MALORCA
Machine Learning of Speech Recognition Models for Controller Assistance

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Covering the sky...

Building Blocks of Assistant Based Speech Recognition for Air Traffic Management Applications

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Founding Members
EUROPEAN UNION EUROCONTROL

Content

- **Motivation for Speech Recognition in Air Traffic Control**
- Building Blocks of Assistant Based Speech Recognition (ABSR)
- How to adapt ABSR to new environments
- Influence of different components of ABSR on the performance
- Conclusions

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From Paper to Electronic Flight Strips

- All flight information available in digital form in the system (and on the radar screen). → **This may result in higher controller workload.**
- Controllers have additional workload. Others have the benefits.

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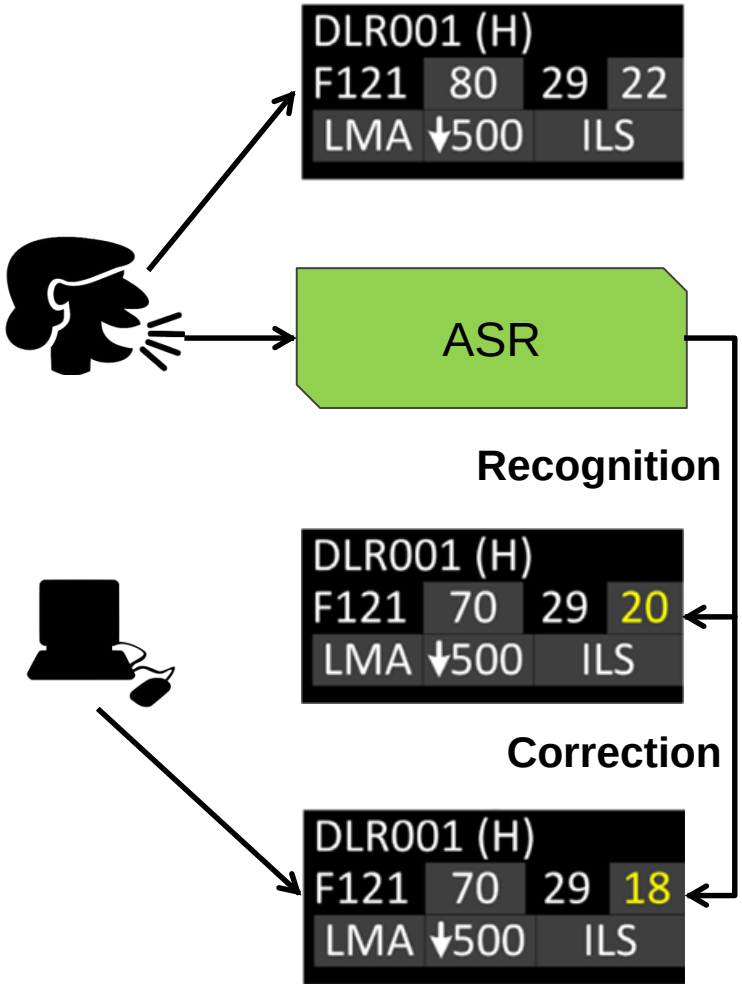
How can Speech Recognition help?

- Automatic Speech Recognition (ASR) can be the solution
  - Analyze controller-pilot communication
  - Extract relevant commands
  - Use commands as label input
  - Manual correction in case ASR fails

- For this DLR and Saarland University developed Assistant Based Speech Recognition (ABSR) to achieve:
  - →High recognition and low error rates on command level
  - →Reduction of controller workload by automating flight strip management



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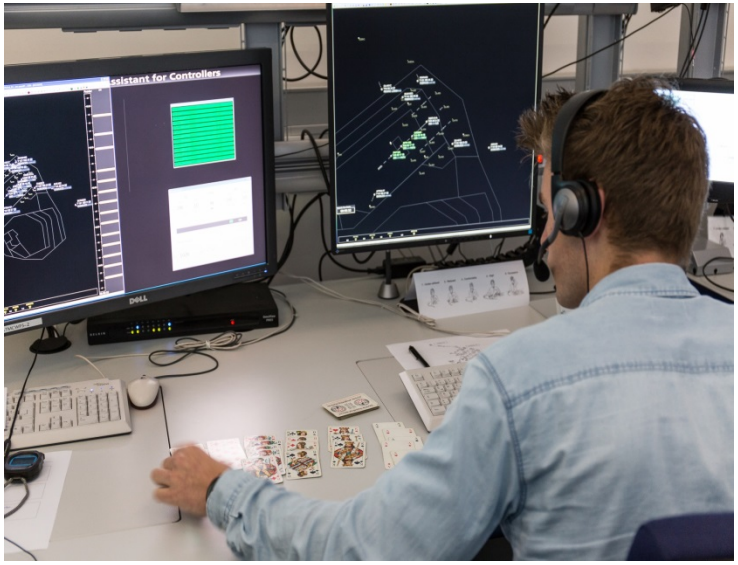
ABSR-Validation at DLR in 2015

- In 2014/2015 > 20 controllers from DFS, Austro Control and ANS CR validated the ABSR system developed by UdS and DLR for Dusseldorf Approach Area.

- **Goals** → Quantify the benefits for ABSR with respect to
  - controllers' workload and
  - ATM efficiency.

- **Baseline:**
  - Commands entered by mouse into radar labels

- **Improved Mode:**
  - Commands entered by ABSR correction if necessary by mouse



ABSR-Results of 2015

- **Performance**
  - → Recognition rate: 95%
  - → Error rate: 2%
- **ANSPs and controllers**
  - → Radar Label maintenance time reduced by a factor of 3
- **Airports**
  - → benefit from increase flow of 1 to 2 landings per hour **Performance**
- **Airlines**
  - → save 50 to 65 liters of kerosene per flight
- **Society**
  - → saves approx. 130 kg of CO2 per flight*

* A320, 0.8 kg / l, 1 kg kerosene results in 3.15 kg C02; 35 landings per hour extrapolation of results of 60 minutes scenarios for 23R, 8 controllers…, see papers at DASC 2016 and FAA/Eurocontrol ATM Seminar 2017

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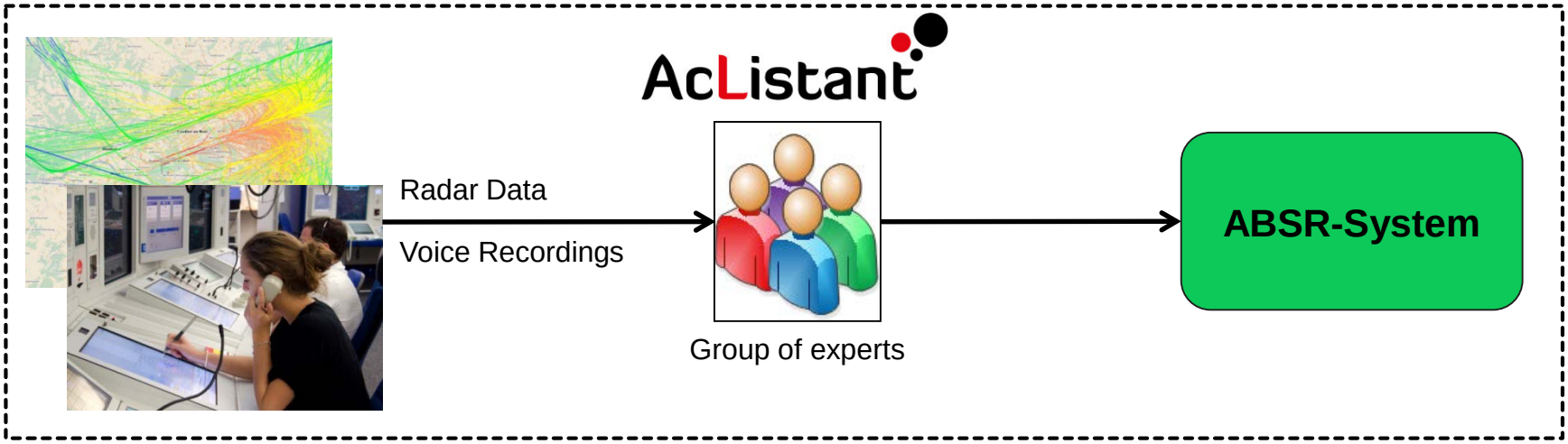
What is the Problem?



- In AcListant® 1.3M Euro were spent for ABSR development and validation just for Düsseldorf Approach
- Adaptation is necessary for other airports and working positions because of:
  - Different accents, working procedures, airspace layouts etc.
- Requires lots of time and expert knowledge
- Adaptation will become necessary again even in an already deployed system due to changes in working procedures, airspace layouts etc. (maintenance)

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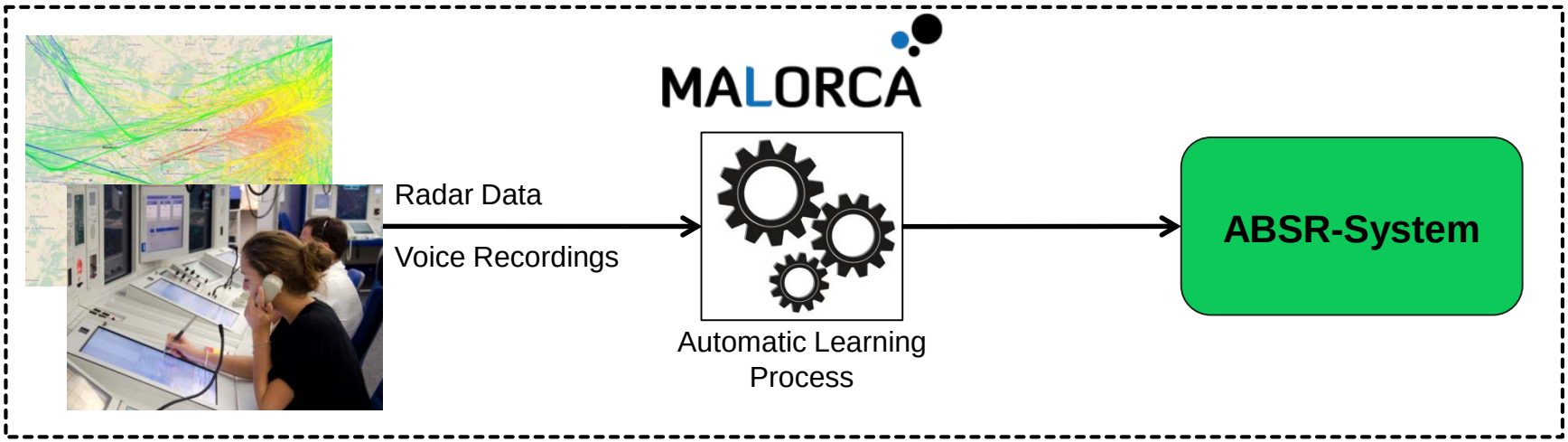
How to solve it?



- Instead of (highly skilled and paid) experts, machine learning is used.
- Horizon 2020 funded project MALORCA (Machine Learning of Speech Recognition Models for Controller Assistance)

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From Speech Signal to HMI

Feature Extractor

DATA | TEXT | COMMAND | USER

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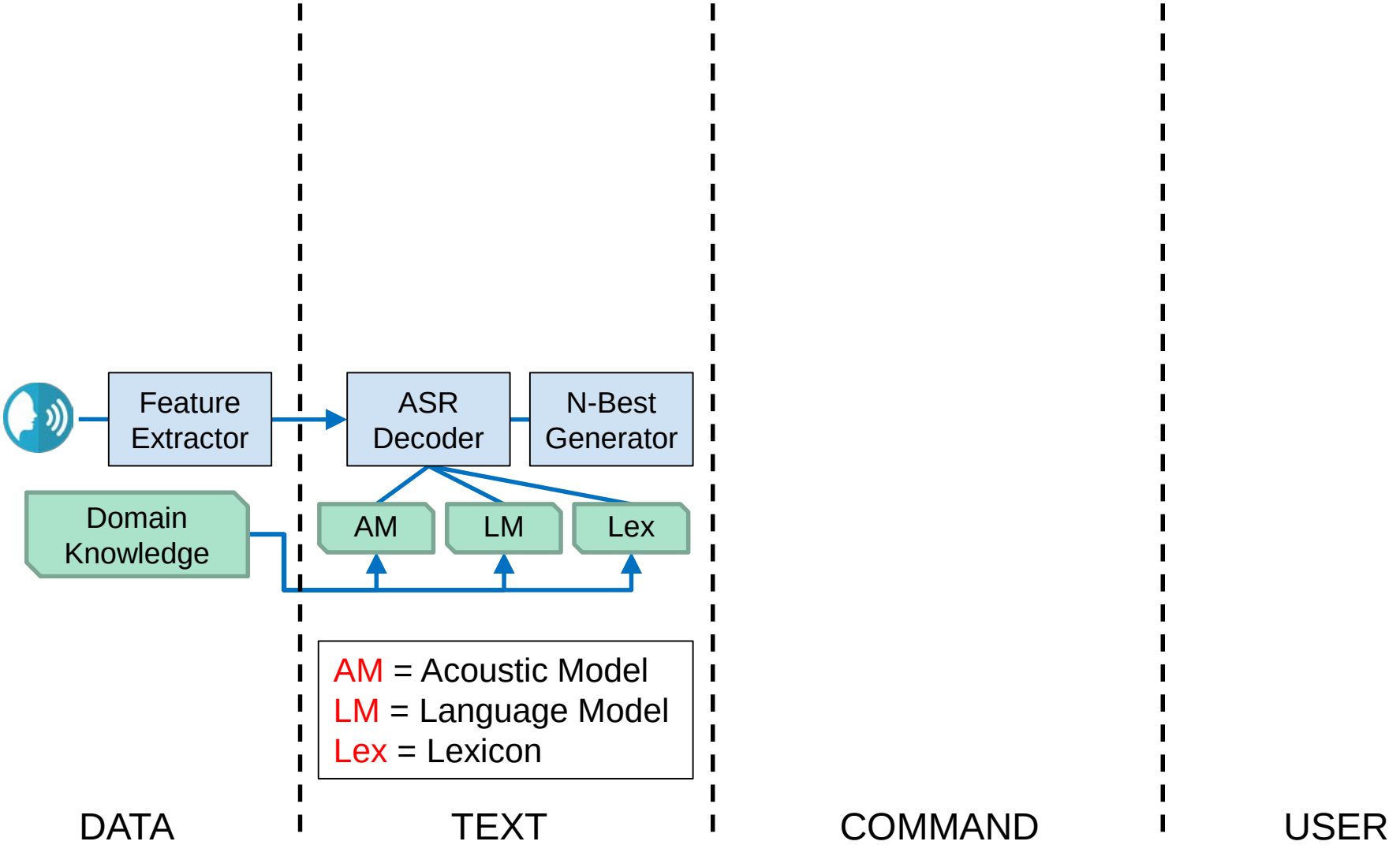
From Speech Signal to HMI



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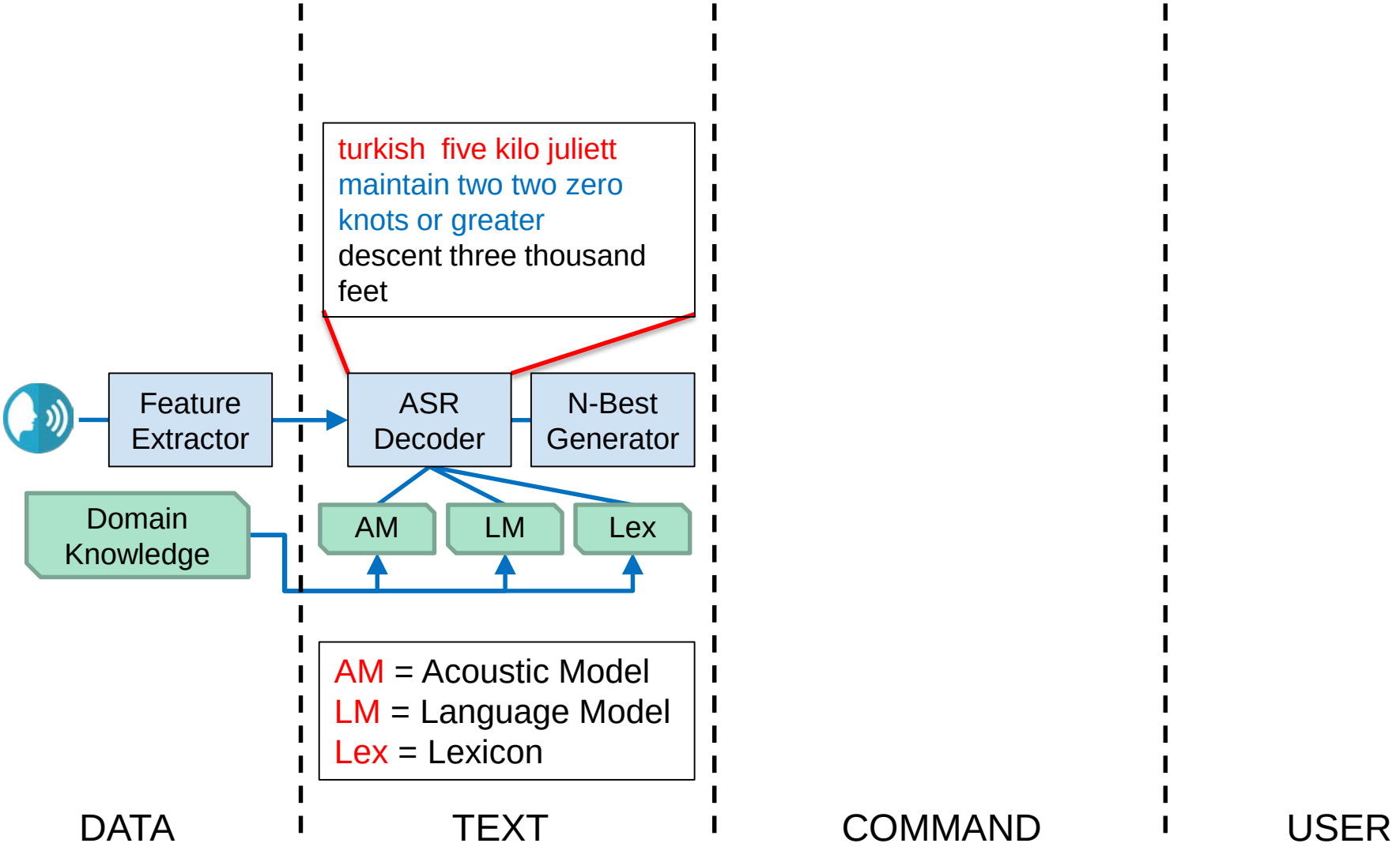
From Speech Signal to HMI



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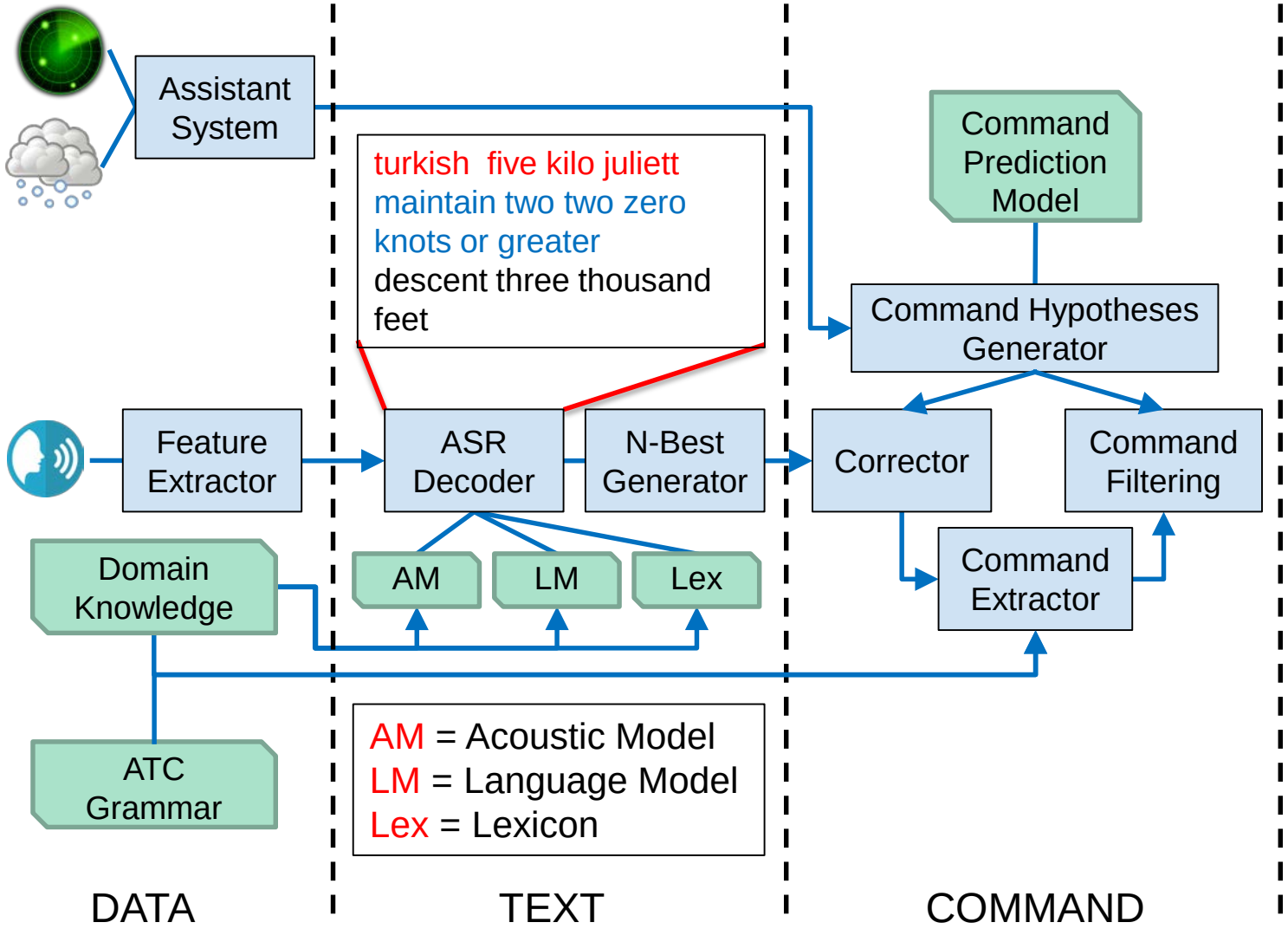
From Speech Signal to HMI



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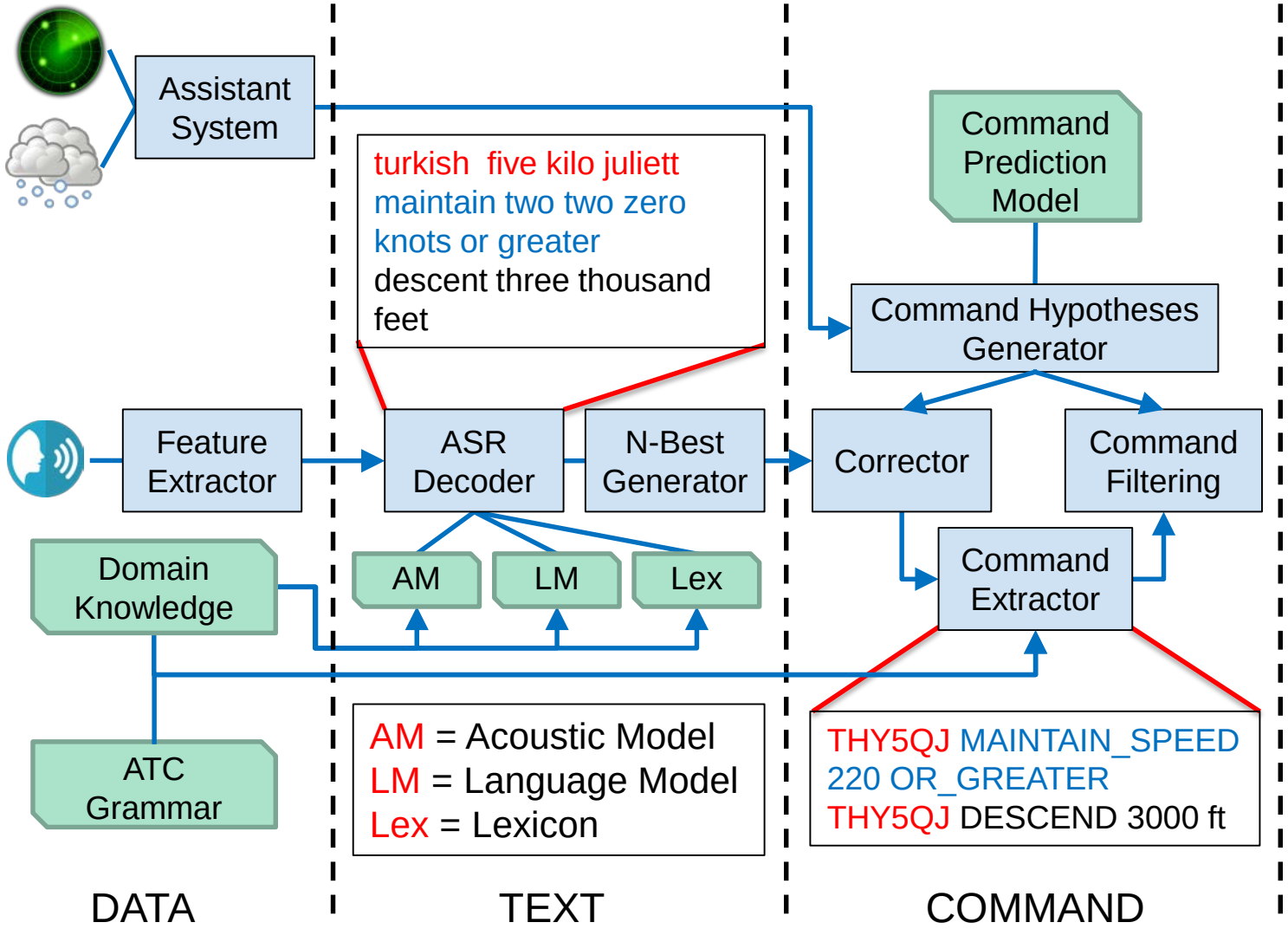

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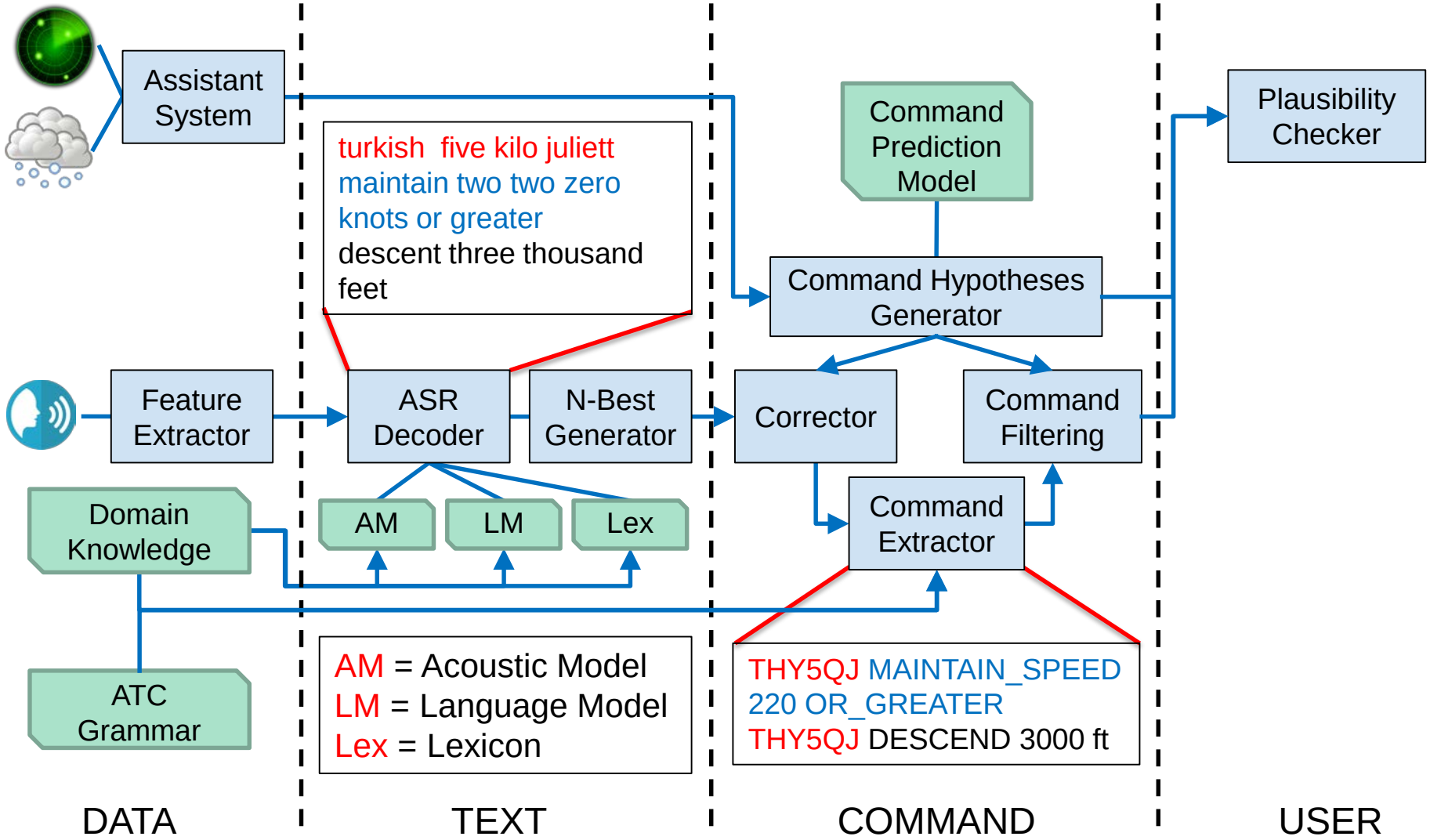

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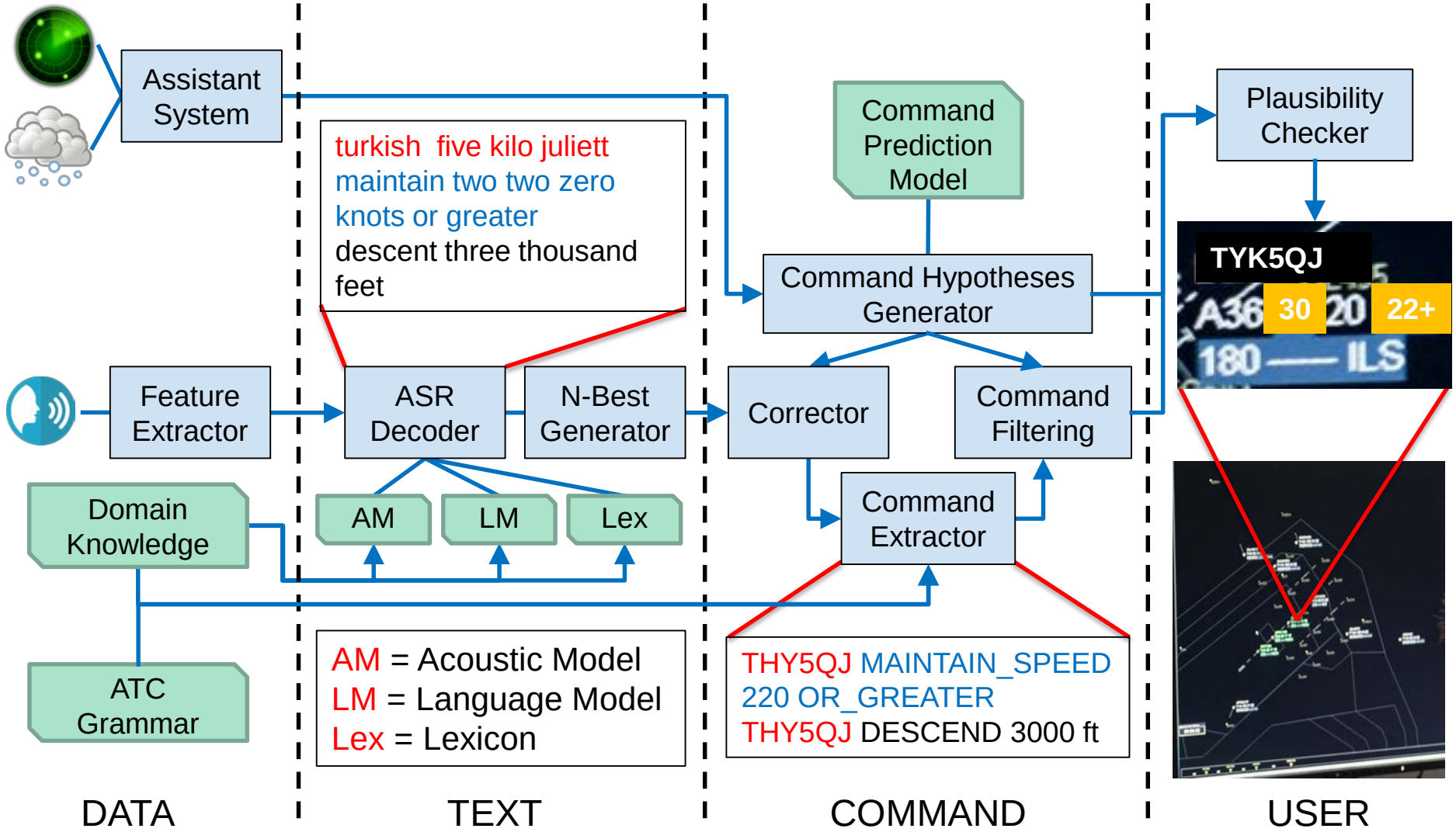
From Speech Signal to HMI



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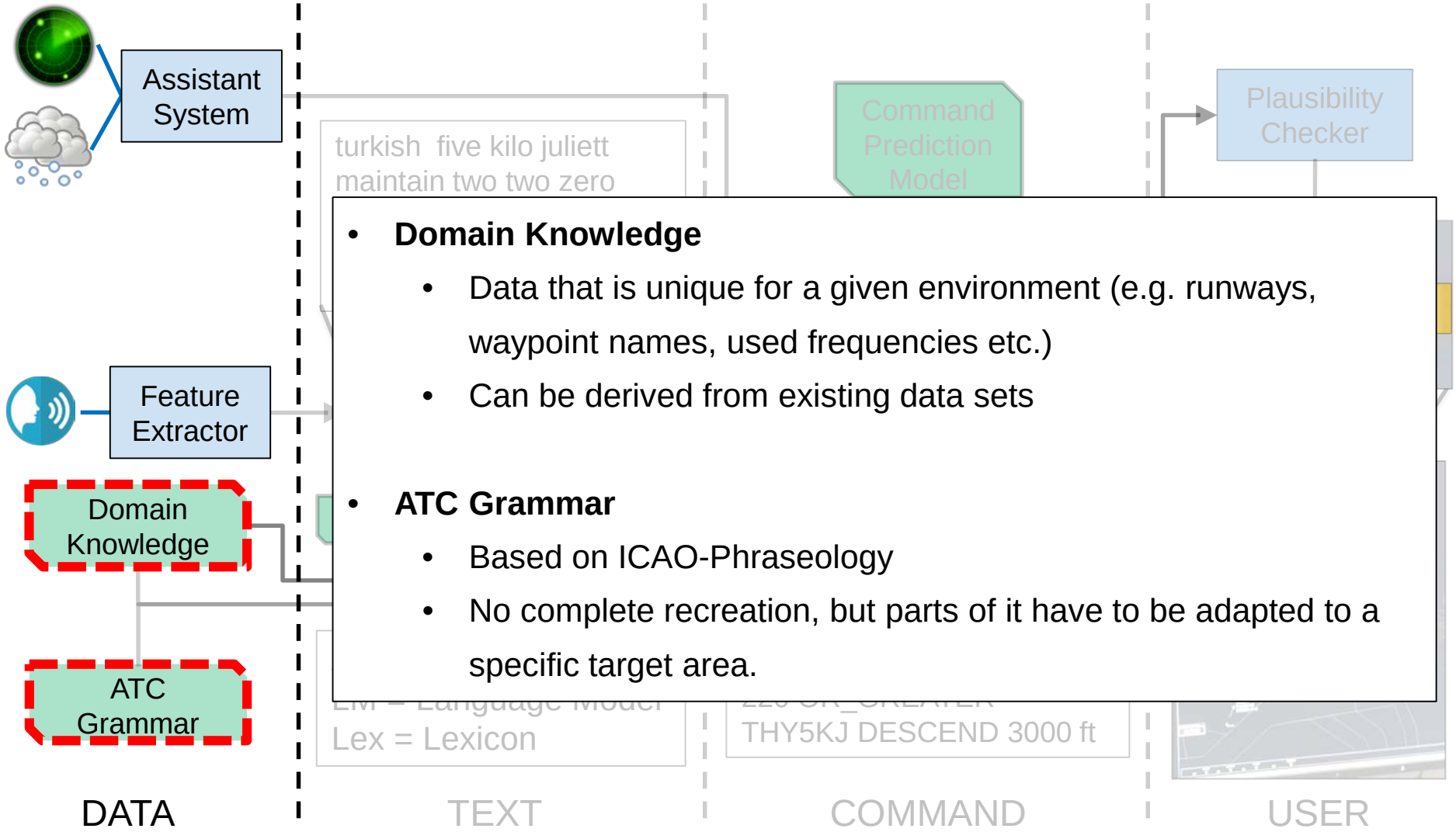
Adaptations to DATA-Module



- **Domain Knowledge**
  - Data that is unique for a given environment (e.g. runways, waypoint names, used frequencies etc.)
  - Can be derived from existing data sets
- **ATC Grammar**
  - Based on ICAO-Phraseology
  - No complete recreation, but parts of it have to be adapted to a specific target area.

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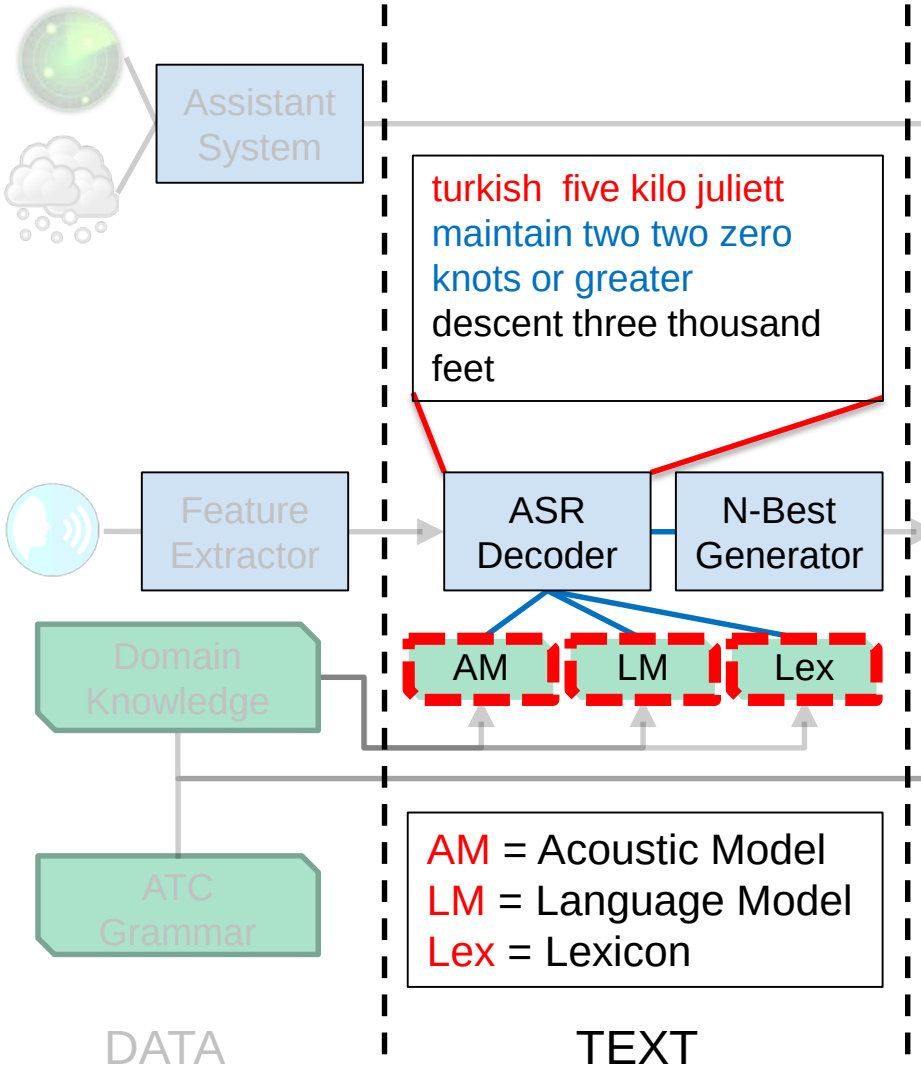
Adaptations to TEXT-Module



- **Acoustic model**
  - Trained from transcribed and/or untranscribed data
  - Speaker-dependent models possible
- **Language model**
  - Learned from labeled ATC text transcriptions
  - Grammar can be used for automatic labeling of training data
  - Data from existing language models can be reused
- **Lexicon**
  - Local Words + pronunciations for a specific environment (e.g. Greetings)

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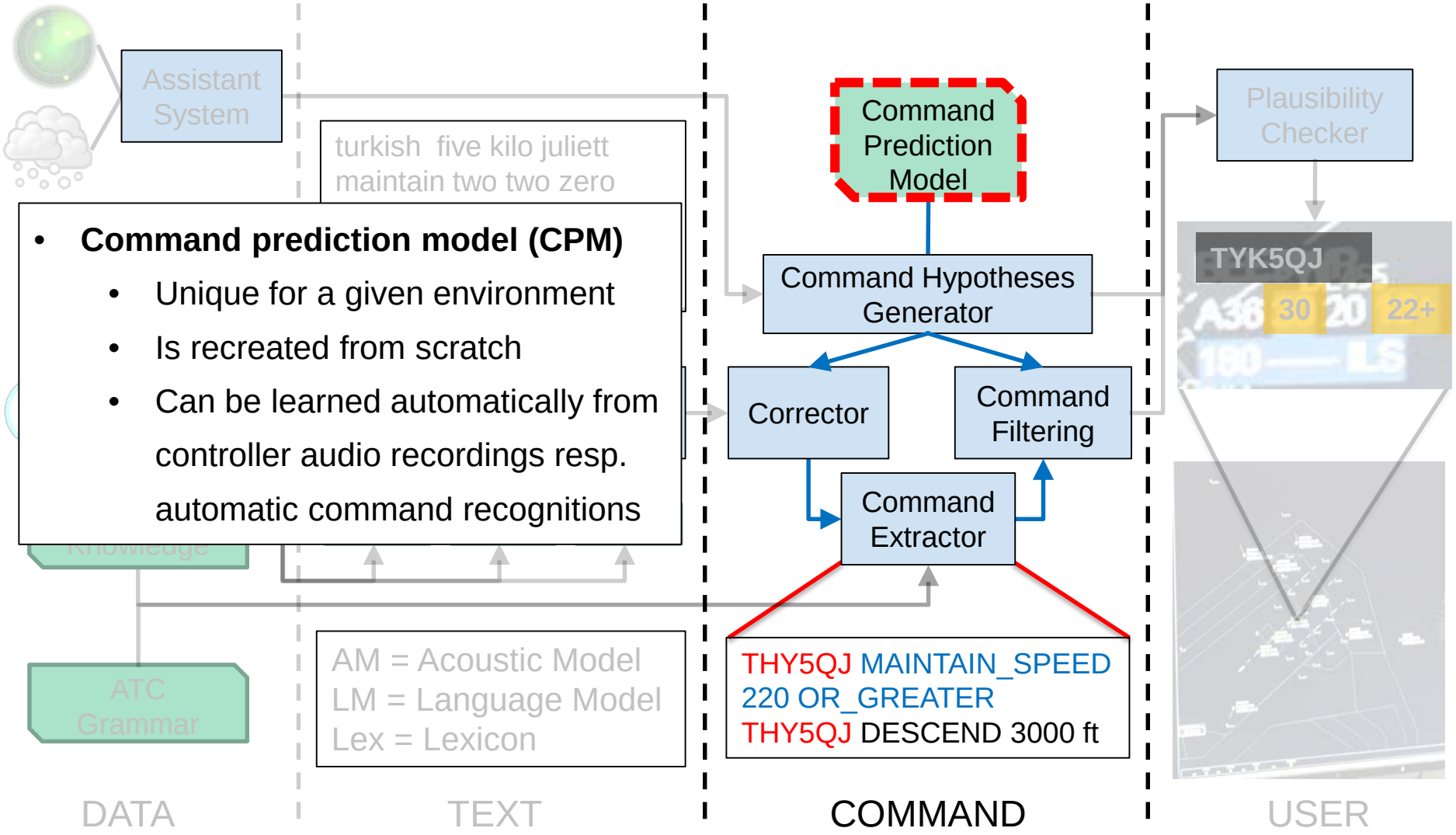
Adaptations to COMMAND-Module



- **Command prediction model (CPM)**
  - Unique for a given environment
  - Is recreated from scratch
  - Can be learned automatically from controller audio recordings resp. automatic command recognitions

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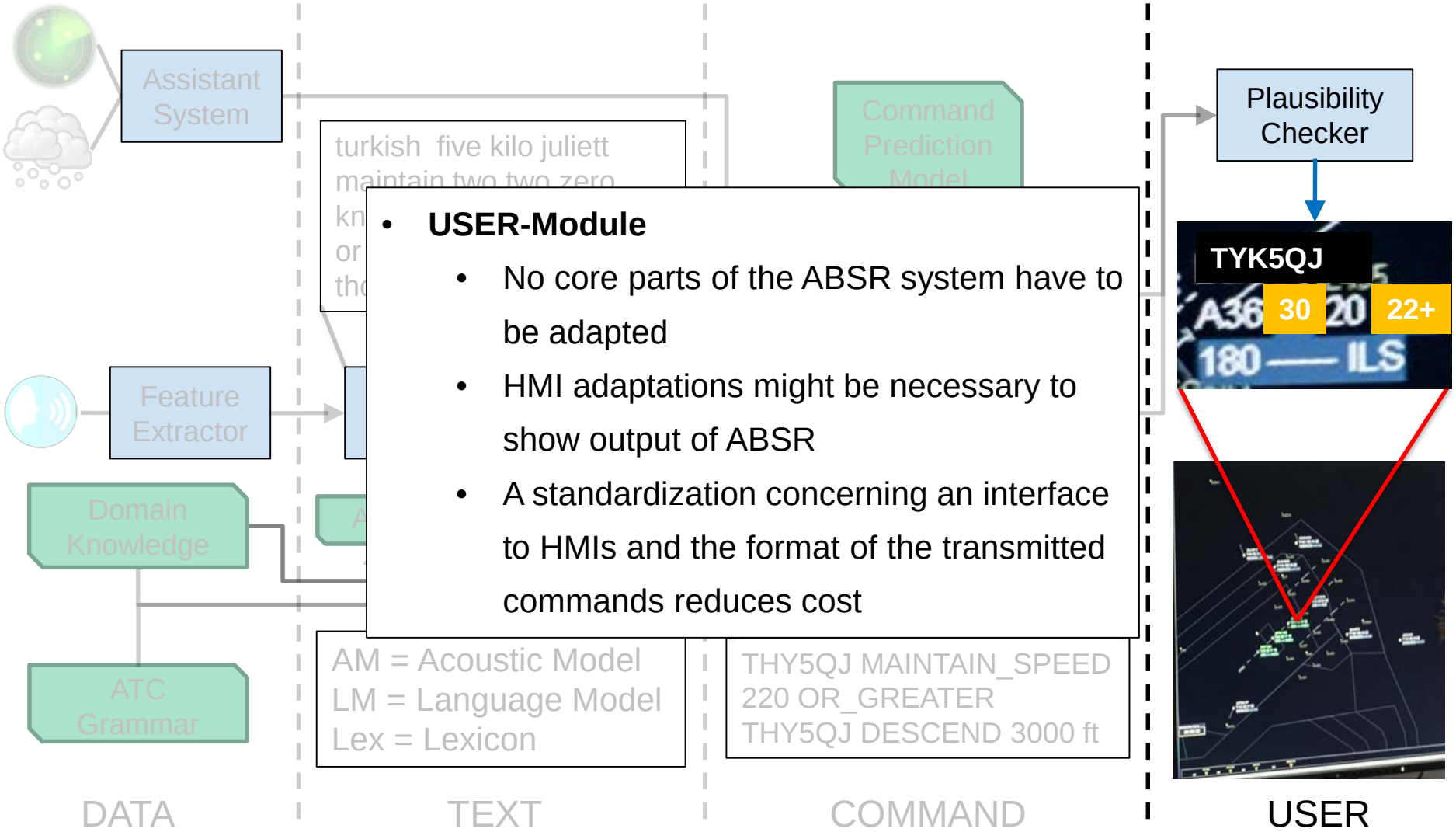
Adaptations to USER-Module



- **USER-Module**
  - No core parts of the ABSR system have to be adapted
  - HMI adaptations might be necessary to show output of ABSR
  - A standardization concerning an interface to HMIs and the format of the transmitted commands reduces cost

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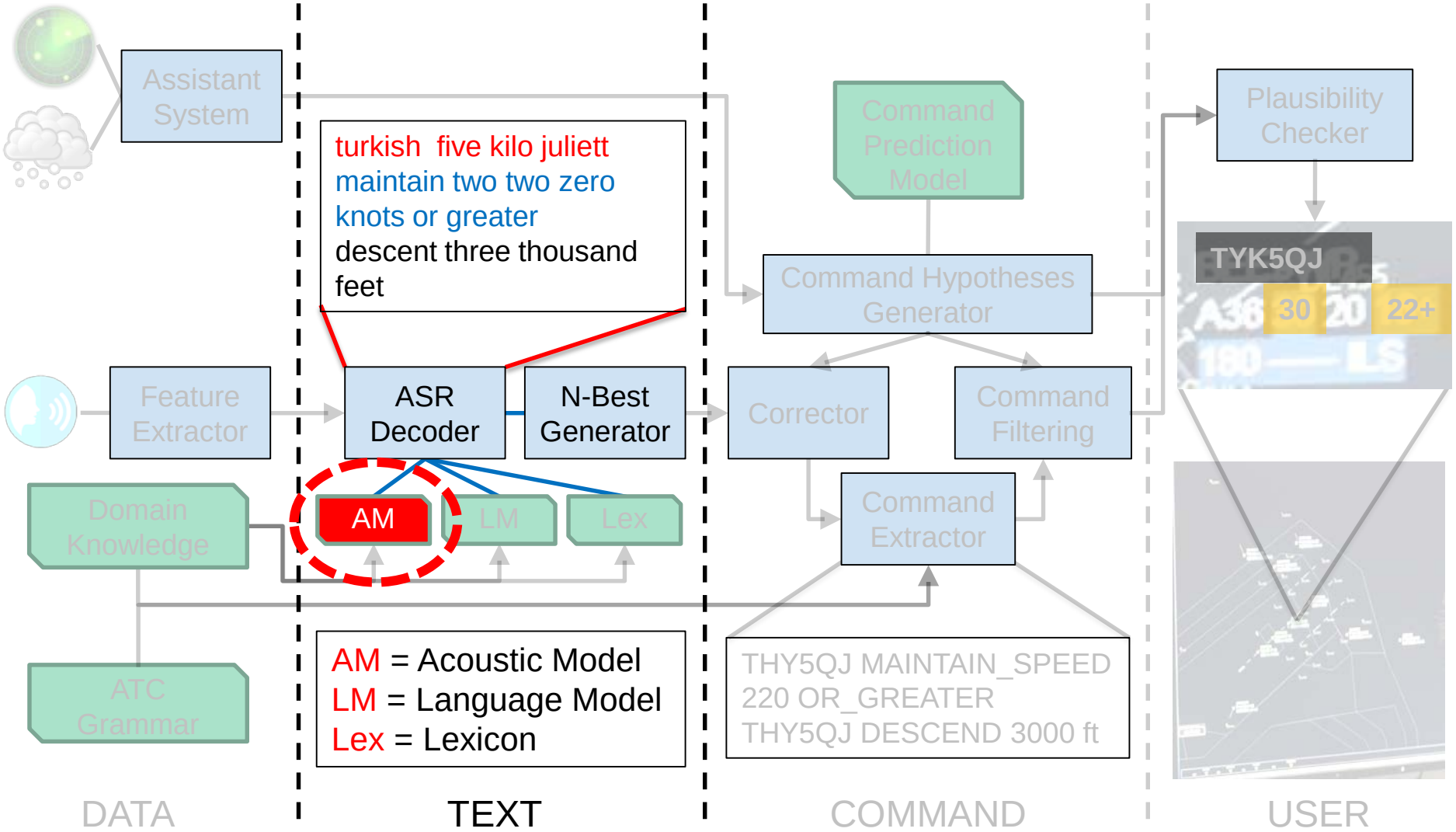
Speaker-Dependent vs Speaker-Independent Acoustic Model



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Speaker-Dependent vs Speaker-Independent Acoustic Model

Prague Approach Area

Baseline (Full ABSR)

Recognition Rate
92.1%
Error Rate:
0.60%

Delta

Recognition Rate: -3.5%
Error Rate: +0.48%

ABSR with Speaker-Independent AM

Recognition Rate
88.6%
Error Rate:
1.07%

Vienna Approach Area

Baseline (Full ABSR)

Recognition Rate
83.3%
Error Rate:
3.21%

Delta

Recognition Rate: -0.7%
Error Rate: +0.21%

ABSR with Speaker-Independent AM

Recognition Rate
82.6%
Error Rate:
3.42%

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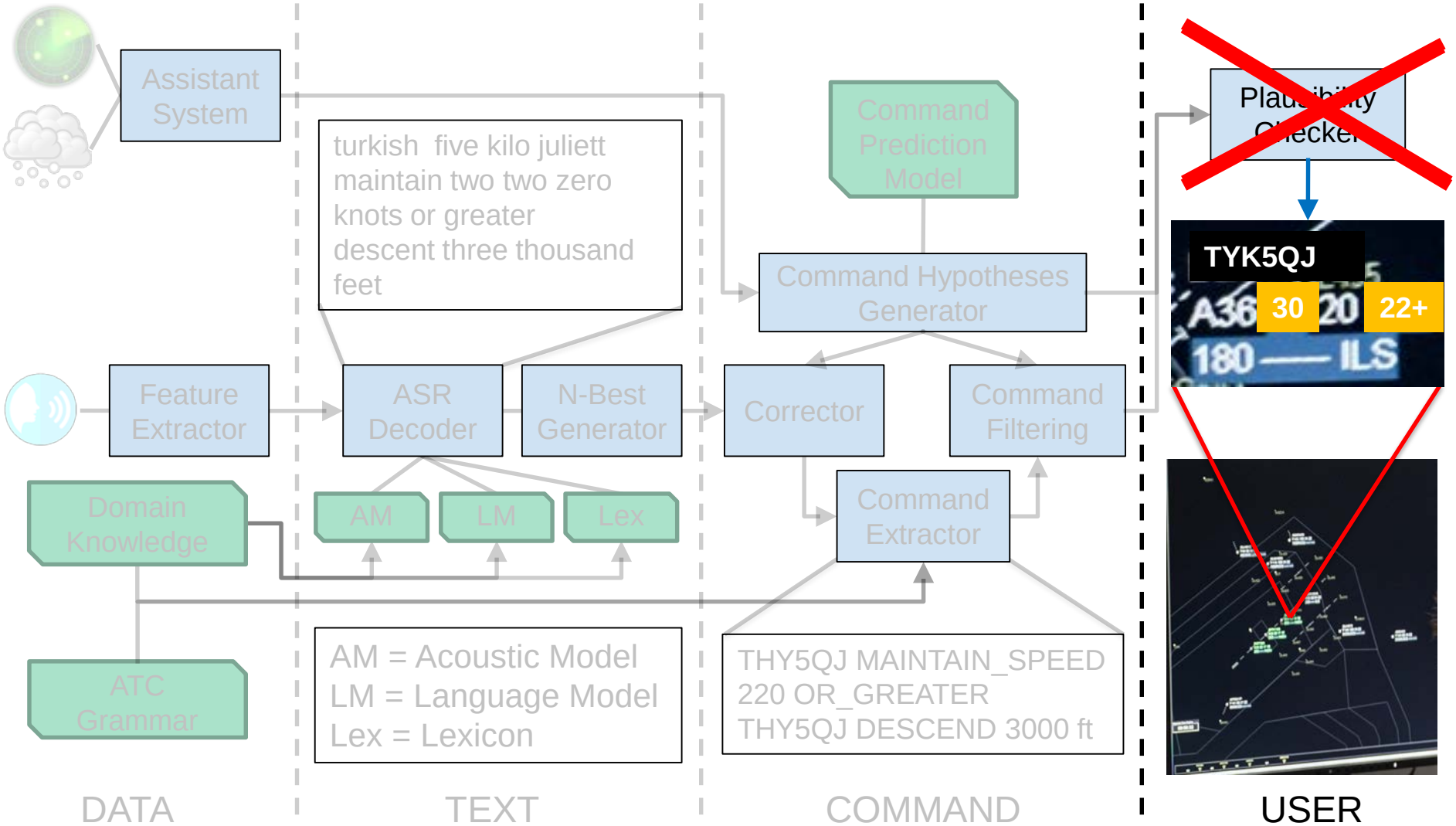
Influence of Plausibility Checker



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Influence of Plausibility Checker

Prague Approach Area

Baseline (Full ABSR)

Recognition Rate
92.1%
Error Rate:
0.60%

Delta
Recognition Rate: +1.9%
Error Rate: +1.23%

ABSR without Plausibility Checker

Recognition Rate
94.0%
Error Rate:
1.83%

Vienna Approach Area

Baseline (Full ABSR)

Recognition Rate
83.3%
Error Rate:
3.21%

Delta
Recognition Rate: +1.6%
Error Rate: +3.00%

ABSR without Plausibility Checker

Recognition Rate
82.6%
Error Rate:
6.21%

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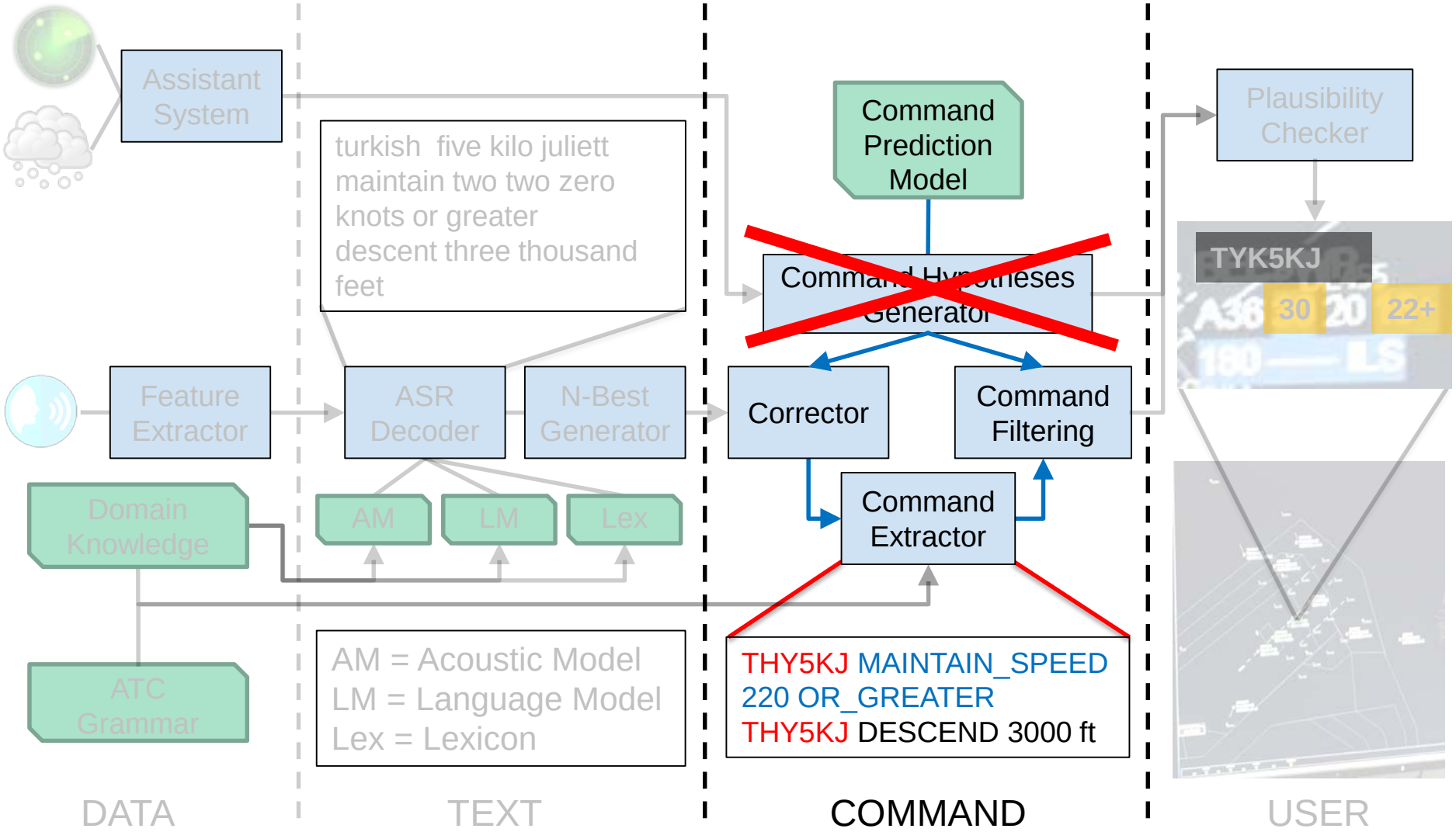
Influence of Command Hypotheses Generator



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Influence of Command Hypotheses Generator

Prague Approach Area

Baseline (Full ABSR)

Recognition Rate
92.1%
Error Rate:
0.60%

Delta
Recognition Rate: -4.5%
Error Rate: +6.07%

ABSR without Hypotheses Generator

Recognition Rate
87.5%
Error Rate:
6.66%

Vienna Approach Area

Baseline (Full ABSR)

Recognition Rate
83.3%
Error Rate:
3.21%

Delta
Recognition Rate: -11.8%
Error Rate: +11.78%

ABSR without Hypotheses Generator

Recognition Rate
71.5%
Error Rate:
15.00%

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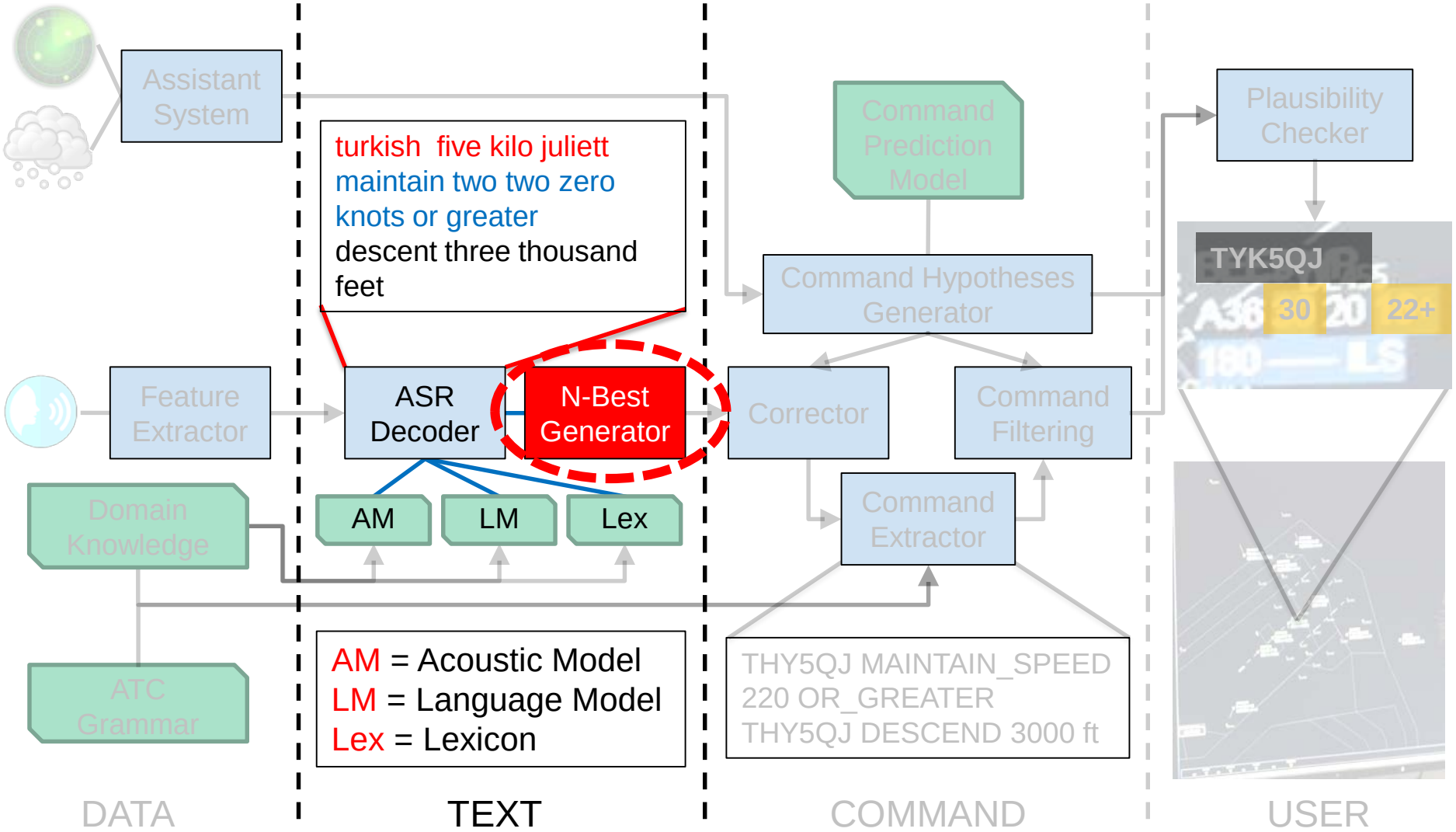
Influence of N-Best Generator



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Influence of N-Best Generator

	Prague Approach Area	Vienna Approach Area
N-Best = 1	Recognition Rate: 91.4% Error Rate: 0.56%	Recognition Rate: 80.8% Error Rate: 2.85%
N-Best = 5 (Baseline)	Recognition Rate: 92.1% Error Rate: 0.60%	Recognition Rate: 83.3% Error Rate: 3.21%
N-Best = 10	Recognition Rate: 92.2% Error Rate: 0.57%	Recognition Rate: 83.7% Error Rate: 3.21%
N-Best = 20	Recognition Rate: 92.1% Error Rate: 0.73%	Recognition Rate: 83.7% Error Rate: 3.22%
N-Best = 50	Recognition Rate: 92.0% Error Rate: 0.62%	Recognition Rate: 83.9% Error Rate: 3.16%

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Conclusion

- The use of **Machine Learning** for an ABSR-System is possible
- **ABSR** divided into different conceptual modules with
  - Reusable Building Blocks (No adaptation necessary)
  - Automatically learned Models (Acoustic-, Language-, Command Prediction Model)
  - Partially manual updates of Data elements
- Not all parts of the system have to be implemented (if decrease in performance is acceptable)
- Command Hypotheses Generator has the biggest influence on the overall performance

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Building Blocks of Assistant Based Speech Recognition for Air Traffic Management Applications

Thank you for your attention!

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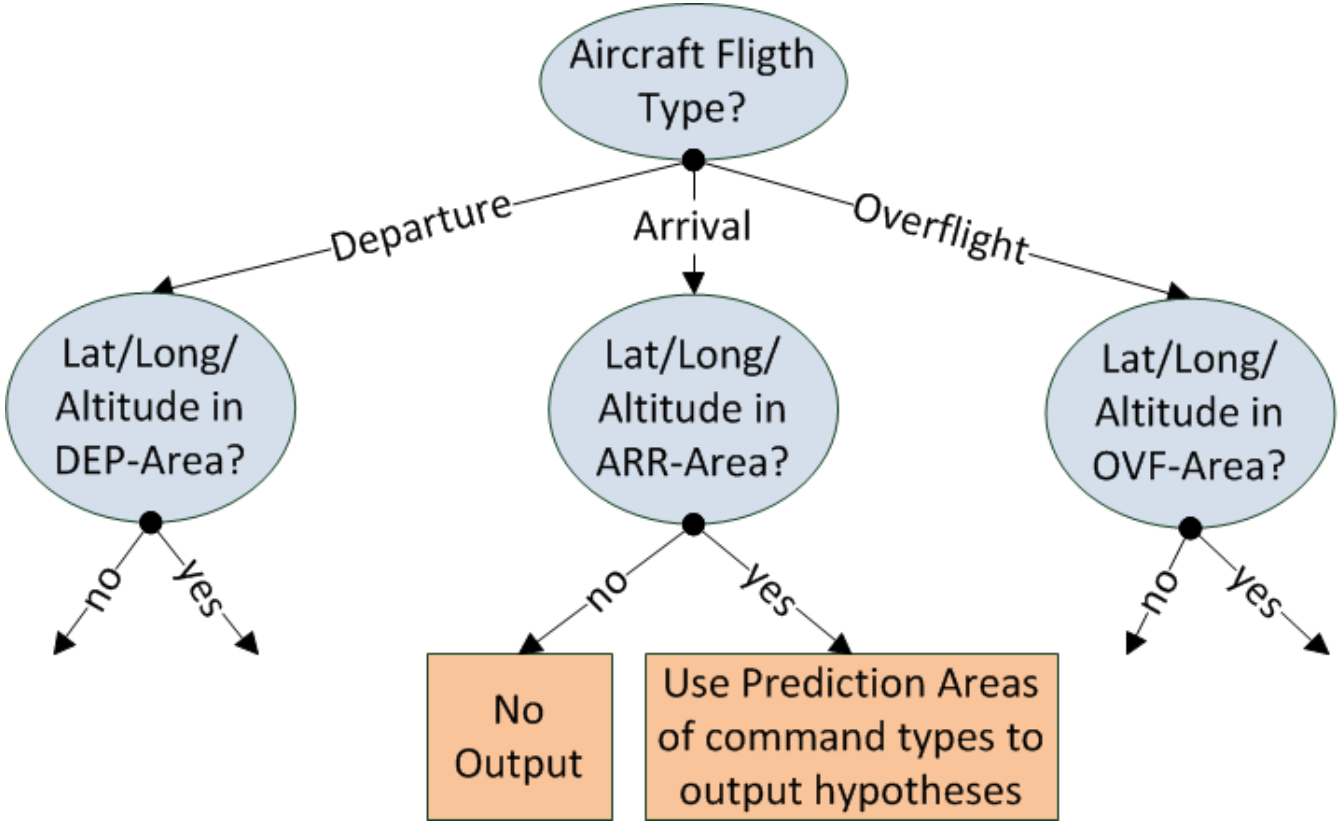
Commmand Prediction Model as Decision Tree



- Specific prediction areas for every command type (e.g. DESCEND, REDUCE, CLEARED ILS)

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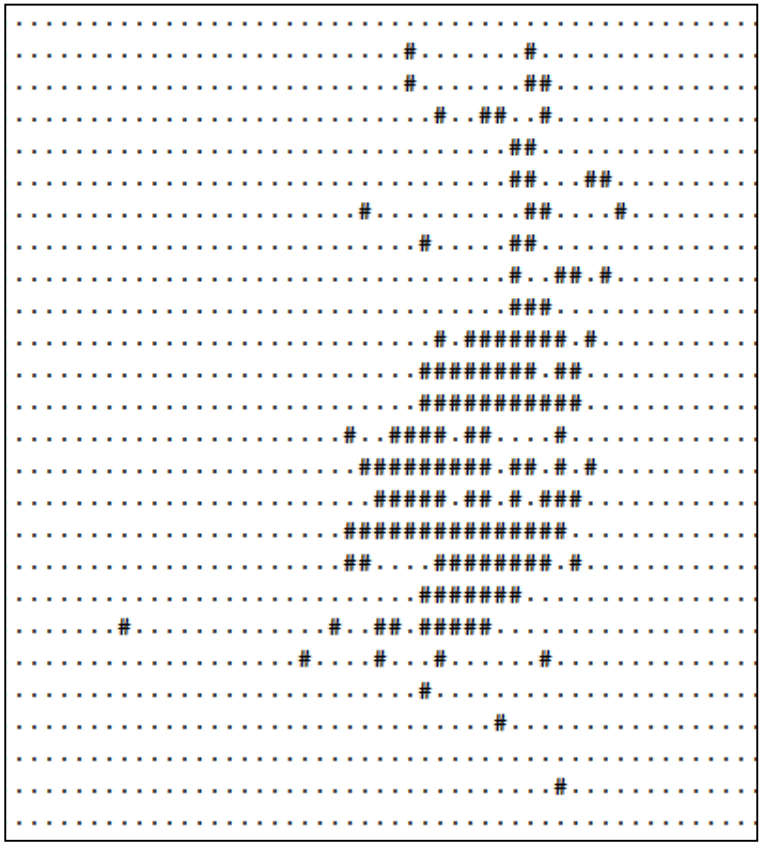
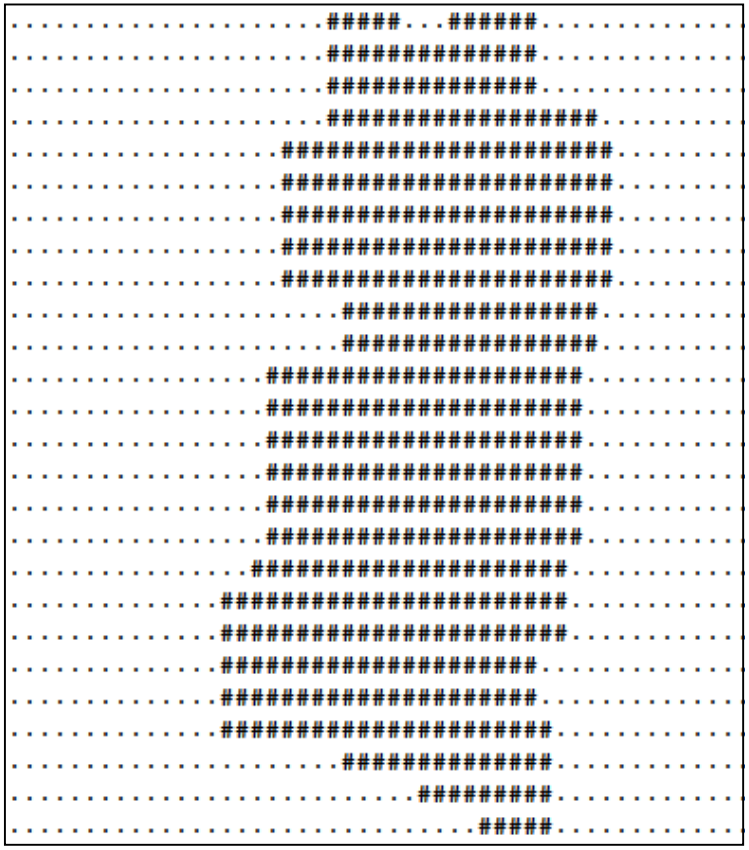
Expanding learned areas with different windows



Before Expansion



After Expansion

Prediction Area of CPM for Cleared ILS commands of Arrivals

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Experimental Set-Up for Proof-of-Concept

- Real world data provided ANS CR and Austro Control
- Four different controller positions
- 18.7h training data for Vienna and 18.1h trainings data for Prague

Configuration	# Total Cmds	# Descend cmds	# ILS clearances
AEC (Prague)	11103	2184	351
PEC (Prague)	5365	920	458
BALAD (Vienna)	5929	1062	13
Feeder (Vienna)	6959	1100	245

Automatically transcribed (used for learning)

Approach Area	# Utterances	# given commands	# sessions
Prague	2582	4563	27
Vienna	2427	3556	19

Transcribed manually (test data)

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User Acceptance (2)

Prague:				
Number of Commands	Number of ABSR Errors/Rejections	Rec Rate	corrected by controller	detected by controller
396	36	90.9%	31	36

Vienna:				
Number of Commands	Number of ABSR Errors/Rejections	Rec Rate	corrected by controller	detected by controller
610	80	86.9%	79	80

No safety issues were observed.

All misrecognitions were detected.

Better Recognition Rate of course would improve even more workload reduction.

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