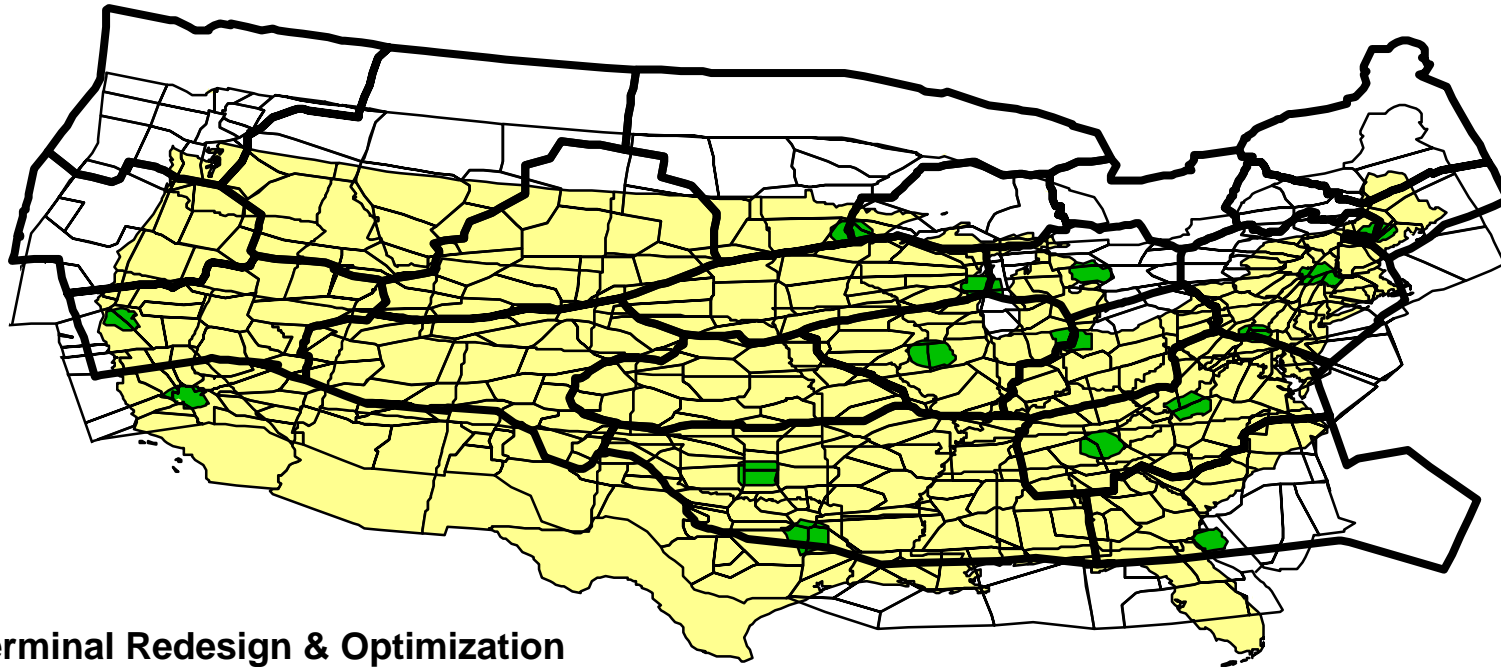


A vertical graphic on the left side of the slide shows a portion of a globe with a grid of latitude and longitude lines. A white airplane is depicted in flight, leaving a white contrail that extends across the globe. The background is a light blue sky with soft white clouds. The globe is partially obscured by a dark blue triangular shape at the bottom left and a yellow triangular shape at the bottom right.

New Research in Airspace Simulation Tools

Thor Abrahamsen
13 January 2002

National Airspace Redesign



Terminal Redesign & Optimization

- New runways
- Consolidation of airspace
- New technologies

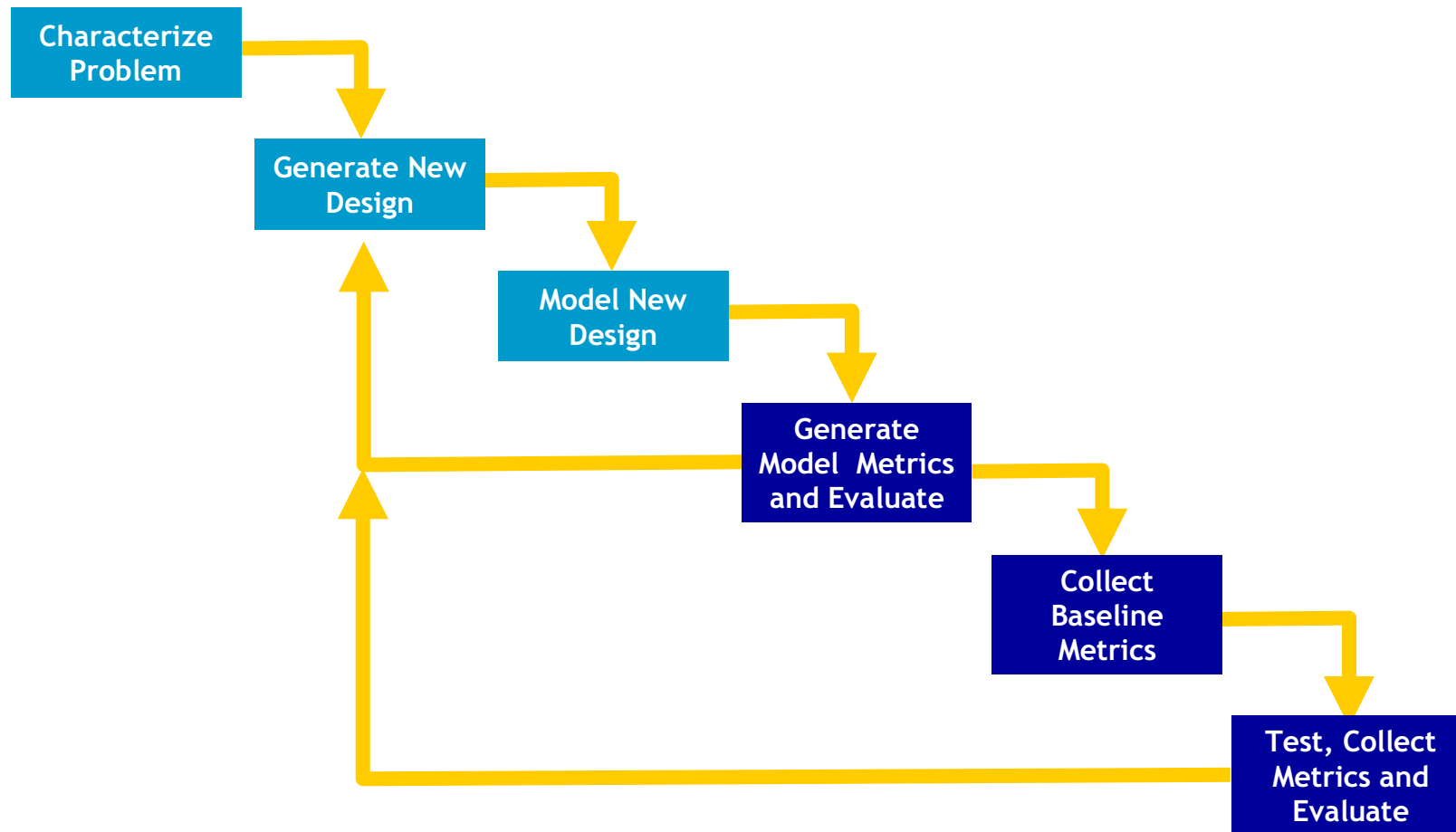
En Route Redesign & Optimization

- Accommodate terminal changes
- Volume and workload balancing

Cross Facility Coordination

- National redesign

Redesign Process



Toolset

- **Existing toolset includes**
 - **Total Airspace and Airport Modeller (TAAM)/RAMS/SIMMOD**
 - **Sector Design and Analysis Tool (SDAT)**
 - **Geographic Information System (GIS) products**
 - **Collaborative Routing Coordination Tools (CRCT)**
 - **INM/Noise Integrated Routing System (NIRS)**
- **Simulation languages**
 - **SLX**

Challenges

- **National Airspace (NAS) redesign has pushed the limits of the existing toolset**
- **Evaluation of some proposed en route designs requires modeling**
 - **Altitude restrictions**
 - **Acceptable delay techniques (vectoring, holding)**
 - **Traffic management initiatives triggered by system conditions**

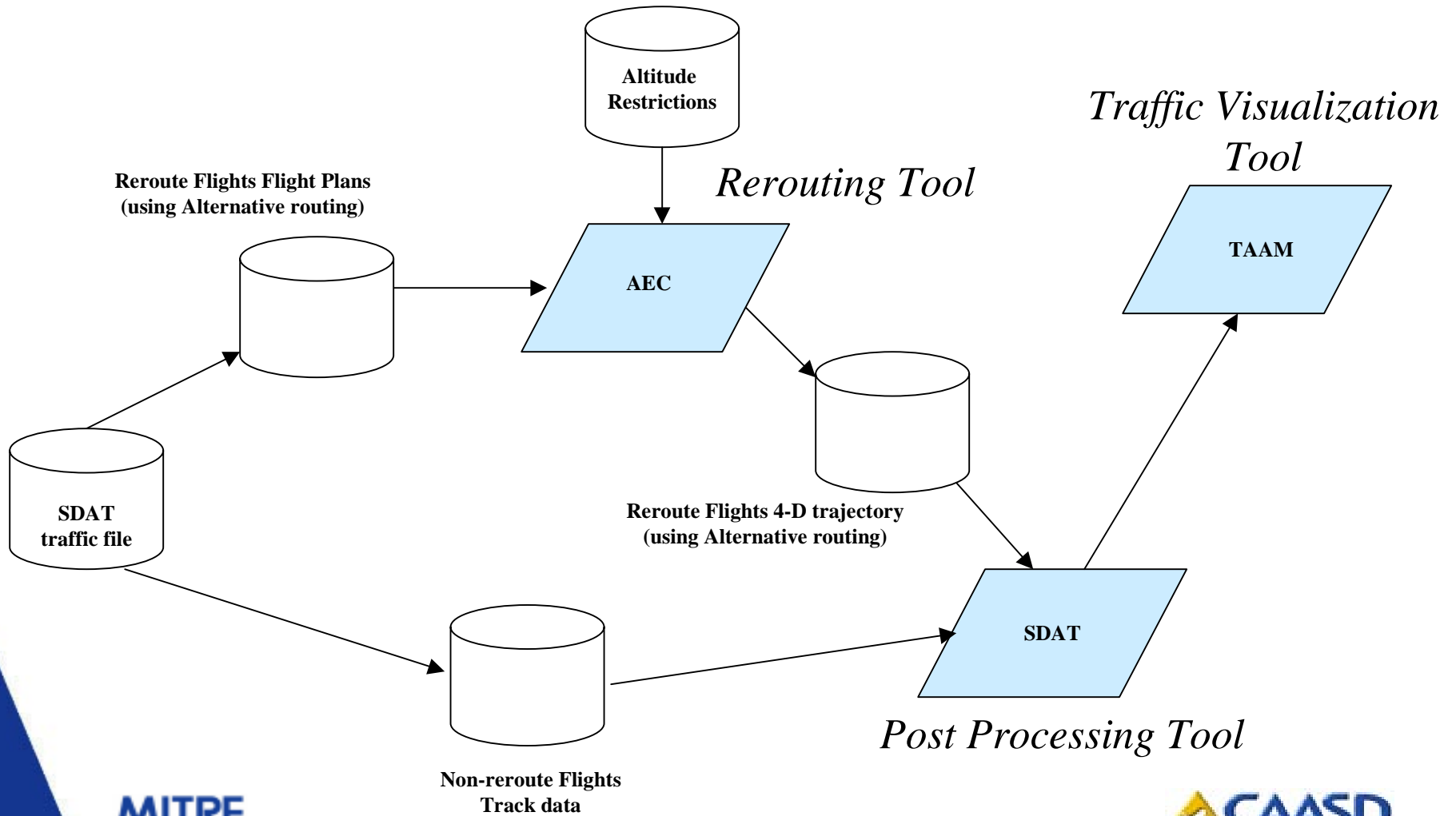
Example Study Requirements

- **Cleveland/Indianapolis study focused on proposed alternative routing**
 - Involving ~1000 flights arriving to/departing from DTW, CLE, CVG, and satellites
 - Goal of proposed routes
 - Reduce congestion at high-volume sectors
 - Relief of departure MIT for major airports
 - Allow airspace to accommodate improved capacity at major airports
- **Metrics:**
 - User: Time and distance comparison between current and proposed routing
 - Airspace: Sector counts; fix loading
- **Traffic flow visualization**
- **Study to be completed within 4 to 6 weeks**

Motivation for Developing New Process

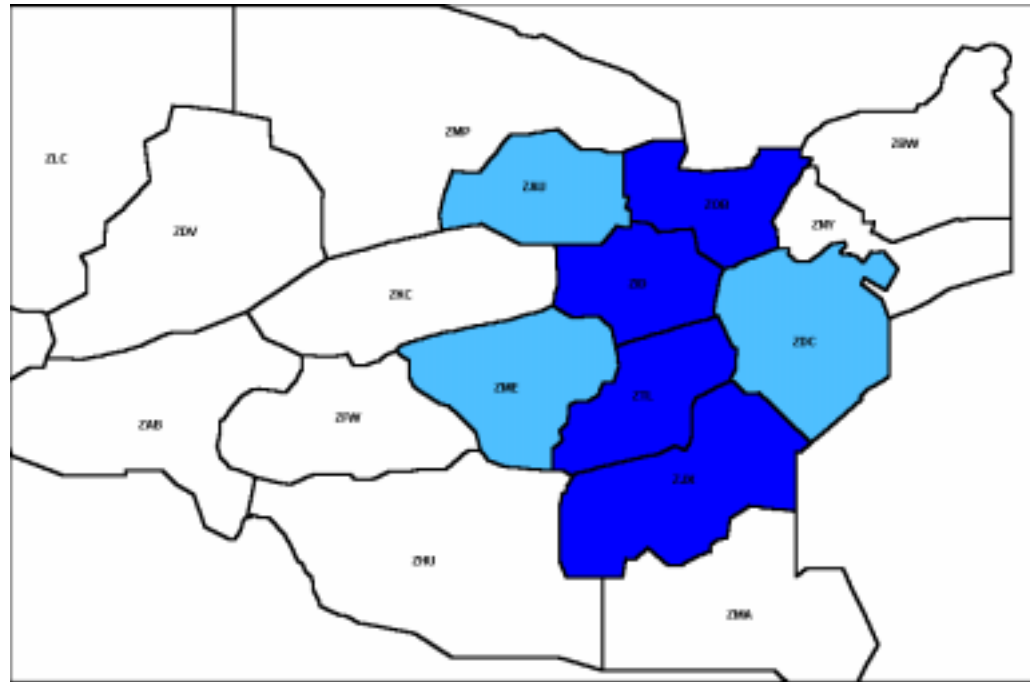
- **Several tools for airspace assessed**
 - TAAM/SDAT/CRCT
- **Each tool had several strengths but no tool met all requirements**
- **Combined tool approach used**
 - URET/AEC *provides trajectories*
 - SDAT *generates reports*
 - TAAM *provides visualization of new traffic flows*
- **These tools are linked by custom pre- and post-processors to form the complete set of analysis known as Traffic Reroute Analysis Capabilities (TRACS)**

TRACS Process Diagram



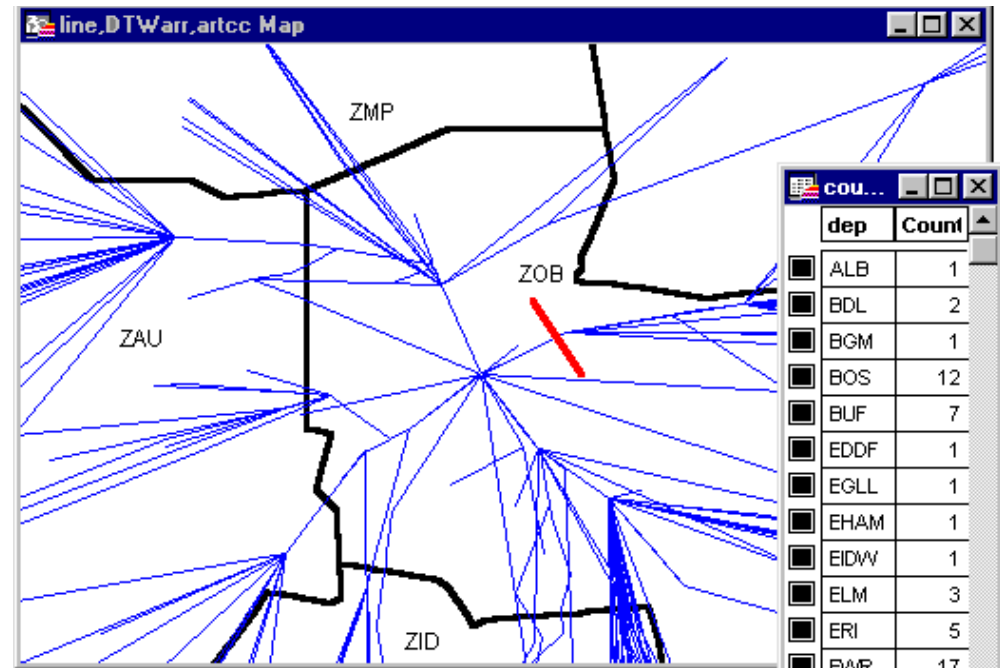
TRACS Use in Projects to-date

- **Cleveland/Indianapolis reroutes**
- **Indianapolis/Atlanta reroutes**
- **Atlanta/Jacksonville (*planned but incorporated in Multicenter*)**
- **Multicenter (*shown right*)**
- **High altitude (*starting*)**



Data Collection

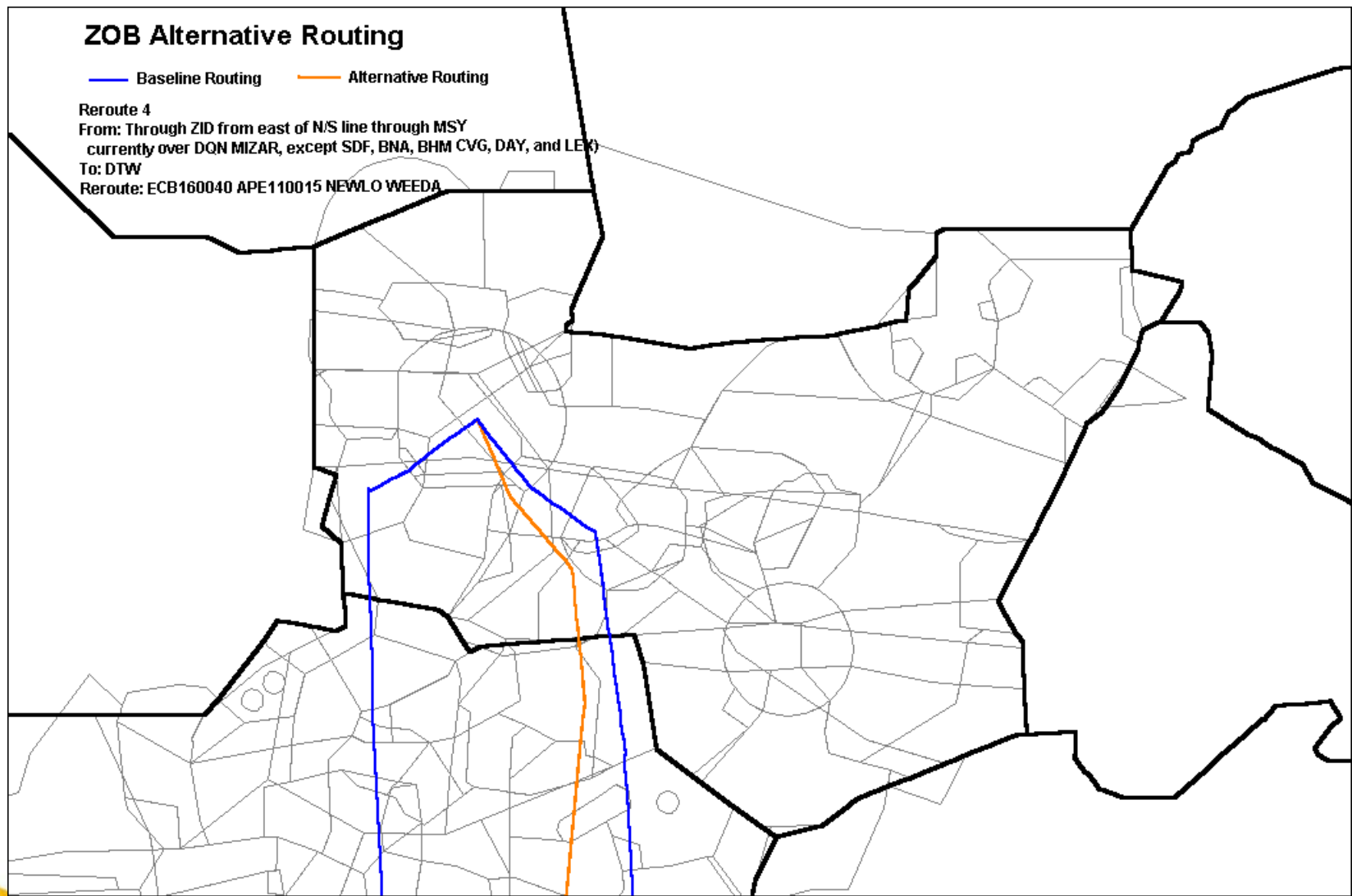
Flight Plans



Reroute Definition

Reroute Number	Departure Airport(s)	Arrival Airport(s)	Aircraft Type (J=jets only; P=props, blank = all)	RNAV Equipage	Originally Files Over	Reroute Definition	Altitude Restrictions
53	LAS, LAX, MCI, MLI, PHX, PIA, SAN, SFO	DTW				MKG POLAR	At or below FL230 at ZAU/ZOB boundary
53	LAS, LAX, MCI, MLI, PHX, PIA, SAN, SFO	DTW				MKG POLAR	At or below FL230 at ZAU/ZOB boundary
54	CYYZ, YFK, YOW, YTZ, YU L, YXU, YQS, ROC, ITH, B UF, LGA, MHHT, YHM, YO O, SYR, TEB, UCA, BDL	YIP, PTK, DET, YQG			HADAR	YQO ECK150039 HADAR	JETS at FL110 at ECK150039 PROPS at or below FL100 at ECK150039

Reroute Depiction

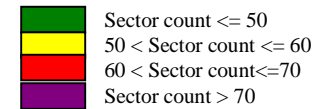


User Impact Metrics

Reroute	From	To	Reroute	Altitude Restrictions	No. Flights	Ave. Time (min)	Ave. Distance (nmi)
1	Through ZID from west of N/S line through MSY currently over DQN MIZAR	DTW	PXV VHP FWA MIZAR (no change to arrival fix)	No change	14	2.3	16.5
2	SDF	DTW	IIU VHP FWA MIZAR3 (no change to arrival fix)	At or below FL310 into ZID	5	3.1	21.4
3	CVG, DAY, LEX, LUK	DTW	Stay over DQN MIZAR3 (no change to arrival fix)	At or below FL230 throughout ZID	26	-1.8	-12.2
4	GSP, MSY (FLL, TPA, ATL, TYS also qualify, but were counted under Reroute 9) Through ZID from east of N/S line through MSY currently over DQN MIZAR, except SDF, BNA, BHM, CVG, DAY, & LEX	DTW	ECB160040 APE110015 NEWLO WEEDA DTW	At or below FL290 at ZID/ZOB boundary	5	4.3	16.6
5	ORD, MDW	DTW	MKG POLAR1 (no change to arrival fix)	No change	29	-0.5	2.1
6	SBN, CMI, LAF, FWA, BMI, (South and east of ORD, ZAU departures)	DTW	MIZAR	No change	21	-0.6	-3.7
7	PIA, GRR (MKE and all other ZAU departures except BEH and AZO)	DTW	POLAR (no change to arrival fix)	No change	31	-1.4	-10.4
8	RIC, DCA, IAD, BWI, and ORF (ZDC traffic only)	DTW	EYTEE GEFES SUMET DJB GETUS (no change to arrival fix)	At or below FL290 at ZID/ZOB boundary	30	6.6	38.4
9	MIA, CHS, FLL, PBI, MYR, TPA, JAX (PDK, ATL, TYS, and all FL airports)	DTW	ECB160040 APE110015 NEWLO WEEDA DTW	At or below FL290 at ZID/ZOB boundary	25	3.6	-11.0
10	RDG, ABE, MDT, UNV, PHL (Originating in ZNY, now through CETUS)	DTW	PSB ERI V221 SPICA	No change	18	1.3	2.6
11	LAS, LAX, MCI, MLI, PHX, PIA, SAN, SFO	DTW	MKG POLAR	At or below FL230 at ZAU/ZOB boundary	27	-0.9	-5.2
12	RSW, MCO, CMH	DTW	ECB160040 APE110015 NEWLO WEEDA	At or below FL290 at ZID/ZOB boundary	18	-0.2	-16.0
13	Currently routes over HADAR intersection	DTW satellites (YIP, PTK, DET, YQG)	YQO ECK150039	JETS at FL110 at ECK150039	30	-0.1	3.5
14	LGA, JFK, EWR	DTW	ULM YQO SPICA		21	-0.4	-5.5

Airspace Impacts—Sector Counts

		EDT															
		7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00
ZOB Sector ID	10	25	19	22	21	14	17	20	19	31	28	36	26	27	18	11	8
	11	27	19	26	28	21	39	28	30	36	25	39	31	37	21	16	12
	12	23	28	28	15	11	18	20	27	44	37	31	24	38	18	19	18
	14	19	19	22	17	12	18	18	18	28	34	33	23	28	14	16	12
	15	21	26	29	22	21	33	22	19	37	47	47	39	41	20	21	13
	18	21	36	42	17	24	24	25	36	33	33	48	40	52	32	26	16
	19	18	33	28	16	11	17	16	25	28	26	34	30	36	29	26	21
	20	29	14	16	14	24	17	23	27	28	21	38	30	18	18	16	13
	21	26	21	27	42	27	39	38	38	37	32	50	48	34	21	16	15
	24	18	19	30	21	13	16	18	24	24	26	22	29	29	17	13	13
	25	72	70	82	53	34	42	56	63	75	72	86	95	70	58	62	40
	26	18	29	23	8	14	18	24	24	30	30	43	36	38	36	31	20
	27	27	32	29	31	19	33	56	41	62	50	64	51	59	39	27	25
	28	25	31	30	8	15	29	21	31	60	43	49	54	51	44	23	28
	29	10	14	12	2	5	13	16	15	30	25	33	23	20	34	22	18
	30	46	29	19	32	23	30	26	43	33	44	40	46	29	27	31	22
	32	54	34	26	31	19	37	33	44	48	45	48	44	39	32	27	34
	33	42	33	29	33	13	30	32	25	34	40	45	29	34	25	27	24
	35	31	19	17	9	6	26	24	24	31	30	26	25	30	23	24	9
	36	35	35	22	40	31	37	41	38	48	50	53	68	45	35	30	27
	38	48	49	36	23	19	30	35	36	35	42	48	56	38	30	29	28
	40	17	34	32	35	24	35	36	39	34	38	55	39	30	20	22	17
	41	17	21	24	31	16	34	39	27	34	49	34	31	33	23	11	8
	46	39	44	45	29	22	45	41	59	61	58	57	58	63	46	35	24
	47	19	28	25	20	18	18	21	26	47	46	42	36	34	41	39	21
	48	45	46	46	36	33	41	45	57	58	67	70	58	54	46	36	24
	49	26	39	33	37	32	37	32	36	63	69	73	64	60	52	42	32
	52	22	31	17	17	12	30	23	28	25	33	30	30	18	22	14	19
	53	28	32	20	22	13	35	33	30	29	42	36	27	36	24	16	12
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	57	40	39	33	21	23	23	28	35	41	46	45	55	27	34	25	41
	59	36	39	29	26	38	31	25	29	45	54	44	35	44	40	38	33
	61	34	21	23	18	13	22	25	34	38	32	28	26	25	29	26	12
	62	33	16	21	12	13	18	12	40	23	22	28	42	16	17	32	9
	64	22	31	40	34	33	42	23	51	28	50	40	44	43	23	15	11
	66	38	43	33	42	34	32	38	55	67	56	51	73	57	51	49	38
	67	38	32	37	32	29	27	32	43	50	54	46	63	55	53	43	42
	68	33	42	39	24	23	32	27	41	50	58	49	59	56	49	35	28
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	71	39	32	30	27	16	24	33	39	24	44	29	26	40	19	14	32
	73	44	30	24	20	17	22	19	37	46	45	40	34	36	25	16	33
	74	41	31	30	31	26	25	31	29	50	46	57	51	30	15	25	24
	77	32	33	27	31	28	39	32	42	44	48	51	60	45	47	34	36
	79	18	26	17	11	13	20	21	24	25	38	52	40	30	34	32	35



Airspace Impacts—Sector Count Difference

		EDT																				
		MAT Value	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00				
ZOB Sector ID	10	11	0	0	-2	4	-2	5	-2	-1	4	-2	3	-1	2	0	1	3				
	11	13	0	0	2	2	-3	-4	-6	-5	1	-2	3	-4	2	-1	0	-1				
	12	14	0	0	3	2	0	0	2	0	6	0	0	3	4	0	0	-1				
	14	14	0	0	0	3	0	1	1	0	3	2	0	0	3	0	0	0				
	15	14	-1	-3	-3	2	-4	-1	-3	-5	-3	-4	-2	-6	-5	0	0	0				
	18	18	0	0	0	2	-1	0	4	1	-2	0	0	1	-1	0	0	0				
	19	15	0	0	-2	0	0	-1	0	0	-1	-1	0	0	-1	0	0	0				
	20	16	0	1	1	4	1	-1	9	4	5	4	11	4	1	1	1	0				
	21	14	0	-1	-4	1	0	1	-3	-3	2	4	-12	-2	5	0	-1	0				
	24	16	0	-1	-1	2	2	-2	3	-2	1	-1	2	0	-2	-1	1	0				
	25	99	0	0	2	3	3	1	5	3	1	0	3	1	1	0	1	0				
	26	16	0	0	0	-1	0	0	-3	0	1	0	0	0	-2	0	0	0				
	27	16	0	1	-2	-2	0	-2	-3	0	0	1	-1	0	-2	-1	-1	0				
	28	14	0	-1	1	3	1	9	6	5	5	7	-2	6	7	2	1	0				
	29	18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
	30	16	0	-1	0	0	0	0	-2	-1	0	-3	-2	0	0	0	0	-1				
	32	17	0	0	-1	0	0	0	1	1	0	0	1	2	0	0	-1	0				
	33	15	0	0	0	-1	0	0	0	0	0	0	0	1	0	0	0	0				
	35	13	0	0	0	-1	0	0	-2	0	-2	-1	-2	0	0	0	0	-2				
	36	18	0	0	0	-2	-2	-1	0	-2	-1	1	-1	-2	0	0	0	0				
	38	18	0	0	0	1	-1	0	0	-3	0	0	-3	0	-2	0	0	0				
	40	13	0	-10	-11	5	-5	1	11	5	4	1	-8	1	7	6	-2	1				
	41	13	0	4	18	0	7	7	-2	9	6	6	11	2	10	-4	1	-3				
	46	14	0	-1	3	-5	-4	-3	-14	-9	-8	-1	-3	-8	-6	0	0	-1				
	47	15	0	0	2	0	0	1	-1	-1	2	0	0	0	0	-1	-1	0				
	48	14	0	-4	-11	-3	-7	-12	2	-2	-8	-14	-6	1	-13	-1	-1	0				
	49	15	0	0	0	1	0	-1	0	1	0	0	2	0	0	-1	0	0				
	52	15	0	0	0	-1	0	0	0	0	0	-1	0	0	0	0	0	-1				
	53	18	0	0	0	-2	0	-1	0	0	0	-1	-2	0	0	0	-1	-1				
	54	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
55	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0					
57	16	-1	-1	-4	-3	-1	0	-5	1	-1	-4	-2	1	-2	0	0	0					
59	18	0	0	-1	2	-2	0	-1	-1	0	-2	0	-1	1	0	0	0					
61	12	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0					
62	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0					
64	12	0	-4	-5	11	0	1	14	3	7	6	7	3	0	-2	-1	4					
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70	12	0	0	0	0	0	0	0	0	0	-1	0	0	0	0	0	0					
71	18	0	0	0	-1	0	-1	0	0	0	-1	-1	0	0	0	0	-1					
73	18	0	0	-2	0	0	0	2	0	0	1	1	0	0	0	-1	0					
74	16	0	0	-1	-1	0	0	0	-1	0	0	0	0	0	0	-1	0					
77	16	1	1	0	1	-1	2	3	-1	6	2	2	1	3	0	0	0					
79	18	1	0	-1	-1	-1	0	-2	-3	1	1	1	2	-1	0	0	0					

Sector count decrease
 No change in sector count
 Sector count increase

Conclusions

- **Current toolset not sufficient for all en route studies**
 - **Future versions of existing modeling tools hold promise**
 - **e.g., TAAM, RAMS**
 - **New tools will expand the capability further**
- **Importance of visual assessment by controllers**