ANALYSIS OF MULTIPLE OPEN MESSAGE TRANSACTIONS AND CONTROLLER-PILOT MISCOMMUNICATIONS

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Systems

- Voice Communications
- Data Link Communications

Study Outline

- Motivation
- Objectives and Scope
- Methodology
- Analysis Results
- Conclusions and Recommendations

Motivation

- Successful transformation of NAS into NextGen will significantly depend on the successful implementation of the Data Communications and automation enhancements
- Look at the existing voice-based system and determine common problems
- What can we learn from problems and mistakes found in the existing system

Motivation

- Studies mostly related to consequences of controller-pilot miscommunications rather than to their causes
- Workload issues
- Frequency utilization sometimes used as a proxy for communication workload -- depends highly on number of aircraft handled
- Communication workload depends on other events as well
- Data Link will lower frequency utilization – what else is there?

Motivation

Previous Literature on Communication Messages Explores:

1) Analysis of the most common message types
2) The impact of miscommunication messages on traffic safety
3) Workload

- Communication Errors and Operational Errors
- Runway incursions and human errors (i.e. miscommunications – readback/hearback, wrong instructions, issuing instructions to wrong aircraft)
- 70% of Operational Errors and Pilot Deviations caused by communication problems
- Message Complexity
  - Need for partial or full repetition of messages increases as the complexity of controller's messages increases
  - Tower-ground and tower-local control communication messages are more complex compared to the ARTCC environment
- Miscommunications and Message Types
  - similar call signs on the same frequency
  - pilot expectations
  - controller workload

Motivation

UC Berkeley/NEXTOR previous studies:

1) Benefits of CPDLC-URET integration
2) Aircraft Excess Distance Analysis
3) Causes of Miscommunications
3) Metrics comparison:
   - ❑ Physical (frequency) Utilization
   - ❑ “Cognitive” Utilization (with open transactions)

NEXTOR

Examples of Miscommunications

corp	acid	text	message_ type	open transaction	reasons	tt
p	usa102	center us air 1 0 2 3 7 0	i	cc		931.913
c	usa102	us air 1 0 2 indi center roger	l	cc		934.608
c	usa102	us air 1 0 2 turn 10 degrees right for traffic	h	c		1355.851
p	usa102	10 right us air 1 0 2	c	c		1359.743
c	usa102	us air 1 0 2 cleared direct farmer	f	c		1561.786
p	usa102	us air 1 0 2 going direct farmer	c	c		1566.157
c	usa102	us air 1 0 2 contact indi center 1 2 3 point 7 7	m	c		1806.522
p	usa102	1 32 77 us air 1 0 2 good day	e p	c	pilot mishears	1810.714
c	usa102	1 2 3 7 7	n	c		1814.1
p	usa102	ok 1 2 3 7 7 us air 1 0 2	d	c		1816.076

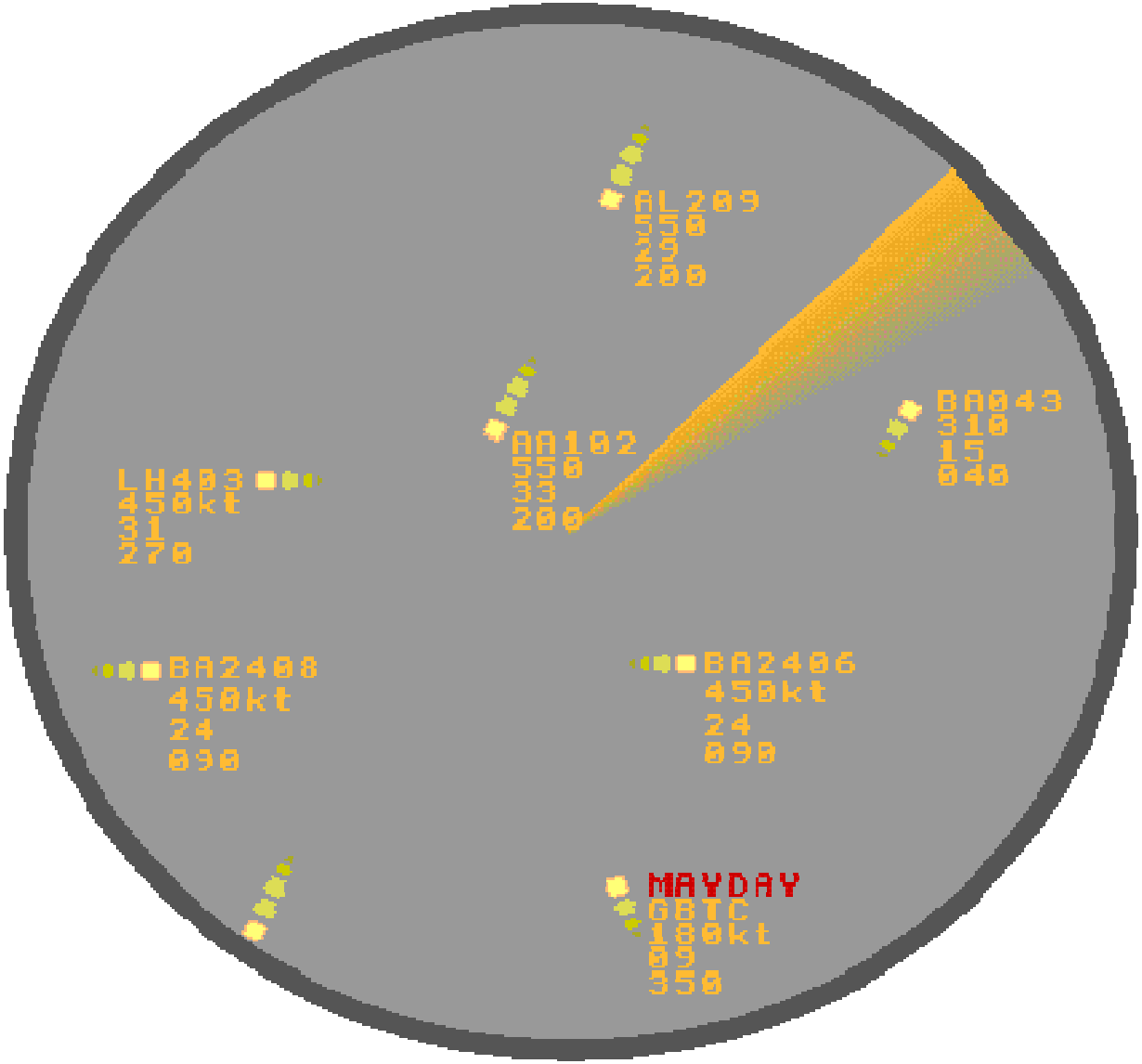
Center Airspace

Sector i921915

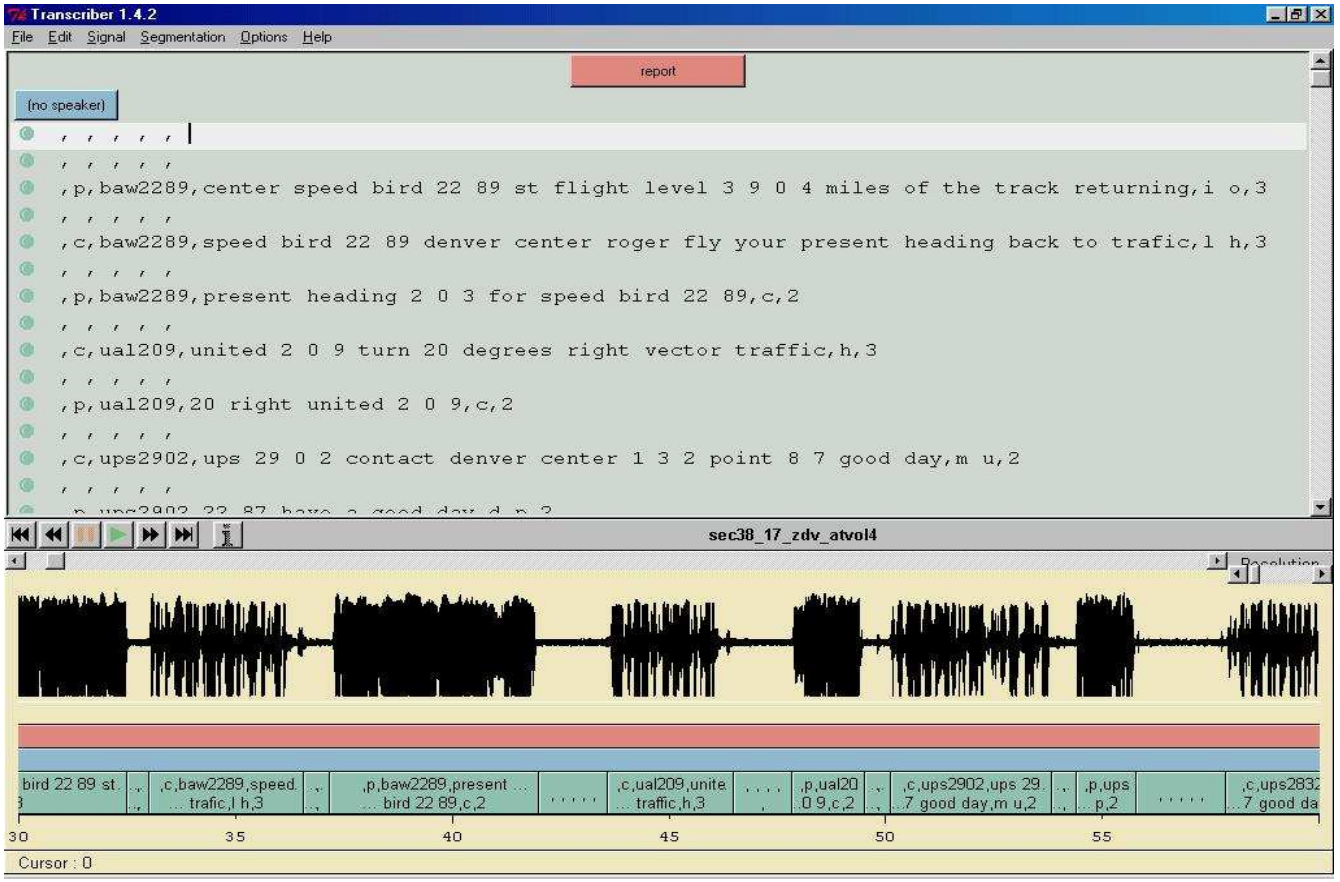
T = 931.913

T = 1806.522

Current System



Communications Systems – Voice



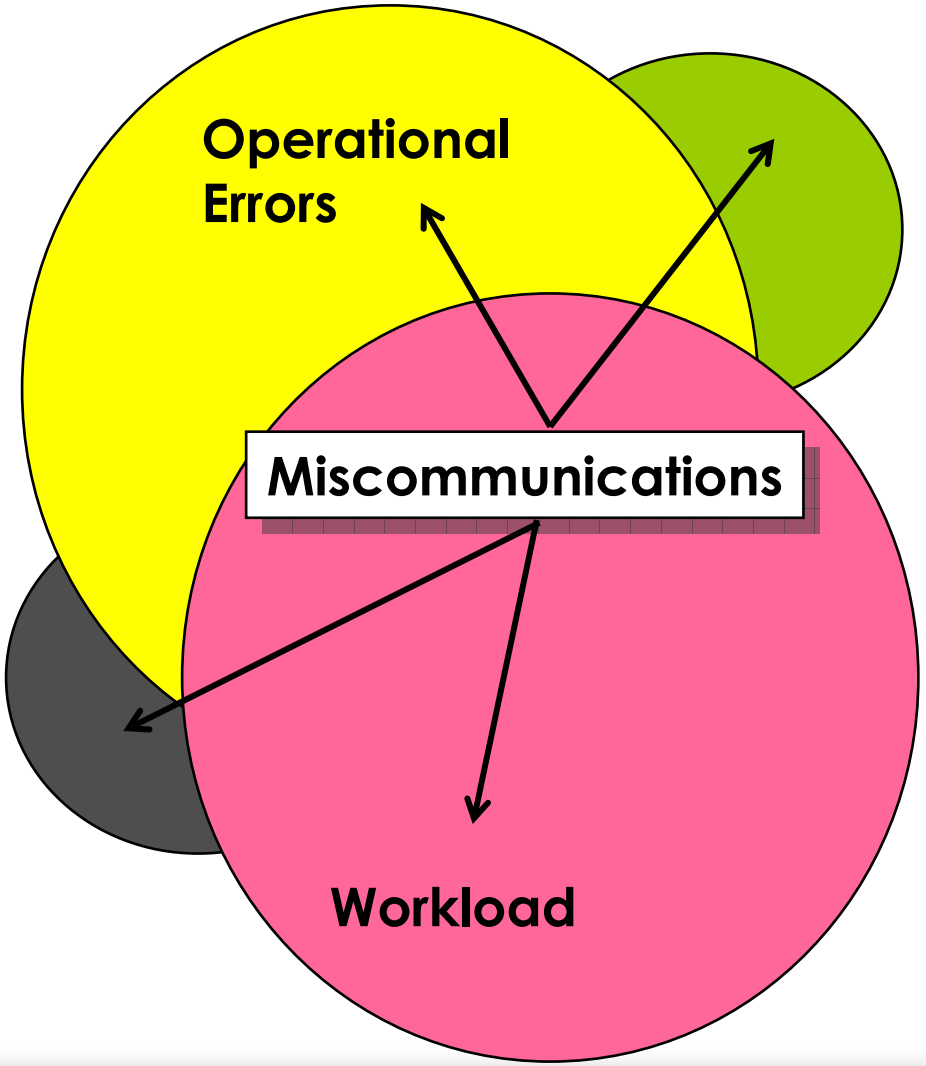
Data Link Benefits

- Reduced frequency congestion, especially under high traffic density
- Benefits assessed as a reduction in frequency occupancy depending on the Data Link Segment in question

Data Link Communications

Previous Studies and Proposed Work

Previous Studies



Current Work

What are the contributing factors?

- Message Complexity
- Number of Open Transactions
- Message Duration
- Sector Capacity

Miscommunications

Data Link Environment

Methodology

Proposed methodology includes the following steps:

(1) determining miscommunication messages (database develped at UC Berkeley/NEXTOR)

(2) general understanding of types and origins of miscommunication messages

(3) formulating metrics and parameters

(4) constructing regression models

Methodology

- 42 30-minute samples from transitional and high altitude sectors
- 5 ARTCCs (Indianapolis, Memphis, Denver, Dallas-Ft. Worth and Atlanta)

Selected Sectors from Indianapolis ARTCC

Sector		Time Interval (ZULU)	Sector Size
Name	Altitude		
92	SH	19:15 – 19:45	med/large
92	SH	21:45 – 22:15	med/large
95	SH	18:45 – 19:15	large
96	SH	20:30 – 21:00	medium
98	SH	22:30 – 23:00	med/large
80	H	18:45 – 19:15	small
83	H	21:15 – 21:45	medium
84	H	21:00 – 21:30	med/large
85	H	20:30 - 21:00	large
87	H	19:30 – 20:00	med/small
89	H	18:45 – 19:15	small

Selected Sectors from Memphis ARTCC

Sector		Time Interval (ZULU)	Sector Size
Name	Altitude		
19	SH	19:15 – 19:45	large
24	SH	20:30 – 21:00	large
32	SH	19:45 – 20:15	large
61	SH	21:00 – 21:30	large
22	H	22:00 – 22:30	large
22	H	19:45 – 21:15	large
25	H	20:00 – 20:30	large
26	H	20:15 – 20:45	large
30	H	22:00 – 22:30	med/large
63	H	20:00 – 20:30	medium
62	H	21:00 – 21:30	med/large
62	H	19:45 – 20:15	med/large

Database

A	B	C	D	E	F	G	H	I	P
sector	corp	acid	text	message_type	open transaction	reasons	complexity	tt	MAP
m63_2000	p	COA1494	continental 1494 330	i	c		1	2.053	15
m63_2000	c	COA1494	continental 1494 roger	l	c		1	4.276	15
m63_2000	p	XXX44118	memphis XXX 44118 250	i	c		1	20.801	15
m63_2000	c	XXX44118	XXX 44118 memphis center good	lut	c		3	25.759	15
m63_2000	p	XXX44118	118 roger	c	c		1	34.01	15
m63_2000	c	N340RE	november 340 romeo echo contac	m	c		1	35.933	15
m63_2000	p	N340RE	35 37 340 romeo good day	dp	c		2	41.071	15
m63_2000	p	COA1682	continental 16 82 290	i	c		1	48.514	15
m63_2000	c	COA1682	continental 16 82 memphis cente	l	c		1	51.539	15
m63_2000	c	N550LH	....0 lima hotel contact memphis	m	c		1	63.856	15
m63_2000	p	N550LH	memphis uh..133 65?	e	c	pilot mishear	1	69.264	15
m63_2000	c	N550LH	yes sir have a good day	nu	c		2	71.658	15
m63_2000	p	N550LH	so long	dp	c		1	73.05	15
m63_2000	p	DAL655	memphis delta 655 out of 27 to 28	i	c		1	99.903	15
m63_2000	c	DAL655	delta 655 memphis center roger	l	c		1	104.469	15
m63_2000	c	BTA4047	bta 4047 climb and maintain flight	j	c		1	119.877	15
m63_2000	p	BTA4047	330 bta 4047	c	c		1	123.923	15
m63_2000	c	DAL655	delta 655 turn left to heading 190	ho	c		3	176.553	15
m63_2000	p	DAL655	190 delta 655	c	c		1	184.434	15
m63_2000	c	N524RH	524 romeo hotel contact indianap	m	c		1	226.482	15
m63_2000	p	N524RH	36 92 romeo hotel good day sir	dp	c		2	232.32	15
m63_2000	c	DAL655	delta 655 clear and direct dreg ror	f	c		2	235.515	15
m63_2000	p	DAL655	delta 655 direct dreg romoramo	c	c		2	239.931	15
m63_2000	c	SWA945	southwest 945 contact indianapol	m	c		1	243.977	15
m63_2000	p	SWA945	133 05 so long	dp	c		2	249.936	15
m63_2000	c	COA1494	continental 1494 contact indianap	m	c		1	268.024	15
m63_2000	p	COA1494	27 02 continental 1494	d	c		1	276.507	15
m63_2000	c	N522CC	2 charlie charlie contact memphis	mo	c		2	279.351	15
m63_2000	p	N522CC	32 1 charlie charlie	d	c		1	284.238	15
m63_2000	c	BTA4047	bta 4047 maintain flight level 350	j	c		1	362.594	15
m63_2000	p	BTA4047	350 bta 4047	c	c		1	366.59	15
m63_2000	c	COA1682	continental 16 82 indianapolis cer	m	c		1	397.764	15
m63_2000	p	COA1682	32 52 continental 16 82	d	c		1	401.679	15
m63_2000	c	DAL655	delta 655 contact memphis cente	mu	c		2	412.411	15
m63_2000	p	DAL655	35 37 deltat 655	d	c		1	416.737	15

Data Fields

Field Name	Description
sector	Sector Name
corp	pilot (p) or controller (c) speaking
acid	aircraft id (“official”)
text	message text
message_type	message type
open transaction	(c) one transaction, (cc) double open transaction, (ccc) triple open transaction, etc, (b) interval between transactions
reasons	reasons for miscommunication and other mistakes (conclusions based on listening to recorded pilot/controller communications)
complexity	number of elements in one message
tt	time each message (transaction) starts (in seconds)
arrival	(1) if an aircraft arrives into a sector, (0) for all other
departure	(1) if an aircraft departs form a sector, (0) for all other
number of a/c	number of aircraft in sector (based on the analysis of messages)
tmin	time each message/transaction begins (in minutes)
MAP	monitor alert parameter = maximum number of aircraft allowed in sector or declared value

Methodology

Recorder and SATORI audio files

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INTERACTIVE TRANSCRIBER

↓

SAS file with transcribed and categorized ATC messages

↓

Analysis of SAS files

↓

Variables of Interest:

1. Message Type
2. Message Complexity
3. Message Duration
4. Message Origin (controller or pilot)
5. Open Transaction
6. Aircraft Arrivals Into Sector
7. Aircraft Departures from Sector
8. Aircraft ID
9. Number of Aircraft in Sector

Probit and Logit Regression Models

Y = dummy dependent binary {0,1} variable

Y = 0 if non-miscommunication message

Y = 1 if miscommunication message

$$P\{Y = 0\} = \Phi(\beta_0 + \bar{\beta}X')$$

→

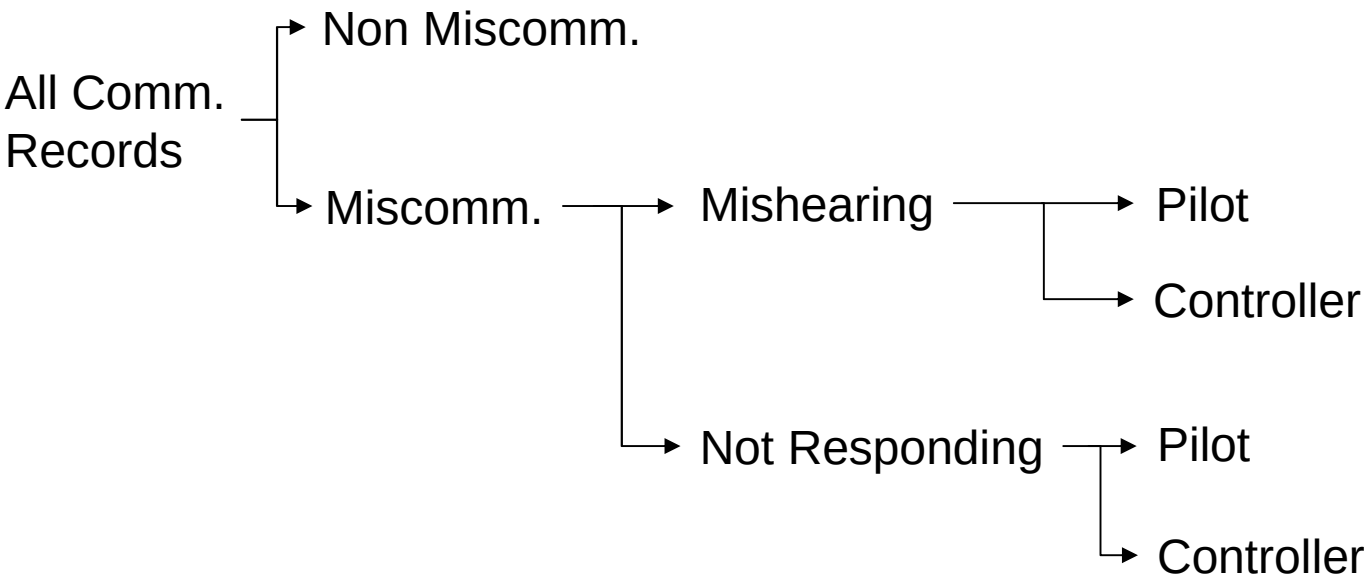
Dependent Variables:

Miscommunication, Non Miscommunication

Mishearing, Not Responding

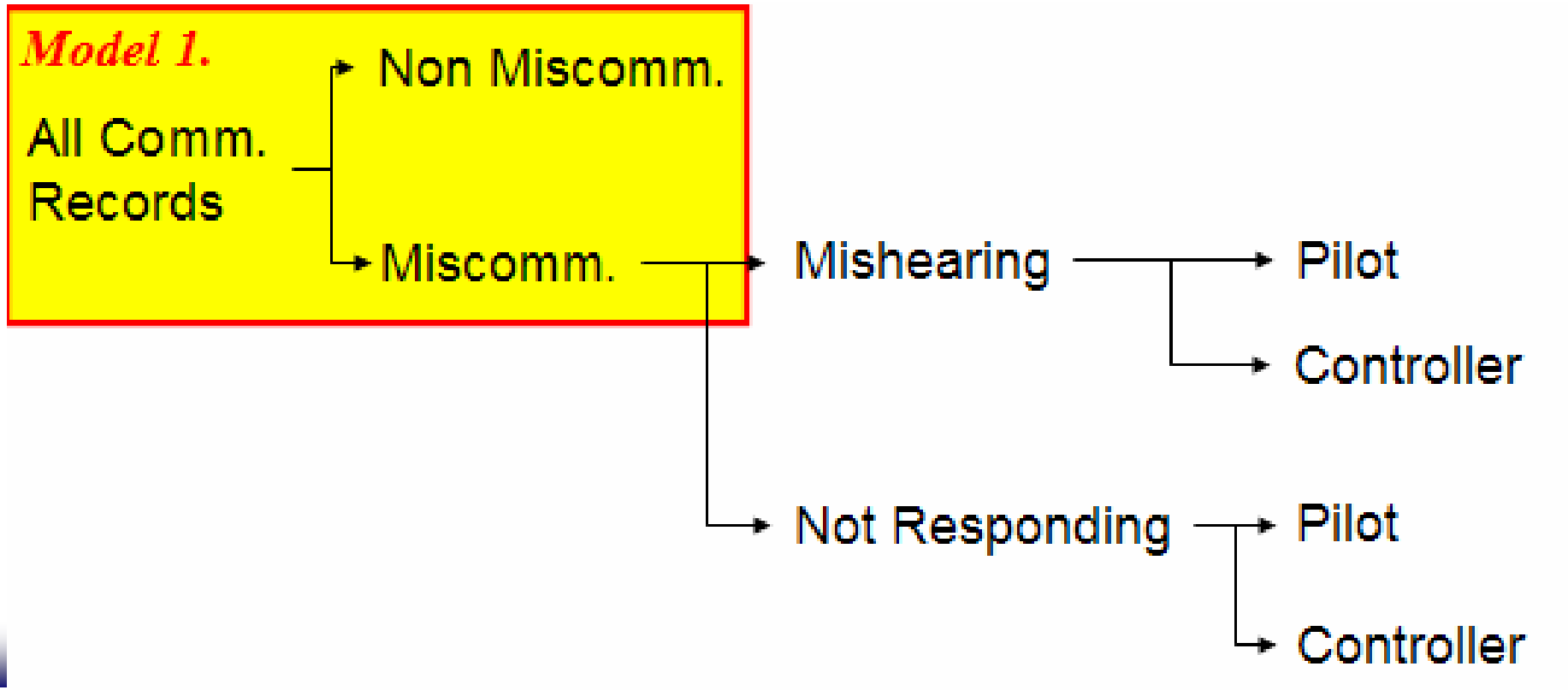
Controller, Pilot

Models

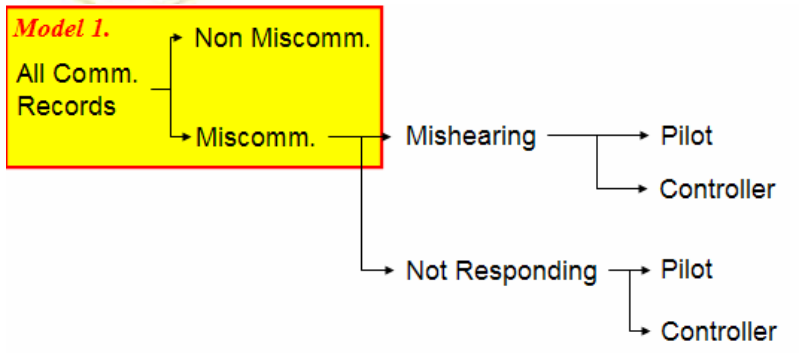

All Comm. Records
Non Miscomm.
Miscomm.
Mishearing
Pilot
Controller
Not Responding
Pilot
Controller

Model 1

Objective:
Analyze the impact of open transactions, complexity, message duration, traffic volume and MAP on miscommunications



Model 1

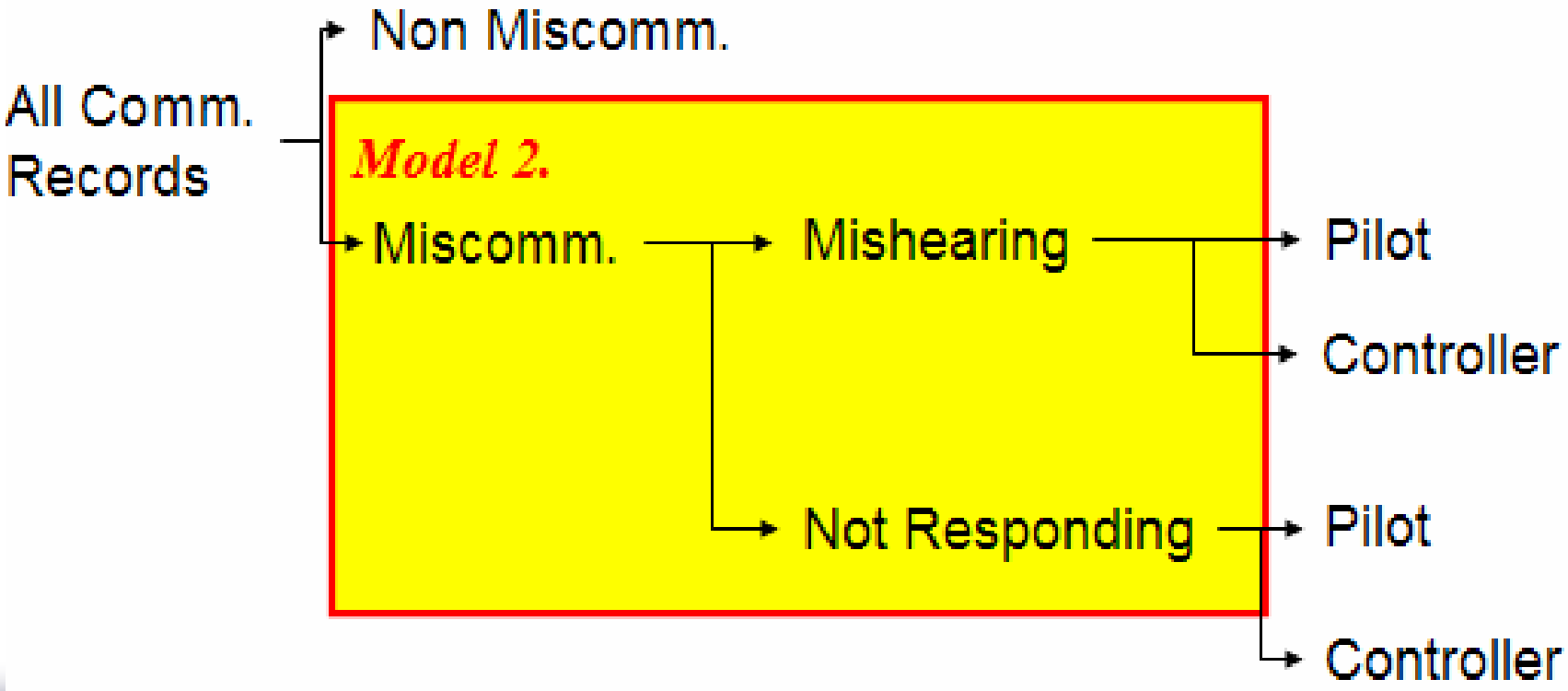


Analysis Results:

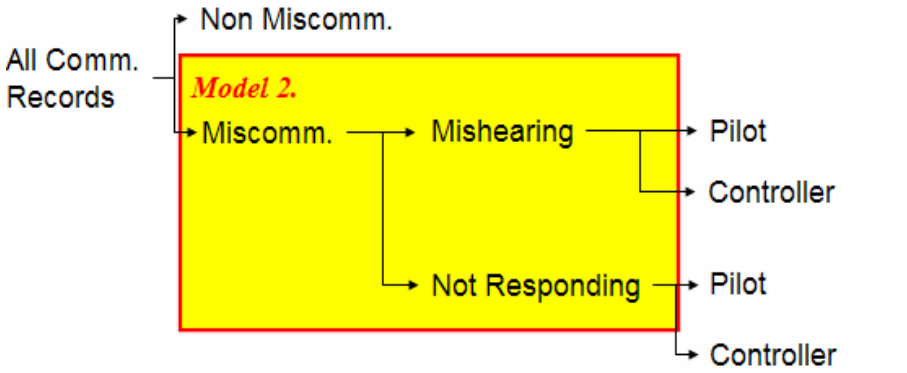
- Communication messages more likely to occur (intuitive)
- Increased number of open transactions affects occurrences of miscommunications
- Arriving aircraft into the sector more prone to miscommunications
- Message duration affects miscommunications (average duration of miscomm. messages 3.46 sec vs 2.94 for successful communications
- Complexity not an issue in our model

Model 2

Objective:
Analyze the impact of open transactions, complexity and message duration on the two most common types of miscommunications (mishearings and delayed responses)



Model 2



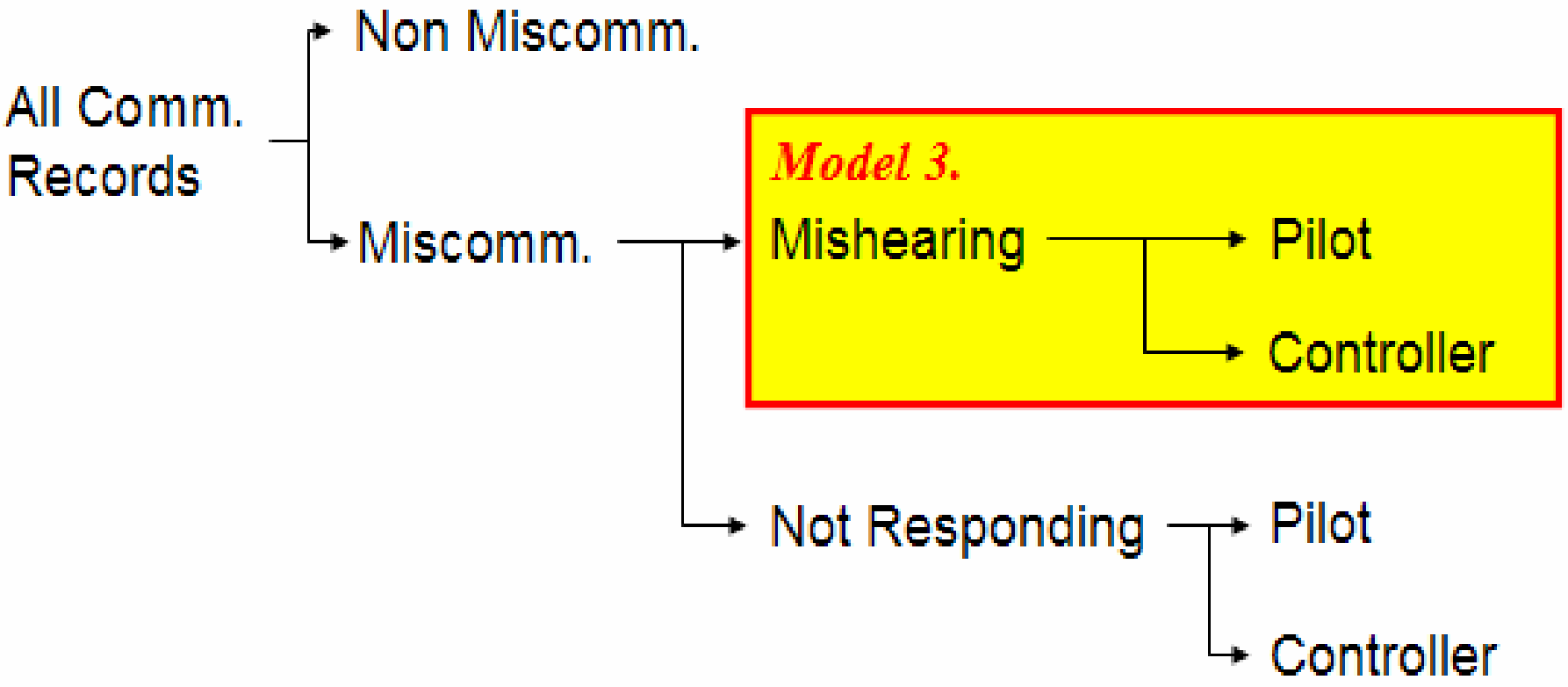
Analysis Results:

- An increase in the number of open message transactions affects delayed responses more than misheard messages

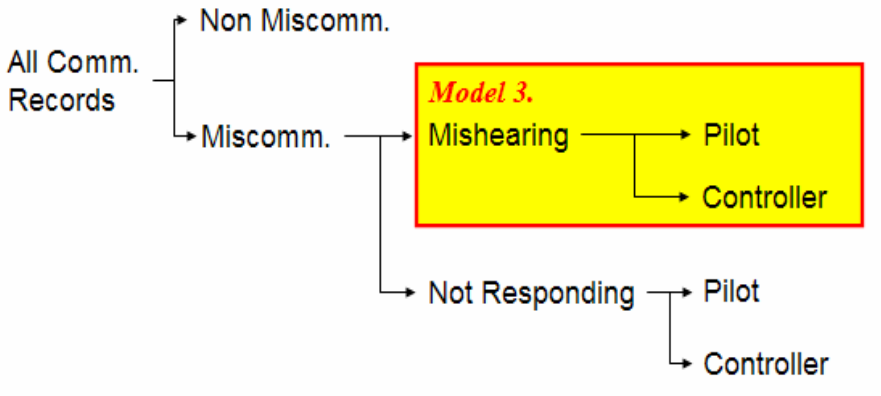
Model 3

Objective:

Determine
(1) who is more prone to mishearing messages
(2) under what conditions misheard messages occur



Model 3



Analysis Results:

- Longer messages cause pilots' message mishearings rather than controllers' (pilots are main recipients of lengthy messages)
- Increase in sector capacity (MAP) affects controllers' ability to hear messages correctly

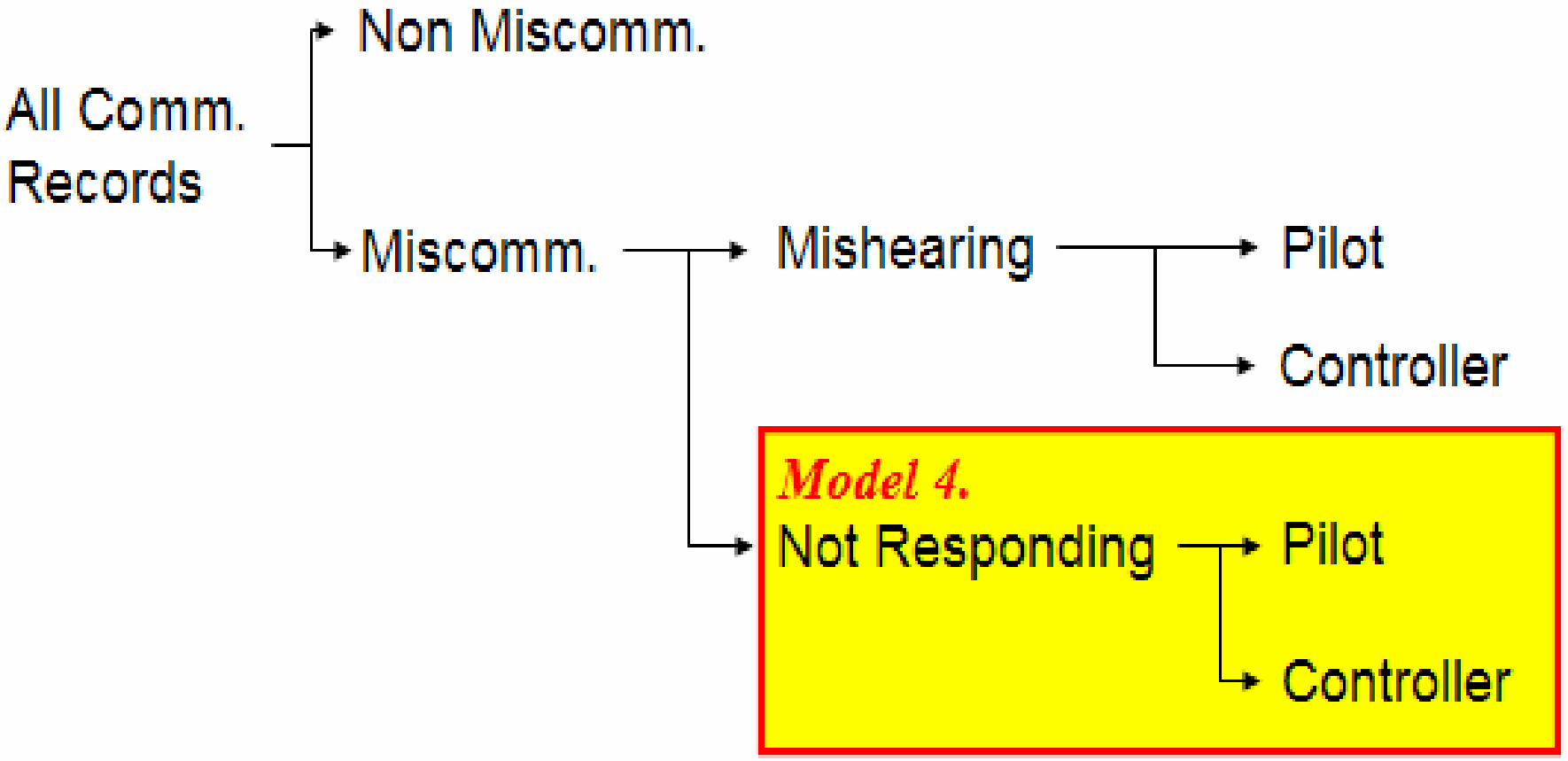
Model 4

Objective:

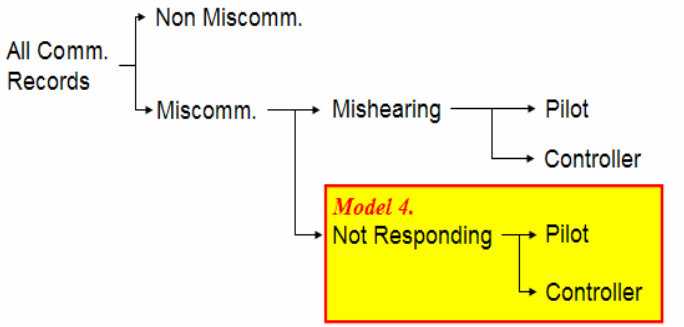
Determine:

(1) the impact of sector traffic and communication characteristics on delayed responses

(2) who is more prone not to respond in a timely manner and under what conditions



Model 4



Analysis Results:

- Because Model 2 indicated that open transactions affect delayed responses, it was important to obtain additional explanations on how delayed responses relate to controllers and pilots
- Sector traffic volume affects delayed responses (controllers)
- Increased number of open message transactions had a larger impact on controllers' delayed responses
  - might appear counterintuitive
  - once a controller initiates too many open transactions, he tends to delay his responses
  - this could also appear in the data link environment

Summary and Recommendations

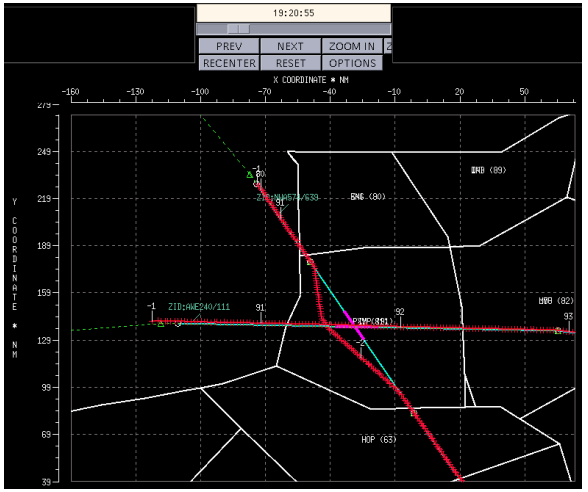
- In support of NextGen, analyzed were important and common problems to both systems: the problem of multiple open transaction and the occurrence of delayed responses
- Increased number of open transactions impacts the occurrence of miscommunications, and in particular, the delayed responses by controllers.
- Since the message transfer time in a data link environment appears to be longer than in the voice-based environment, any further delays in message transactions with data link should be avoided

Summary and Recommendations

Future work should include the following studies:

- Juxtaposing the en route traffic and communication messages with the objective to:
  - Study the effect of open transactions on controllers' delayed responses -- and the impact on routing efficiency.

A/C ID	Conflict with aircraft (from URET)	Time message issued (from voice tapes)	Controller's Message (from voice tapes)
NWA574	AWE 240	19:25:32	"turn right 20 degrees please for traffic"
NWA574	AWE 240	19:29:25	"turn left 10 degrees"
NWA574	AWE 240	19:30: 04	"you are cleared left turn now on course"



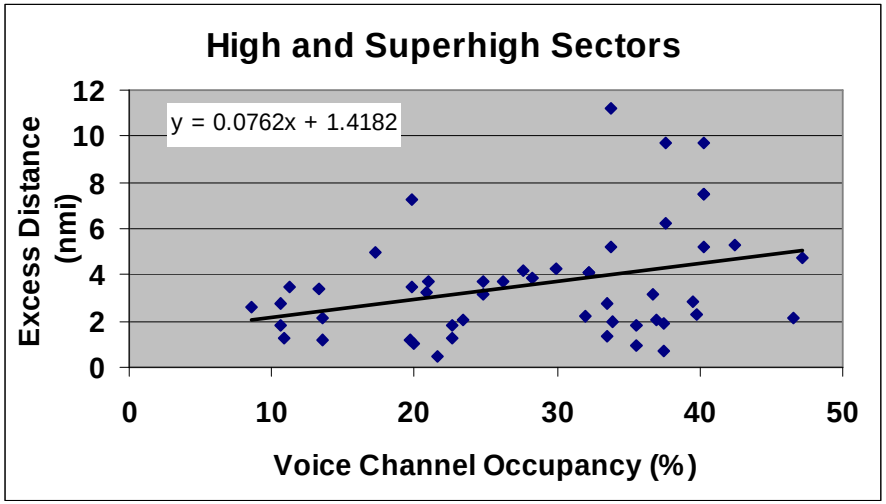
planned route

actual route

conflict

Summary and Recommendations

- Study the effect of open transactions on controllers' delayed responses – and the impact on routing efficiency:



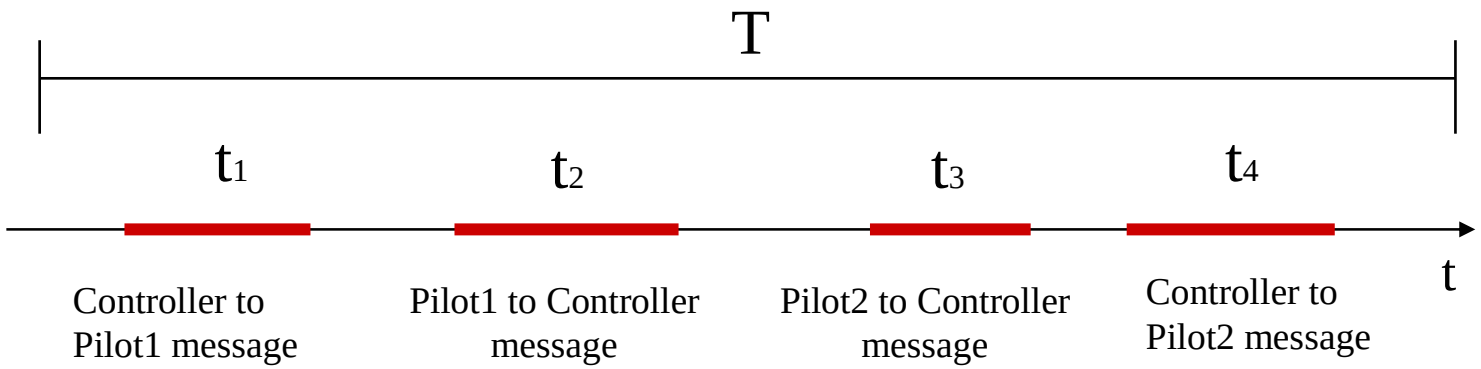
- Controller productivity in the same environment

- BACK UP slides

Previous Study and Motivation

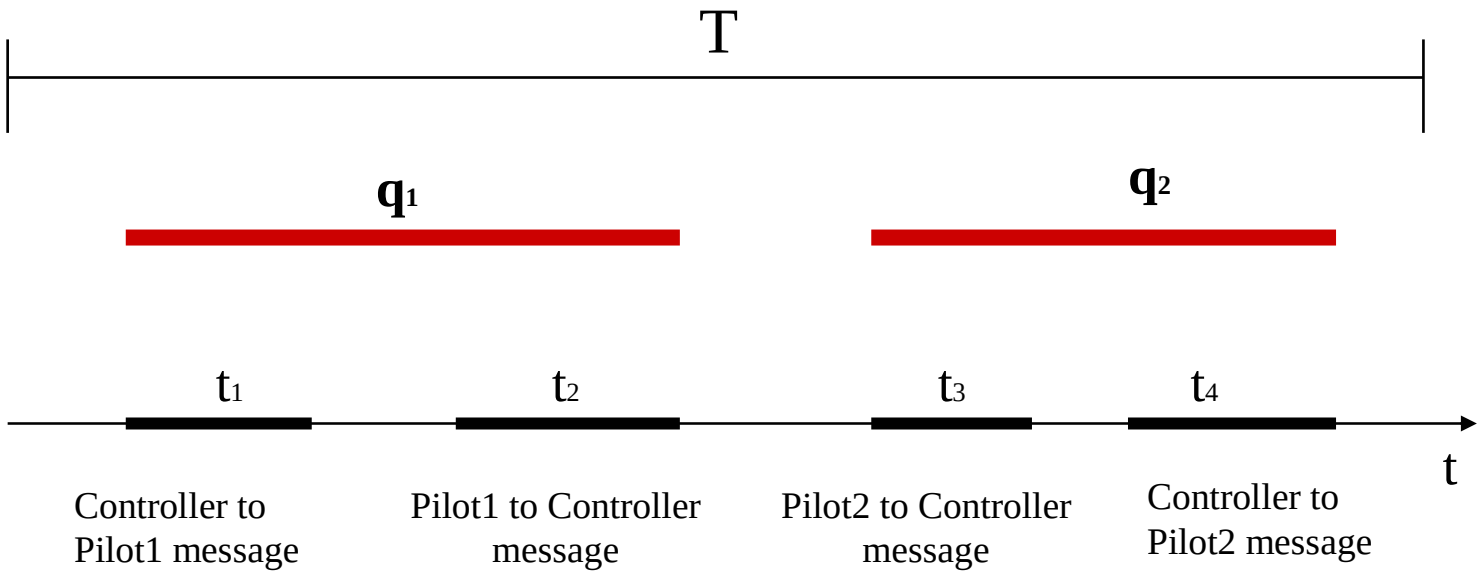
- Two metrics compared:
  - Physical (frequency) Utilization
  - "Cognitive" Utilization (open transactions)
- Voice communication transcription
- 15 30-minute samples from 15 transitional and high altitude sectors (5 ARTCCs)
- Metrics calculated for each 5 minute interval

Physical Utilization



$$P = \frac{100 \sum_{i=1}^{n} t_i}{T}$$

Cognitive Utilization



$$Q = \frac{100\int_{0}^{T} q(t)dt}{T}$$

Cognitive Utilization and The Concept of Open Transactions

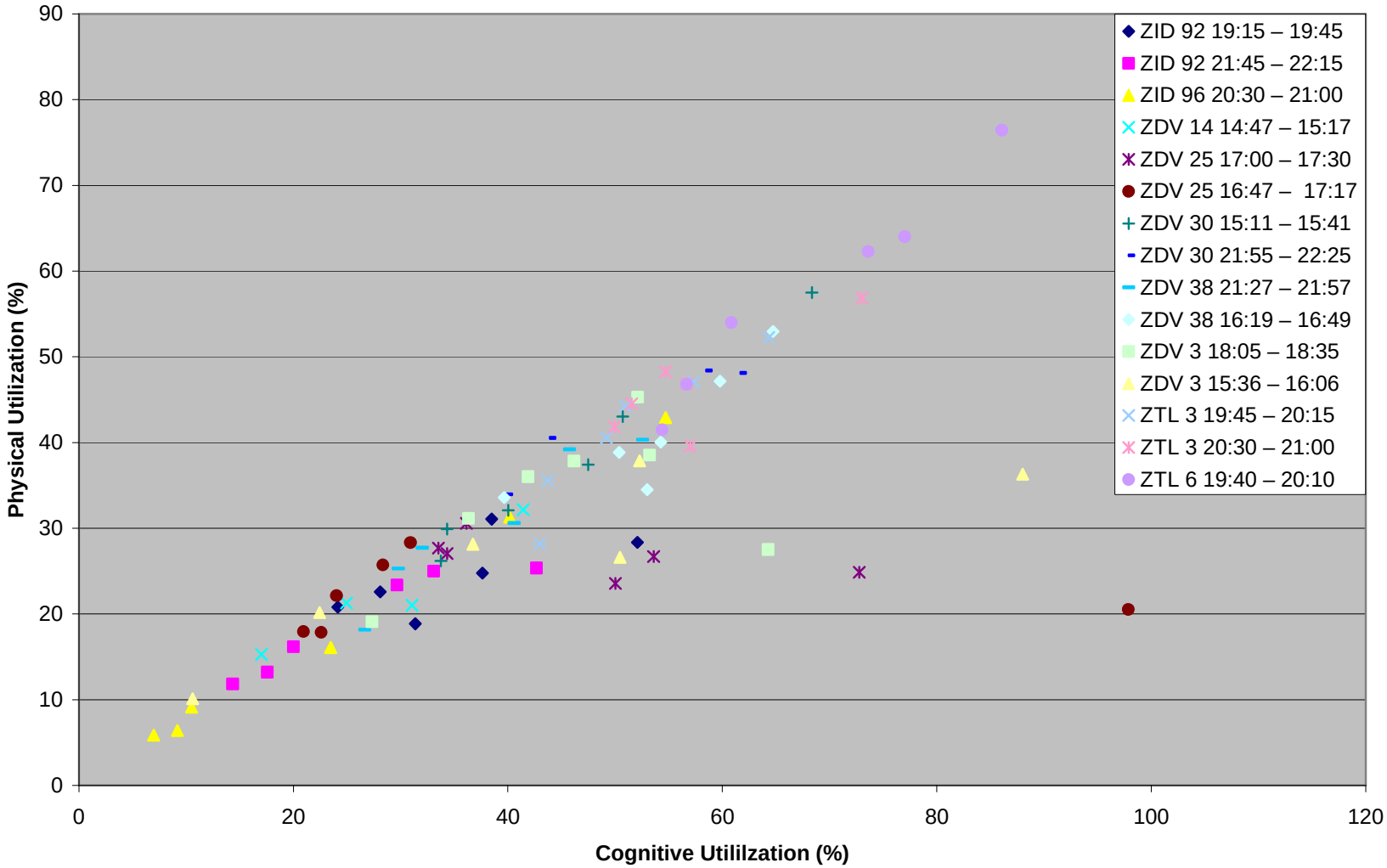
The term “cognitive” is based on the idea that during the time when a given communications transaction is open the controller must continue to be **aware** of it.

It is the sum of all the time intervals during which at least one communication “transaction” remains open. A “transaction” considers the time needed to complete (for example) the initial call, which would include time from the pilot’s initial call until the end of the controller’s acknowledgement of the pilot’s call.

Cognitive Utilization and The Concept of Open Transactions

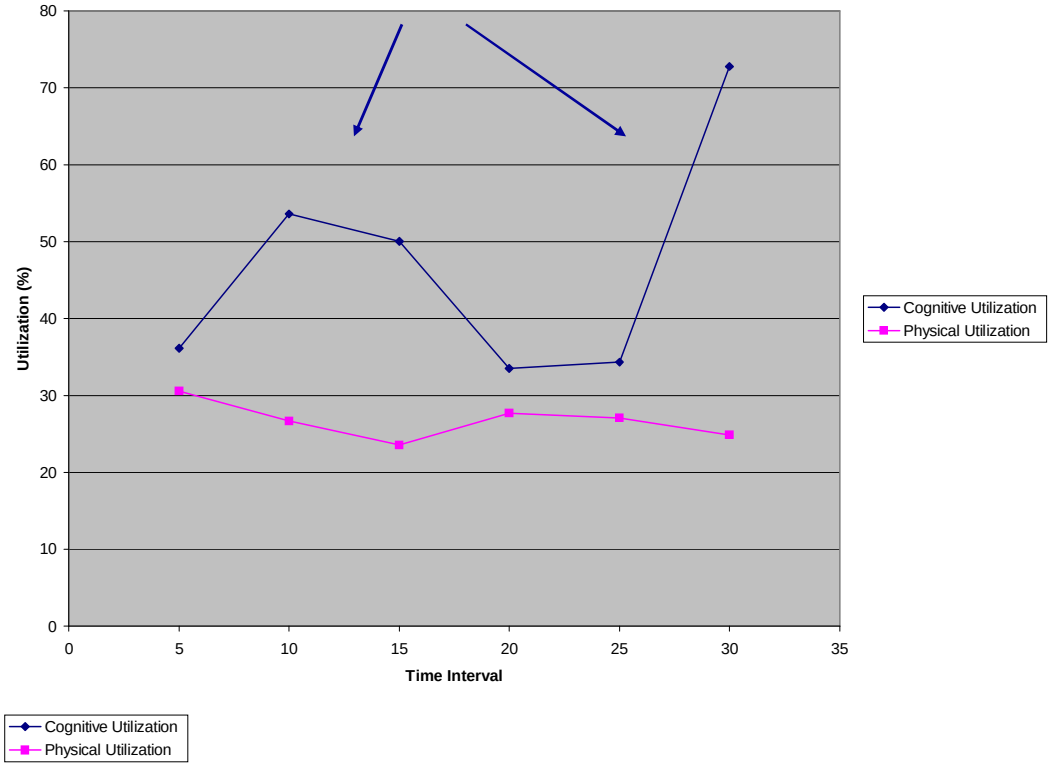
When several aircraft approach one sector at the same time:

1. Controller has to ‘open’ transactions (communications) at about the same time
2. Controller has to ‘think’ about each task simultaneously rather than consecutively
3. Communication with pilots occurs in some consecutive order

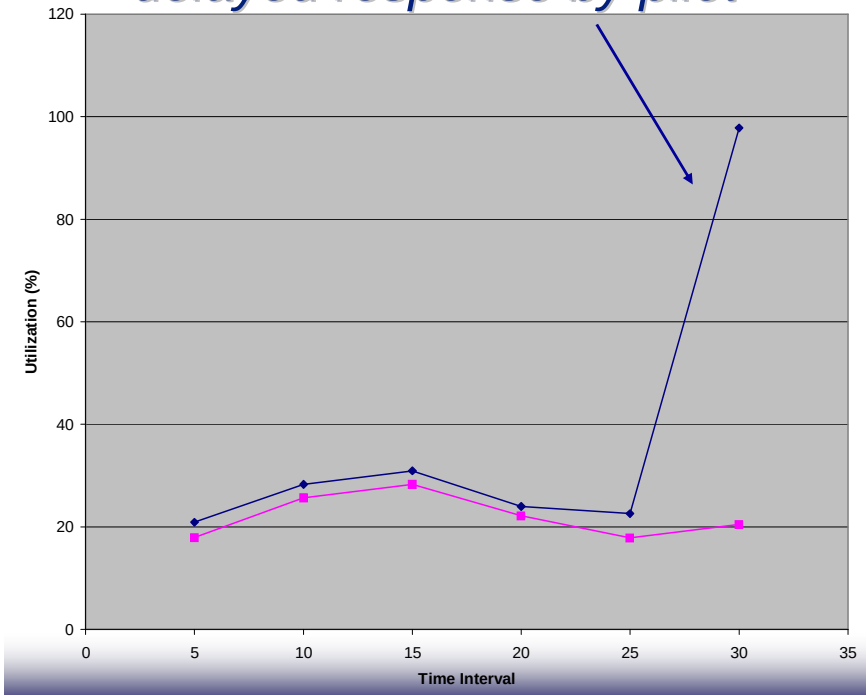


Cognitive vs. Physical Utilization for 33 Sectors

Stepped-on messages, delayed response, several transactions open at the same time



delayed response by pilot



Conclusions

- Cognitive utilization encompasses additional information about “out-of-the-ordinary” communication events: miscommunications, stepped-on messages, delayed pilot response
- High cognitive utilization can significantly diminish communication capacity
- Good descriptive metric for communication workload and situation awareness

Conclusions

- Can be used in the future CPDLC environment
- Better metric for addressing the influence of increased transaction time (CPDLC environment) on the controller workload and/or situation awareness
- Traditional metrics (time spend communicating, number of communication events, number of communication events by category) not longer appropriate indicators of communication workload