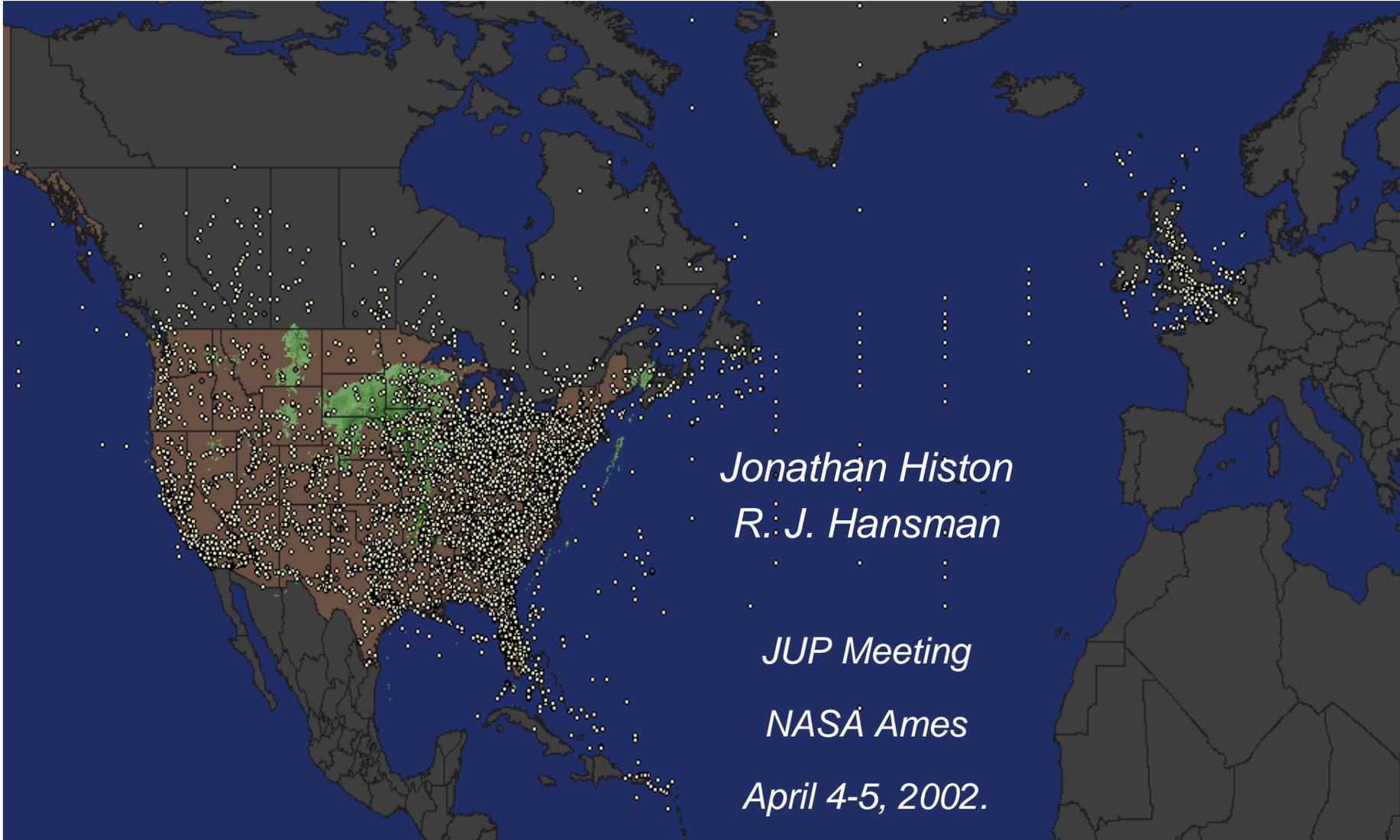




# Investigating the Relationship Between Structure and Commands in ATC





# Project Background

- **Cognitive Complexity in Air Traffic Control**
  - What makes Air Traffic Control difficult?
  - What is the role of structure?
- **Cognitive Complexity Represents Limiting Factor in ATC Operations.**
  - Limit Acceptable Level of Traffic due to safety concerns.
  - Represents limiting factor in sector and system capacity.
- **Improved Understanding of Structure's Impact on Cognitive Complexity Can Be Used To:**
  - Better define controller operational limits.
    - ◆ i.e. acceptable levels of traffic (e.g. Monitor Alert in ETMS)
  - Provide guidance for airspace and procedure design to reduce complexity.



# Project Approach

- **Collaborative effort between MIT and Centre d'Etudes de la Navigation Aérienne (CENA).**
- **Observations to Identify Factors Influencing Cognitive Complexity (MIT / CENA)**
  - Field Observations
  - Analysis of Standard Operating Procedures
  - Focused Interviews with Controllers
  - ETMS Data Analysis
  - Sector Focused Analysis
- **Preliminary Models of How Structure Influences Cognitive Complexity (MIT)**
  - Based on key structural factors.
  - Separates impact of structure on both controller inputs and outputs.
  - Focus on effect of structure on situational awareness on input side.
- **Preliminary Measures Including Structural Considerations (CENA / MIT)**
  - Explicit inclusion of identified structural factors.
  - Cluster-based approach.
  - Kolmogorov entropy.

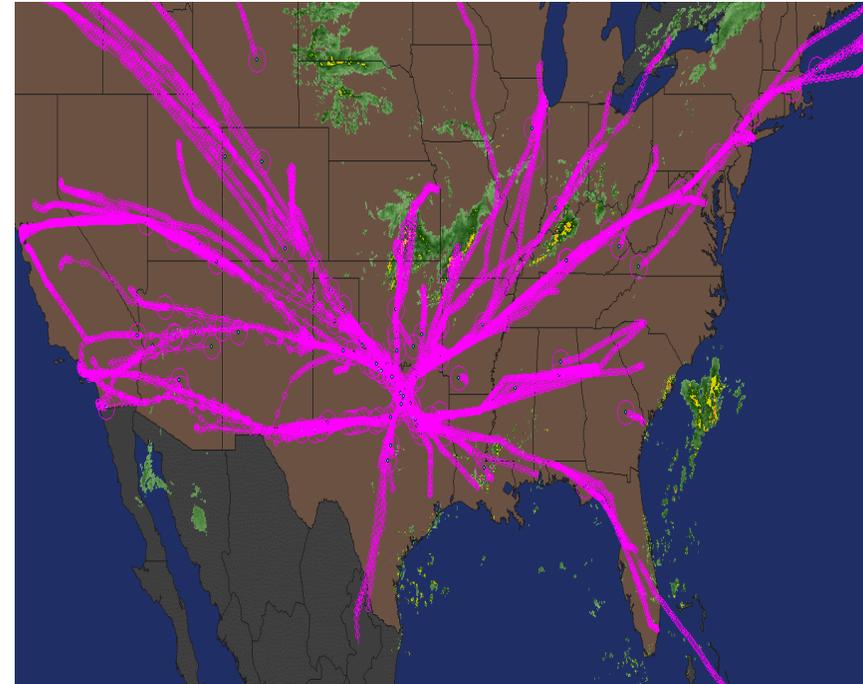


**TODAY'S TALK**



# Sector Focused Analysis (1)

- **Recent Quantitative Research Opportunities Have Focused on Aggregate Analysis of Traffic Flow**
  - ETMS Data
  - Observing Traffic Flow Patterns
- **New Data Opportunity Recently Discovered:**
  - Web Broadcast of Controller – Pilot Communications
    - ◆ [www.atcmonitor.com](http://www.atcmonitor.com)
  - Can synchronize with ETMS based displays of traffic situation (Flight Explorer)
  - Provides *realtime* audio and visual display of traffic situations.



*All Inbound Traffic, Dallas Fort Worth  
June 20, 2001 (153 Aircraft)*



# Sector Focused Analysis (2)

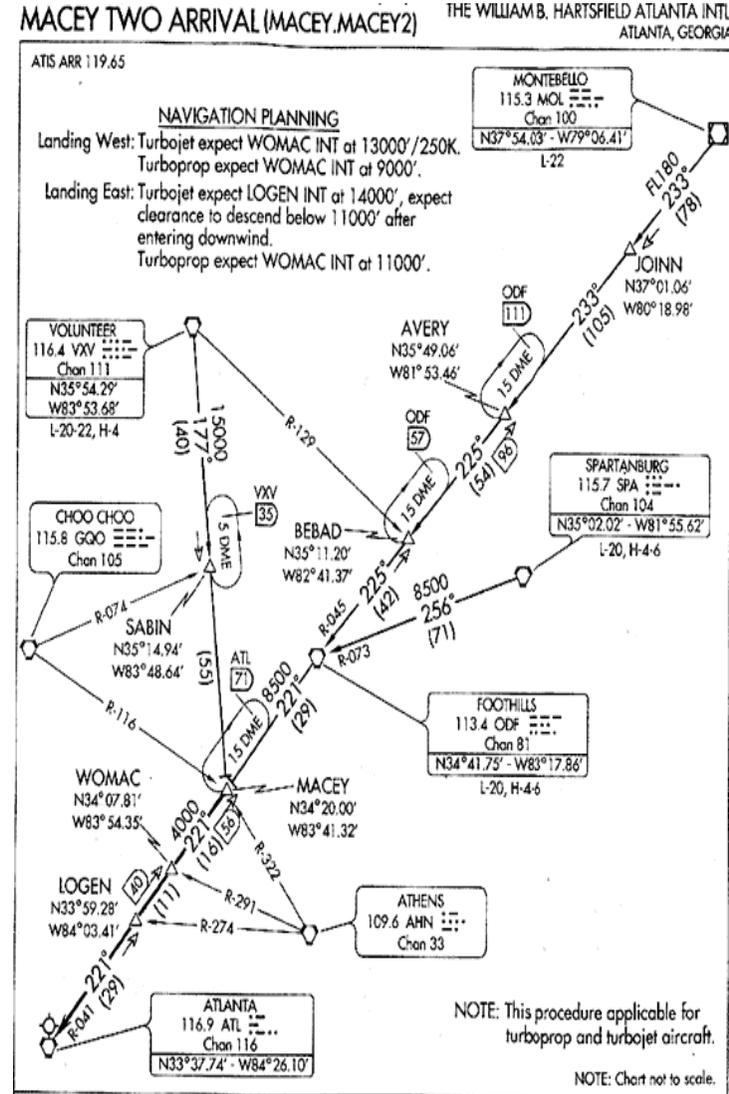
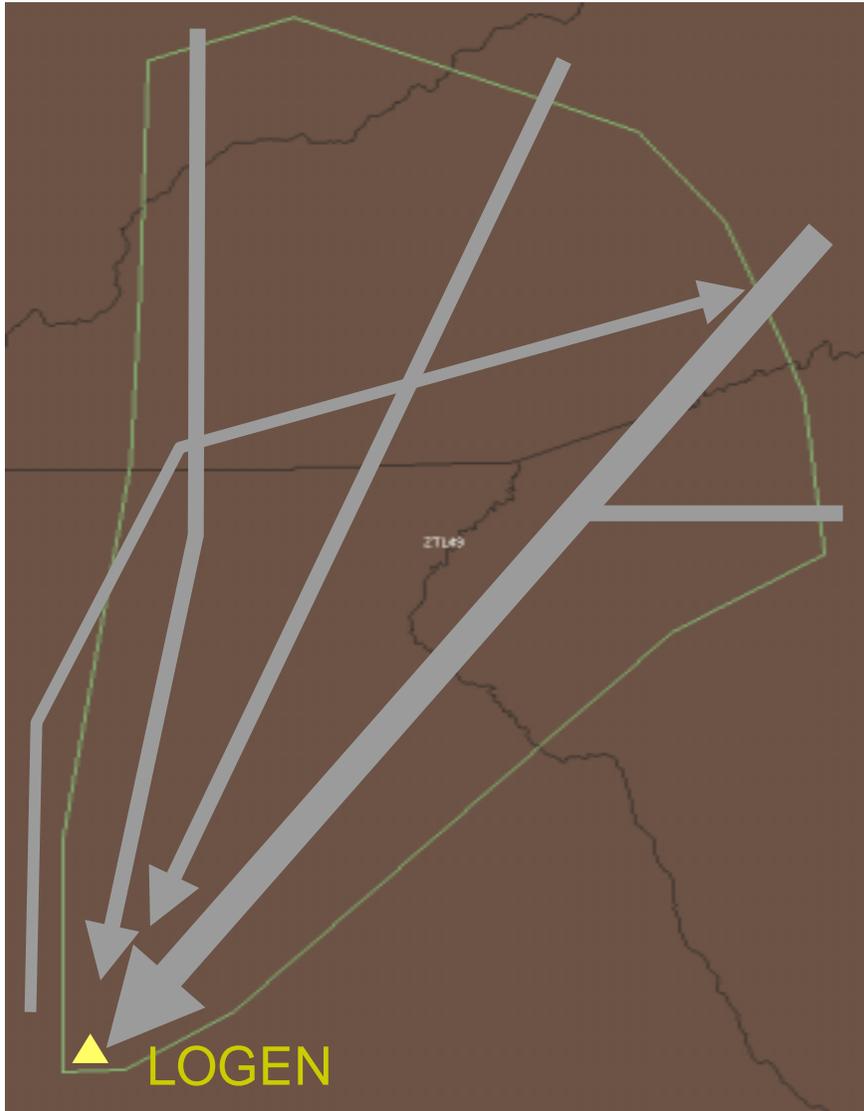
- **Sector Focused Analysis**
  - Correlate observed traffic patterns with commands given by the controller.
  - Investigate role/use of structure in those commands.
- **Procedure**
  - Developed Coding Scheme to Capture Significant Communication Events
  - Investigated Relationship Between Observed and Known Structural Elements and Commands Captured in Coding Scheme
- **Pilot Study Data Sample:**
  - Monday March 11, 2002,
  - 1:15 pm → 3:30 pm
  - No significant weather



# Atlanta Center, North-East Arrival Sector



# Observed Flow Patterns





# Sample Transcript Using Microsoft Speech Engine

- **ACTUAL:**

*“Delta 783 Increase speed to Three Zero Zero Knots”*

- **MICROSOFT VERSION:**

*“Tonight in a trip to San and ”*



# Data Collection Tool:

Main User From

Frame1

START PAUSE STOP

3/27/2002 1:28:58 PM

Frame2

CHECK IN

Climb and Maintain Direct to <Flc> Traffic Call

Descend and Maintain Clearance Intercept Arrival Route

Cross <Flc> at <to> Knot Roger Discretion (Altbude)

Cross <Flc> at <to> Feet Speed Command For Traffic

Unknown Command Heading Change Resume Own Navigation

Asked Question Discussion For Speding

Altimeter Setting Other Controller Voice Change

CHECK OUT

Double Click ADDs with

Unknown  
 CAA 67  
 DAL 575  
 DAL 873  
 5929  
 DAL 499  
 N4149R  
 DAL 619  
 DLH 444 Heavy  
 ACA 562  
 CAA 117  
 LXJ 412  
 DAL 589

MANUAL REMOVAL

Map Callouts:

- H3457U 875P 119
- H3205C 1710T 172 TYS EWN 2340 02:06p
- JU551T 110T 4 448 090 211 SDF ORD CAE 8KT PA28 81:43p
- N490PM 090 211
- RW781 878 182 TYS LGA PAS4 01:47p
- N3259C 0741 17 30H 5068 REC 12:23p
- DAL1933 240T 451 CVG ATL MD88 81:43p
- DAL3511 140T 424 DCA ATL MD88 81:43p
- CAA755 148T 292 LGA ATL CRJ2 81:26p
- CAA273 118T 270 AUL ATL AT72 01:40p
- N3577V 118T 2 247 POK GSP C628 81:31p
- FA2816 170T 388 BL CLC 845 02:07p
- DAL632 188C 357 ATL LGA MD80 02:03p
- DAL693 140T 387 GWR ATL B752 81:25p
- N88978 878 142 POK CLT C182 82:13p
- 4392 07 322 DAL320 135C 327 AUL ATL PHL B7C2 02:06p
- MD80 01:46p
- DAL146 148T 251 FLL ATL B738 01:17p
- DAL626 133C 428 ATL LGA B738 02:47p
- N32333 228 186 SKY AYC C348 82:14p

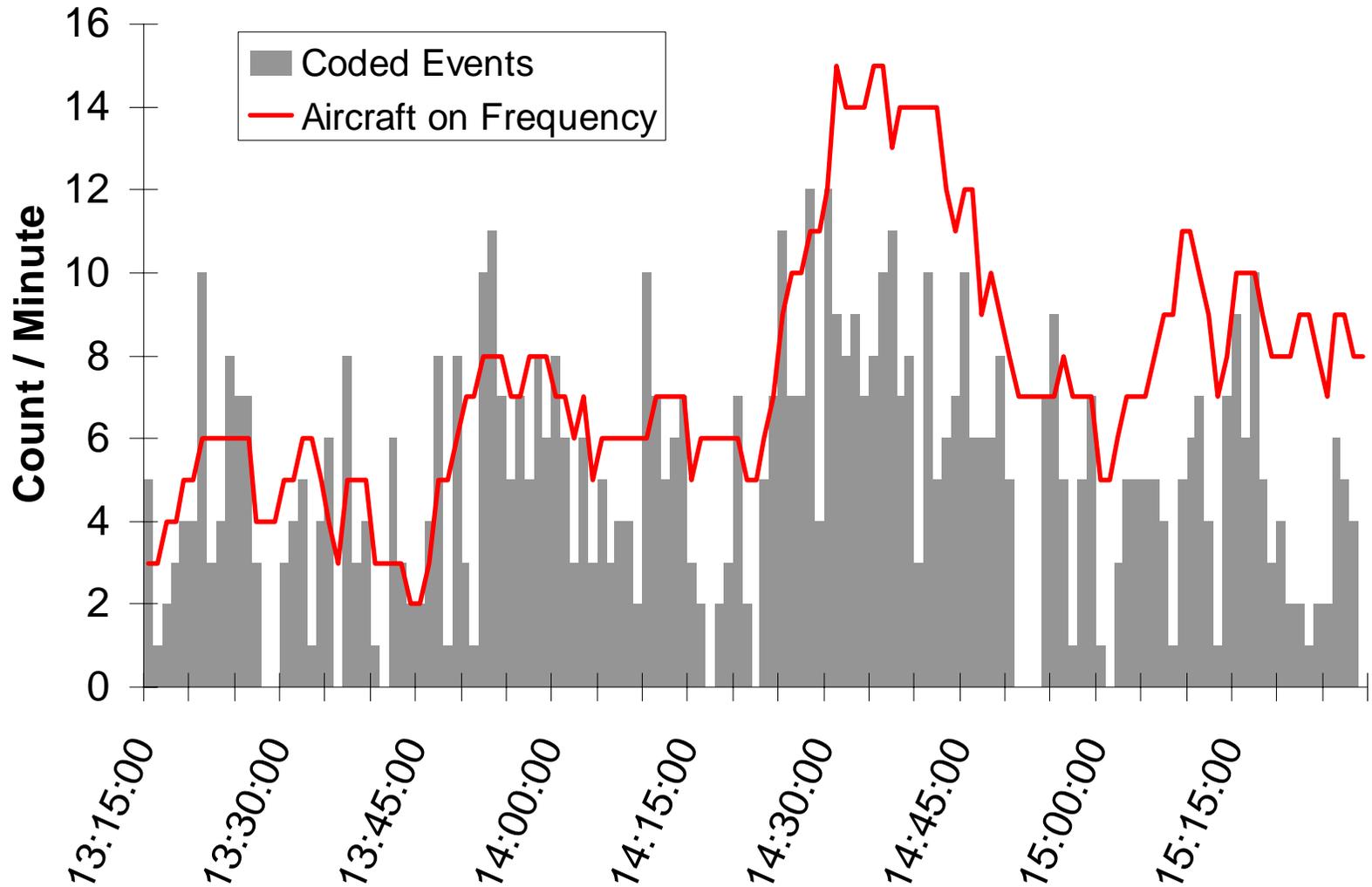


# Sample of Resulting Coding

14:25:01	DAL 961	<i>Traffic Discussion</i>
14:25:13	TRS 575	<i>Checkin (240)</i>
14:25:16	TRS 575	<i>Roger / Acknowledgement</i>
14:25:20	TRS 575	<i>Cross &lt;Logen&gt; at &lt;140&gt; Feet</i>
14:25:21	TRS 575	<i>Gave Altimeter Setting</i>
14:25:30	UAL 323	<i>Checkin (240)</i>
14:25:41	UAL 323	<i>Roger / Acknowledgement</i>
14:25:43	UAL 323	<i>Cross &lt;Logen&gt; at &lt;140&gt; Feet</i>
14:25:46	UAL 323	<i>Gave Altimeter Setting</i>
14:25:58	DAL 761	<i>Change Speed to &lt;300&gt; Knots &lt;maintain&gt; (&lt;UNRESTRICTED&gt;)</i>
14:25:59	DAL 761	<i>&lt;&gt; For Spacing</i>
14:26:07	DAL 873	<i>Asked A Question: &lt;On Frequency Check&gt;</i>
14:26:10	BTA 3017	<i>Checkout</i>

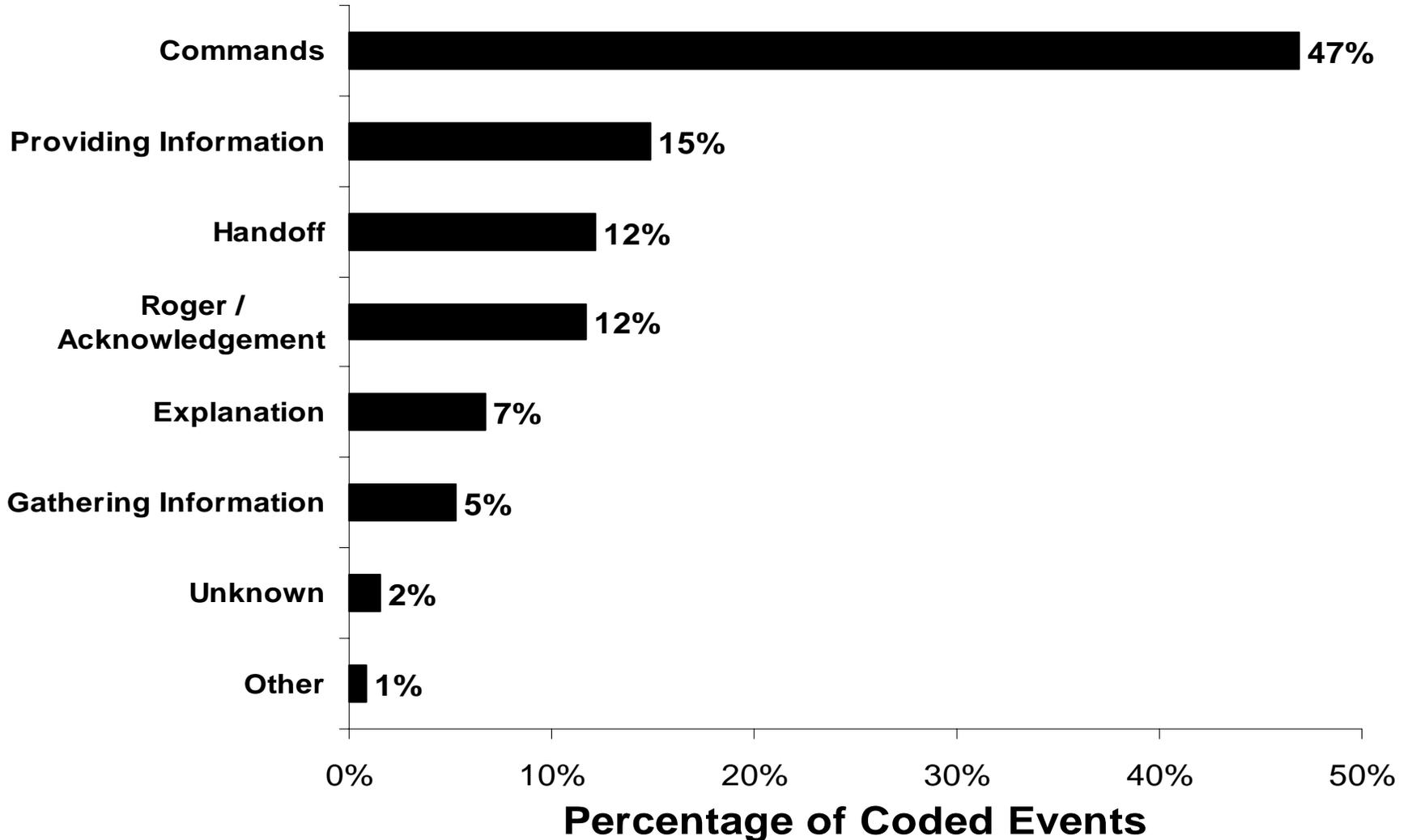


# Relationship Between Coded Events and Number of Aircraft on Frequency



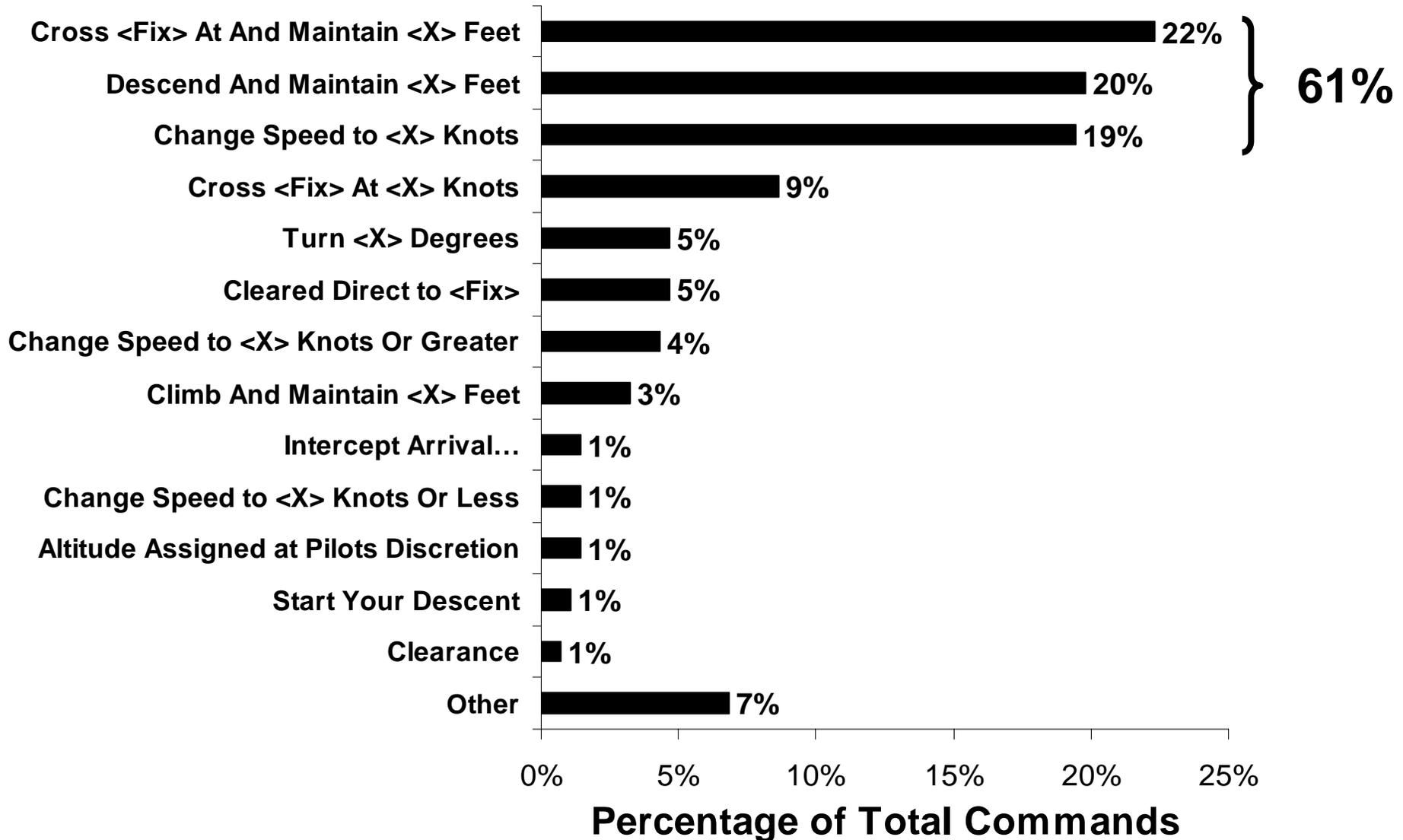


# Coded Communication Events



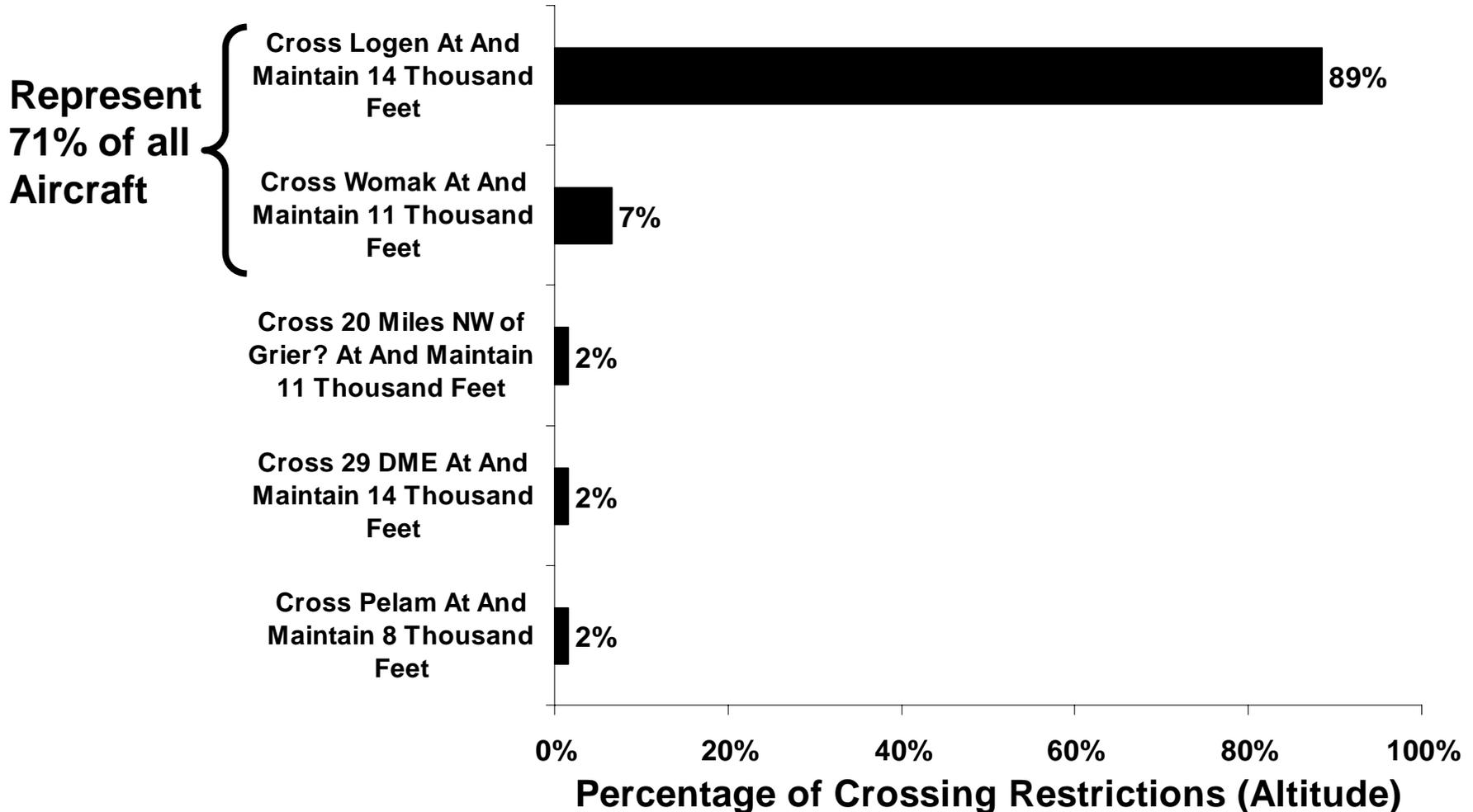


# Common Syntax Commands





# Crossing Restrictions (Altitude)



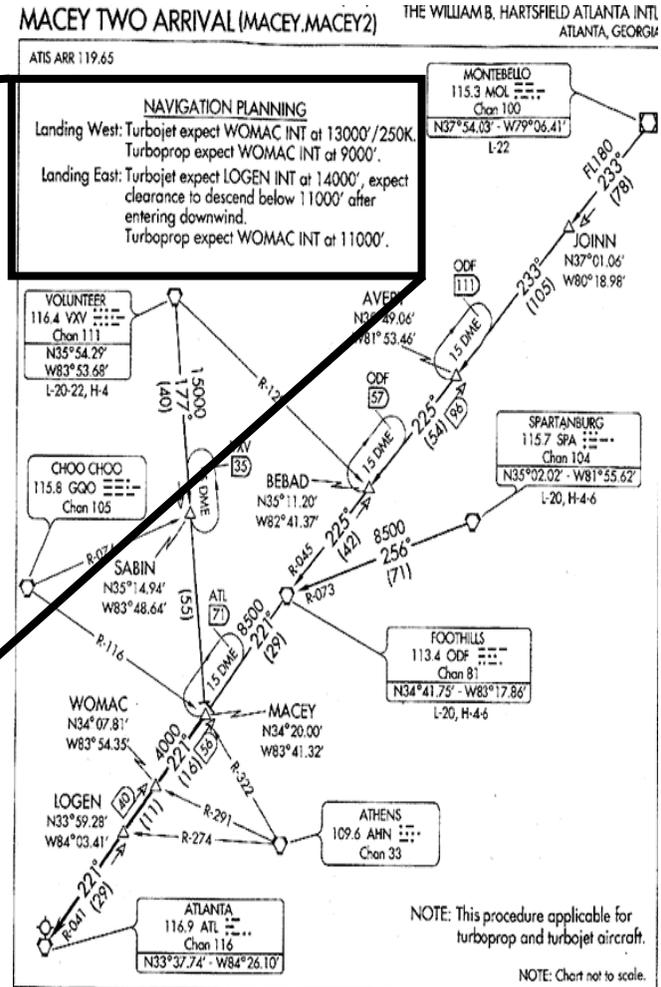


# Controllers are Using Structure Provided by Standard Procedure

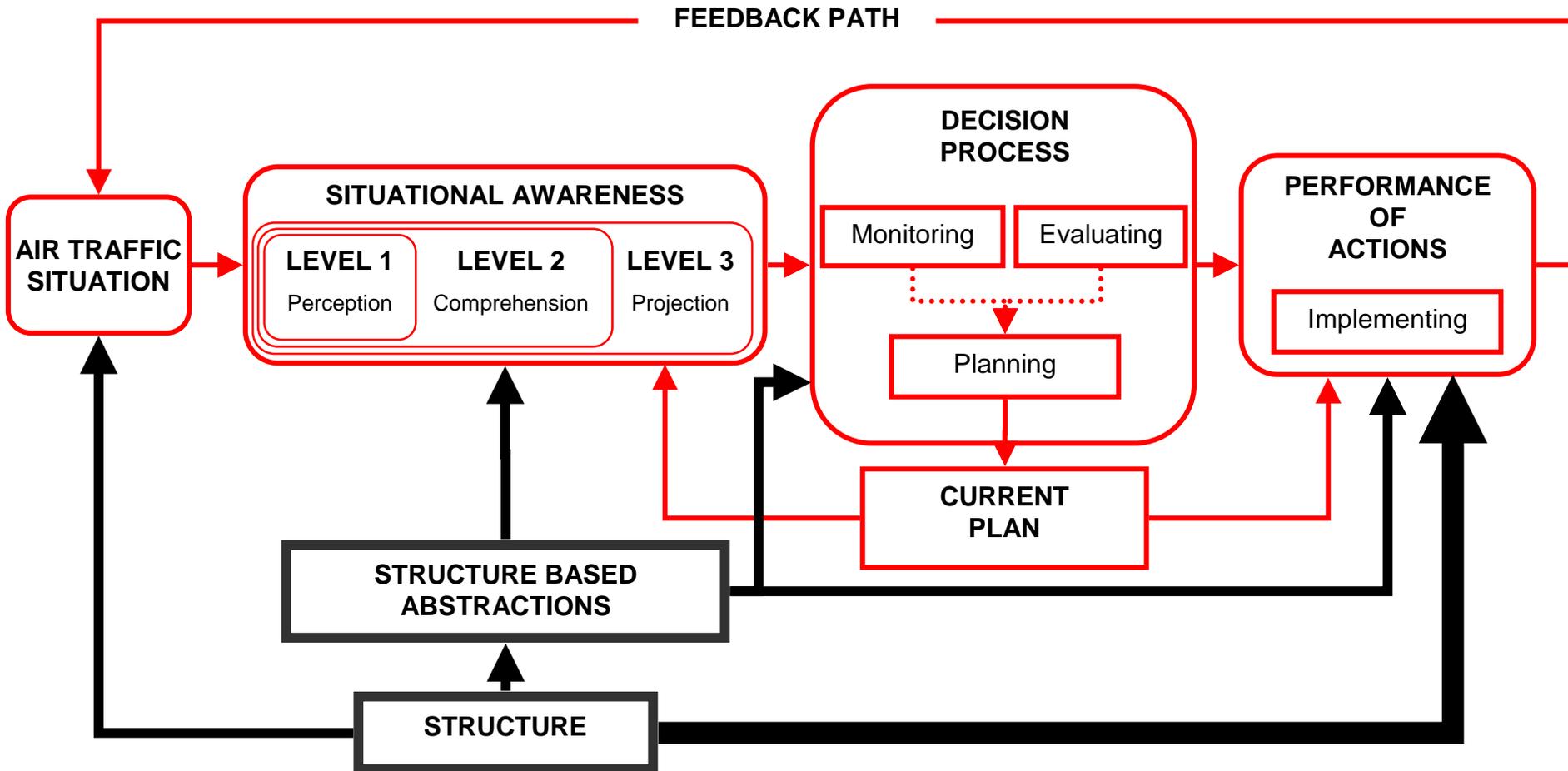
## NAVIGATION PLANNING

Landing West: Turbojet expect WOMAC INT at 13000'/250K.  
Turboprop expect WOMAC INT at 9000'.

Landing East: Turbojet expect LOGEN INT at 14000', expect clearance to descend below 11000' after entering downwind.  
Turboprop expect WOMAC INT at 11000'.



# Structure as a Basis for Implementing Control Actions





# Summary / Future Work

- **Summary**

- Limited Coding Syntax Sufficient to Capture Most Communication Events
  - ◆ 3 Distinct Syntax Captured 61% of All Commands
- Structure In the Form of Standard Procedure Provides Basis For Command Implementation

- **Future Work**

- Examine Command Use Across Various Conditions
  - ◆ Atlanta Runway Configuration
  - ◆ Impact of Weather
  - ◆ Varying Traffic Mix