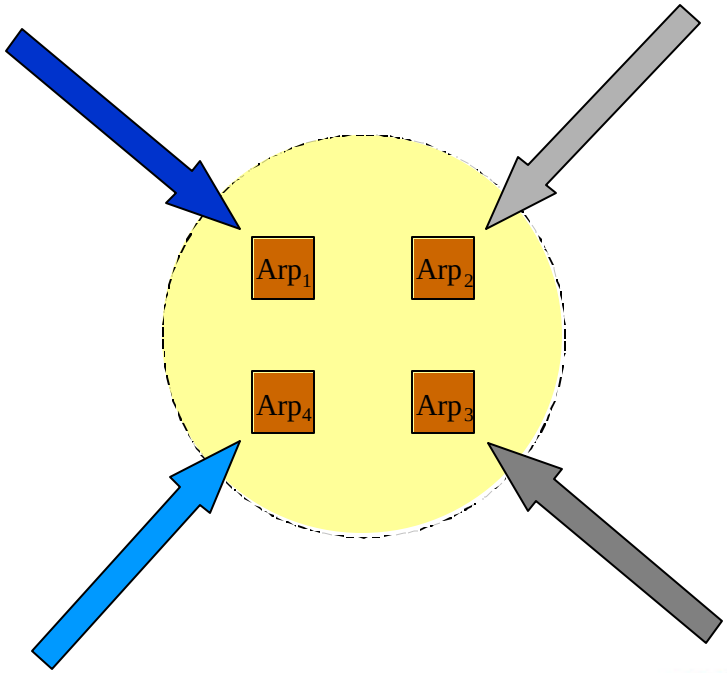
Multi-Fix GDP Objective

- Need to develop algorithms/procedures for controlling multiple flows into GDP airport
- Issues:
  - efficient arrival fix balancing
  - equity among fixes (distribute delay evenly)
  - modify current substitution practices
- Note: in FSM, we have single fix control capabilities only

METRON AVIATION

Multi-Airport GDP Objective

- To develop algorithms/procedures to coordinate GDPs at several airports
- Issues:
  - efficient use of regional airspace
  - equitable access to regional airspace by all airports
  - modify current substitution practices



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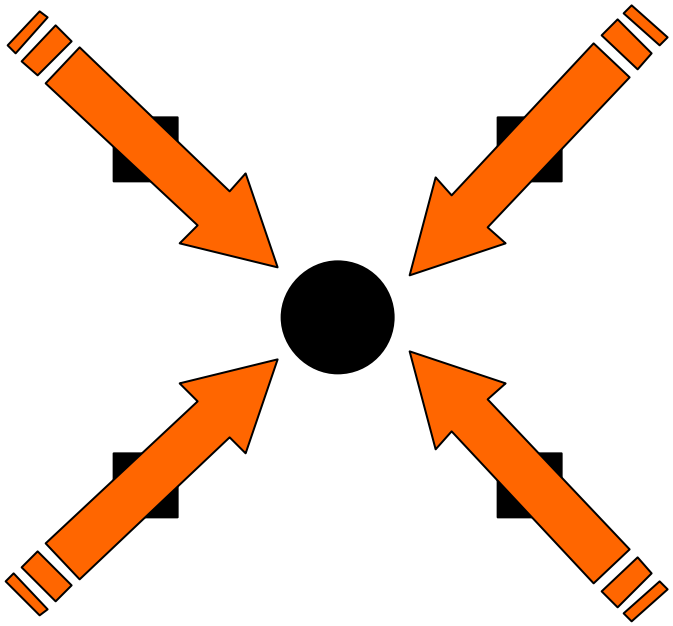
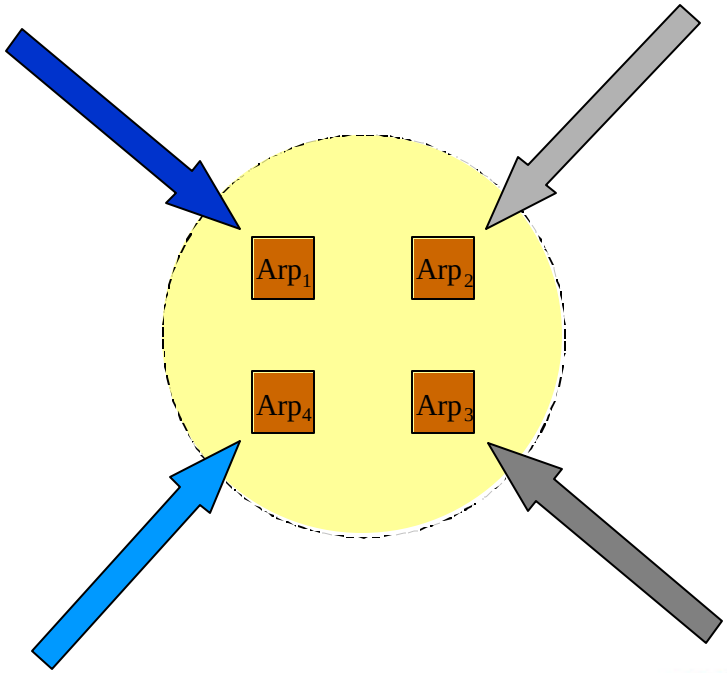
Multi-Fix Vs. Multi-Airport GDP

- Abstractly, each problem balances multiple flows into a common resource
- Solution to one is solution to other





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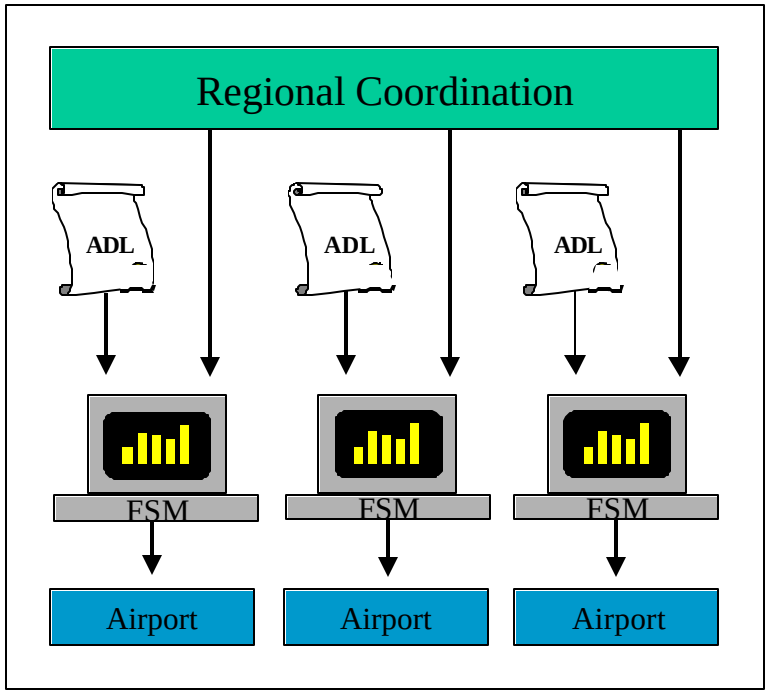
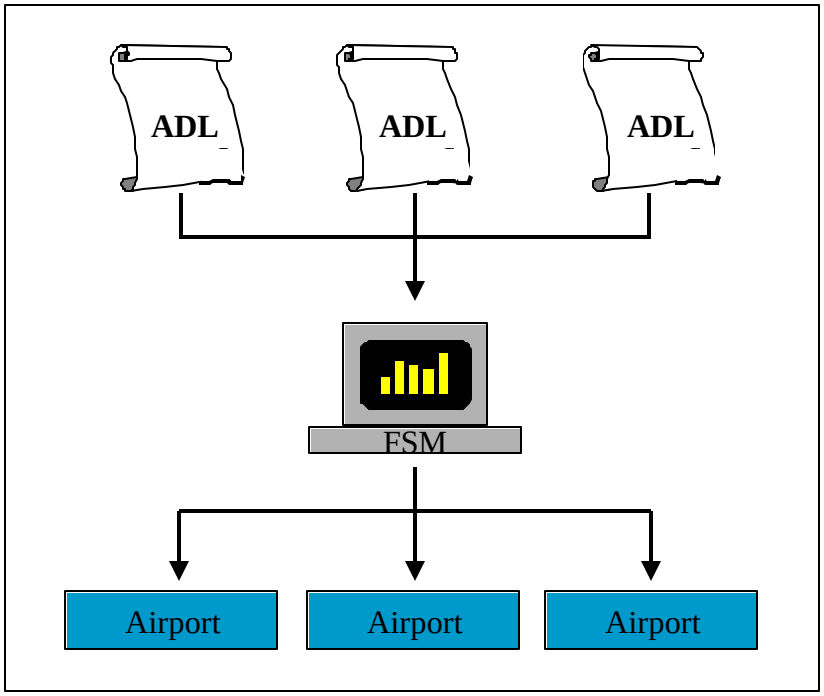
What's been done on Multi-airport GDP?

- MetronVolpe/UMD have outlined the various approaches and...





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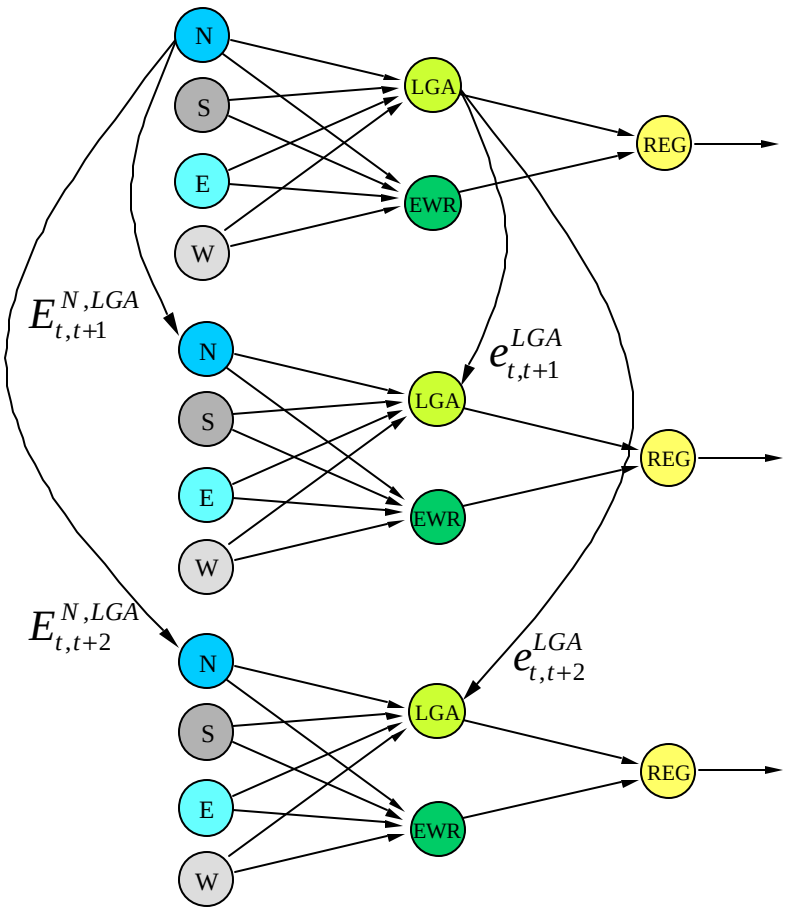
What's been done on Multi-airport GDP?

- flow model has been developed with equity a primary consideration
- Complex model has simple RBS-like solution
- Works on multi-fix GDP too



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Where do we go from here?

- Finish theoretical model/solution
- Test model performance with real data
- Summary document/recommendations for CDM community
- Begin implementation after 2001 convective wx season

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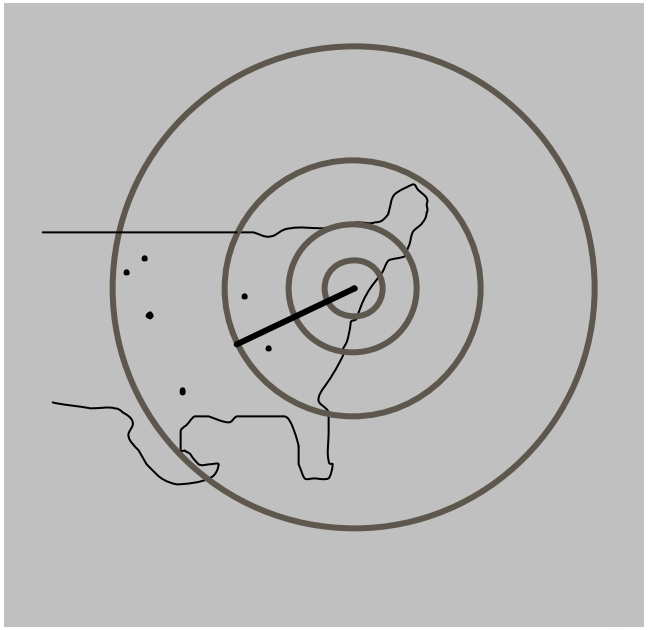
Objective of Distance-based GDPs

- Implement the FSM option to set program inclusion based on distance or ETE
  - this can co-exist with tiers
  - start with prototype FSM



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Issues for Distance-based GDPs

- Provide guidance to TFM in selecting an appropriate GDP distance
- Stochastic optimization
- Equitable distribution of delay
  - avg delay per flight, carrier
  - long-haul vs. short-haul

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Best performance GDP can occur between tiers

- Example: (Bos 2 Feb 99) Unrecoverable delay minimum occurs at 410 miles

Distance	350	410	1000	1090
Unrecov. Delay	407	390	525	507
Avg Delay	54	49	32	31
Max Delay	115	109	77	77

Moving in either direction increases unrecoverable delay. This suggests use of a graphical tradeoff curve...

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Can we leverage off dist-based GDPs to optimize GDP planning?

- Yes, but in a limited way: only for finding the optimal distance(s) that minimize a tradeoff curve
- TFM must still use judgement regarding other factors of GDP.

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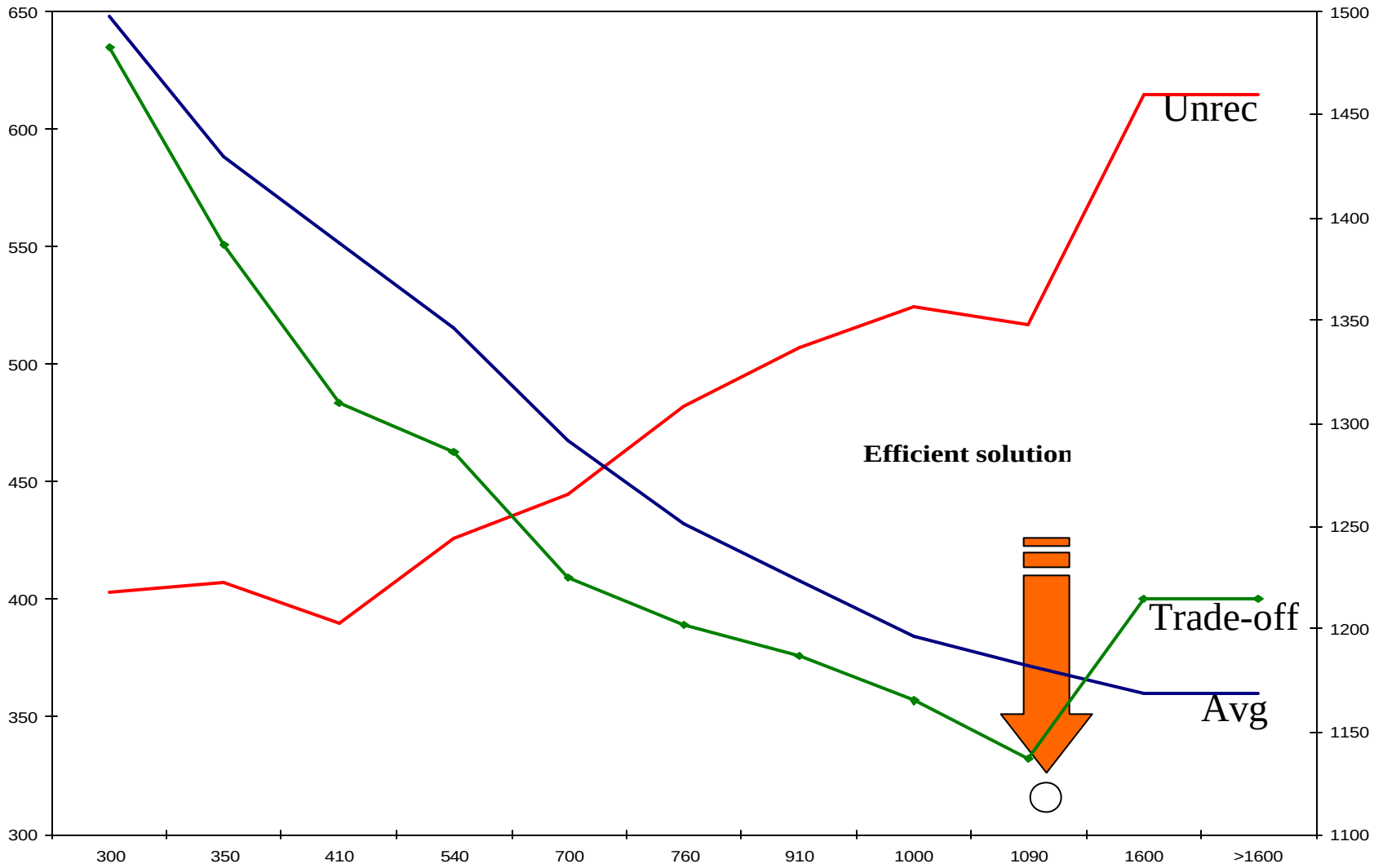
Example Tradeoff: Avg Delay Vs. Unrecoverable Delay
BOS Feb 2, 1999



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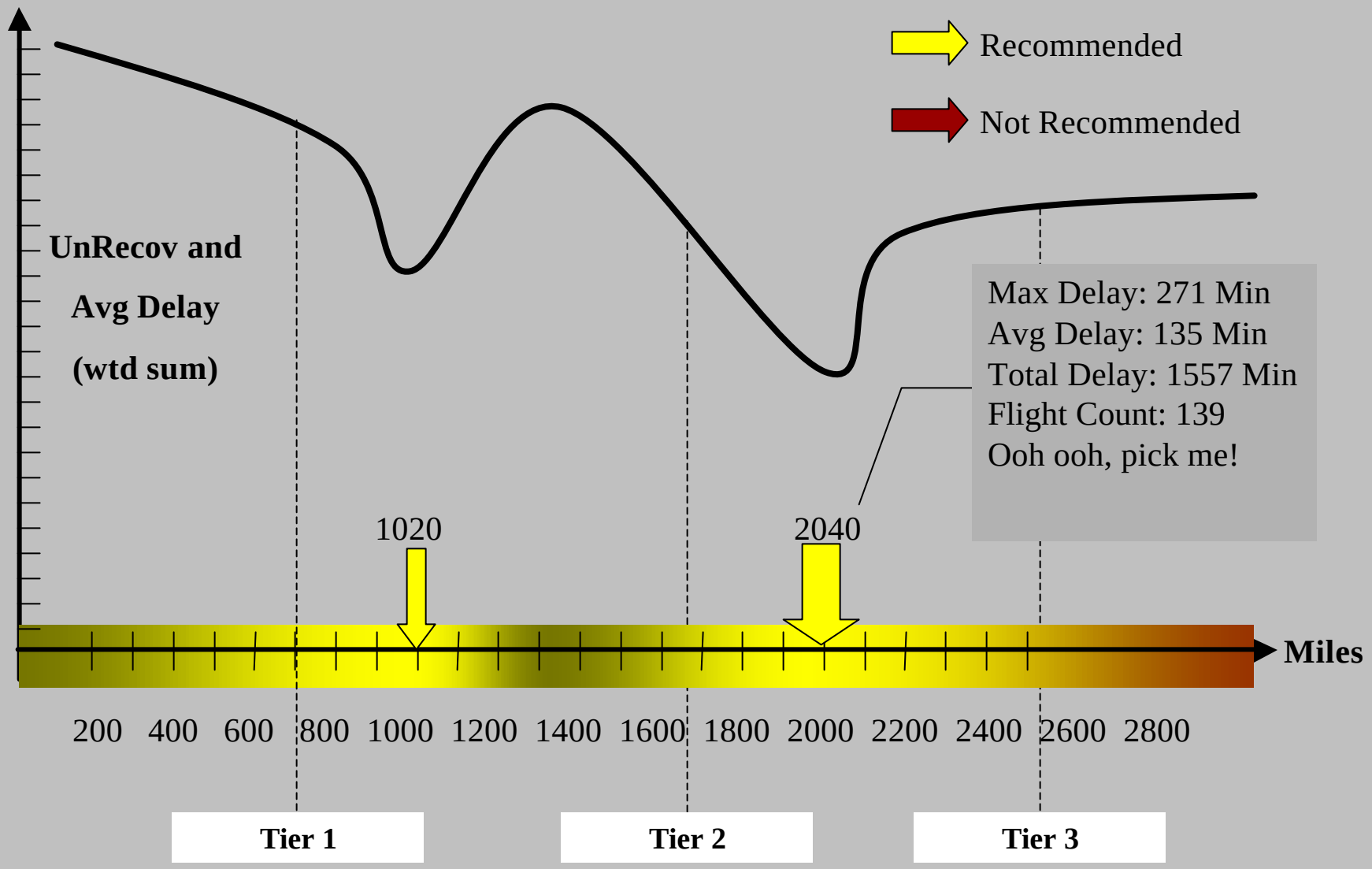
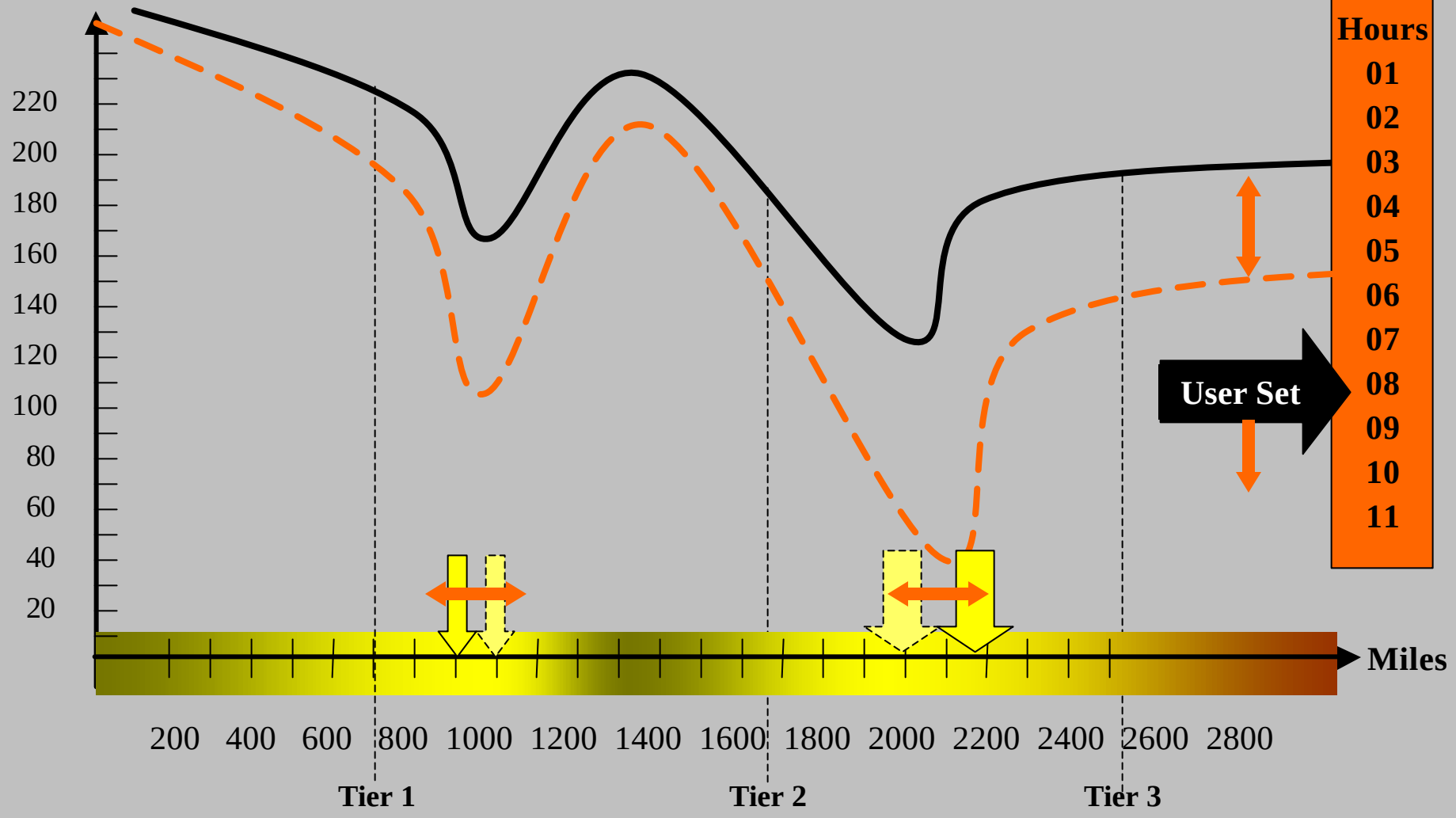
One possible Graphic

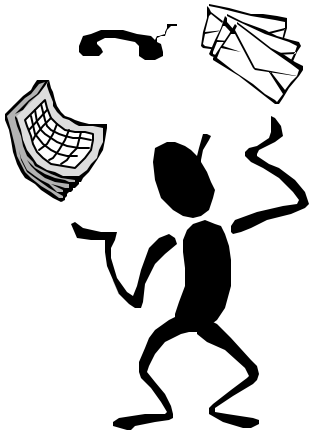


Tradeoff Curve is a function of MinExpected Duration of GDP



Chance to revamp Power Run optimization feature:

- Old Power Run was discrete, based on tier combinations; many stats
- With a continuum of radii to choose from, we can display a continuum of statistics...
- Go graphical!



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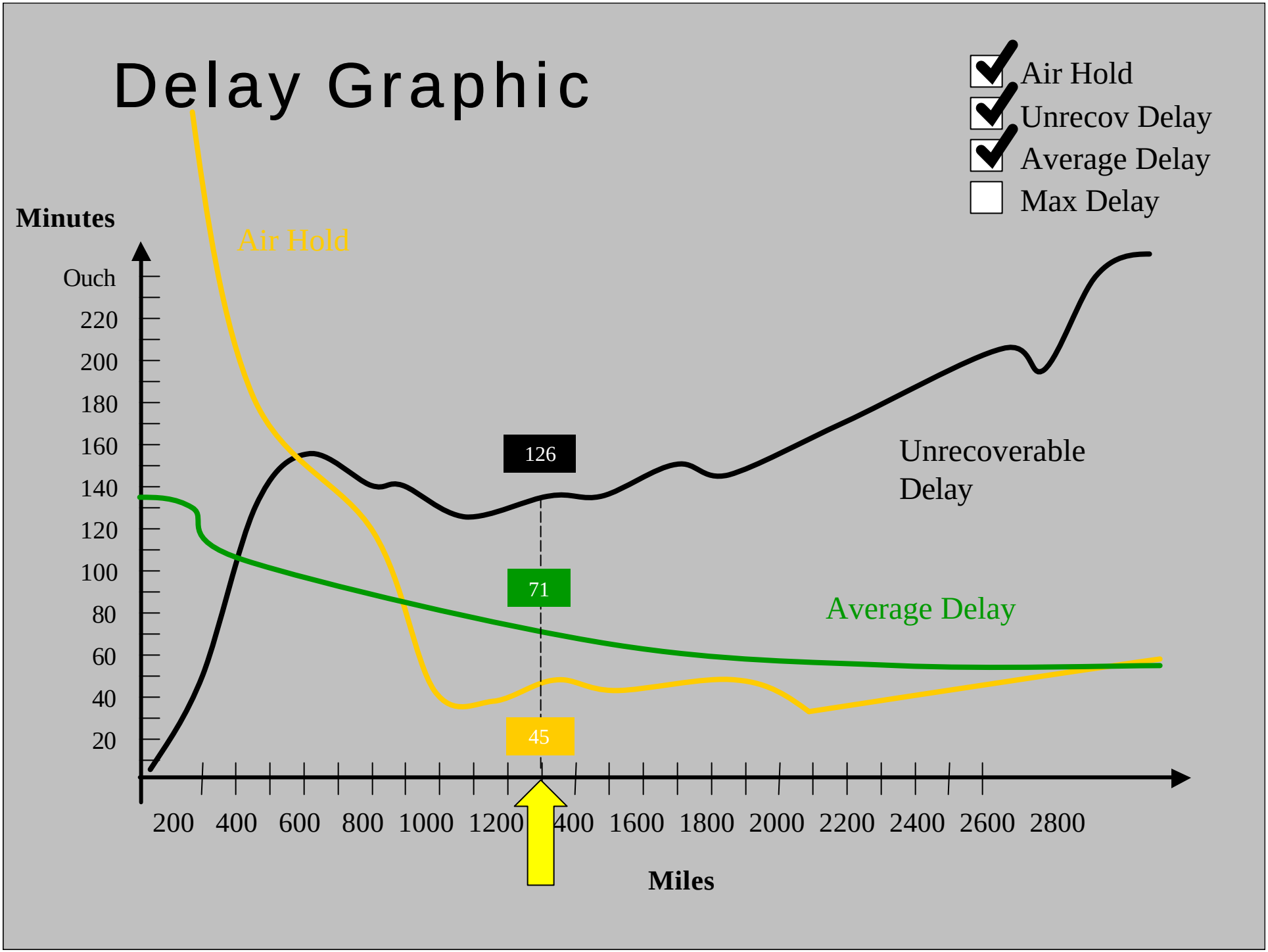
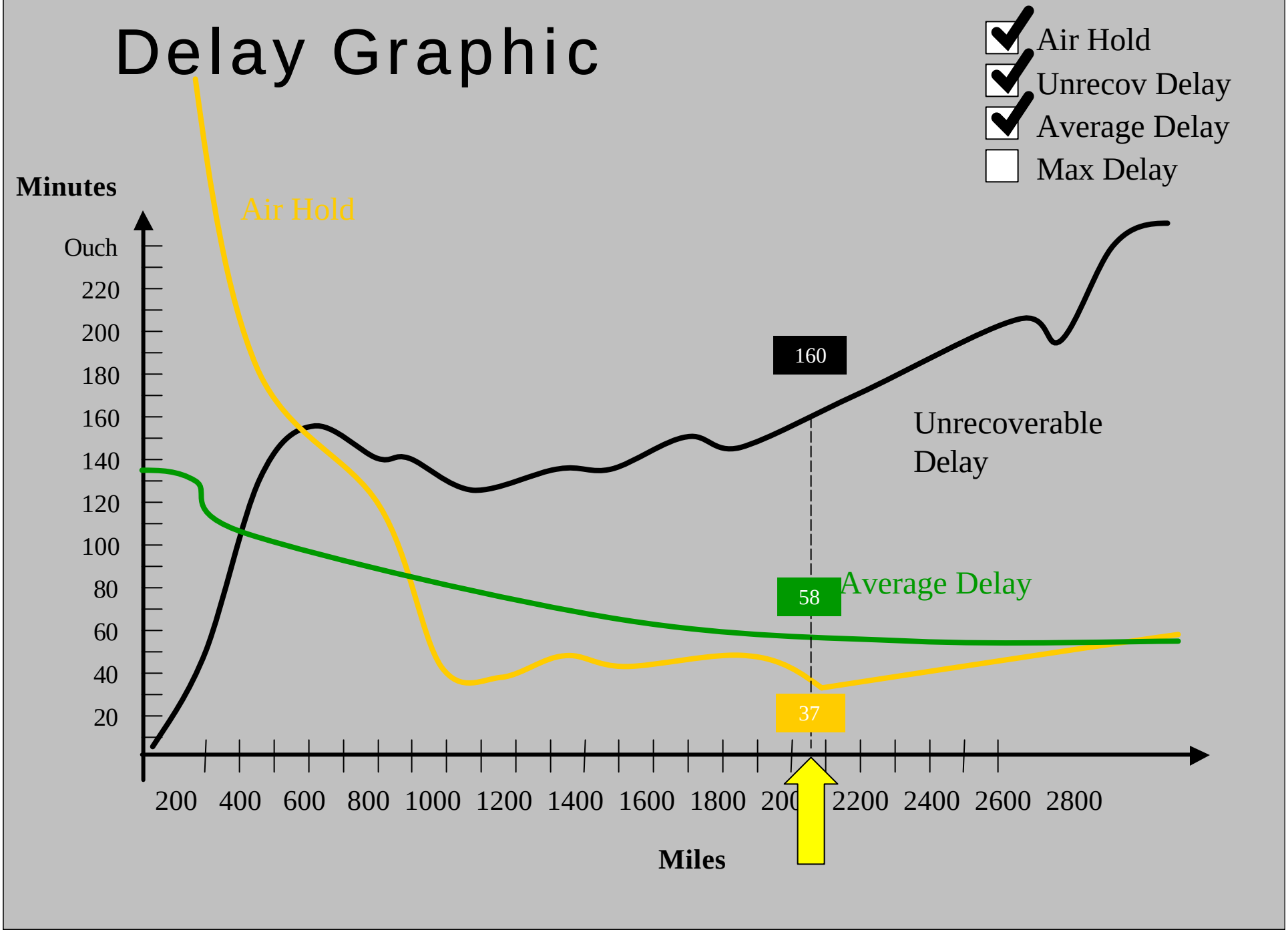
Delay Graphic



Delay Graphic



What's been done on Distance-based GDPs?

- Metron/UMD report/analyses on optimal distance selection
- Created mock displays for GDP inputting/selecting distance
- Connectivity with Power Run of prototype version of FSM

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What's next for Distance-based GDPs?

- Finish prototype FSM with distance-based capabilities
- Graphical Power Run (end of summer 2001)
- Demo to ATCSCC (fall 2001)
- Reshape tools based on input

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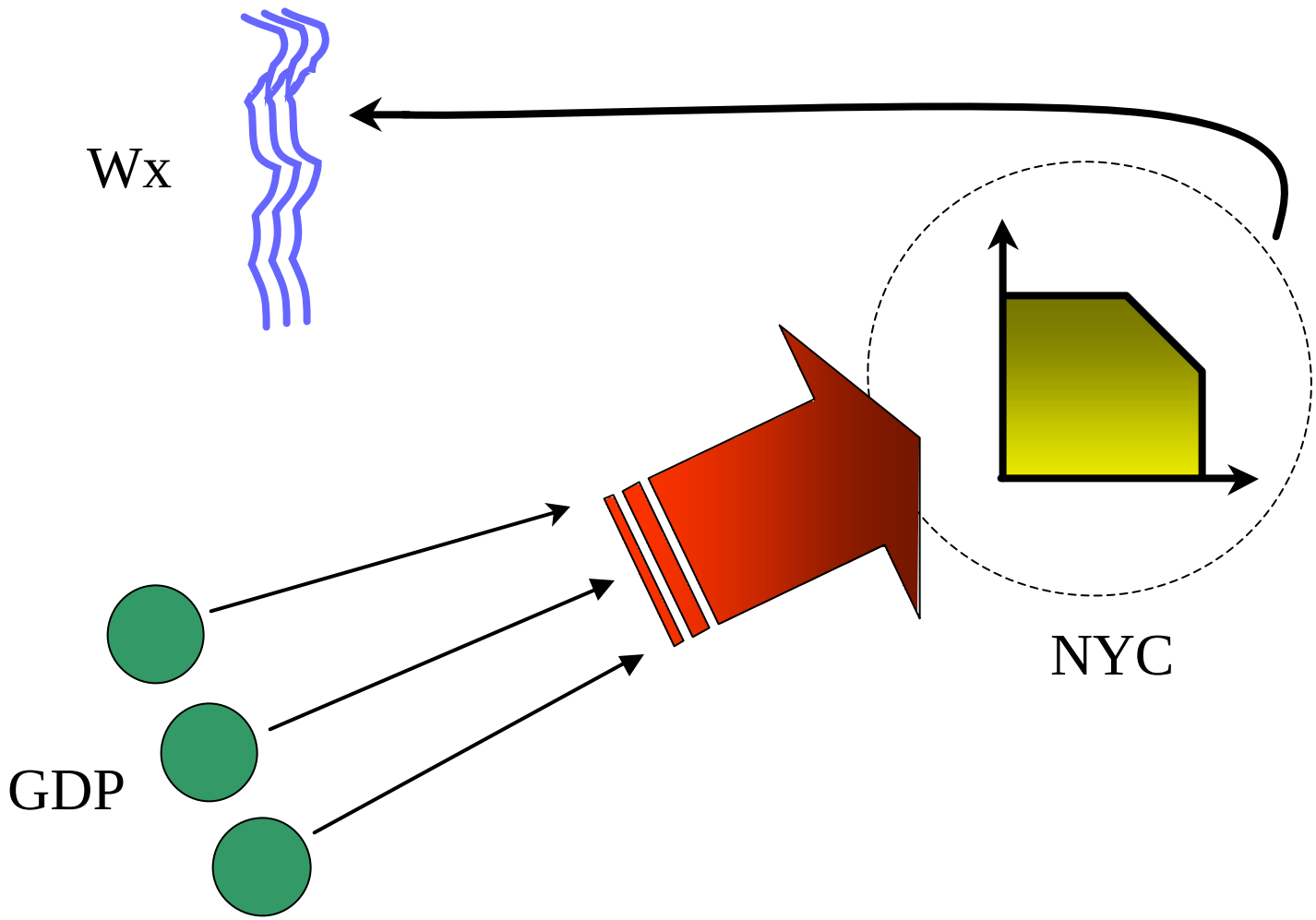
Arrival/Departure Throughput R&D

GDP in support of SWAP Concept



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Two Phase Project

- Phase 1: Determine departure capacities at NY airports (or similar)
  - based on historical data at first; later based on actual demand
  - units could be capacity rates or departure delays
- Phase 2: Offer guidance in setting GDP rates to prevent airport gridlock

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Phase 1

- Web-based display table of predicted departure delays
- Use ADC architecture to display, Summer 2001
- Met with TFM for feedback, Spring 2001

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Departure Fix Restriction Worksheet

	Coate	Neion	Haays	Gayel	Brezy	Eliot	Parke	Lanna	Biggy	Dixie	White	Wave	Greki	Merit	
Restriction															
Capacity															
Demand															**TOTAL**
LGA															
JFK															
EWR															
TEB															
Total															
Excess															
Avg for Hour 1															
															TOTAL
Delay Minutes															
LGA															
JFK															
EWR															
TEB															

Delay per Flt	**AVG**
LGA	
JFK	
EWR	
TEB	

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Reference Table 1											
Conversion Table: Restriction to Hourly Capacity											
Restriction	Unrest.	15 MIT	20 MIT	25 MIT	30 MIT	4 MINIT	5 MINIT	6 MINIT	7 MINIT	8 MINIT	Closed
Capacity	40	16	12	10	8	15	12	10	8	7	0

Reference Table 2													
Average Delay per Flight for 1st Hour													
Capacity	**Excess Demand**												
	£ 0	**2**	**4**	**6**	**8**	**10**	**12**	**14**	**16**	**18**	**20**	**22**	**24**
20	0	3	6	9	12	15	18	21	24	27	30	33	36
24	0	3	5	8	10	13	15	18	20	23	25	28	30
28	0	2	4	6	9	11	13	15	17	19	21	24	26
32	0	2	4	6	8	9	11	13	15	17	19	21	23
36	0	2	3	5	7	8	10	12	13	15	17	18	20
40	0	2	3	5	6	8	9	11	12	14	15	17	18
44	0	1	3	4	5	7	8	10	11	12	14	15	16
48	0	1	3	4	5	6	8	9	10	11	13	14	15
52	0	1	2	3	5	6	7	8	9	10	12	13	14
56	0	1	2	3	4	5	6	8	9	10	11	12	13
60	0	1	2	3	4	5	6	7	8	9	10	11	12
64	0	1	2	3	4	5	6	7	8	8	9	10	11
68	0	1	2	3	4	4	5	6	7	8	9	10	11
72	0	1	2	3	3	4	5	6	7	8	8	9	10
76	0	1	2	2	3	4	5	6	6	7	8	9	9
80	0	1	2	2	3	4	5	5	6	7	8	8	9

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Phase 2: How to set arrival rates?

- Assume departure capacities are known
- Balancing arrival and departure delays is OK but a GDP will reduce the departure delays
- How do we set arrival rates at airports to prevent gridlock?

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Gridlock Predictor/Preventer

- Provide “No GDP Action” predictions for airports with departure restrictions
- Offer guidance for setting GDP rates to prevent gridlock
- NEXTOR, Volpe, Metron

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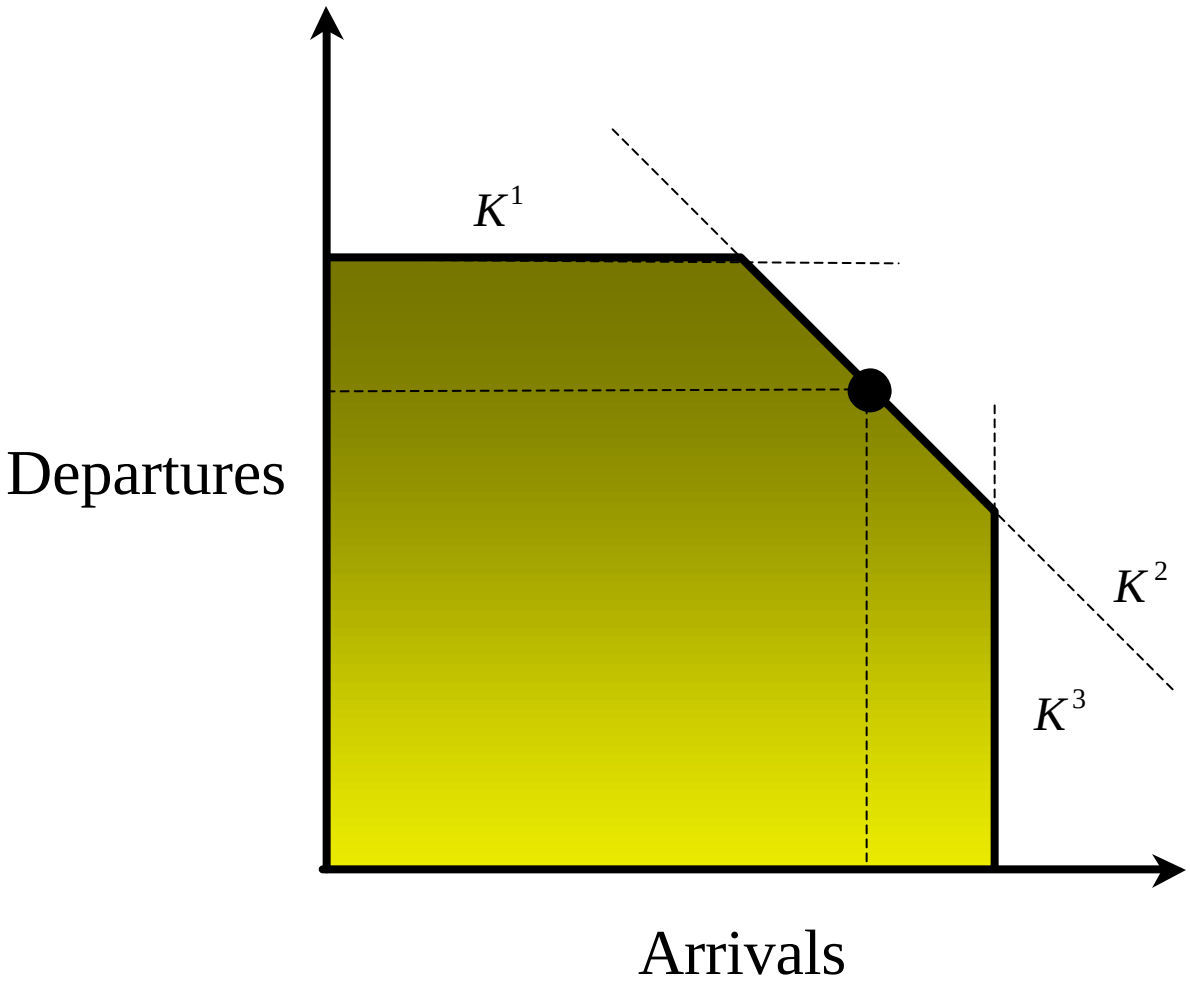
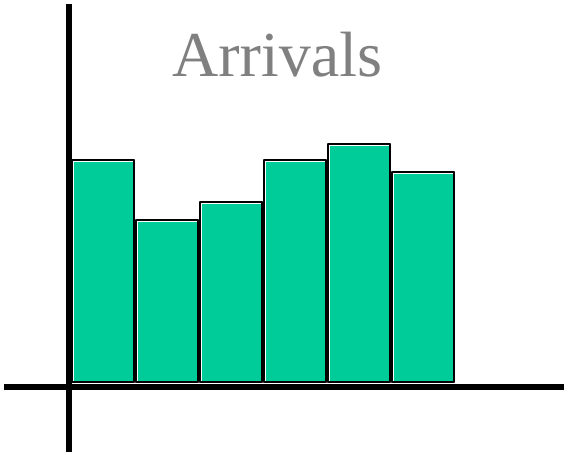
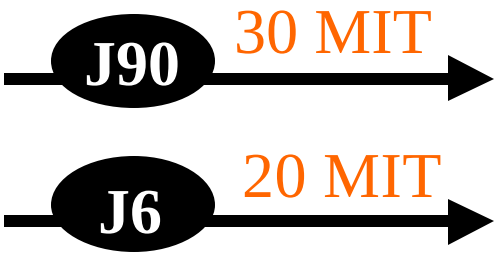
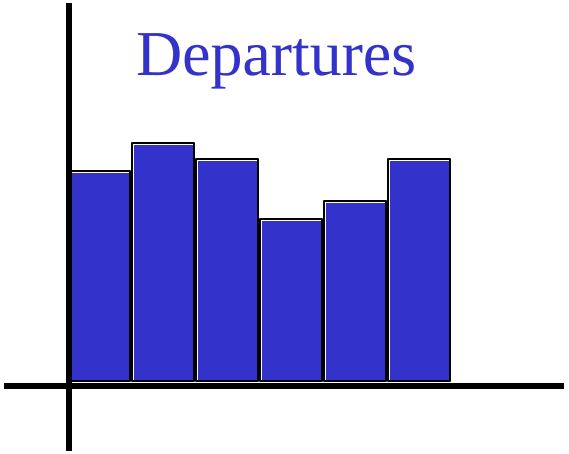
Balancing airport resources between arrivals and departures

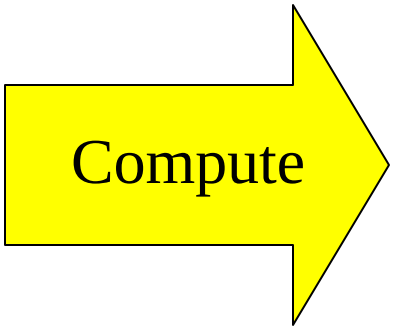


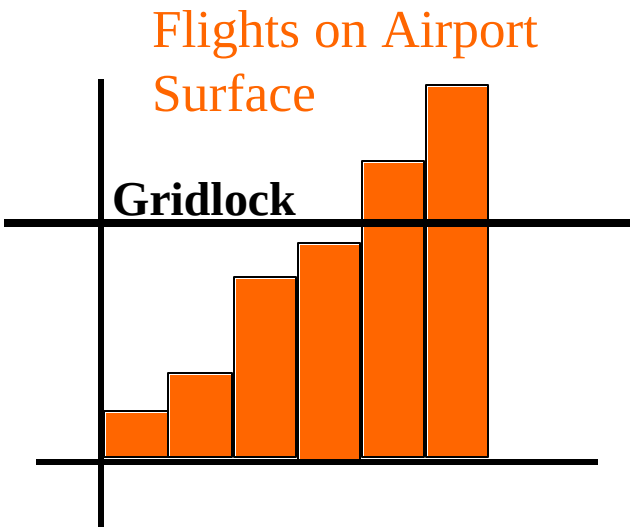
Prediction for No GDP Scenario

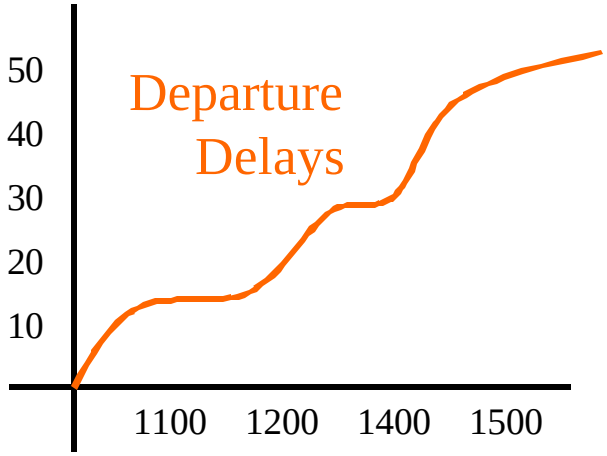












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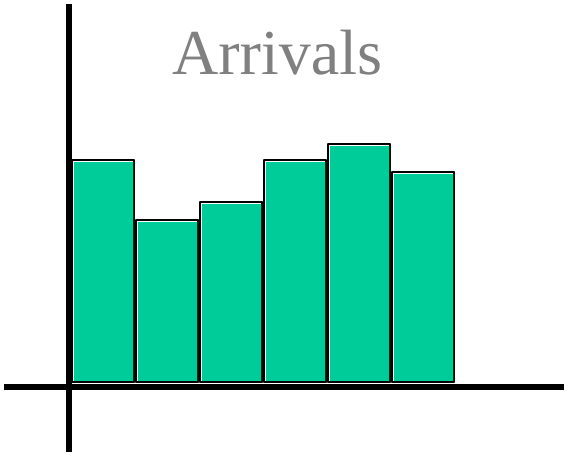
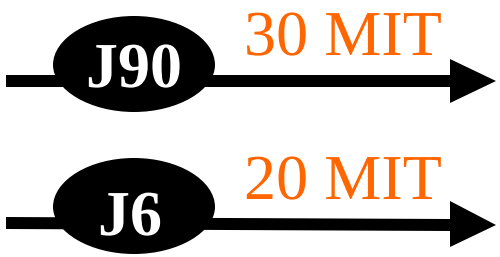
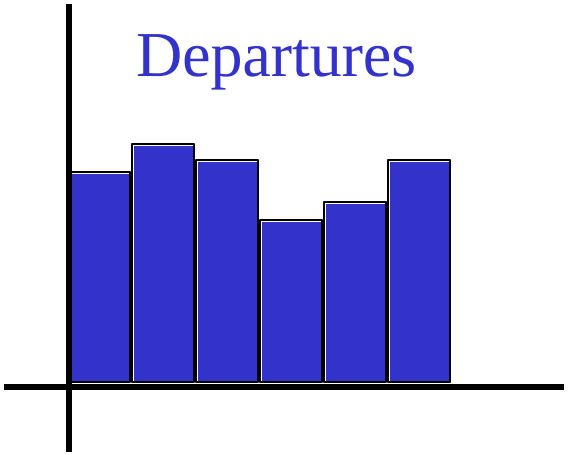
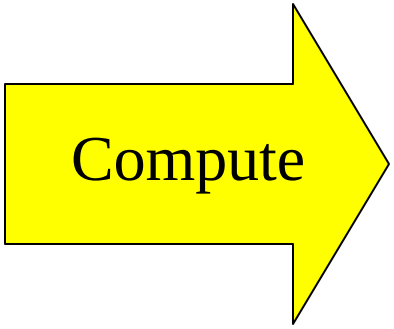
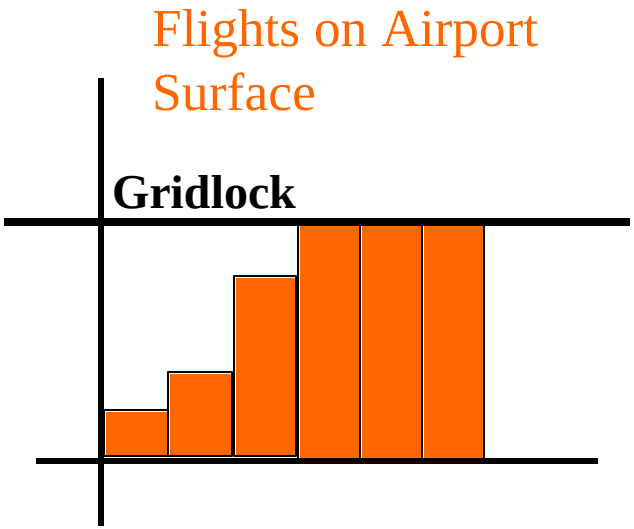
Rates for Gridlock Prevention





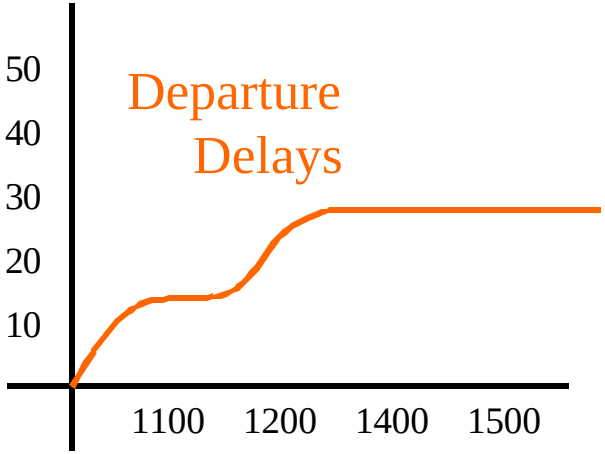






GDP Rates

32 32 40 40 38



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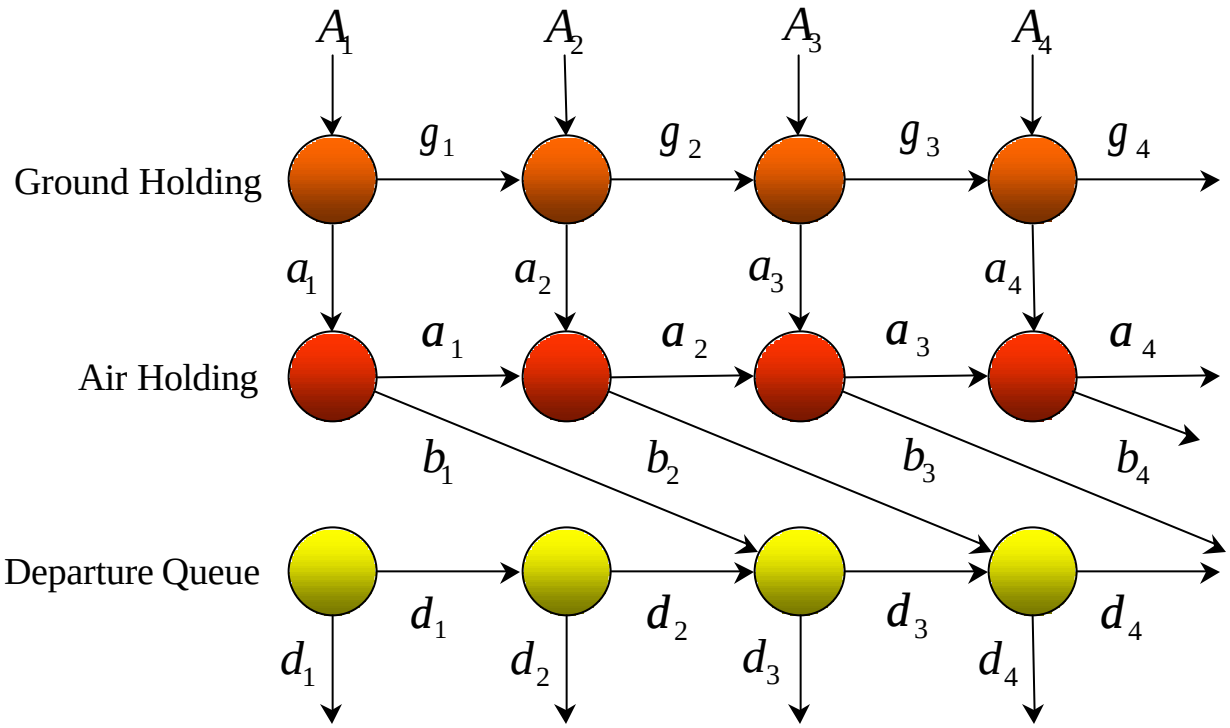
“Thruflow” Network Flow Model



Flow Diagram for GHP with Departure Constraints (T = 4, p = 2)

2 Model Formulation

Demand and Capacity Parameters at ARP

A_t = arrival demand for period t

AC_t^i = arrival capacity (flights per unit time) for period t, i in index set I_t

DC_t = departure capacity (flights per unit time) for period t

SC_t = surface capacity (flights per unit time) for period t

K_t^i = maximum number of airport operations in period t,

p = number of time periods for an aircraft to turnaround

Queueing Variables

γ_t = number of flights ground held to delay arrival at ARP from t to $t+1$

δ_t = number of flights in departure queue at ARP in period t

α_t = number of flights in arrival queue at ARP in period t

Decision Variables

a_t = number of flights planned (by GDP) to land at ARP in period t

b_t = number of flights actually landed at ARP in period t

d_t = number of flights departing ARP in period t

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$$\text{Minimize } W_\gamma \sum_{t=1}^{T} \gamma_t + W_\delta \sum_{t=1}^{T} \delta_t + W_\alpha \sum_{t=1}^{T} \alpha_t \tag{1}$$

Subject to

$$\gamma_{t-1} + A_t - \gamma_t - a_t = 0 \quad \text{for } t \in \tau \quad \text{(Consv of GDP flights)} \tag{2}$$

$$\alpha_{t-1} + a_t - \alpha_t - b_t = 0 \quad \text{for } t \in \tau \quad \text{(Consv of Arrivals)} \tag{3}$$

$$b_{t-p} + \delta_{t-1} - \delta_t - d_t = 0 \quad \text{for } t \in \tau \quad \text{(Consv of Departures)} \tag{4}$$

$$m^i d_t + b_t \leq AC_t^i \quad \text{for } t \in \tau\,;\ i \in I_t \quad \text{(ARP Capacity)} \tag{5}$$

$$d_t \leq DC_t \; for t \in \tau \quad \text{(Departure Capacity)} \tag{6}$$

$$\delta_{t-1} + \sum_{k=t-p}^{t-1} b_k \leq SC_t \quad \text{for } t \in \tau \quad \text{(Surface Capacity)} \tag{7}$$

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Next steps

- Currently looking for simple way to model aircraft turnaround without complicating model to much
- Test ability of model to prevent airport gridlock
- Deliver to ATCSCC

METRON AVIATION

Recent Findings

Recent Findings

- Airspace GDP issues
- Airspace Demand Uncertainty
- Data Quality Example

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Airspace GDP Issues

- ***Domain of concern:*** how big is the FCA? In an airport GDP, this is always the airport, so no decision needs to be made.
- Demand unpredictability
- Capacity of the domain (more easily determined for an airport because it's based on runway configuration)
- ***Resource usage:*** not all aircraft spend same amount of time in the domain
- ***Complexity:*** en route domains may have more complex traffic patterns than airport arrival runways, so complexity of airspace may have to be taken into account
- ***Substitutions:*** will use of an en route domain be modeled as "slots"? If so, the ordinary sub process may work. If not, what does a sub mean?
- ***Cancellations:*** Big problem here. In an airport GDP, when a flight cancels, it truly disappears from the system (usually). But an en route cancellation out of an en route domain could just mean that the flight has chosen another route.
- ***Control:*** can we really control flights bound for an en route domain? The reason an airport GDP is so effective is that the destination of a flight is fixed. However, the en route resources used by a flight could change.

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Airspace GDP Issues (cont.)

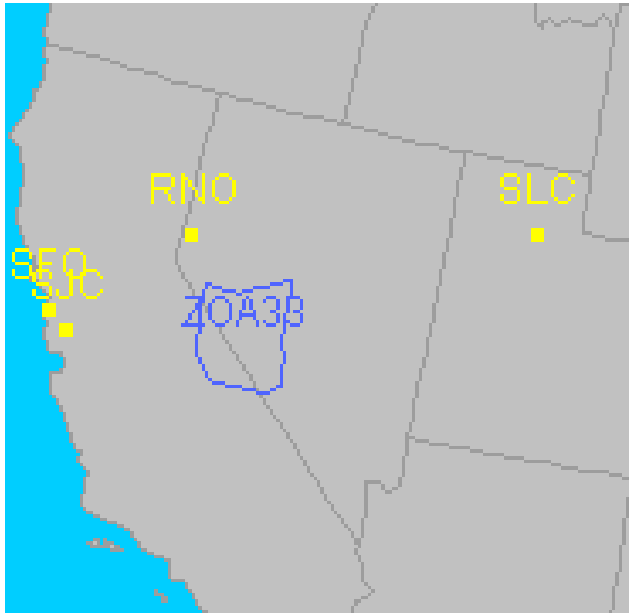
- ***Early intention:*** in an airport GDP, we usually know well ahead of time which flights will arrive at a GDP airport, because their destination is fixed. However, en route, we might not get meaningful en route usage intention notices until just before departure.
- ***Compression:*** in theory, temporal compression may work en route, as it does in an airport GDP. However, shouldn't there be a spatial compression as well, to handle the case in which too many flights have rerouted around an en route domain, and we have space available to push them back?
- ***OAG time:*** what is OAG time for en route? There is no SGTD/SGTA field for en route. Perhaps one could be constructed by back-calculating from scheduled arrival times.
- Popups (unexpected demand) will be much more prevalent en route, since flights can easily 'drift' into an en route domain.
- How will MIT be coordinated with an en route GDP?
- ***Moving target:*** airports don't move, but FCAs probably do. With the target domain constantly changing, the computed and scheduled arrival times of the flights will be constantly changing as well. Could place heavy demands on revisions and AOC subn/cnx processes. The arrival order would constantly shift as well

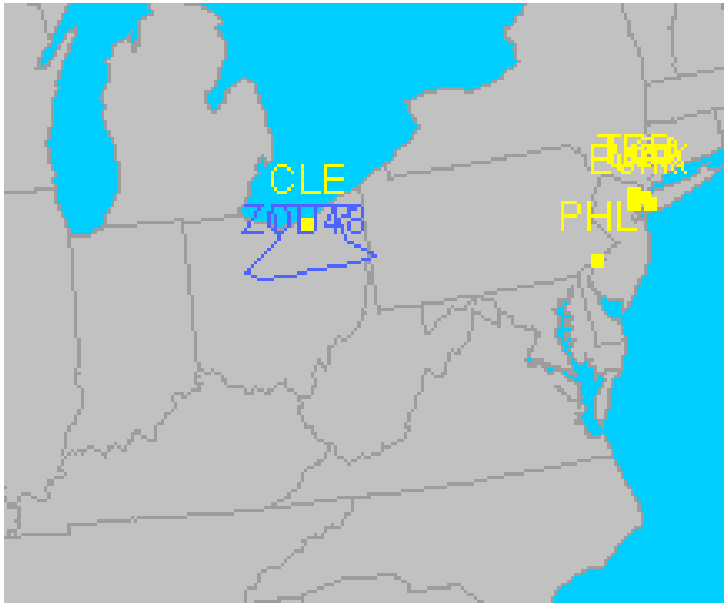
Airspace Demand Uncertainty

- Key factor in the success of conducting an airspace (FCA or sector) GDP
- Used CCSD to explore demand variability over time for two different sectors
- Used POET to explore demand prediction errors for select sectors

METRON AVIATION

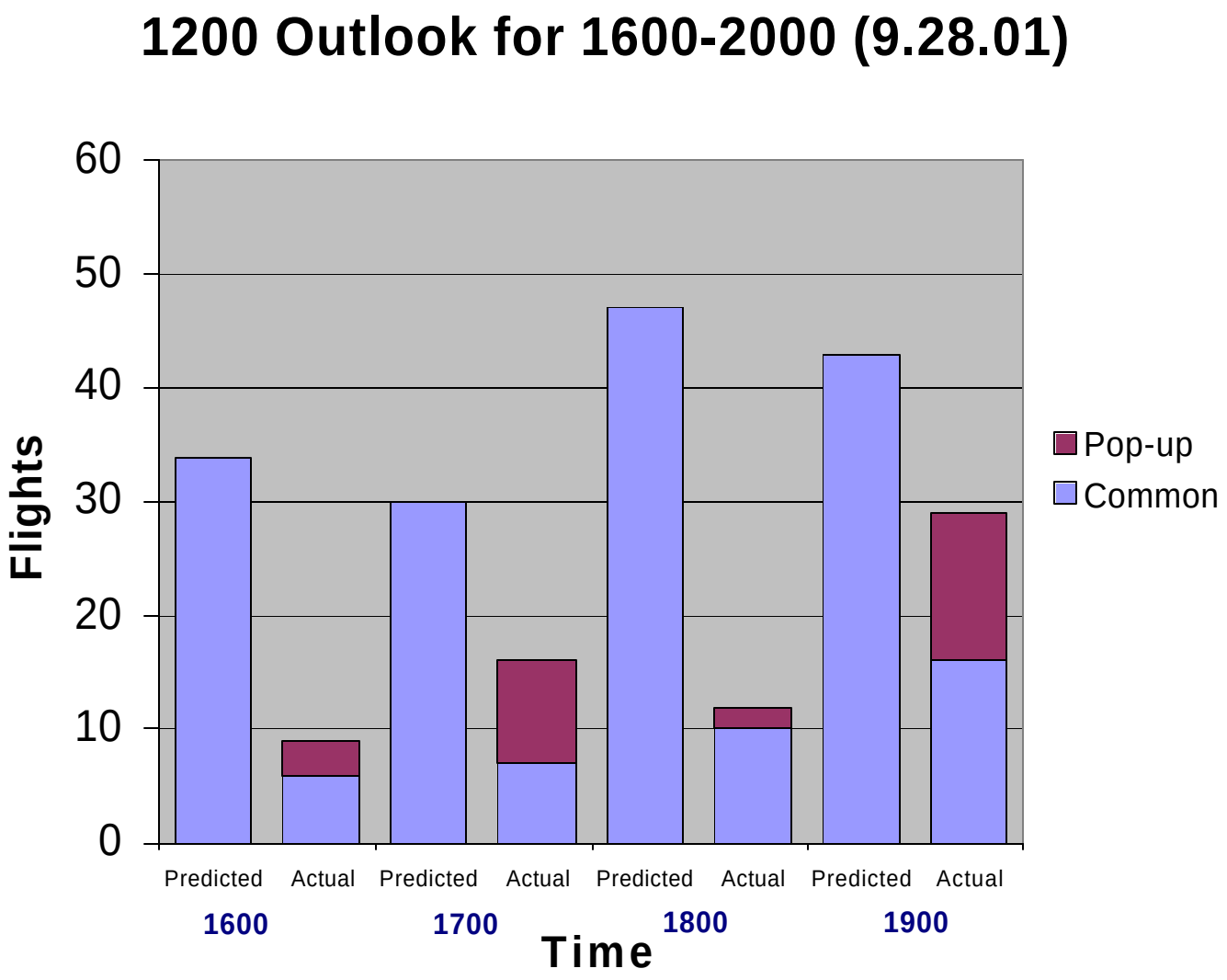
Demand Variability: Selected Sectors





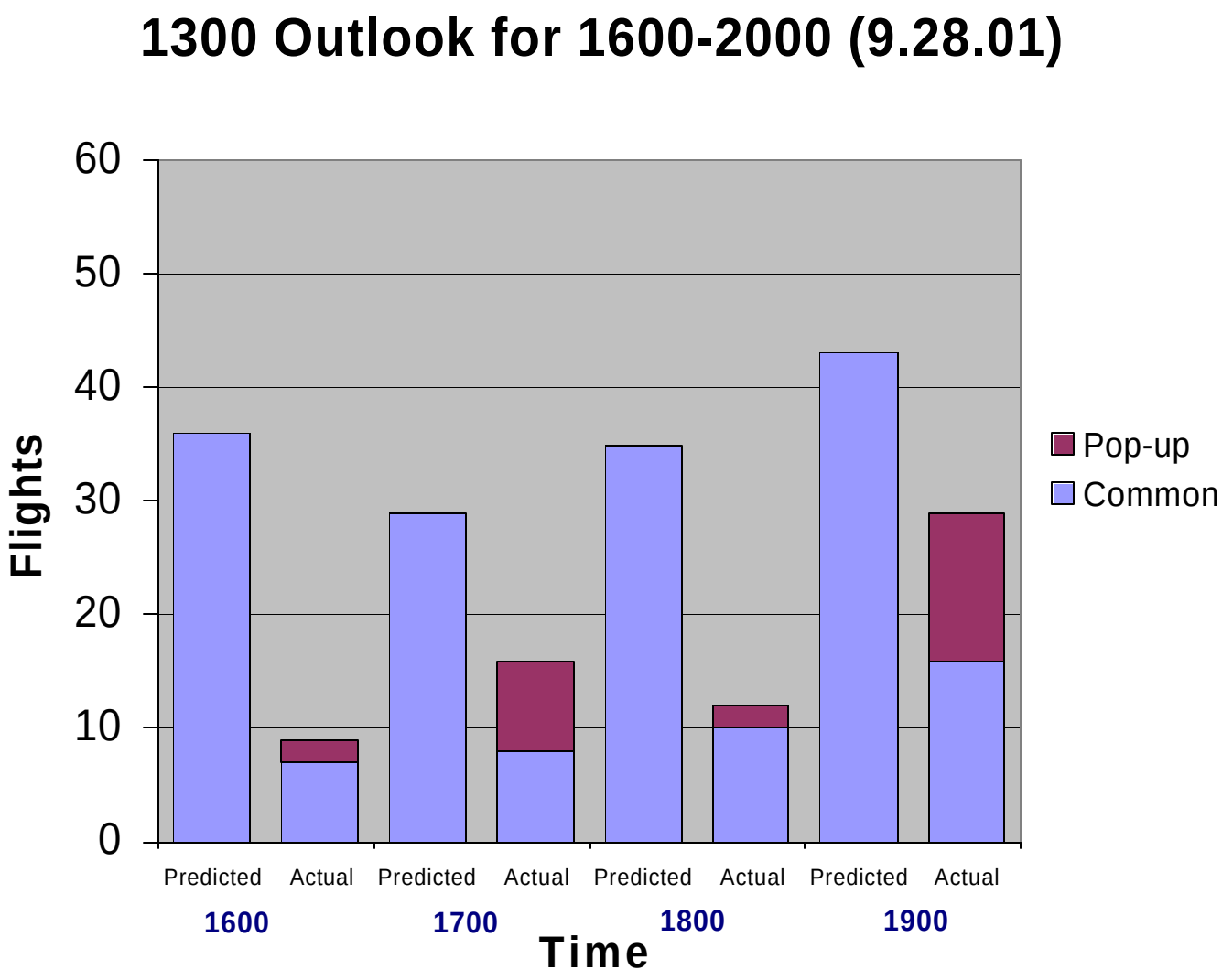
METRON AVIATION

Demand Variability ZOB48



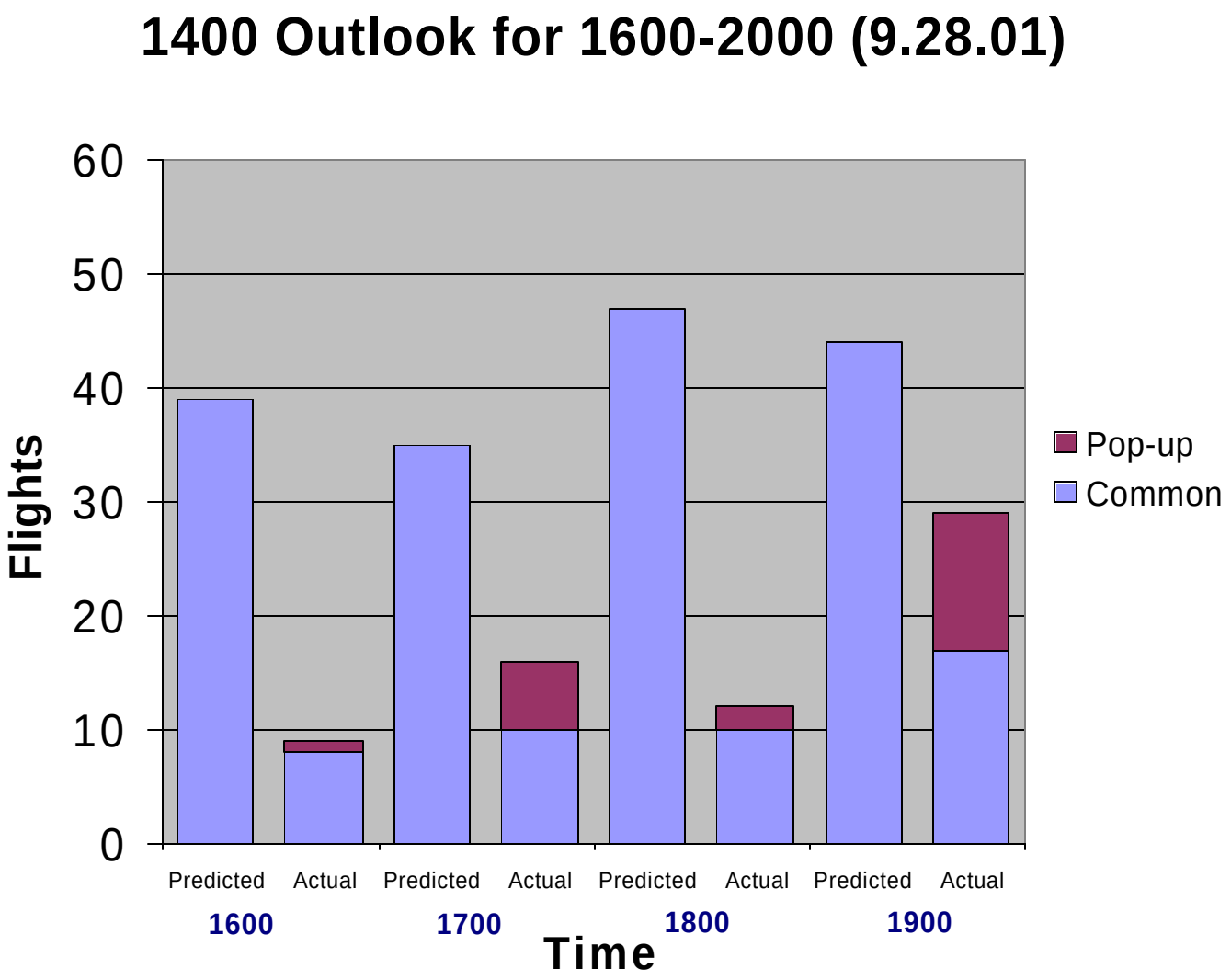
METRON AVIATION

Demand Variability ZOB48



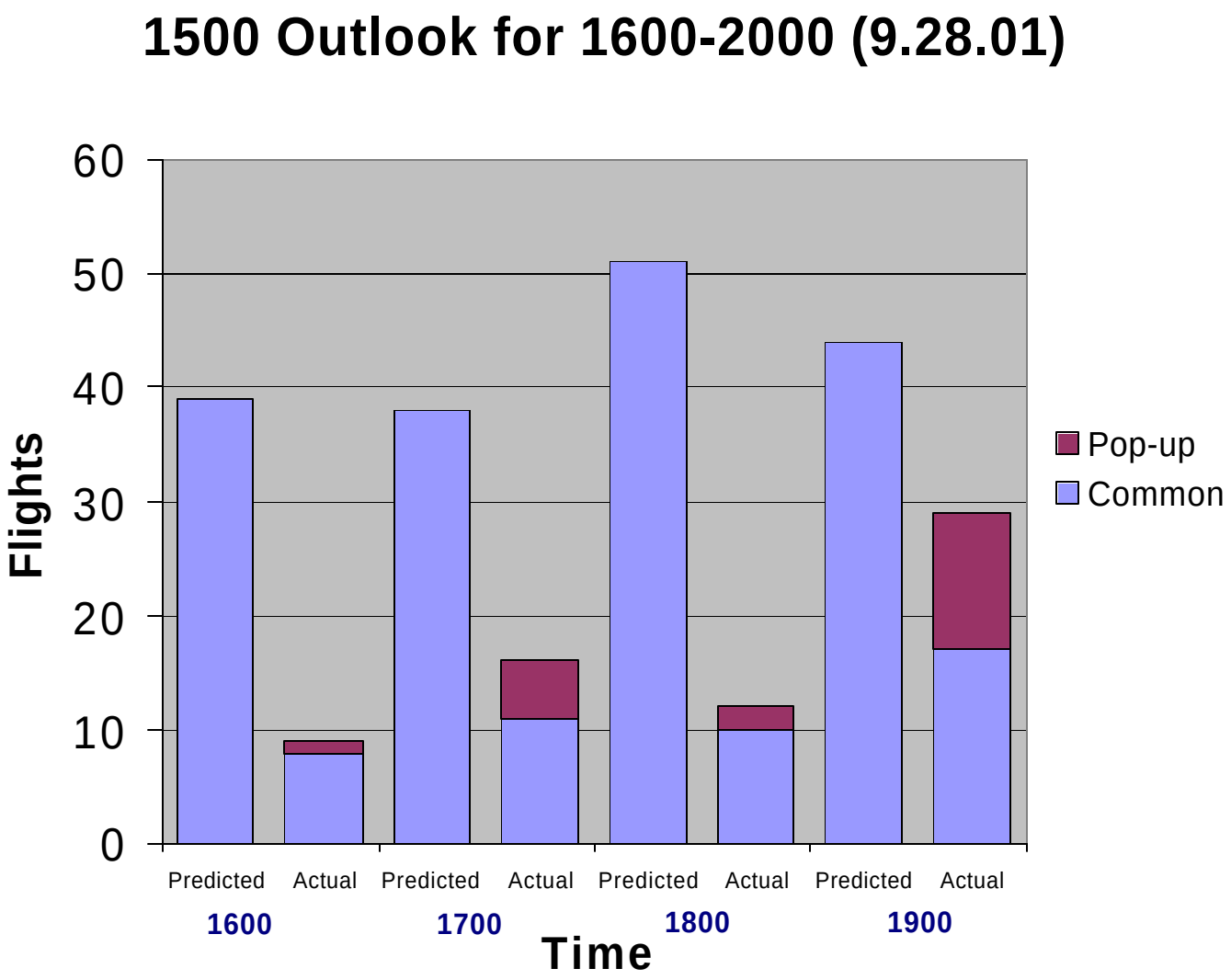
METRON AVIATION

Demand Variability ZOB48



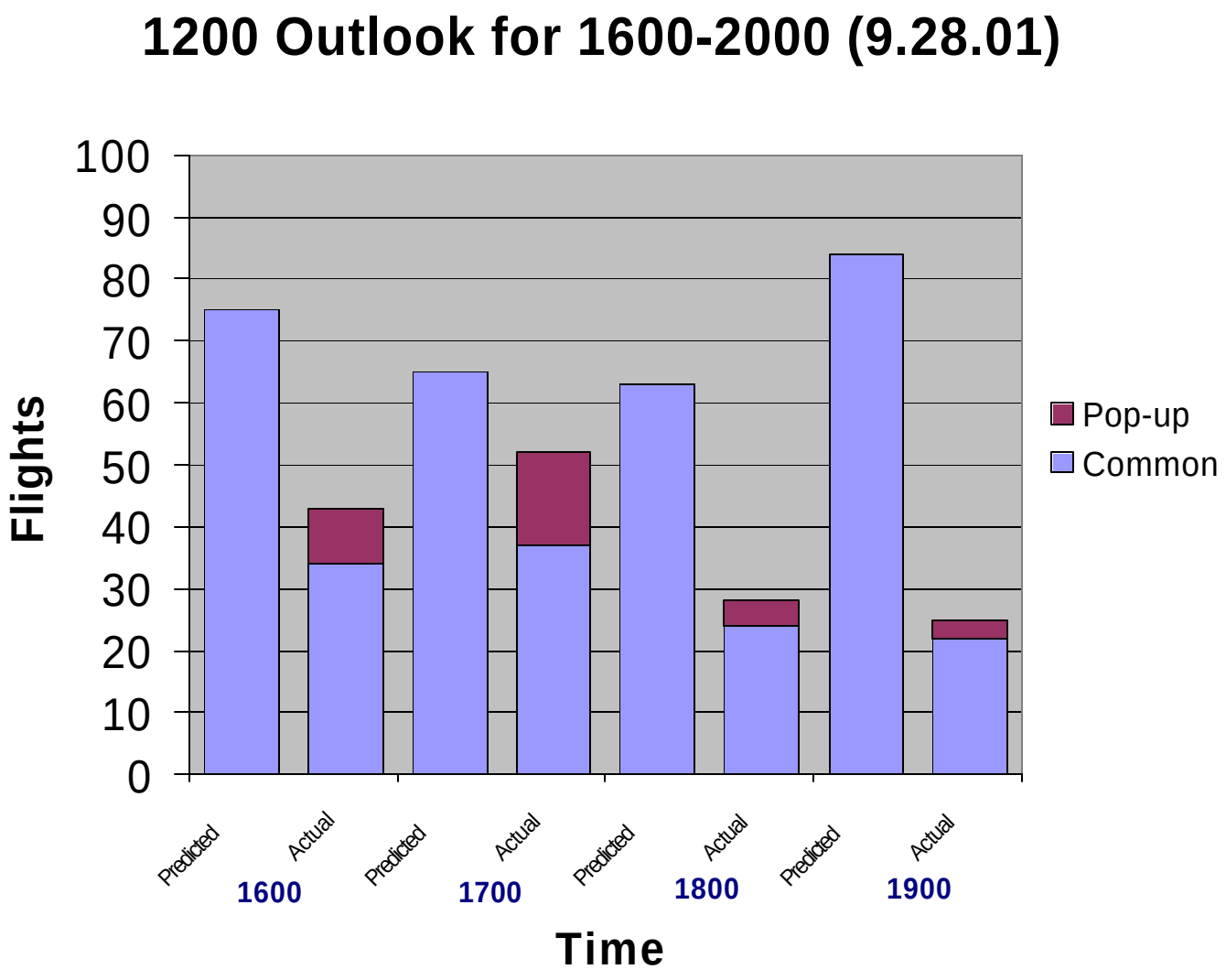
METRON AVIATION

Demand Variability ZOB48



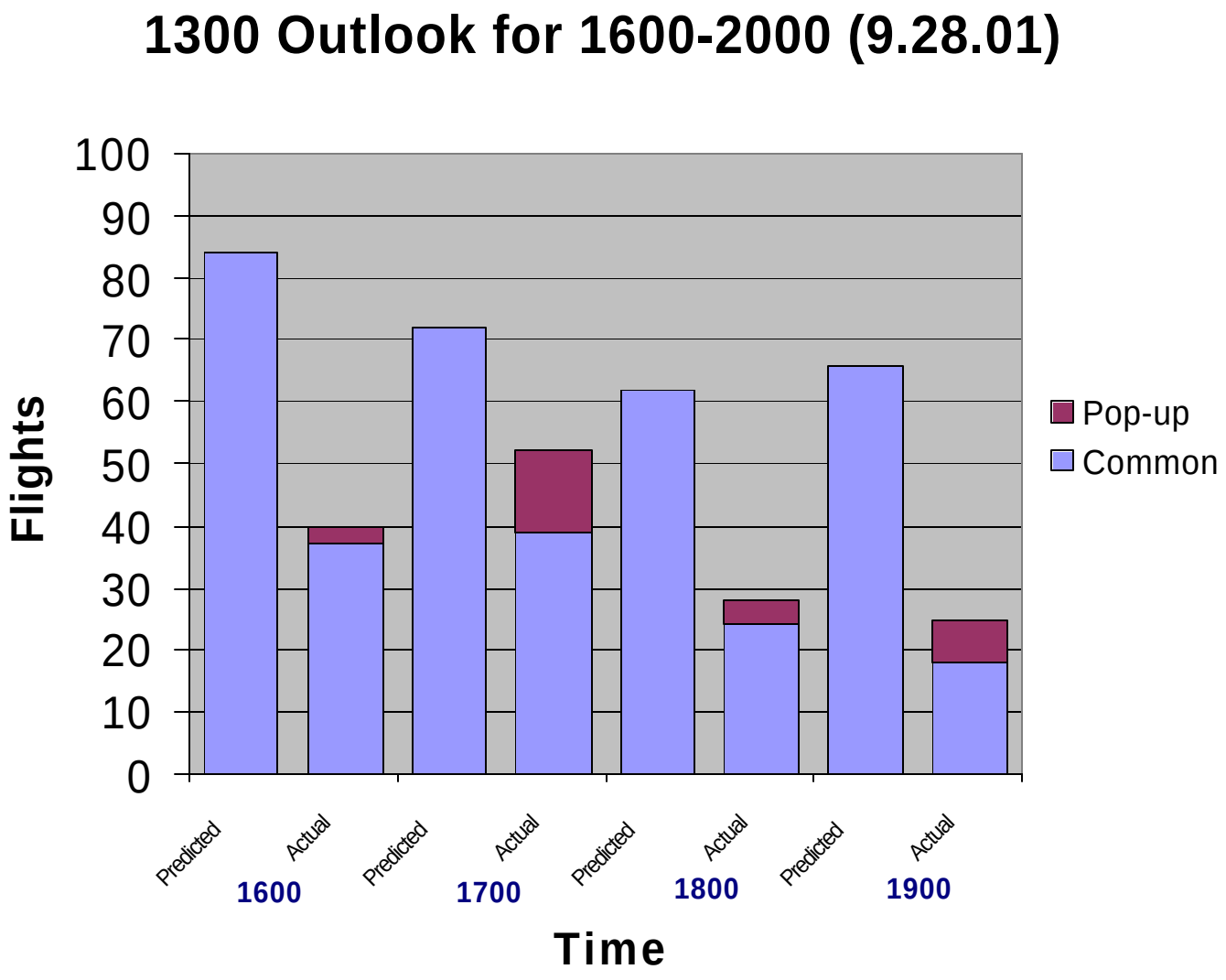
METRON AVIATION

Demand Variability ZOA33



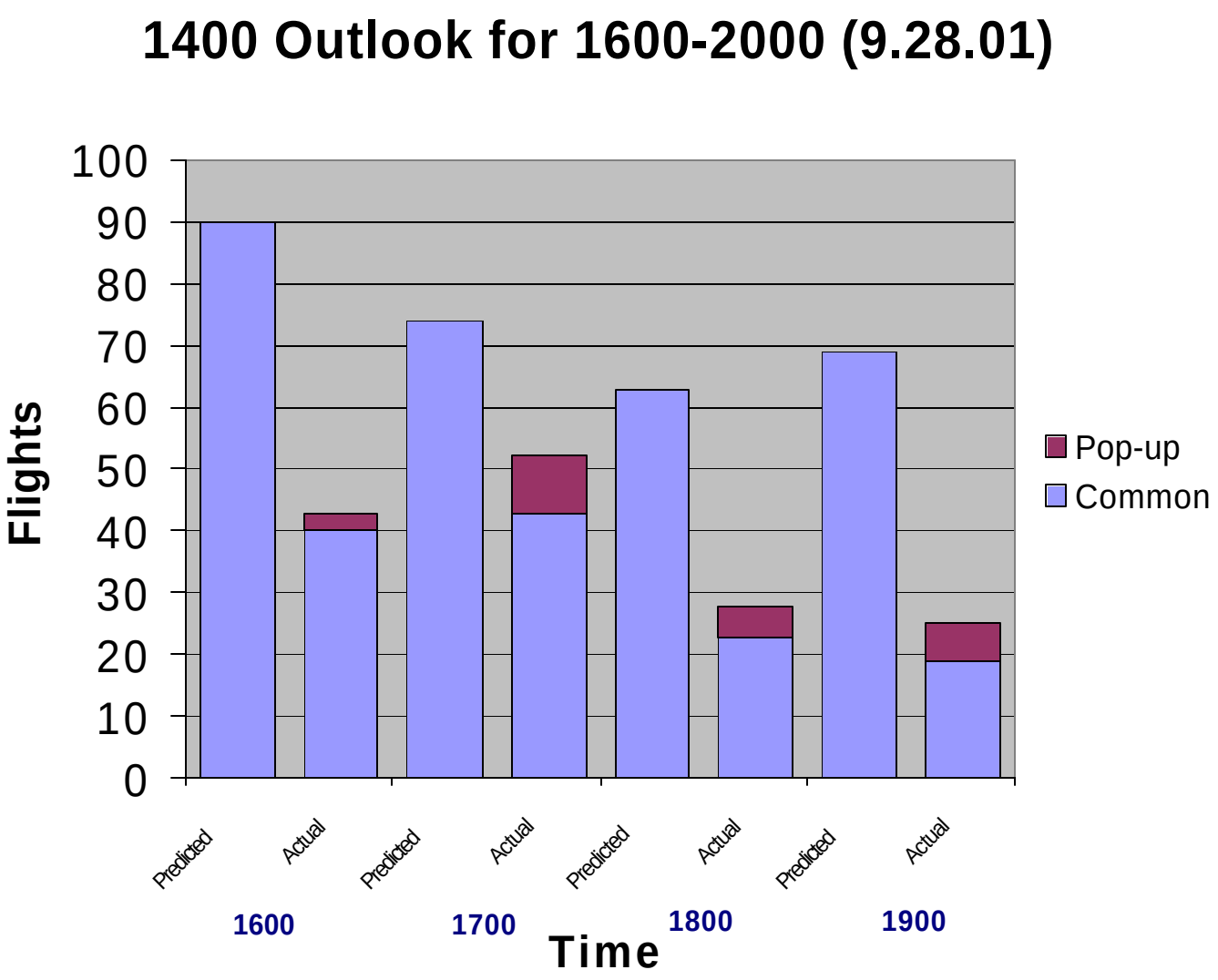
METRON AVIATION

Demand Variability ZOA33



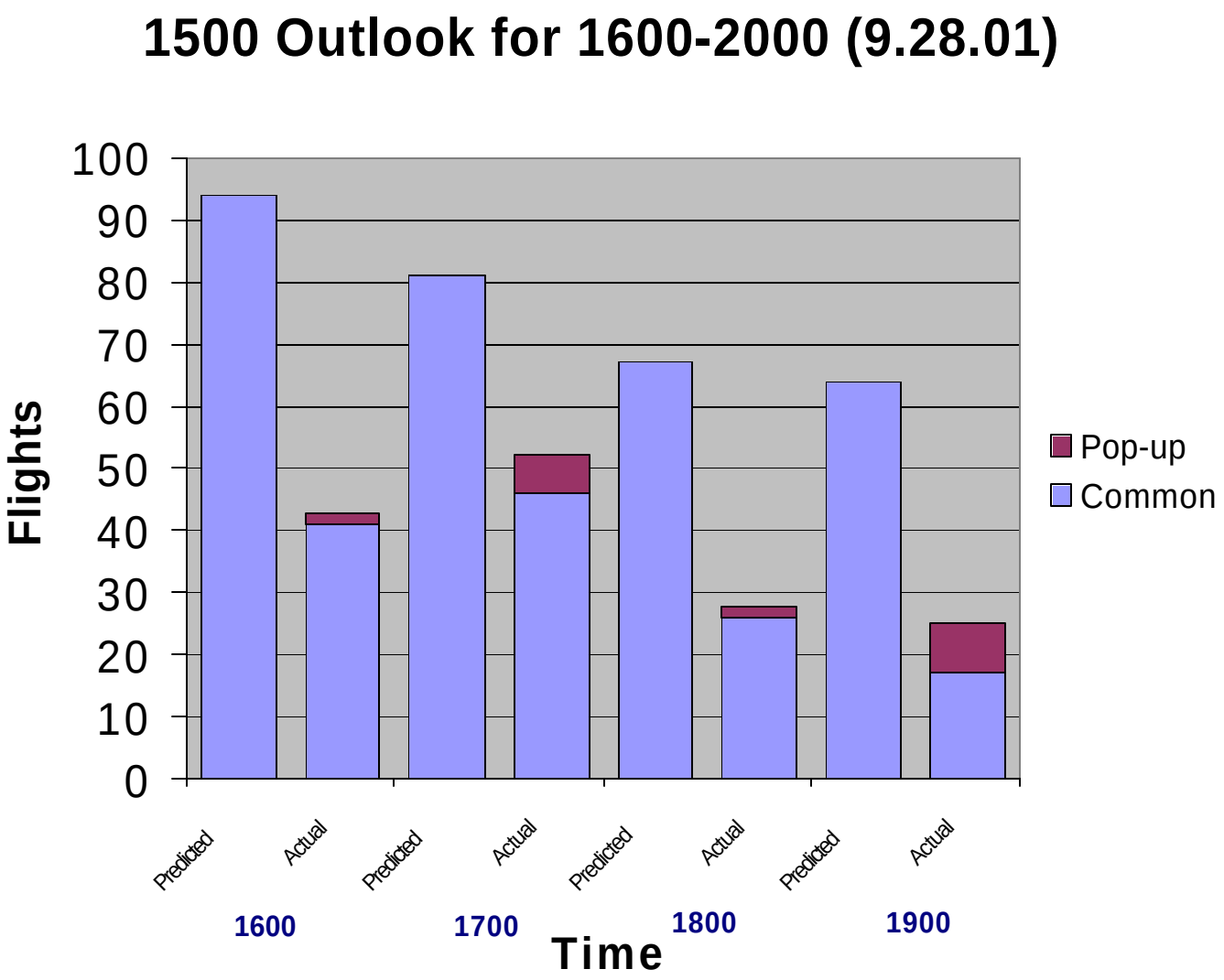
METRON AVIATION

Demand Variability ZOA33



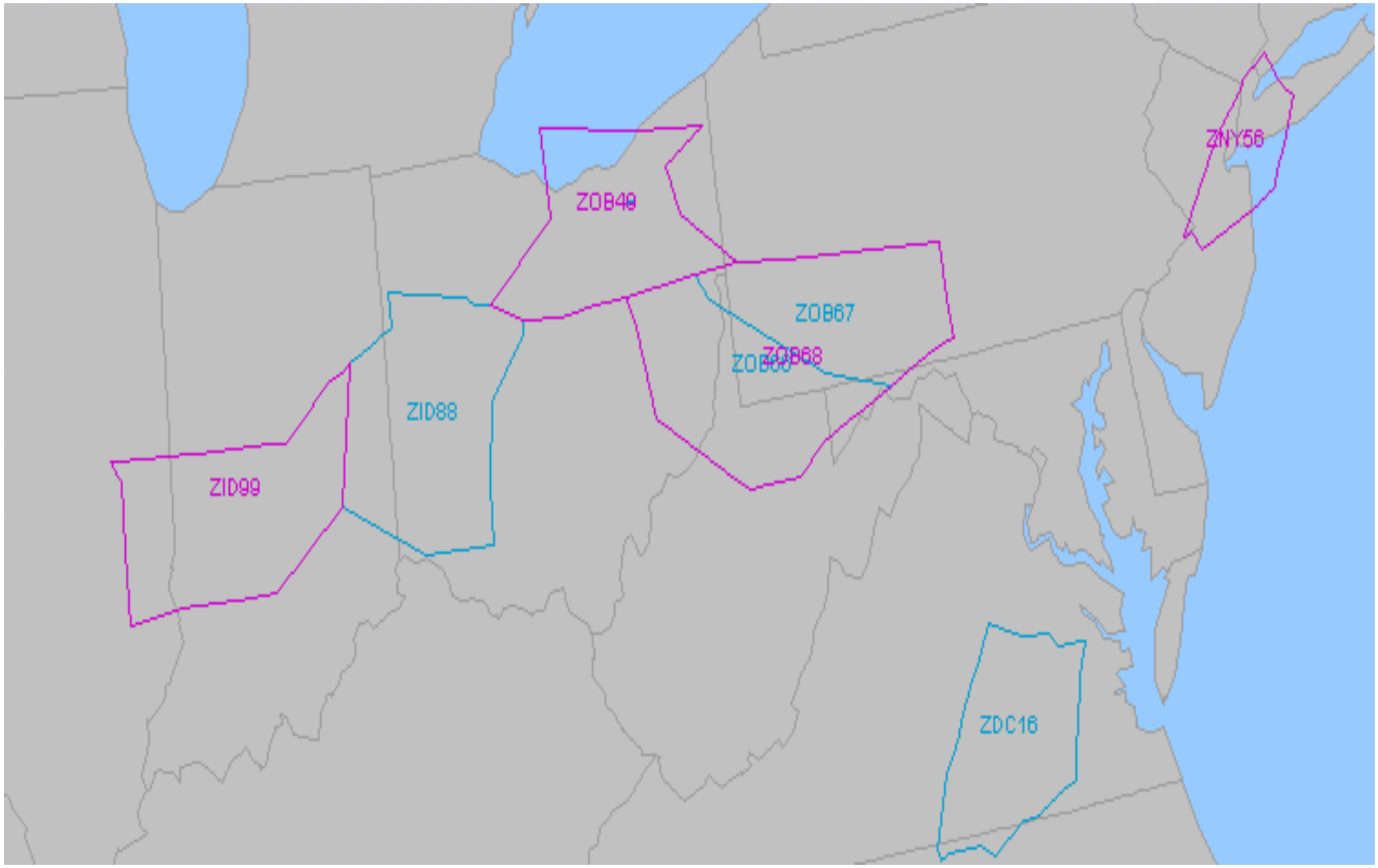
METRON AVIATION

Demand Variability ZOA33



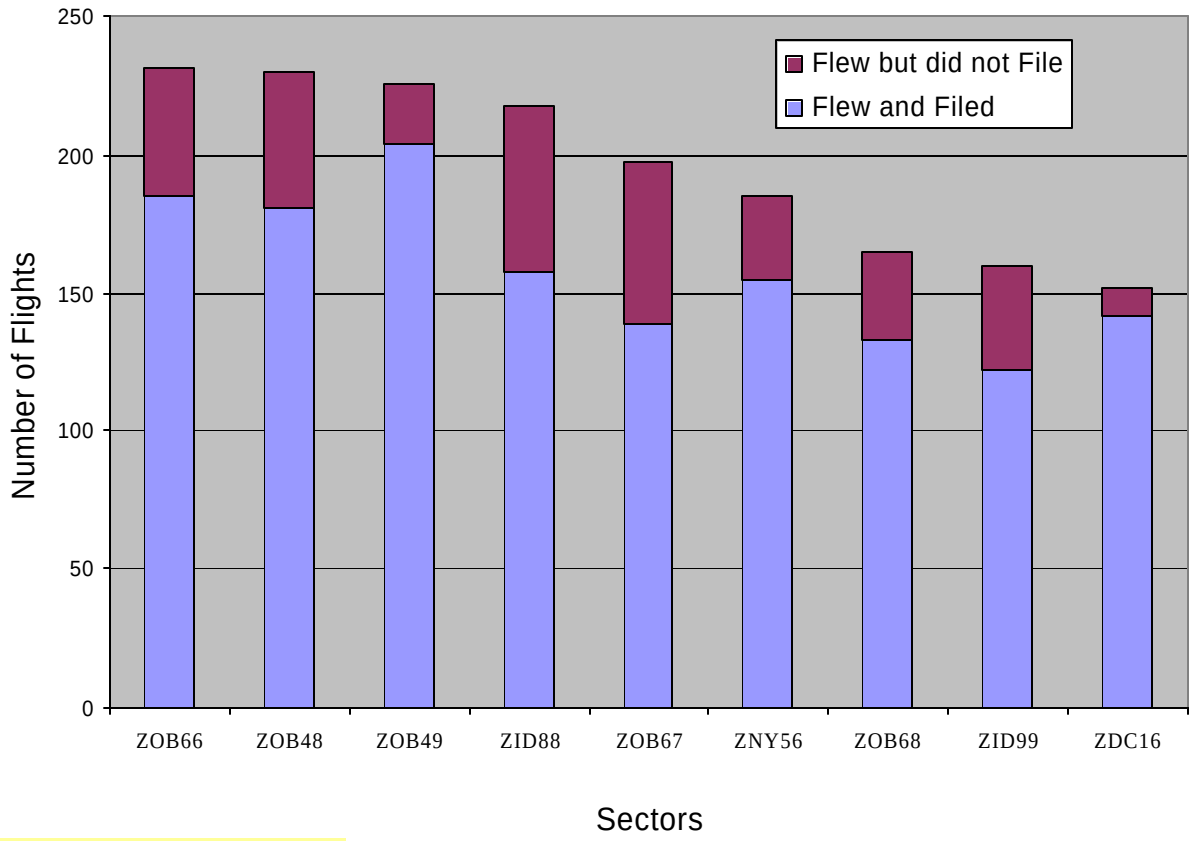
METRON AVIATION

Demand Prediction Error - Selected Sectors



METRON AVIATION

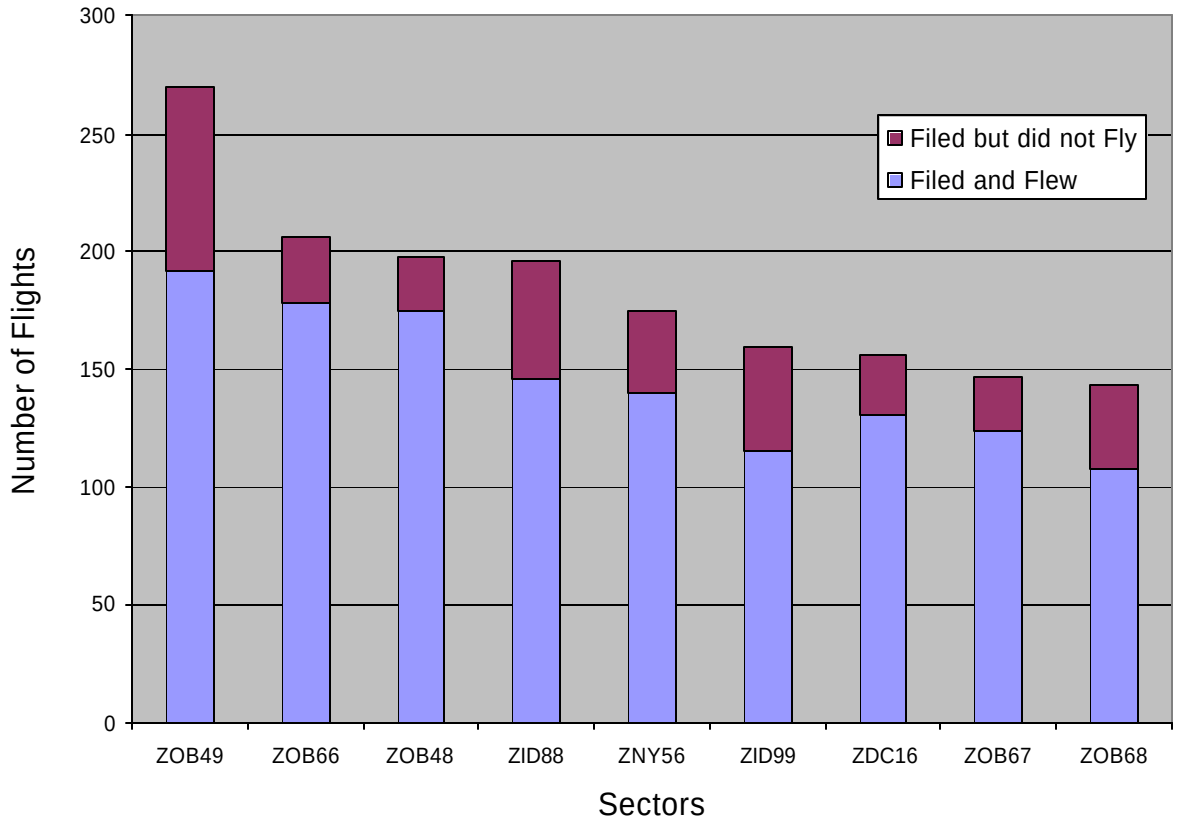
Flights Flown but not Filed



Data from 1900-2300z on Wednesday, September5th

METRON AVIATION

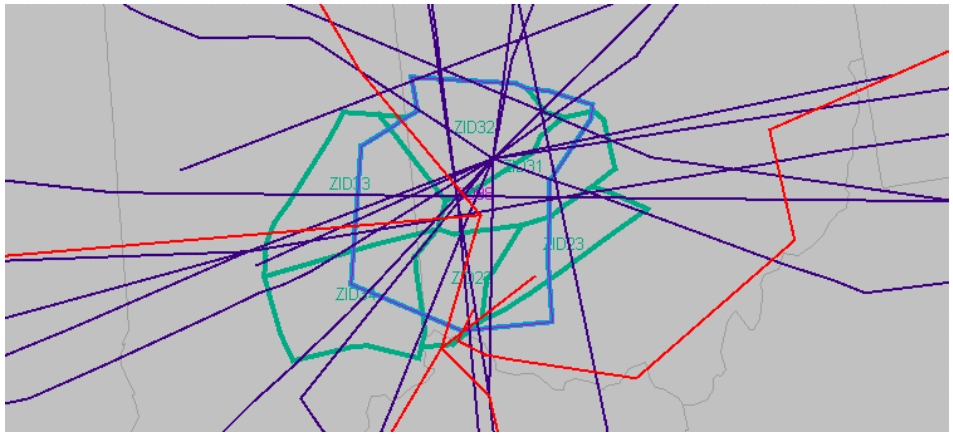
Flights Filed but not Flown

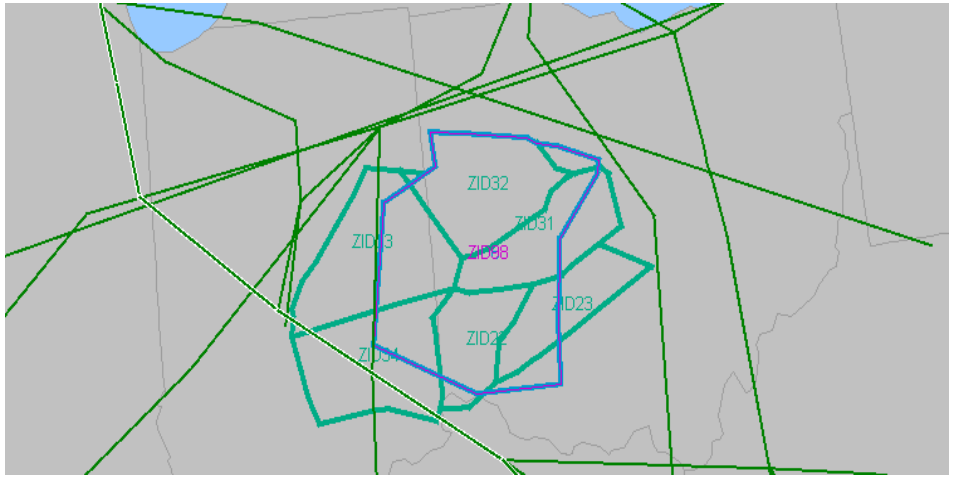


Data from 1900-2300z on Wednesday, September5th

METRON AVIATION

Flights Flown but did not File ZID88





37	Flights Filed for ZID98
5	Flights Filed for Lower ZID Sectors
+ 18	Flights Filed Around ZID88
60	(out of 218) Flew but did not File ZID88

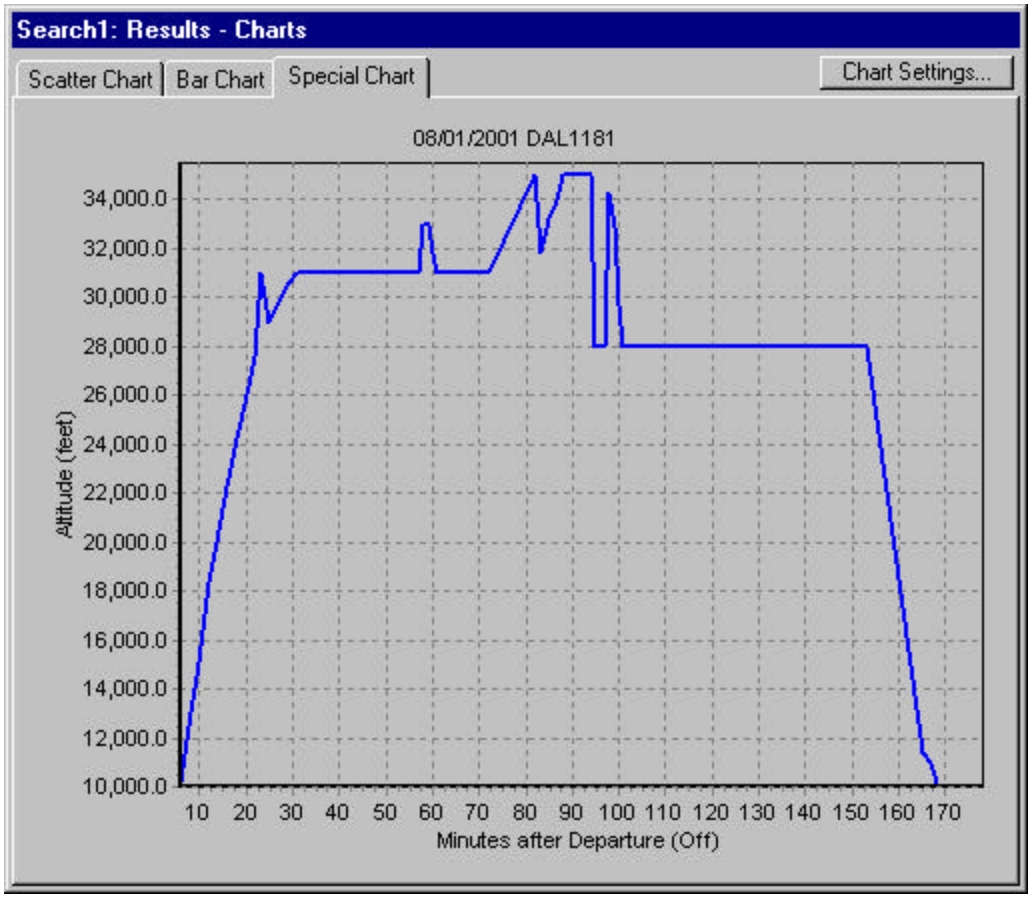
METRON AVIATION

Data Quality Examples

- TZ altitudes
- Actual departure/arrival times
- Duplicate flights
- Missing arrival message?

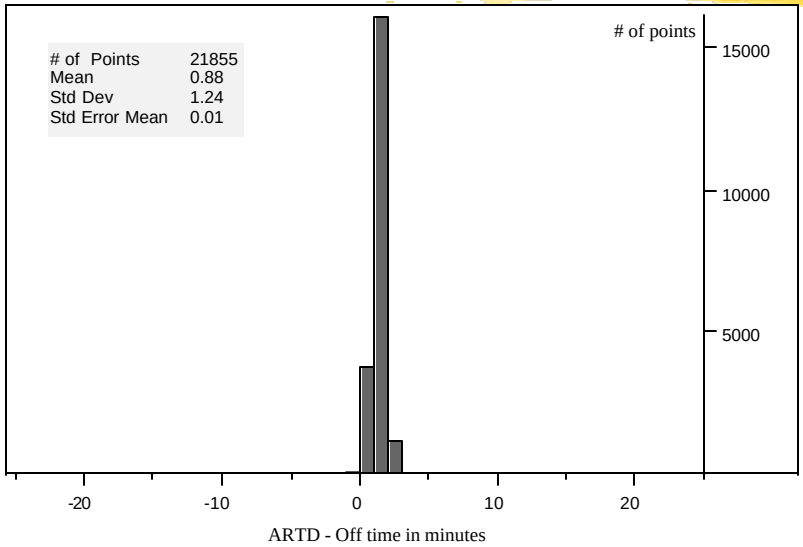
METRON AVIATION

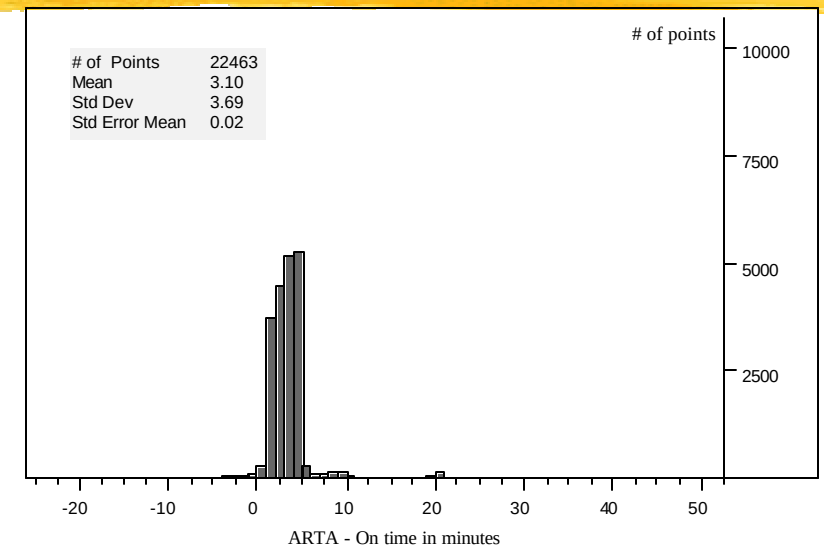
TZ Altitudes

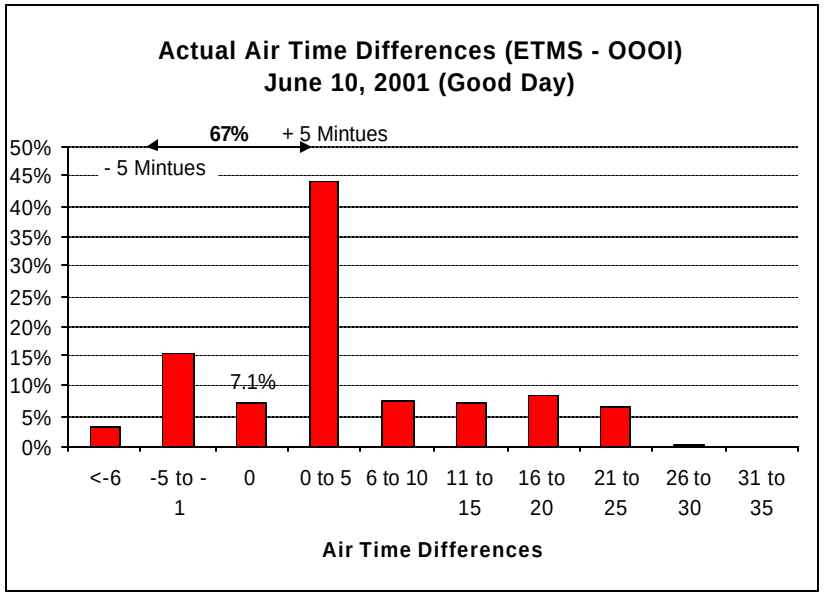


METRON AVIATION

ETMS Departure/Arrival Times

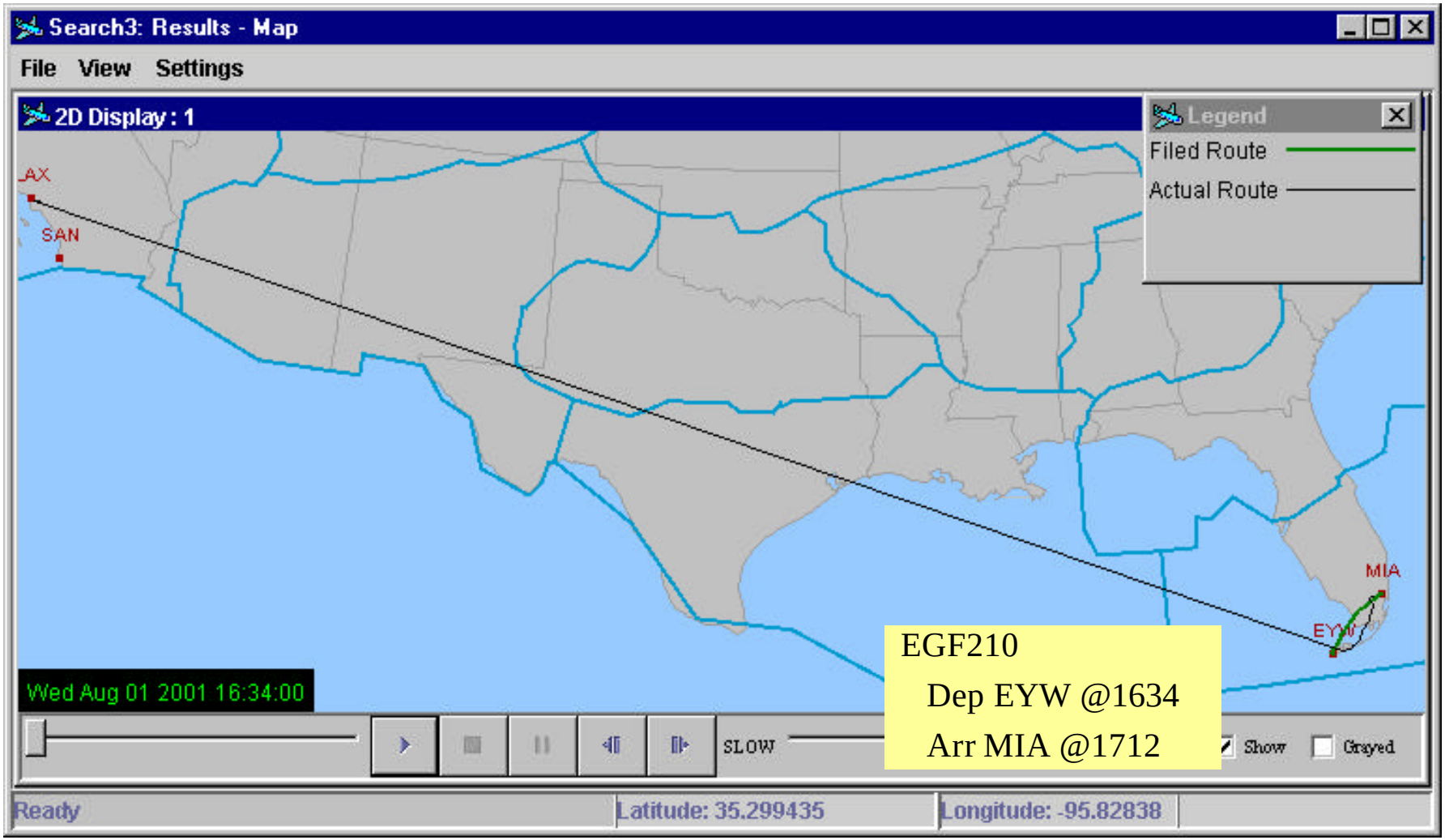






METRON AVIATION

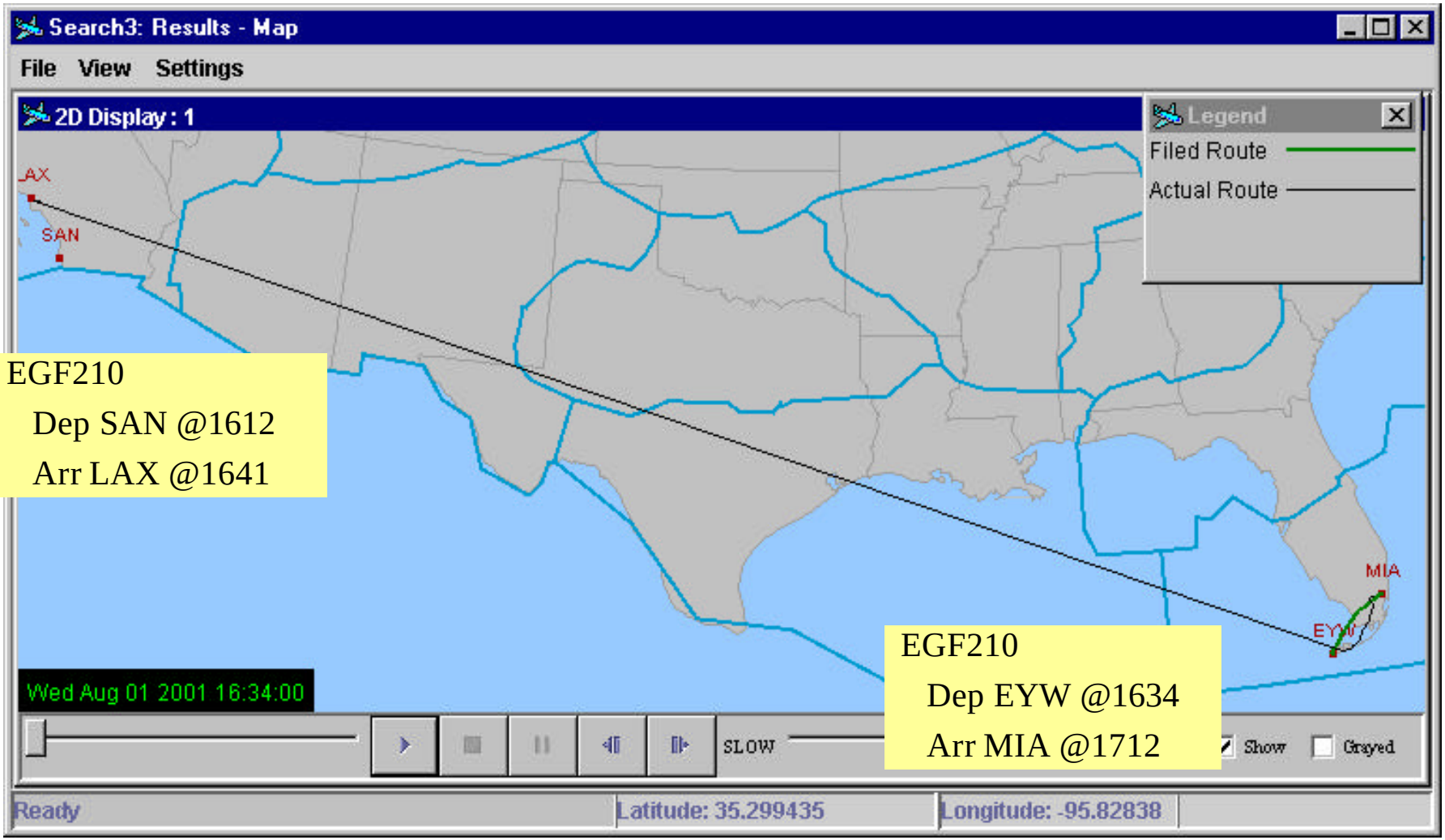
The flight of EGF210 (8/1/01)



EGF210
Dep EYW @1634
Arr MIA @1712

METRON AVIATION

The flight of EGF210 (8/1/01)



EGF210
Dep SAN @1612
Arr LAX @1641

EGF210
Dep EYW @1634
Arr MIA @1712

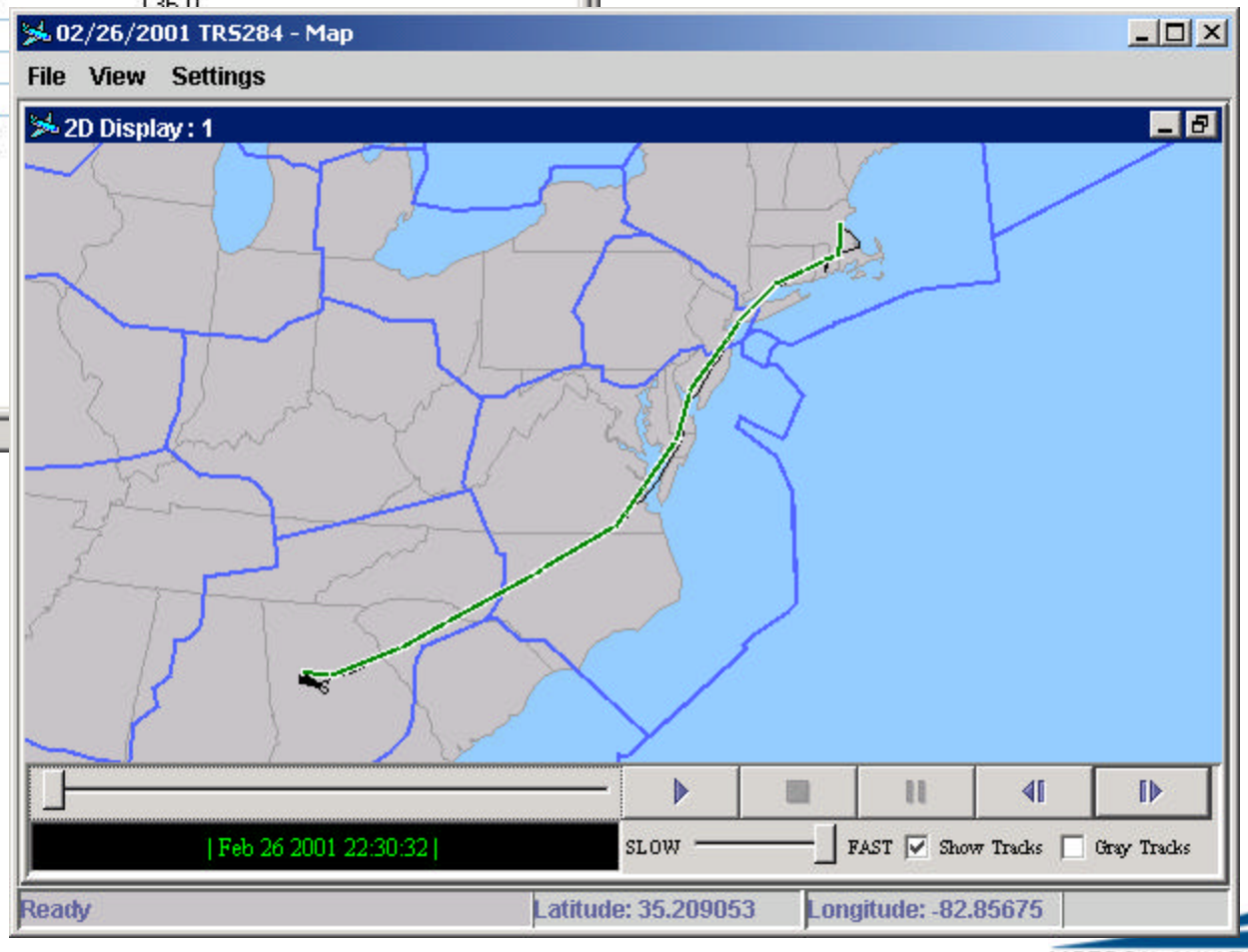
METRON AVIATION

The flight of TRS284 (2/26/01)

02/26/2001 TRS284

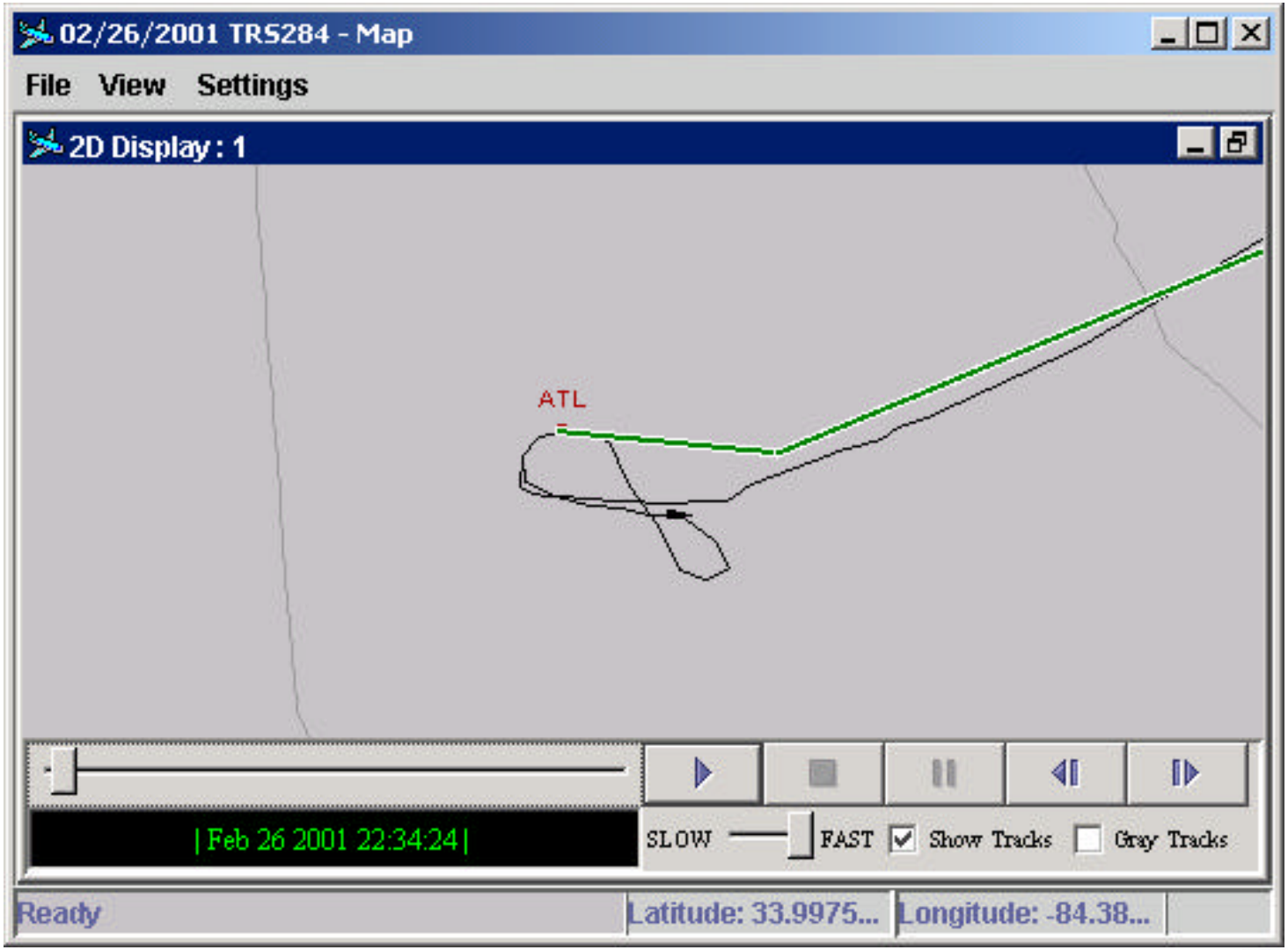
General Information | Performance Metrics | Routing Information

Performance Metrics	Planned	Actual	Difference (Actual - Planned)	
Departure Time (OFF)(Z)	2213	2227	14.0	
AirTime(mins)	127.0	250.0	123.0	96.9%
Arrival Time (ON)(Z)	0021	0237	136.0	
NRP(%)				
Circular Holding(%)				
Changed Arrival Fix(%)				
Distance(miles)	<null>	<null>		



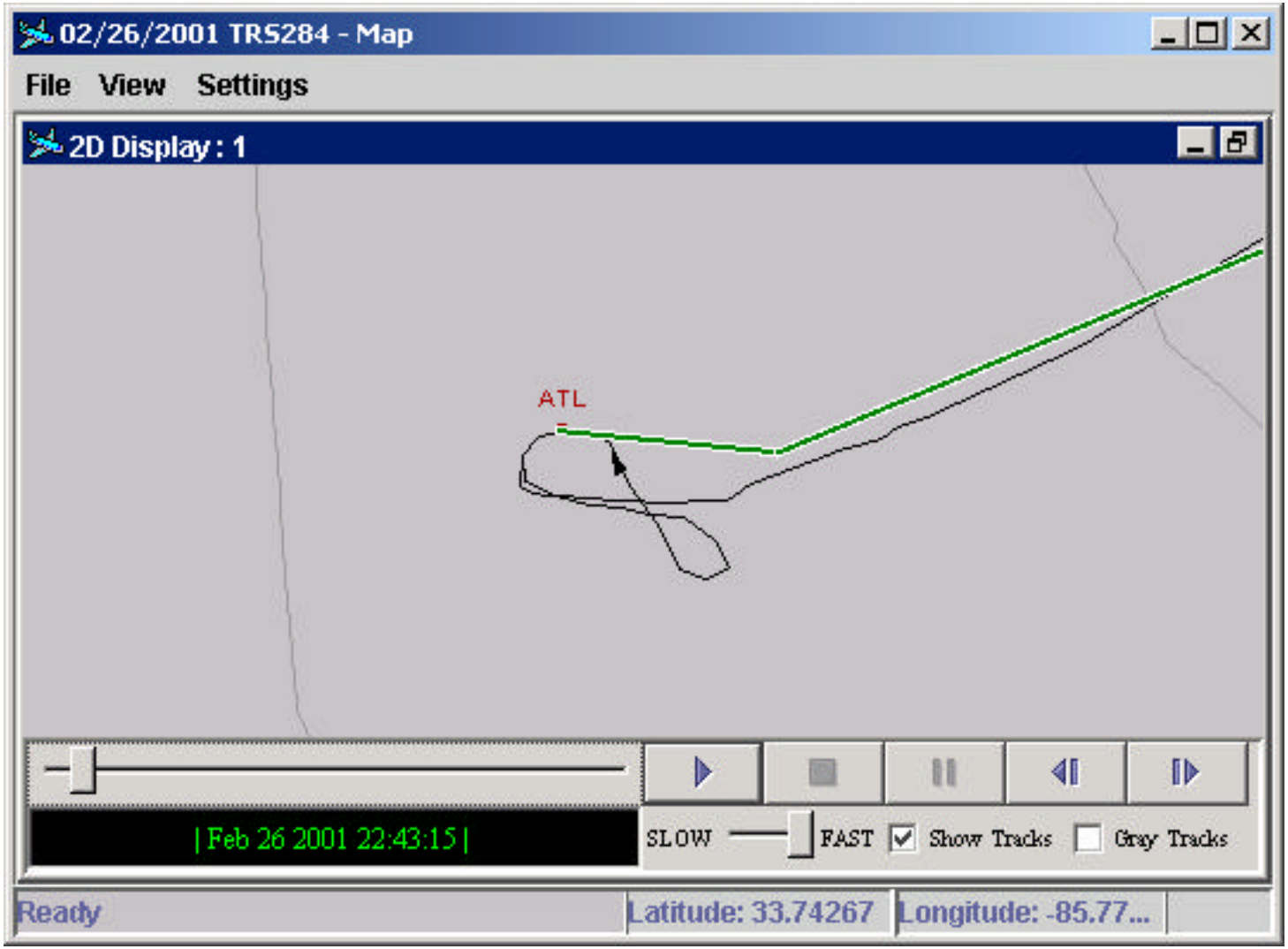
METRON AVIATION

The flight of TRS284 (cont)



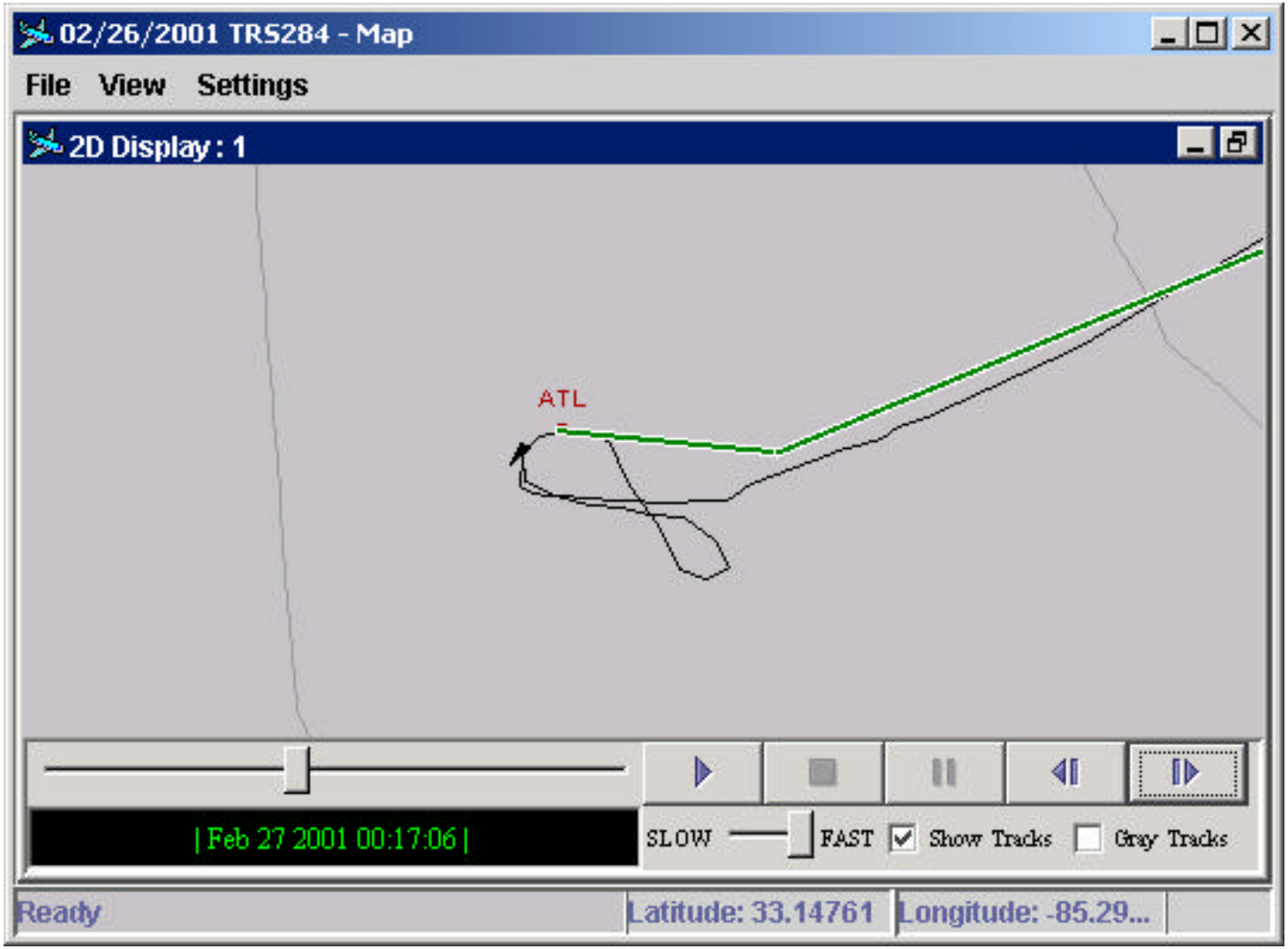
METRON AVIATION

The flight of TRS284 (cont)



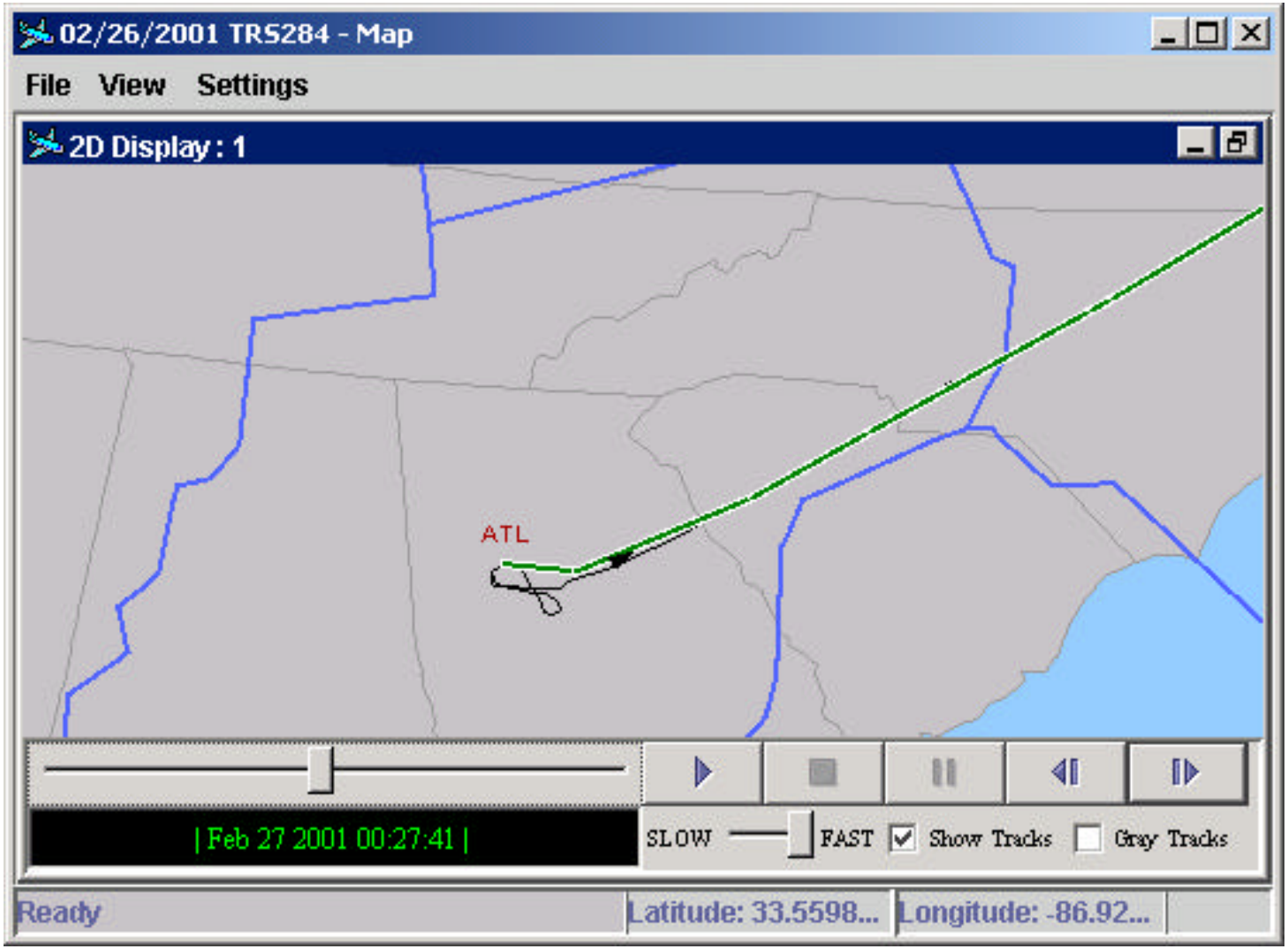
METRON AVIATION

The flight of TRS284 (cont)



METRON AVIATION

The flight of TRS284 (cont)



METRON AVIATION