Data Link and Technology Integration Benefits to NAS Performance

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Outline

- Issues
- Background
- Methodology
- Results
- Summary and Recommendations

Issues

- URET and Data Link Communications Integration Benefits
- Data Link Benefit Analysis

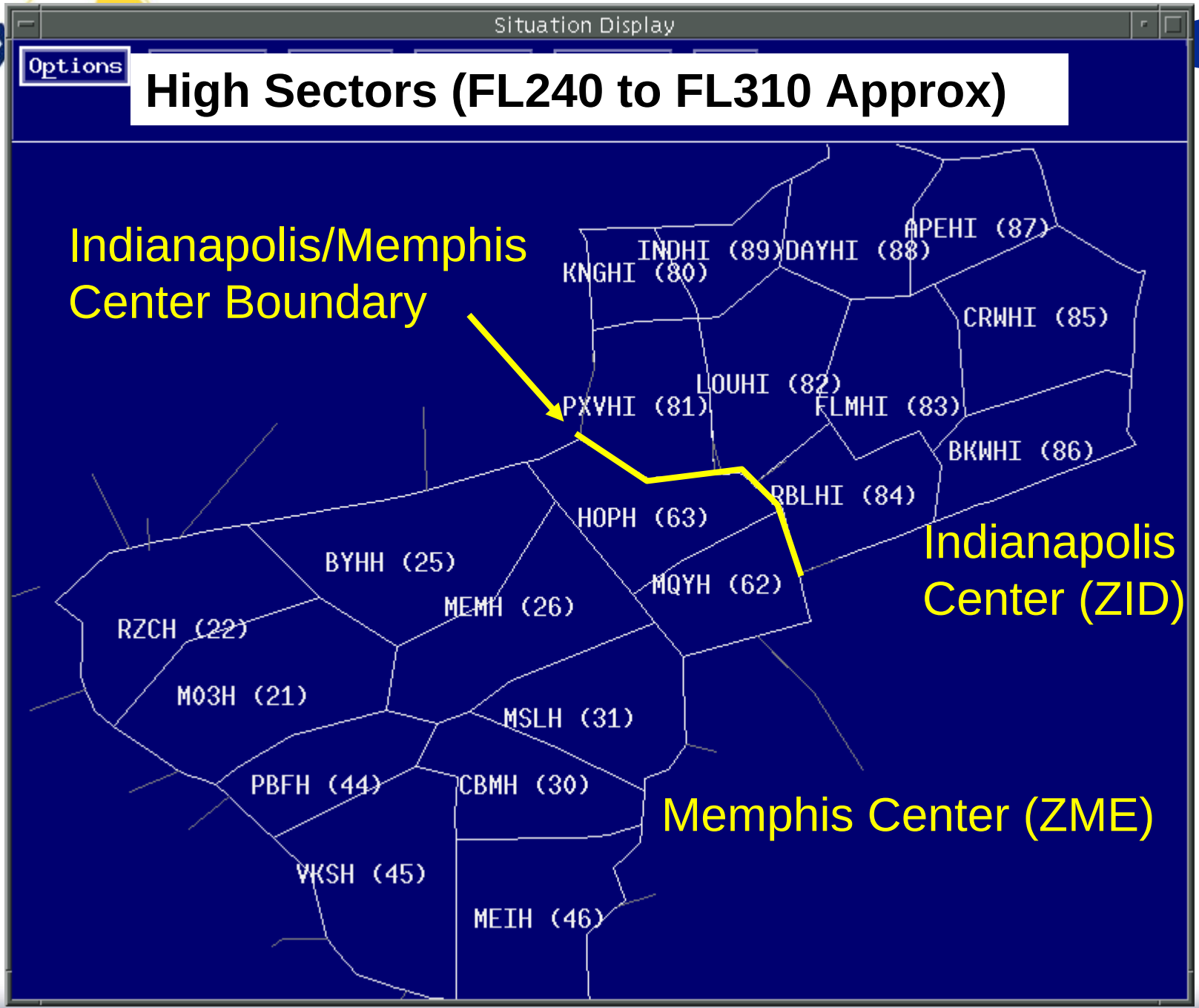
Background

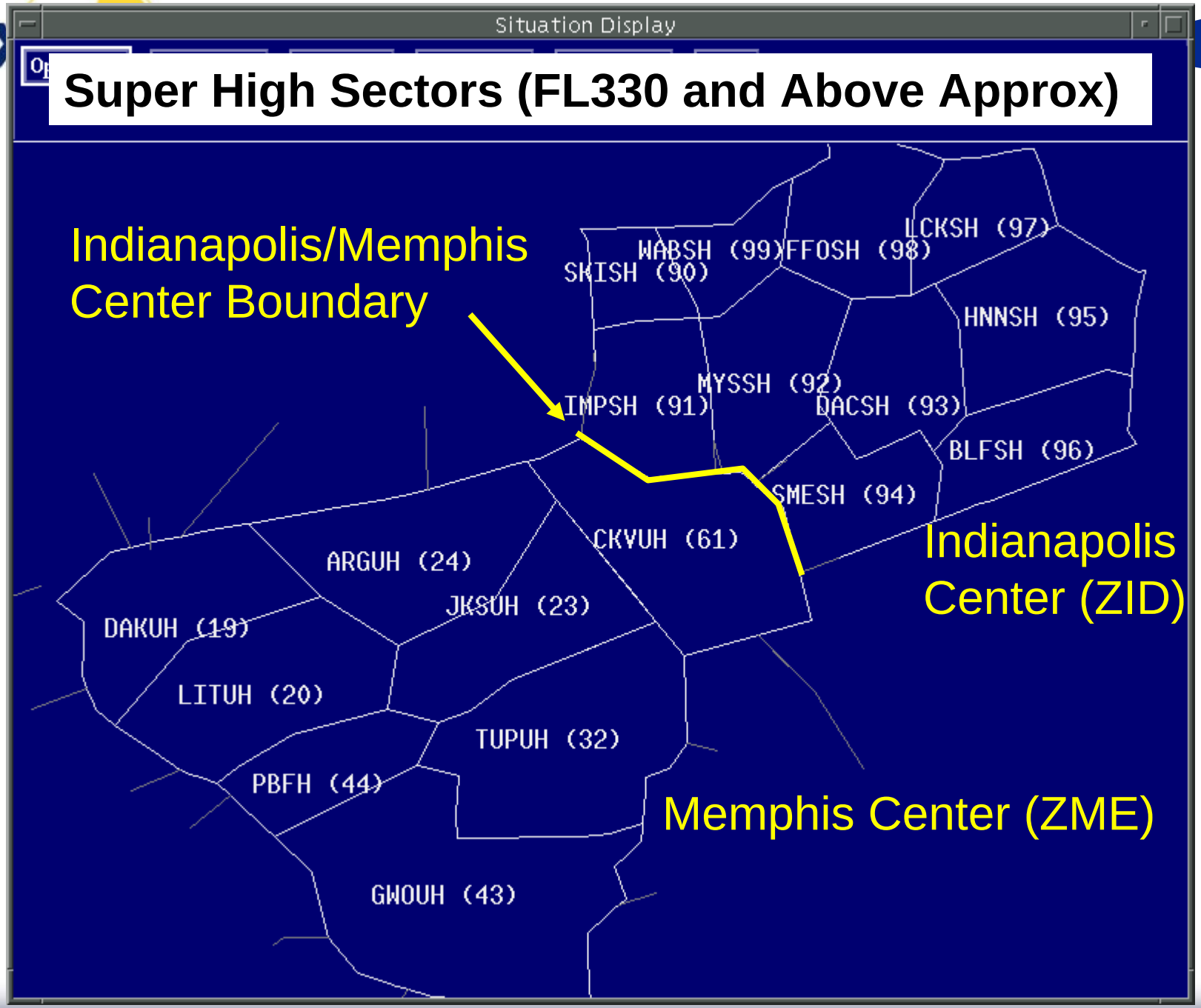
- Data Link Communications
- Benefits assessment
- User Request Evaluation Tool (URET)
- Benefits of Data Link-URET integration
- Excess Distance Analysis

Data Link

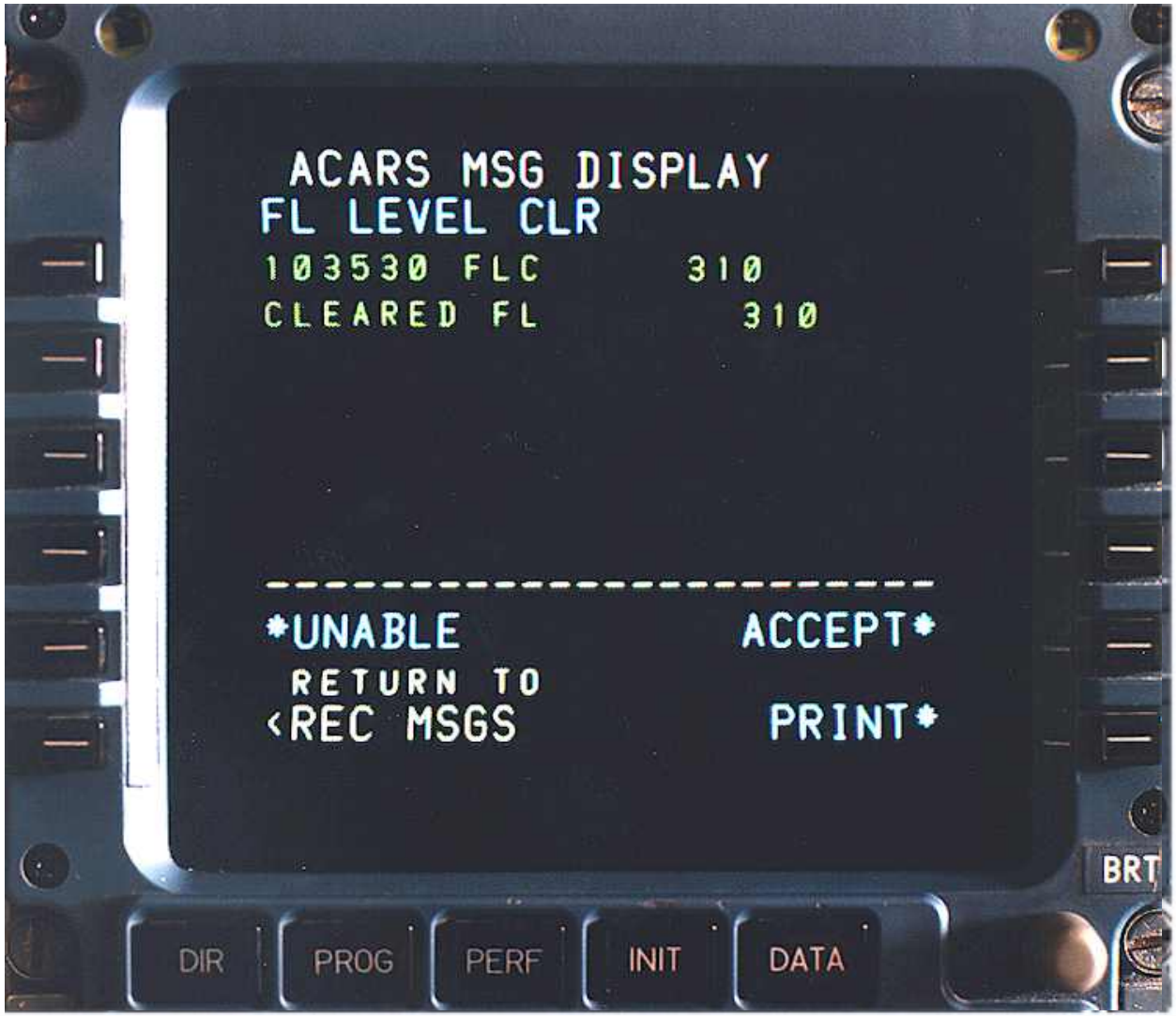
Data Link Communications is the Aeronautical Data Link System (ADLS) that provides data communications between aircraft and ground automation system in the en route sector.

The Controller Pilot Data Link System complements voice communications and provides a link that is only used (in the initial stages, i.e., in the Build I phase) for routine messages, which make up about a half of all controller/pilot communications messages.


Situation Display
Options
High Sectors (FL240 to FL310 Approx)
Indianapolis/Memphis Center Boundary
APEHI (87)
INDHI (89)
DAYHI (88)
KNGHI (80)
CRWHI (85)
LOUHI (82)
PXVHI (81)
FLMHI (83)
BKWHI (86)
RBLHI (84)
HOPH (63)
Indianapolis Center (ZID)
BYHH (25)
MQYH (62)
MEMH (26)
RZCH (22)
M03H (21)
MSLH (31)
PBFH (44)
CBMH (30)
Memphis Center (ZME)
VKSH (45)
MEIH (46)


Situation Display
Super High Sectors (FL330 and Above Approx)
Indianapolis/Memphis
Center Boundary
LCKSH (97)
WABSH (99)
FFOSH (98)
SKISH (90)
HNNSH (95)
MYSSH (92)
IMPSH (91)
DACSH (93)
BLFSH (96)
SMESH (94)
CKVUH (61)
ARGUH (24)
JKSUH (23)
DAKUH (19)
LITUH (20)
TUPUH (32)
PBFH (44)
GWOUH (43)
Indianapolis
Center (ZID)
Memphis Center (ZME)

Data Link


ACARS MSG DISPLAY
FL LEVEL CLR
103530 FLC 310
CLEARED FL 310
*UNABLE
ACCEPT*
RETURN TO
<REC MSGS
PRINT*
BRT
DIR
PROG
PERF
INIT
DATA

Data Link

- Build I
  - Transfer of communication
- Build IA
  - Assignments of speed, heading, altitude
  - Pilot initiated requests
  - Non-time critical messages from controller to pilot
- Build II
  - Enhancements, with emphasis on integration with DSTs

Benefits and Benefits Assessment

- Reduced frequency congestion, especially under high traffic density
- Benefits assessed as a reduction in frequency occupancy depending on the Data Link build in question
- Human factors should be looked at as well

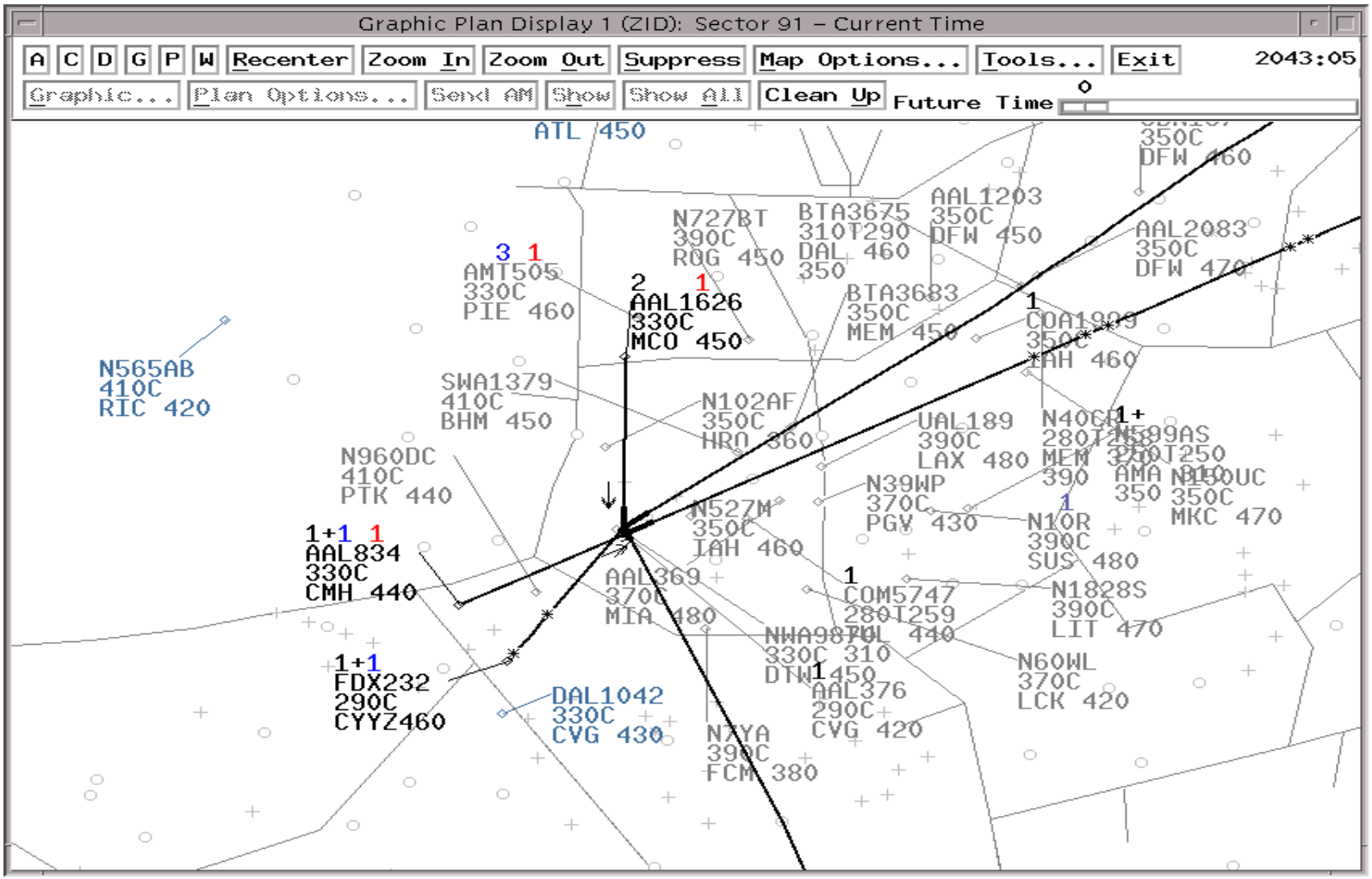
URET

The User Request Evaluation Tool (URET) is the en route controller tool used:

- to automatically detect and solve aircraft-to-aircraft and aircraft-to-airspace conflicts
- for trial planning of proposed Flight Plan amendments
- for automated controller coordination of problem resolutions
- for enhanced flight data management

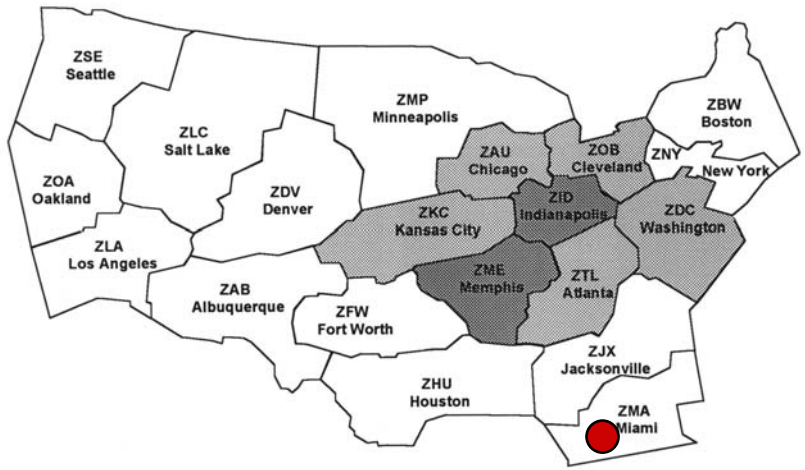
The benefits and performance of URET have continuously been evaluated since 1997.

URET


Graphic Plan Display 1 (ZID): Sector 91 – Current Time
A C D G P W Recenter Zoom In Zoom Out Suppress Map Options... Tools... Exit
2043:05
Graphic... Plan Options... Send AM Show Show All Clean Up Future Time
ATL 450
N727BT 390C R0G 450
BTA3675 310T290 DAL 460 350
AAL1203 350C DFW 450
350C DFW 460
AAL2083 350C DFW 470
3 1 AMT505 330C PIE 460
2 1 AAL1626 330C MCO 450
BTA3683 350C MEM 450
1 COA1909 350C AH 460
N565AB 410C RIC 420
SWA1379 410C BHM 450
N102AF 350C HRO 360
UAL189 390C LAX 480
N960DC 410C PTK 440
N39WP 370C PGV 430
N527M 350C IAH 460
1+1 1 AAL834 330C CMH 440
AAL369 370C MIA 480
1 COM5747 280I259
N10R 390C SUS 480
N1828S 390C LIT 470
1+1 FDX232 290C CYYZ460
DAL1042 330C CVG 430
NWA987 330C 310 DTW 450
AAL376 290C CVG 420
N60WL 370C LCK 420
N7YA 390C FCM 380

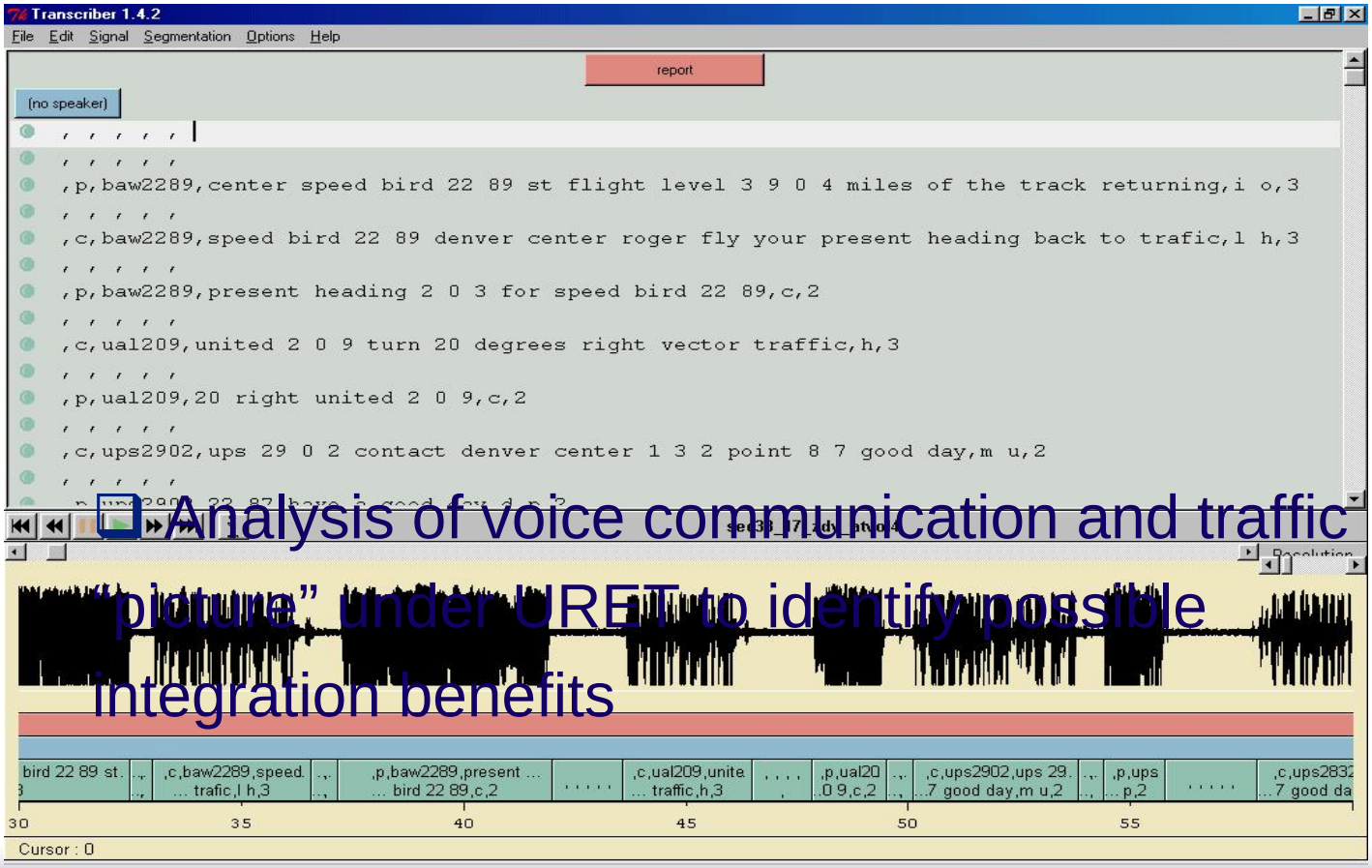
Data Link-URET Integration

- Benefits often assessed separately which can underestimate them
- Is it possible to send some conflict resolution messages via data link



Methodology

- Two parts:

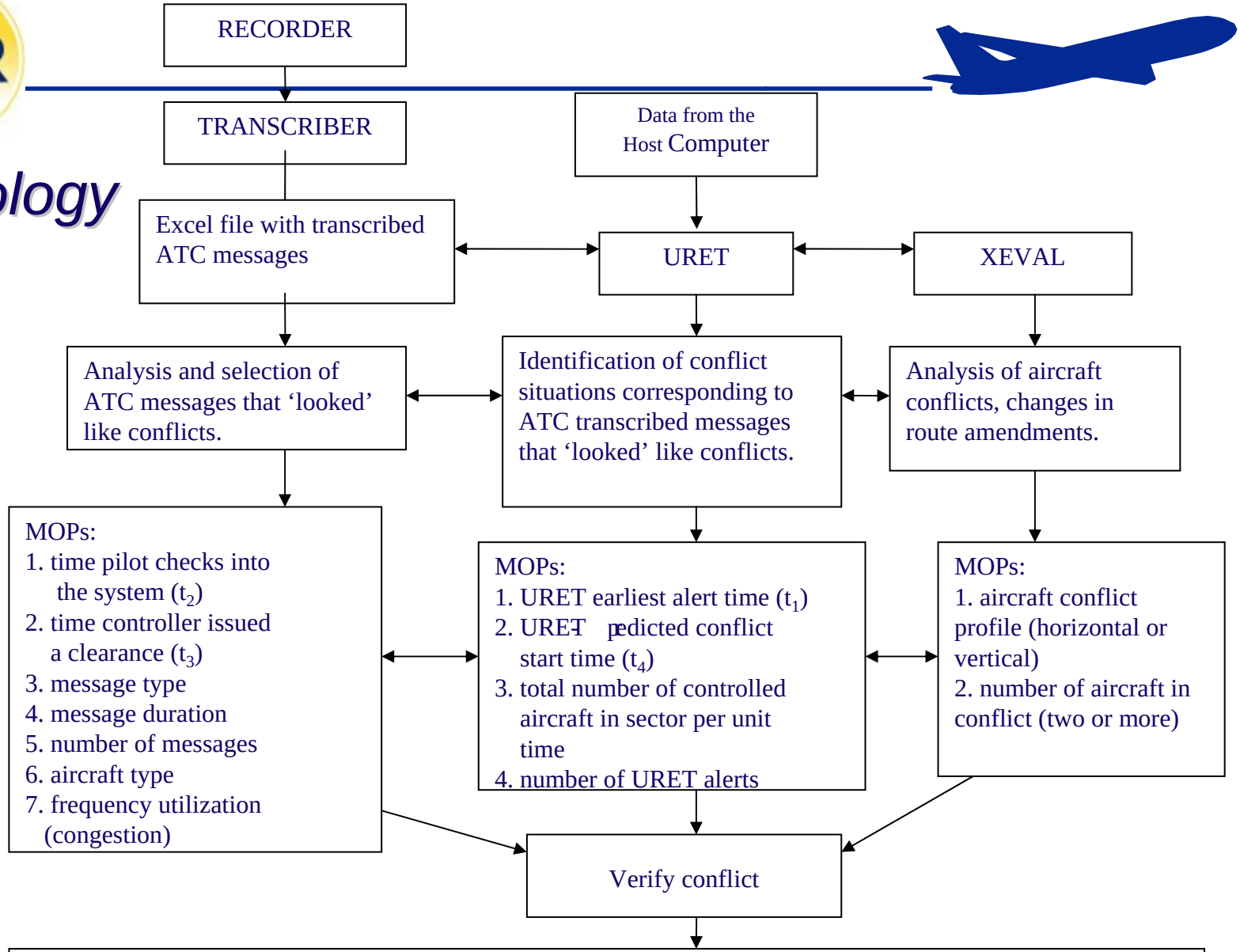


- Analysis of voice communication and traffic "picture" under URET to identify possible integration benefits

Transcribed Messages: Sample

Message No.	Time	Headway	Type	A/C		Message Text
1	18:44:41		REQ	N34H	214	'32 to 39' " "
2	18:44:48	7	REM	N34H	214	" ' indi center roger' "
3	18:44:53	5	REM	UAL1235	447	" ' contact kansas city center at 133.22' "
4	18:44:55	2	REQ	UAL1235	447	'33 22 k c so long' " "
5	18:45:00	5	REM	RJX6160	243	" ' contact indi center 134.27' "
6	18:45:03	3	REQ	RJX6160	243	'34 27 good day' " "
7	18:45:16	13	RTE	UAL214	766	F ____ " ' charleston' ' cleared present position direct to ____'
8	18:45:20	4	REQ	UAL214	766	'directly to charleston' " "
9	18:46:40	80	REQ	N92WG	988	'31 7 for 350' " "
10	18:46:44	4	REM	N92WG	988	" ' indi center roger' "
11	18:46:57	13	REM	N34H	214	" ' contact memphis center 124.12' "
12	18:47:02	5	REQ	N34H	214	'24 12' " "
13	18:50:20	198	REM	NWA286	333	" ' contact indi center 134.17' "
14	18:50:22	2	REQ	NWA286	333	'34 17 good day' " "
15	18:51:10	48	REM	UAL8170	567	" ' contact indi center 134.27 34 27' "
16	18:51:15	5	REQ	UAL8170	567	'34 27 good day' " "
17	18:51:26	11	REQ	UAL1940	355	you don't happen to have at 330 the wind and the ride do ya?' " "
18	18:51:36	10	REQ	SWA266	756	'370 good afternoon' " "
19	18:51:46	10	REM	SWA266	756	" ' i appreciate it thanks' "
20	18:51:51	5	REQ	TWA520	898	'crossing flight level 300 for 310' " "
21	18:51:57	6	ALT	TWA520	898	330 N " " C ' indi center' ' climb and maintain FL 330'
22	18:52:00	3	REQ	TWA520	898	'330' " "

Methodology



Voice Communication Analysis

- Message analysis:
  - Type
    - i.e. initial call, handoff message
    - Different message types will be covered in different CPDLC builds
  - Complexity
  - Frequency occupancy and message duration

Voice Analysis Results

	Number of Messages	**%(total)**
Pilots	605	50.17
Controllers	601	49.83
Total	1206	100.00

Voice Analysis Results

Pilots' Message Type	No. of Messages	%(pilot)	%(total)
Initial call (I)	158	26.12	13.10
Request (Q)	10	1.65	0.83
Acknowledgement (A)	348	57.52	28.86
Other (O)	89	14.71	7.38
Total (pilot)	605	100.00	50.17

Voice Analysis Results

Controllers' messages by TYPE	No. of Messages	% (controller)	% (total)
Heading (H)	54	8.99	4.48
Altitude (L)	44	7.32	3.65
Fix (F)	42	6.99	3.48
Route Amendment (R)	12	2.00	1.00
Routine Message (M)	292	48.59	24.21
Other (W)	157	26.12	13.02
Total (controller)	601	100.00	49.83

URET- Data Link Integration Analysis

- Metric definition
- Identify clearances used for resolution of URET conflict alerts
- Identify the clearances that could be sent via data link

Question

Are there any **clearances** given to pilots
to resolve traffic conflicts
a sufficient time before the start
that we might consider delivering by data link?

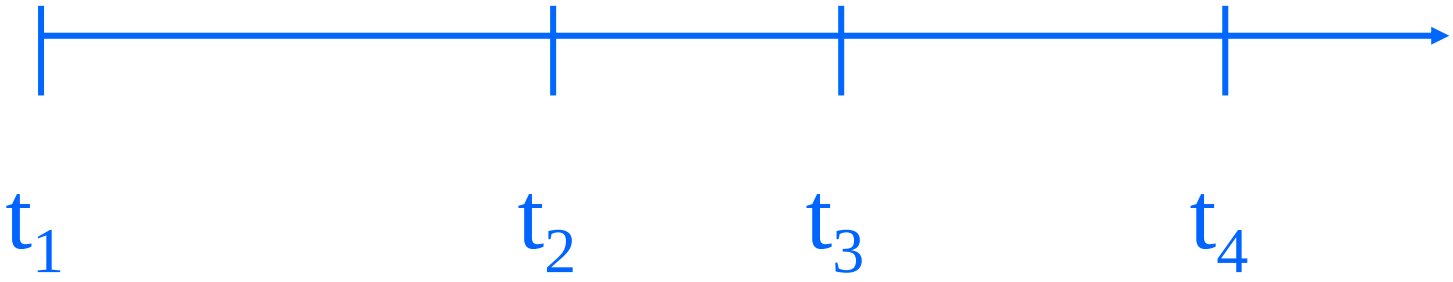
Question

Is it feasible to communicate conflict resolution messages using data link in the integrated URET/Data Link environment?

Question

If it is feasible,
what would be the impact on
frequency utilization?

Metric Definition: Relevant Times



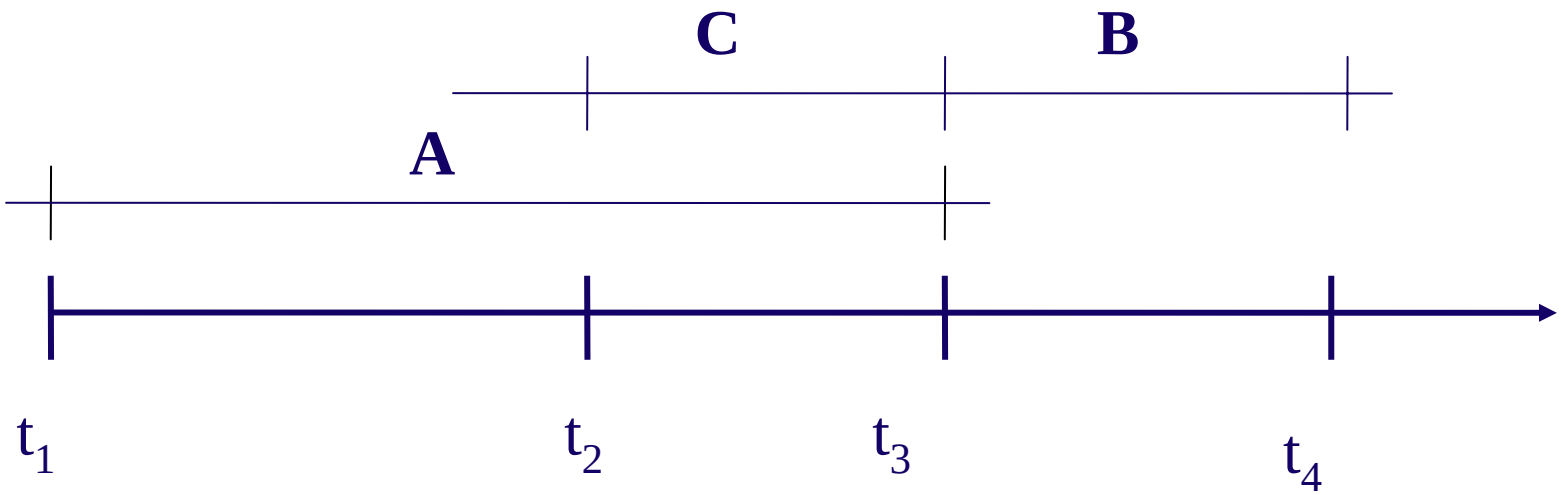
t_1 = time of URET conflict alert, which will occur at t_4

t_2 = time of initial call

t_3 = controller issued a conflict resolution clearance

t_4 = URET-predicted conflict start time

Metric Definition

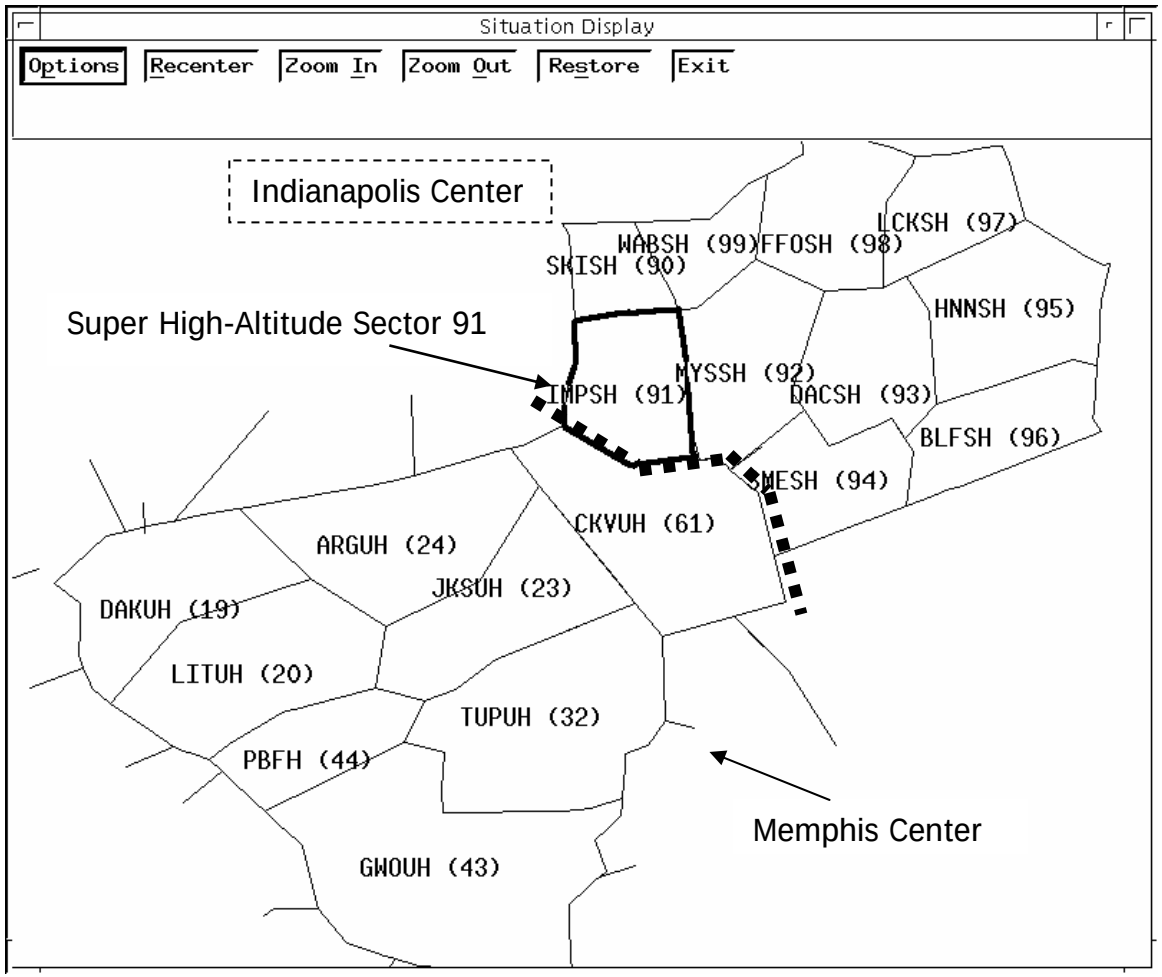


A = t_3 - t_1 = time between controller's clearance and URET's conflict notification

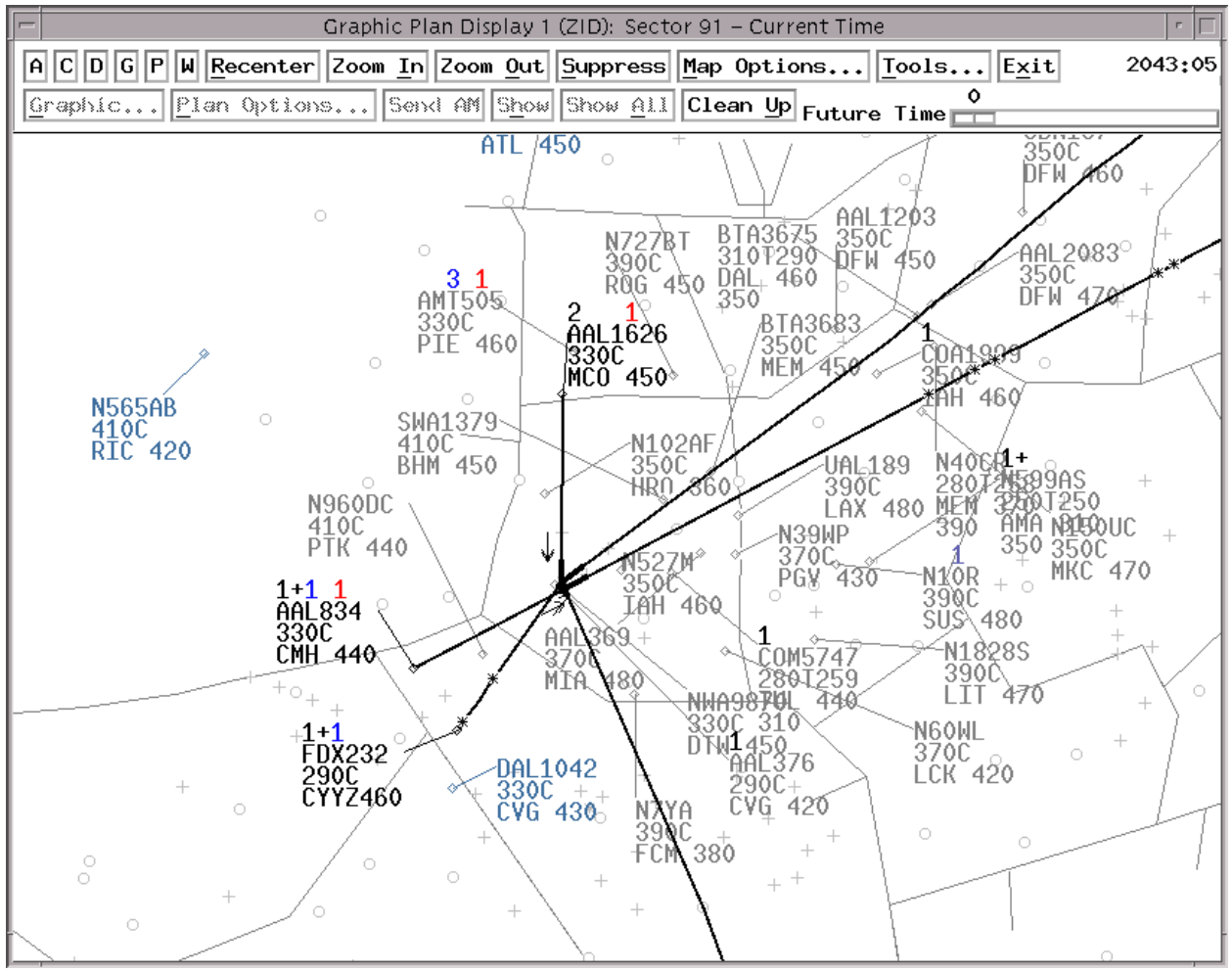
B = t_4 - t_3 = time between URET-predicted conflict start time and controller's clearance

C = t_3 - t_2 = time between controller's clearance and the first time aircraft checks in.

Description of the Study Area

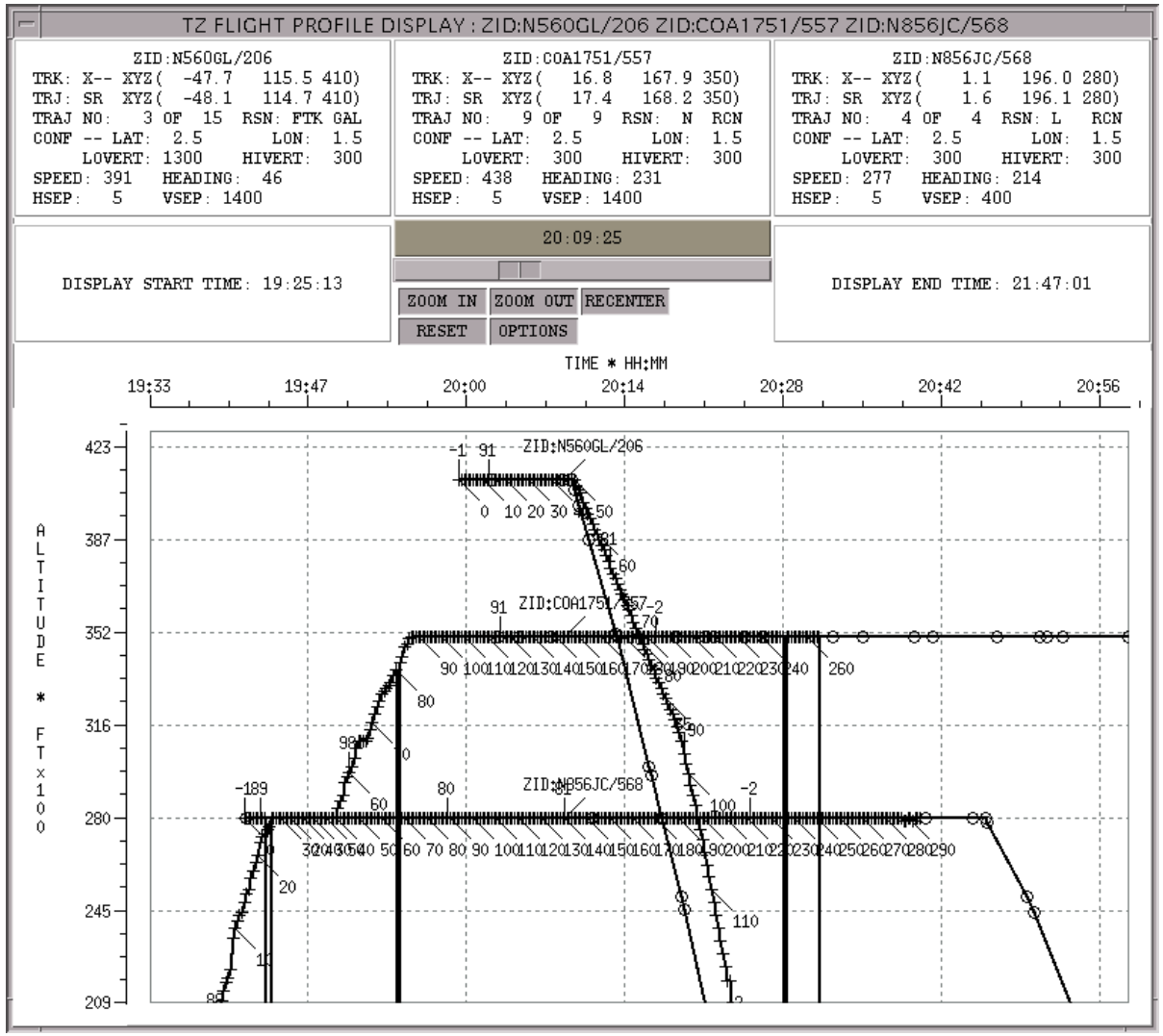


URET Conflict Display for Three Aircraft

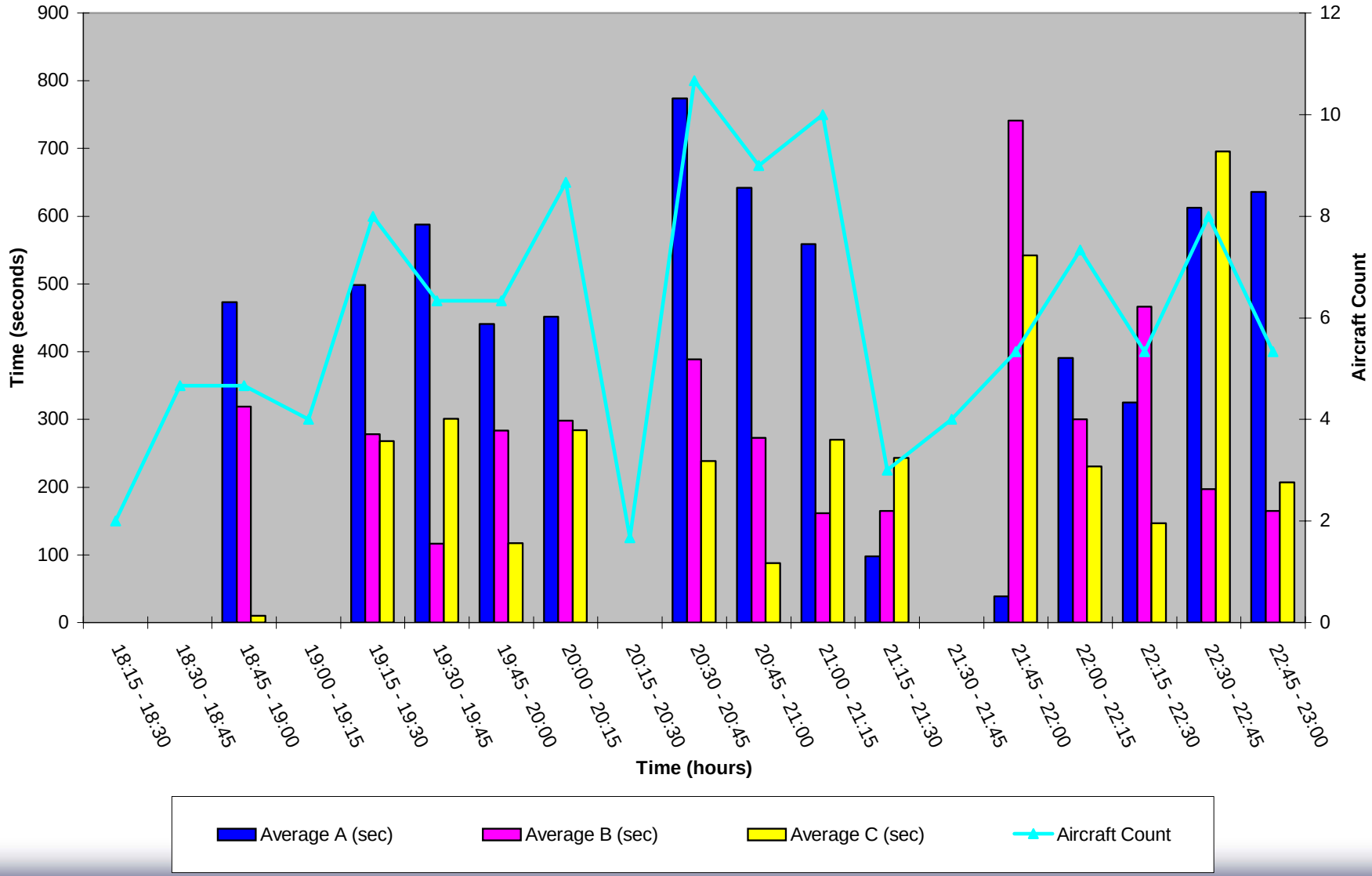


XEVAL
Control Panel

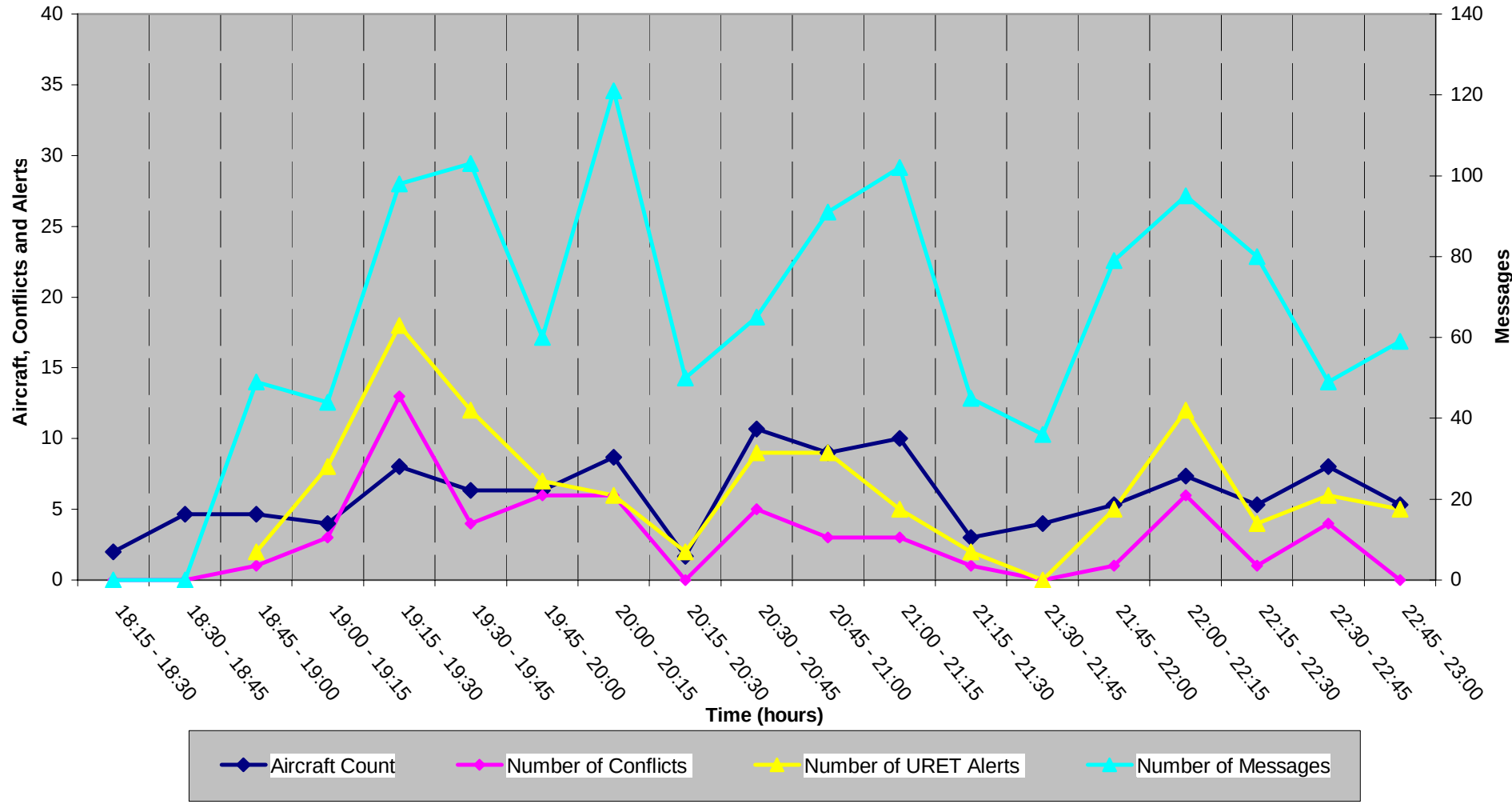
XEVAL Vertical Conflict Analysis for Three Aircraft



Comparison of Relevant Time Intervals Durations with Aircraft Count

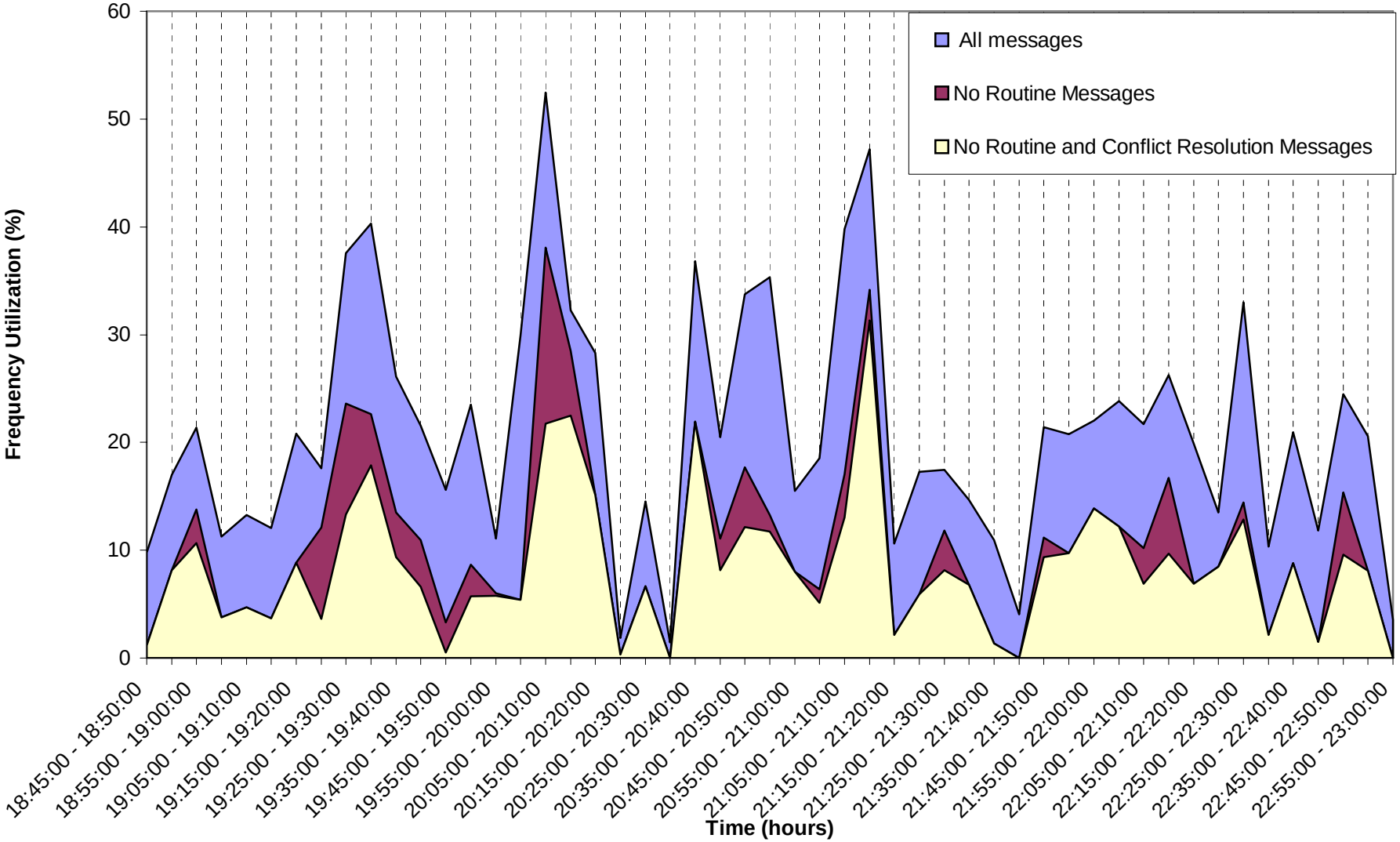


Comparison of Number of Messages with the Number of Aircraft Present, Potential Conflicts and URET Alerts



Correlation	Number of Aircraft In Sector	Number of Conflicts	Number of Messages	Number of URET Alerts
Number of Aircraft in Sector	1			
Number of Conflicts	0.581	1		
Number of Messages	0.669	0.666	1	
Number of URET Alerts	0.527	0.745	0.574	1

Frequency Utilization for Different CPDLC Builds



Conclusions

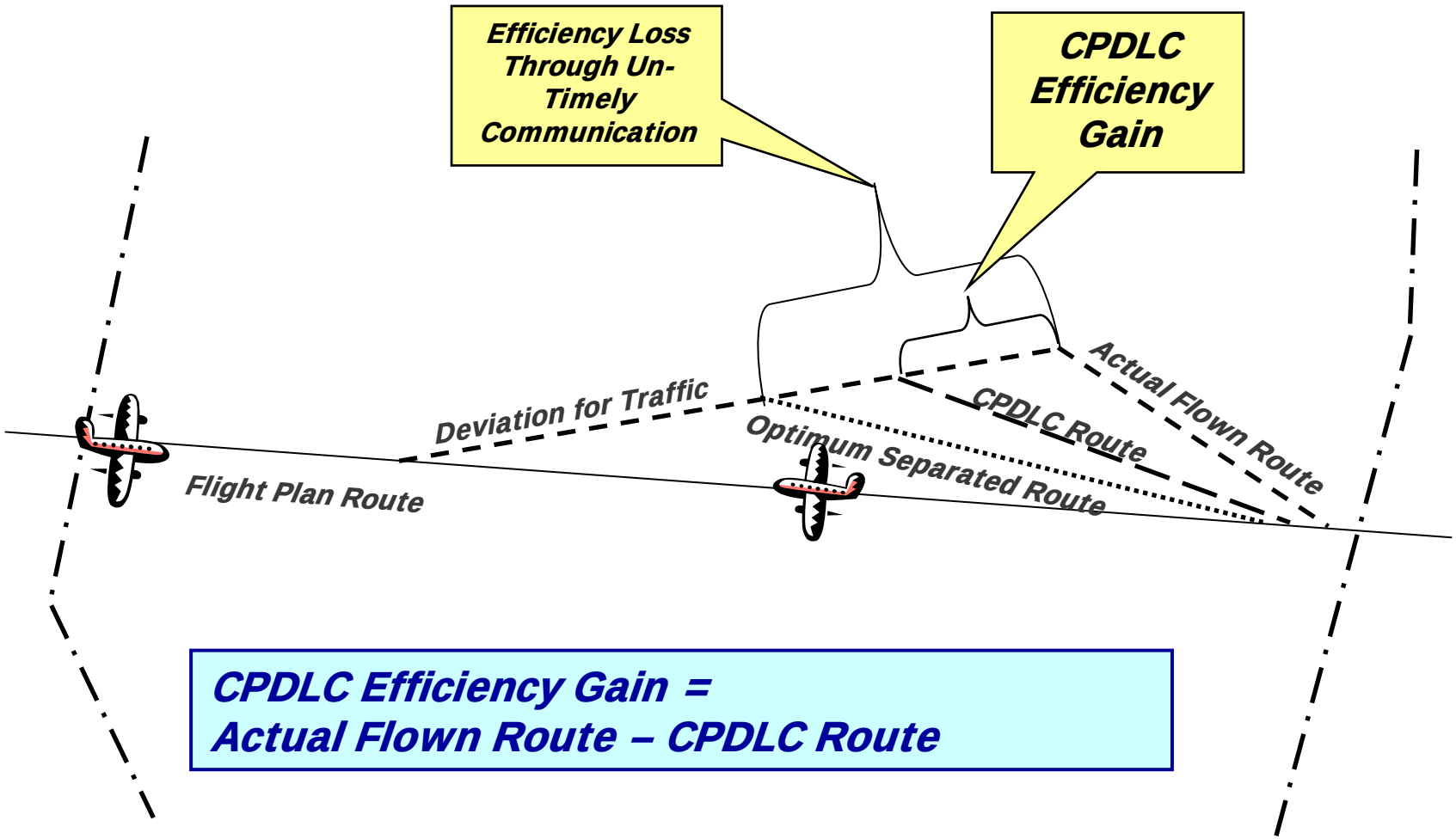
- There are significant benefits in frequency reduction
- Largest benefits during busy hours
- Possibility of lowering of communication errors

Data Link Efficiency Analysis

Objective

- Correlate Frequency Congestion and Aircraft Excess Distance

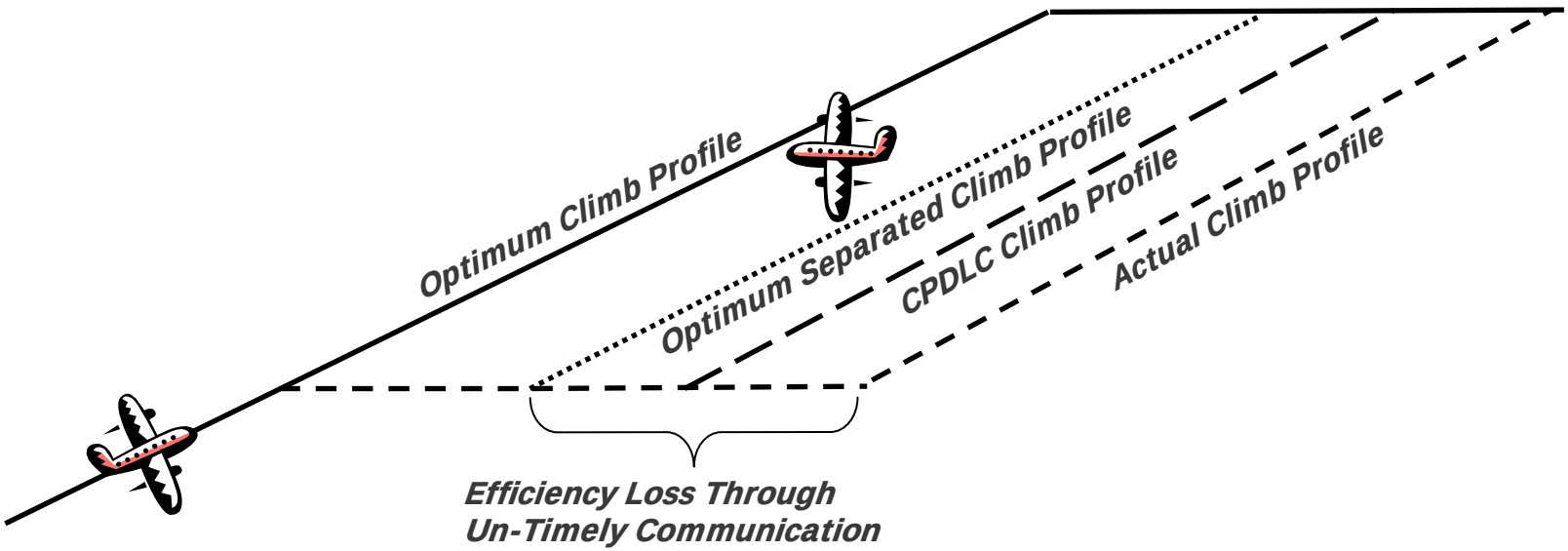
Example of Potential Benefits



CPDLC Efficiency Gain =
Actual Flown Route – CPDLC Route

Source: FFP1 Metrics Team

Example of Potential Benefits

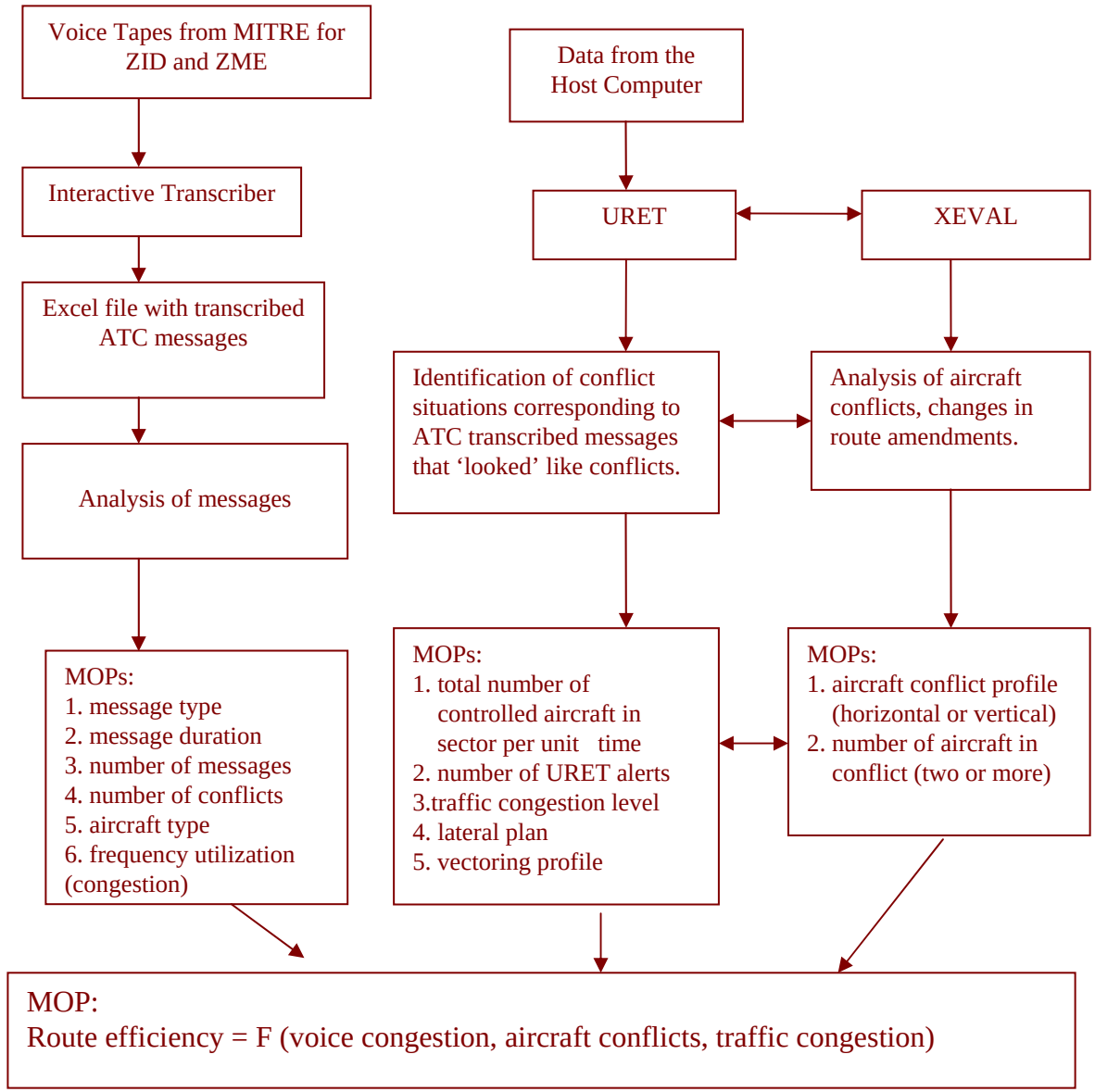


CPDLC Vertical Efficiency Benefit = Fuel Burn for Actual Climb Profile – Fuel Burn for CPDLC Climb Profile

Source: FFP1 Metrics Team

Conceptual Framework: URET Sectors

Methodology



Example

- *Sector 91, ZID Center*

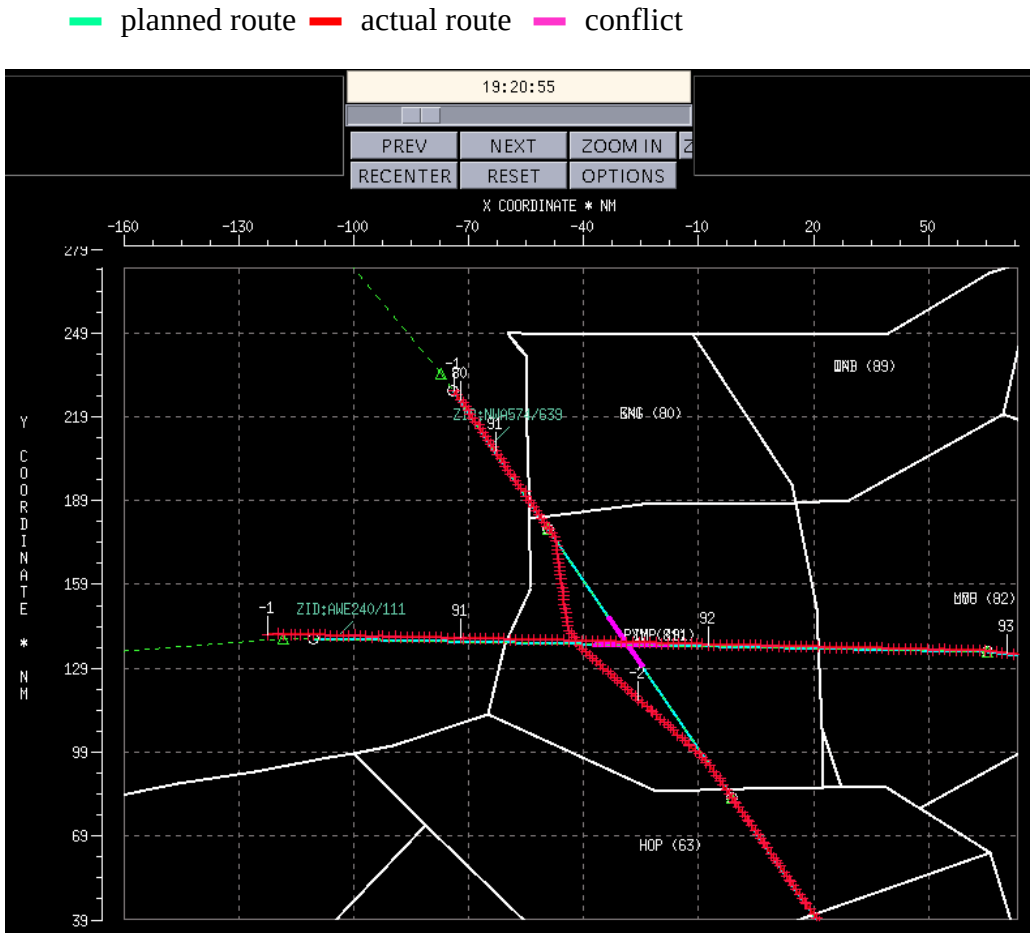
  URET traffic was analyzed and conflicts were detected.

  Xeval was used for detailed analysis of conflicts/vectored aircraft.

Example

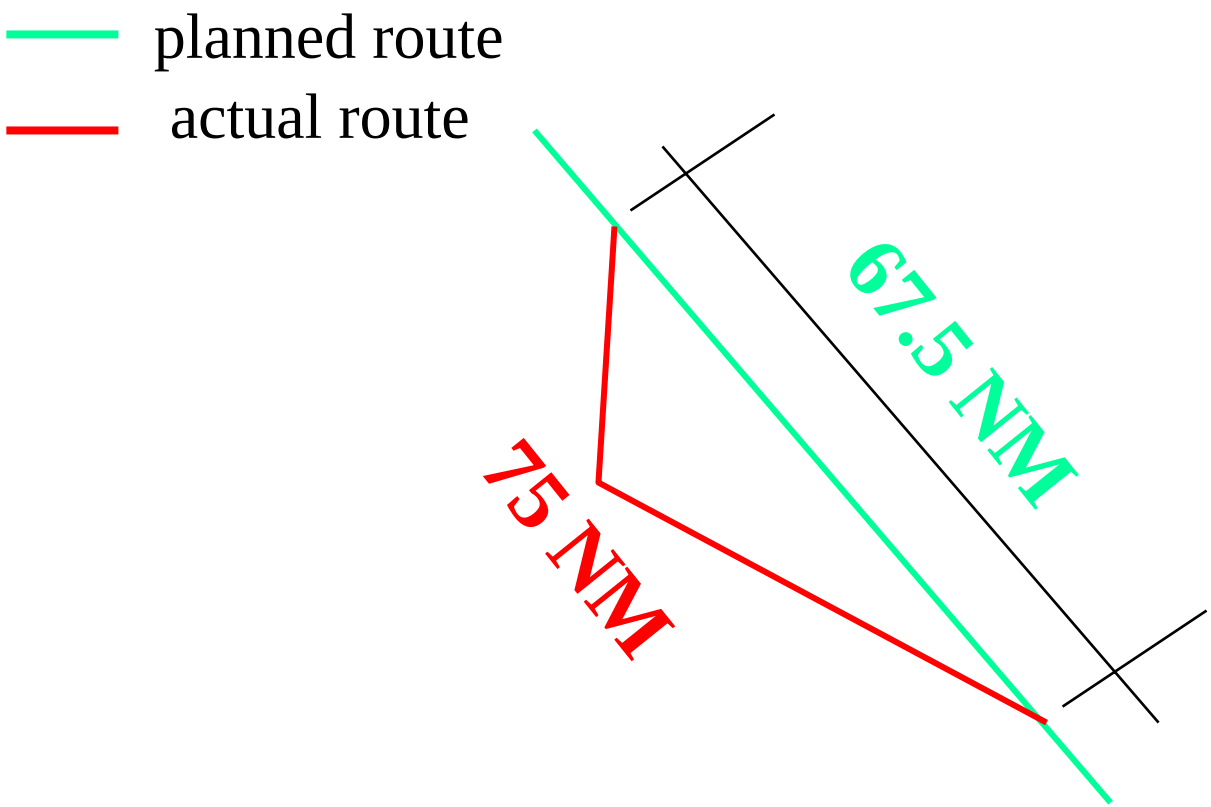
From voice tapes and URET

A/C ID	Conflict with aircraft (from URET)	Time message issued (from voice tapes)	Controller's Message (from voice tapes)
NWA 574	AWE 240	19:25:32	"turn right 20 degrees please for traffic"
NWA 574	AWE 240	19:29:25	"turn left 10 degrees"
NWA 574	AWE 240	19:30: 04	"you are cleared left turn now on course"



Example: Aircraft NWA574

Excess Distance from Xeval:



excess distance = 7.5 NM

Relevant Information

TIME INTERVAL: 19:15 – 19:30 PM

Number of Communication Messages:		**98**
Aircraft in Sector 91:		**8**
Aircraft URET Alerts:		**18**
Conflicts:		**13**
Frequency Utilization:	**19:15-19:20**	**20%**
	19:20-19:25	**17.61%**
	19:25-19:30	**37.57%**
	19:30-19:35	**40%**

List of Analyzed Sectors:

Indianapolis ZID Center

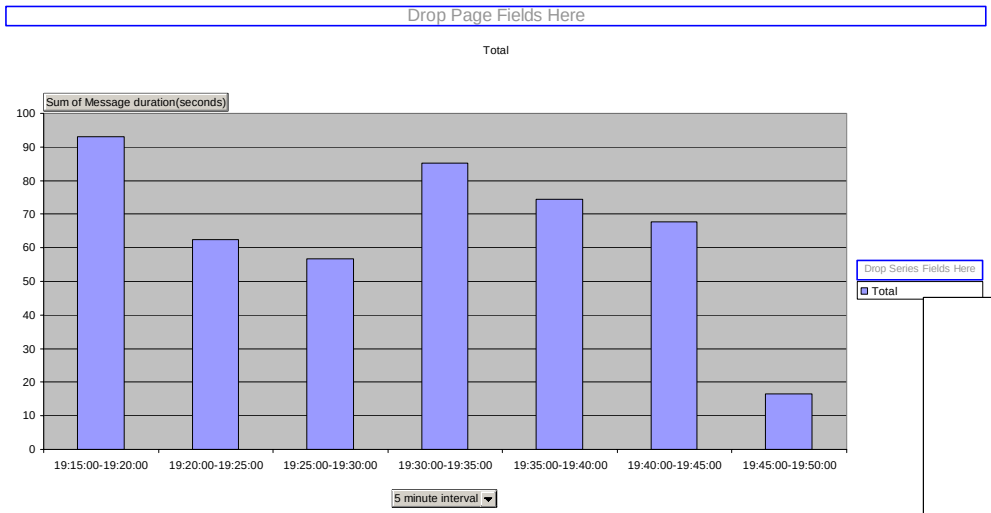
Sector		Time Interval (ZULU)	Sector Size	Conflicts (#) (derived from URET)
Name (#)	Altitude			
92	SH	19:15 – 19:45	med/large	peak
92	SH	21:45 – 22:15	med/large	low
95	SH	18:45 – 19:15	large	peak
98	SH	22:30 – 23:00	med/large	desc. peak
80	H	18:45 – 19:15	small	first peak
83	H	21:15 – 21:45	medium	low
84	H	21:00 – 21:30	med/large	medium
85	H	20:30 - 21:00	large	low
87	H	19:30 – 20:00	med/small	med. peak
89	H	20:45 – 21:15	small	second peak
89	H	22:00 – 22:30	small	second peak

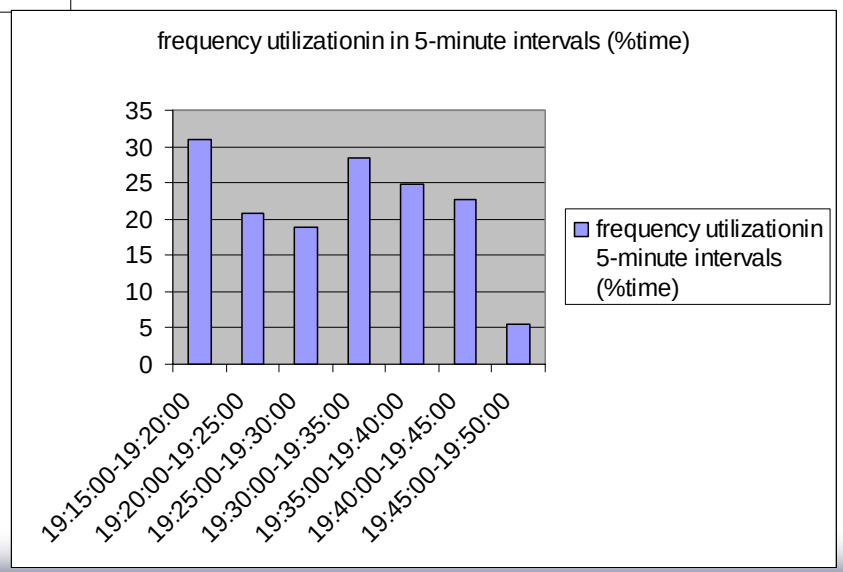
Representative sample was made up of various sectors with different:

- *altitudes (H and SH)*
- *time intervals,*
- *sector sizes*
- *traffic demands and*
- *conflict types and counts.*

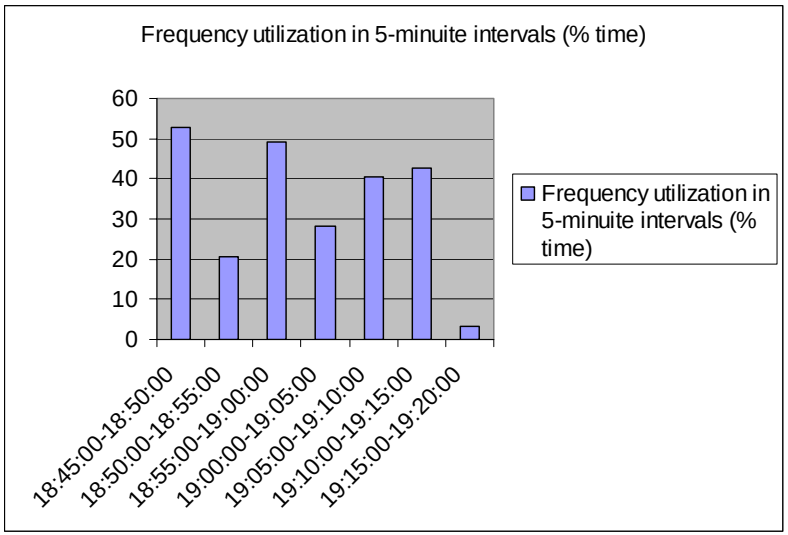
Frequency utilization was calculated for 30-minute segments, for previously listed sectors. Some sectors included more than one sample.

ZID 92, TIME: 19:30-20:00 ZULU

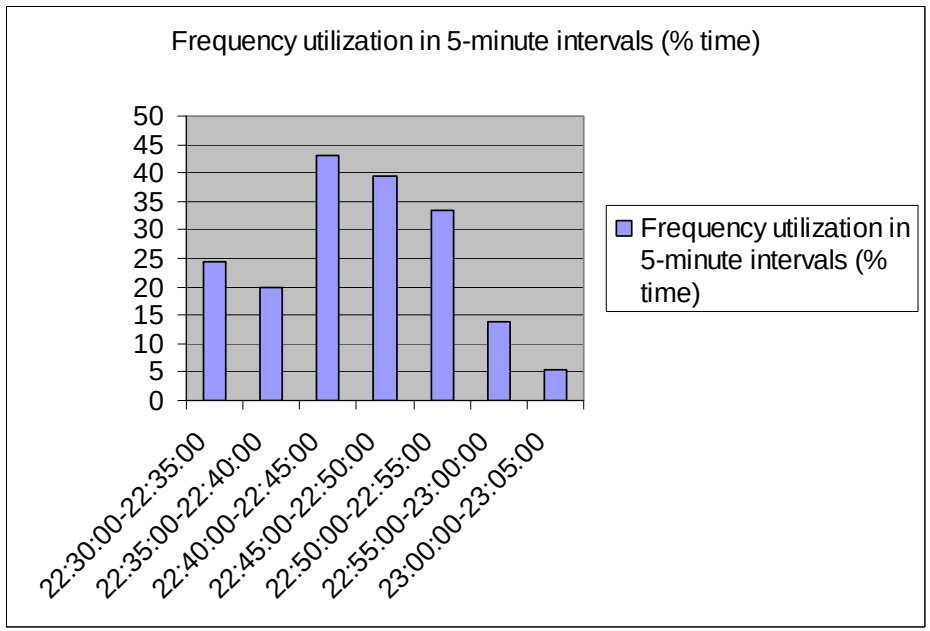




Sector 80, Time period: 18:45-19:15 (ZULU)



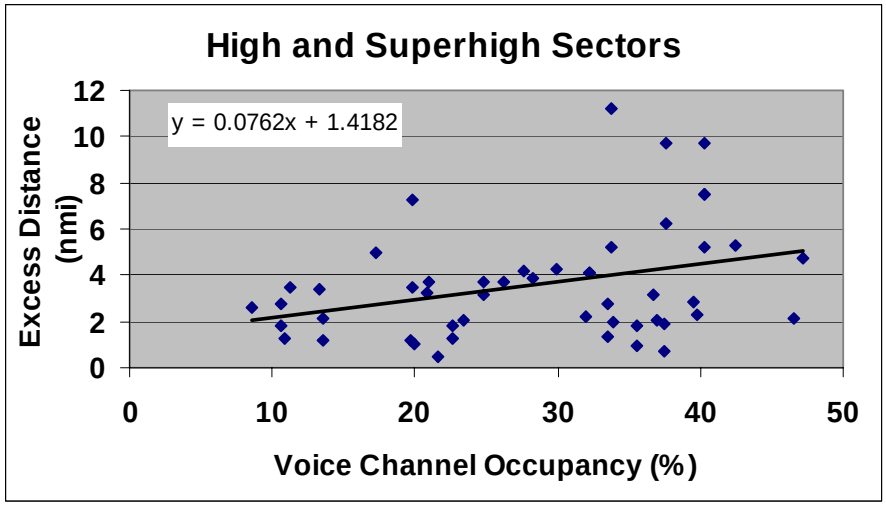
Sector 98, Time period: 22:30 – 23:00 (ZULU)



High and Super-High Sectors

- Transcribed a total of ~18 hours of voice communications
- Used URET XEVAL tool to analyze conflicts and determine excess distance
- Excess distance increases by 0.076 nmi for each percent voice channel occupancy
- Example: if CPDLC reduces voice channel occupancy by 20 percentage points, expect 1.4 miles in savings per laterally resolved conflict
- 50% of conflicts resolved laterally

Sector		Time Interval (ZULU)	Sector Size	Conflicts (#) (derived from URET)
Name (#)	Altitude			
92	SH	19:15 – 19:45	med/large	peak
92	SH	21:45 – 22:15	med/large	low
95	SH	18:45 – 19:15	large	peak
98	SH	22:30 – 23:00	med/large	desc. peak
80	H	18:45 – 19:15	small	first peak
83	H	21:15 – 21:45	medium	low
84	H	21:00 – 21:30	med/large	medium
85	H	20:30 - 21:00	large	low
87	H	19:30 – 20:00	med/small	med. peak
89	H	20:45 – 21:15	small	second peak
89	H	22:00 – 22:30	small	second peak



Summary

- Engineering approach for solving complex Data Link issues was presented.
- Methodology using URET, Xeval and Transcriber proved to be very useful and well-designed.
- Future work should include HUMAN FACTORS ISSUES:
  - Controller's and pilots workload
  - Situation Awareness
  - Change in workload distribution from aural to primarily visual