ENRI International Workshop on ATM/ CNS

# Applying Cognitive Work Analysis to Study Airport-Collaborative Decision Making

**PhD Research Project**

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# Outline

- Introduction to Airport Collaborative Decision Making (A-CDM)
- The A-CDM Environment
- Objectives of the Research Project
- Method of Applied Cognitive Work Analysis
- Data Collection & Initial Results
- Conclusion



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# The Challenge

## One Process

Arrival – Turn-round – Departure
Link airports to the Air Traffic Management Network

## Requirements

Create transparent overview by Sharing Information
All Airport partners needed for CDM success
Mutual Understanding of operations
Culture change and process improvement



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# The Airport CDM Concept Elements

Collaborative Management of Flight Updates

CDM in Adverse Conditions

Collaborative Predeparture Sequence

Variable Taxi Time Calculation

The Milestones Approach

Airport CDM Information Sharing



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# Information Sharing & Milestone Approach

**Principle**

Foundation for CDM

**Right info ➔ Right Time ➔Right People**

**Requirement**

One Common Information Platform is required

Develop procedures and actions for each milestone

**Benefits**

Brings partners together ➔ Promotes trust

Common situational awareness ➔ efficient use of resources

Improved predictability ➔ maximises operational efficiency



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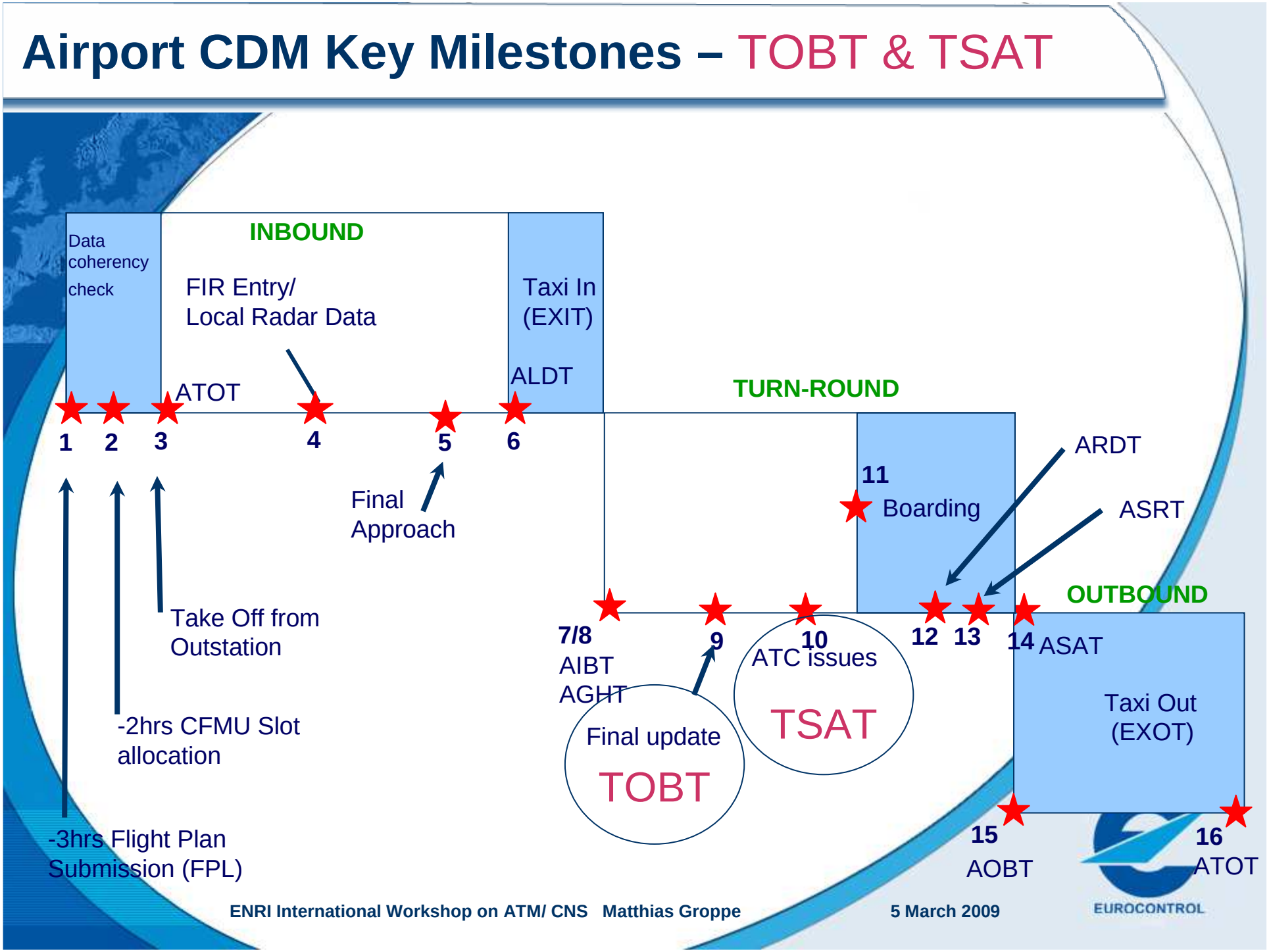
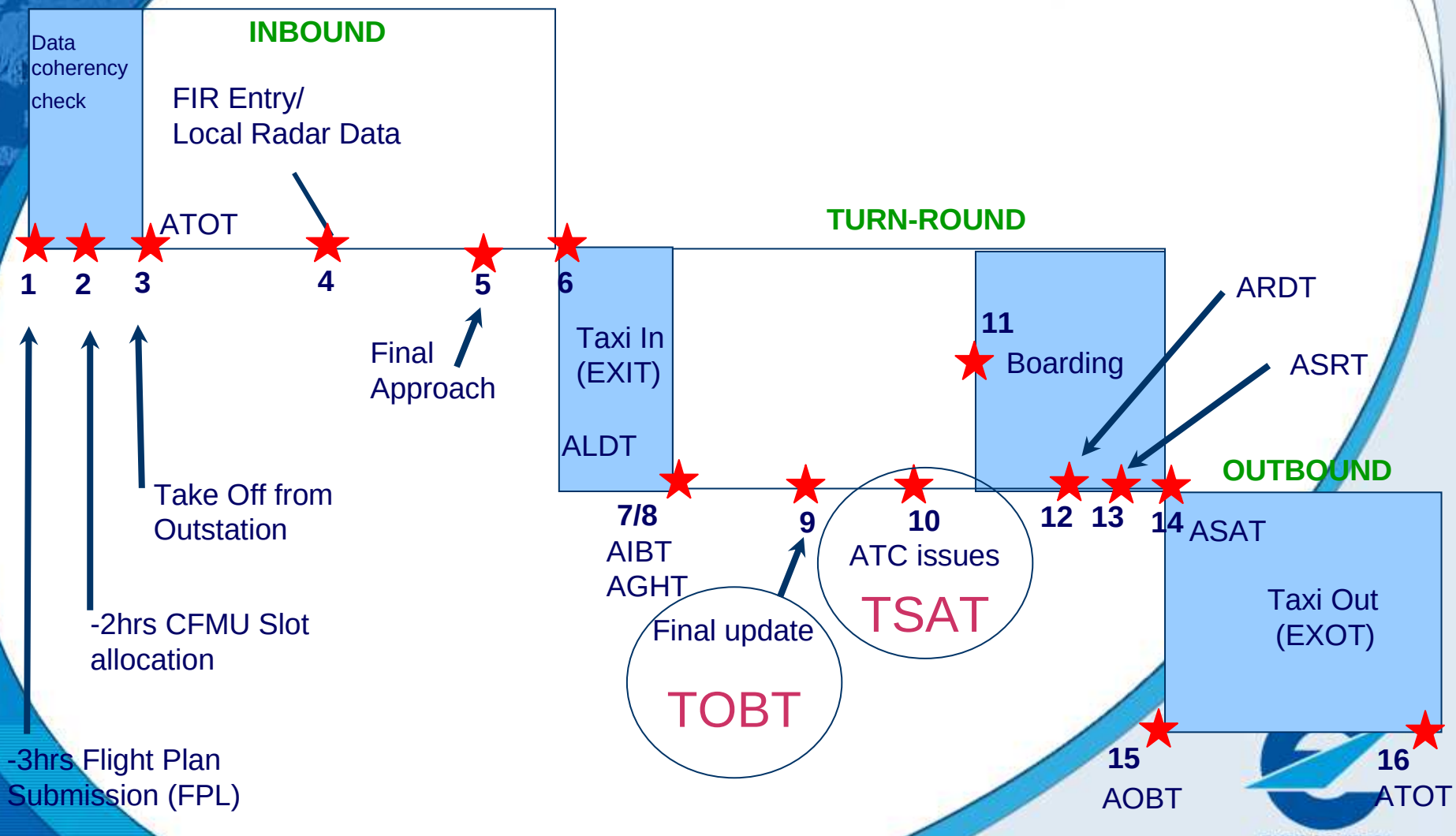
# Airport CDM Key Milestones – TOBT & TSAT



# Airport CDM Key Milestones – TOBT & TSAT



# Airport CDM Key Milestones – TOBT & TSAT

## TOBT (Target Of Block Time)

***The time that an aircraft operator / handling agent estimates that an aircraft will be ready, all doors closed, boarding bridge removed, push back vehicle available, ready to start up / push back immediately upon reception of clearance from the TWR.***

## TSAT (Target Start Approval Time)

***The time provided by ATC taking into account TOBT, CTOT and / or the traffic situation that an aircraft can expect to receive start-up / pushback approval (when start-up and pushback are issued together)***



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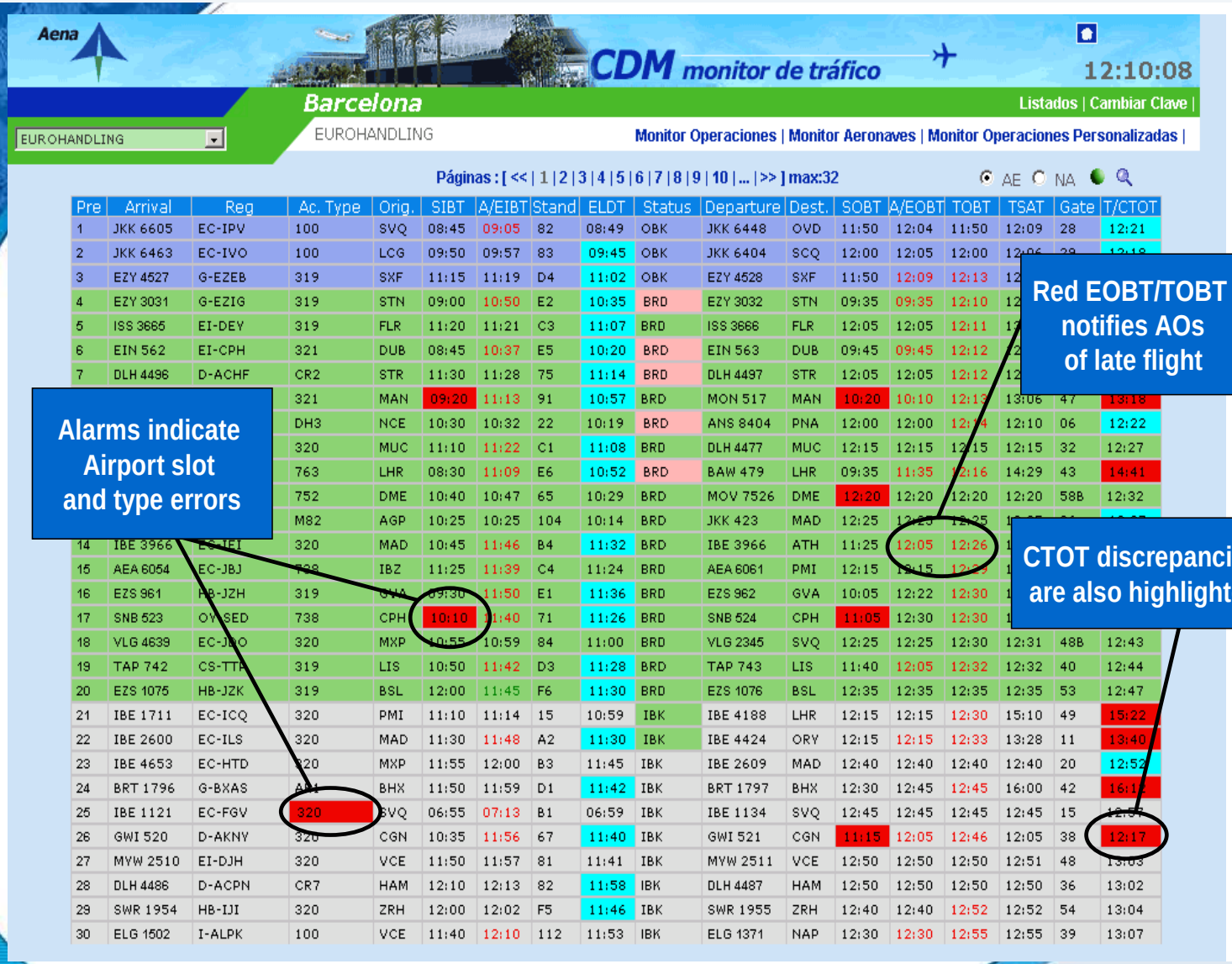
# Barcelona Airport CDM Platform




| Pre | Arrival | Reg | Ac. Type | Orig. | SIBT | A/EIBT | Stand | ELDT | Status | Departure | Dest. | SOBT | A/EOBT | TOBT | TSAT | Gate | T/CTOT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | JKK 6605 | EC-IPV | 100 | SVQ | 08:45 | 09:05 | 82 | 08:49 | OBK | JKK 6448 | OVD | 11:50 | 12:04 | 11:50 | 12:09 | 28 | 12:21 |
| 2 | JKK 6463 | EC-IVO | 100 | LCG | 09:50 | 09:57 | 83 | 09:45 | OBK | JKK 6404 | SCQ | 12:00 | 12:05 | 12:00 | 12:06 | 28 | 12:18 |
| 3 | EZY 4527 | G-EZEB | 319 | SXF | 11:15 | 11:19 | D4 | 11:02 | OBK | EZY 4528 | SXF | 11:50 | 12:09 | 12:13 | 12 | | |
| 4 | EZY 3031 | G-EZIG | 319 | STN | 09:00 | 10:50 | E2 | 10:35 | BRD | EZY 3032 | STN | 09:35 | 09:35 | 12:10 | 12 | | |
| 5 | ISS 3665 | EI-DEY | 319 | FLR | 11:20 | 11:21 | C3 | 11:07 | BRD | ISS 3666 | FLR | 12:05 | 12:05 | 12:11 | 12 | | |
| 6 | EIN 562 | EI-CPH | 321 | DUB | 08:45 | 10:37 | E5 | 10:20 | BRD | EIN 563 | DUB | 09:45 | 09:45 | 12:12 | 12 | | |
| 7 | DLH 4496 | D-ACHF | CR2 | STR | 11:30 | 11:28 | 75 | 11:14 | BRD | DLH 4497 | STR | 12:05 | 12:05 | 12:12 | 12 | | |
| | | | 321 | MAN | 09:20 | 11:13 | 91 | 10:57 | BRD | MON 517 | MAN | 10:20 | 10:10 | 12:13 | 13:06 | 47 | 13:18 |
| | | | DH3 | NCE | 10:30 | 10:32 | 22 | 10:19 | BRD | ANS 8404 | PNA | 12:00 | 12:00 | 12:14 | 12:10 | 06 | 12:22 |
| | | | 320 | MUC | 11:10 | 11:22 | C1 | 11:08 | BRD | DLH 4477 | MUC | 12:15 | 12:15 | 12:15 | 12:15 | 32 | 12:27 |
| | | | 763 | LHR | 08:30 | 11:09 | E6 | 10:52 | BRD | BAW 479 | LHR | 09:35 | 11:35 | 12:16 | 14:29 | 43 | 14:41 |
| | | | 752 | DME | 10:40 | 10:47 | 65 | 10:29 | BRD | MOV 7526 | DME | 12:20 | 12:20 | 12:20 | 12:20 | 58B | 12:32 |
| | | | M82 | AGP | 10:25 | 10:25 | 104 | 10:14 | BRD | JKK 423 | MAD | 12:25 | 12:25 | 12:25 | | | |
| 14 | IBE 3966 | EC-JEJ | 320 | MAD | 10:45 | 11:46 | B4 | 11:32 | BRD | IBE 3966 | ATH | 11:25 | 12:05 | 12:26 | | | |
| 15 | AEA 6054 | EC-JBJ | 738 | IBZ | 11:25 | 11:39 | C4 | 11:24 | BRD | AEA 6061 | PMI | 12:15 | 12:15 | 12:29 | | | |
| 16 | EZS 961 | HB-JZH | 319 | GVA | 09:30 | 11:50 | E1 | 11:36 | BRD | EZS 962 | GVA | 10:05 | 12:22 | 12:30 | | | |
| 17 | SNB 523 | OY-SED | 738 | CPH | 10:10 | 11:40 | 71 | 11:26 | BRD | SNB 524 | CPH | 11:05 | 12:30 | 12:30 | | | |
| 18 | VLG 4639 | EC-JDO | 320 | MXP | 10:55 | 10:59 | 84 | 11:00 | BRD | VLG 2345 | SVQ | 12:25 | 12:25 | 12:30 | 12:31 | 48B | 12:43 |
| 19 | TAP 742 | CS-TTF | 319 | LIS | 10:50 | 11:42 | D3 | 11:28 | BRD | TAP 743 | LIS | 11:40 | 12:05 | 12:32 | 12:32 | 40 | 12:44 |
| 20 | EZS 1075 | HB-JZK | 319 | BSL | 12:00 | 11:45 | F6 | 11:30 | BRD | EZS 1076 | BSL | 12:35 | 12:35 | 12:35 | 12:35 | 53 | 12:47 |
| 21 | IBE 1711 | EC-ICQ | 320 | PMI | 11:10 | 11:14 | 15 | 10:59 | IBK | IBE 4188 | LHR | 12:15 | 12:15 | 12:30 | 15:10 | 49 | 15:22 |
| 22 | IBE 2600 | EC-ILS | 320 | MAD | 11:30 | 11:48 | A2 | 11:30 | IBK | IBE 4424 | ORY | 12:15 | 12:15 | 12:33 | 13:28 | 11 | 13:40 |
| 23 | IBE 4653 | EC-HTD | 320 | MXP | 11:55 | 12:00 | B3 | 11:45 | IBK | IBE 2609 | MAD | 12:40 | 12:40 | 12:40 | 12:40 | 20 | 12:52 |
| 24 | BRT 1796 | G-BXAS | A81 | BHX | 11:50 | 11:59 | D1 | 11:42 | IBK | BRT 1797 | BHX | 12:30 | 12:45 | 12:45 | 16:00 | 42 | 16:12 |
| 25 | IBE 1121 | EC-FGV | 320 | SVQ | 06:55 | 07:13 | B1 | 06:59 | IBK | IBE 1134 | SVQ | 12:45 | 12:45 | 12:45 | 12:45 | 15 | 12:57 |
| 26 | GWI 520 | D-AKNV | 320 | CGN | 10:35 | 11:56 | 67 | 11:40 | IBK | GWI 521 | CGN | 11:15 | 12:05 | 12:46 | 12:05 | 38 | 12:17 |
| 27 | MYW 2510 | EI-DJH | 320 | VCE | 11:50 | 11:57 | 81 | 11:41 | IBK | MYW 2511 | VCE | 12:50 | 12:50 | 12:50 | 12:51 | 48 | 13:03 |
| 28 | DLH 4486 | D-ACPN | CR7 | HAM | 12:10 | 12:13 | 82 | 11:58 | IBK | DLH 4487 | HAM | 12:50 | 12:50 | 12:50 | 12:50 | 36 | 13:02 |
| 29 | SWR 1954 | HB-IJI | 320 | ZRH | 12:00 | 12:02 | F5 | 11:46 | IBK | SWR 1955 | ZRH | 12:40 | 12:40 | 12:52 | 12:52 | 54 | 13:04 |
| 30 | ELG 1502 | I-ALPK | 100 | VCE | 11:40 | 12:10 | 112 | 11:53 | IBK | ELG 1371 | NAP | 12:30 | 12:30 | 12:55 | 12:55 | 39 | 13:07 |



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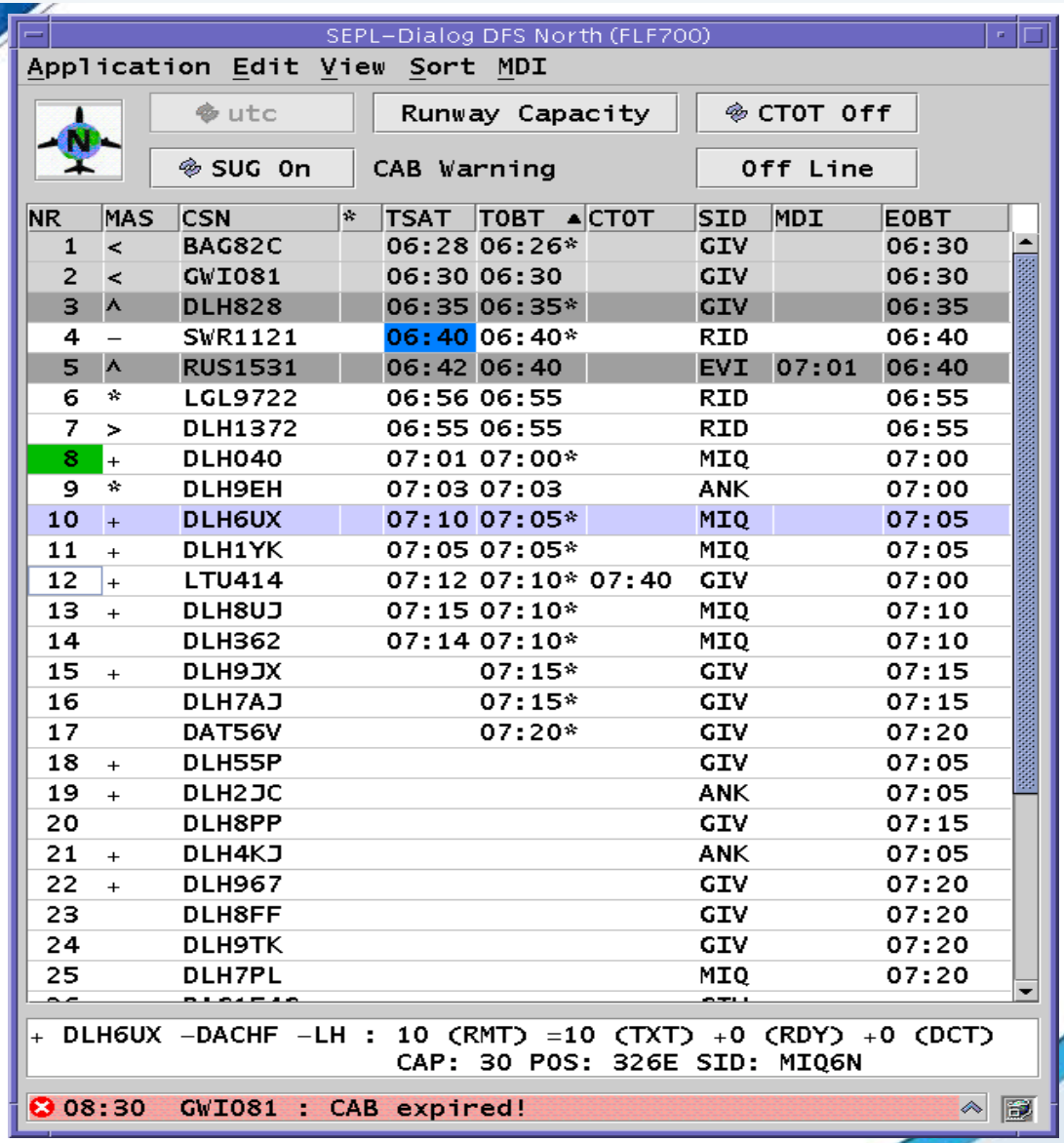
# Sequence Display Examples: Munich



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# Benefits for Airport Partners

- Improved infrastructure usage
- Reduced ATCO workload with enhanced planning
- Reduced Apron and Taxiway congestion
- Improved airport image (passengers perception of smooth operations)
- Better situational awareness during times of disruption and delay

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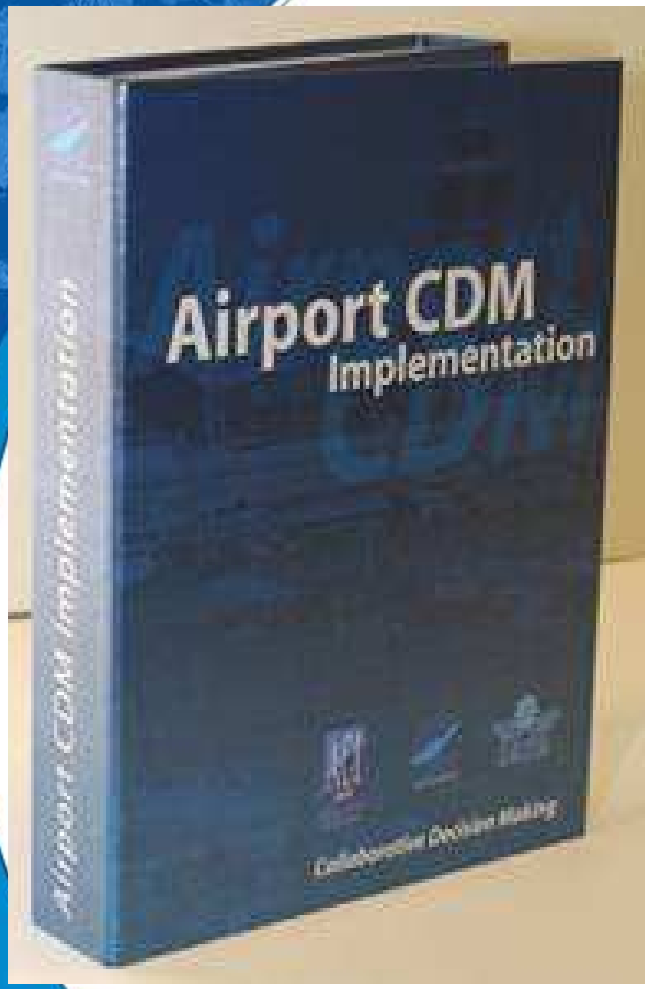
# Airport CDM Implementation



**Over 21 ECAC Airports Implementing**



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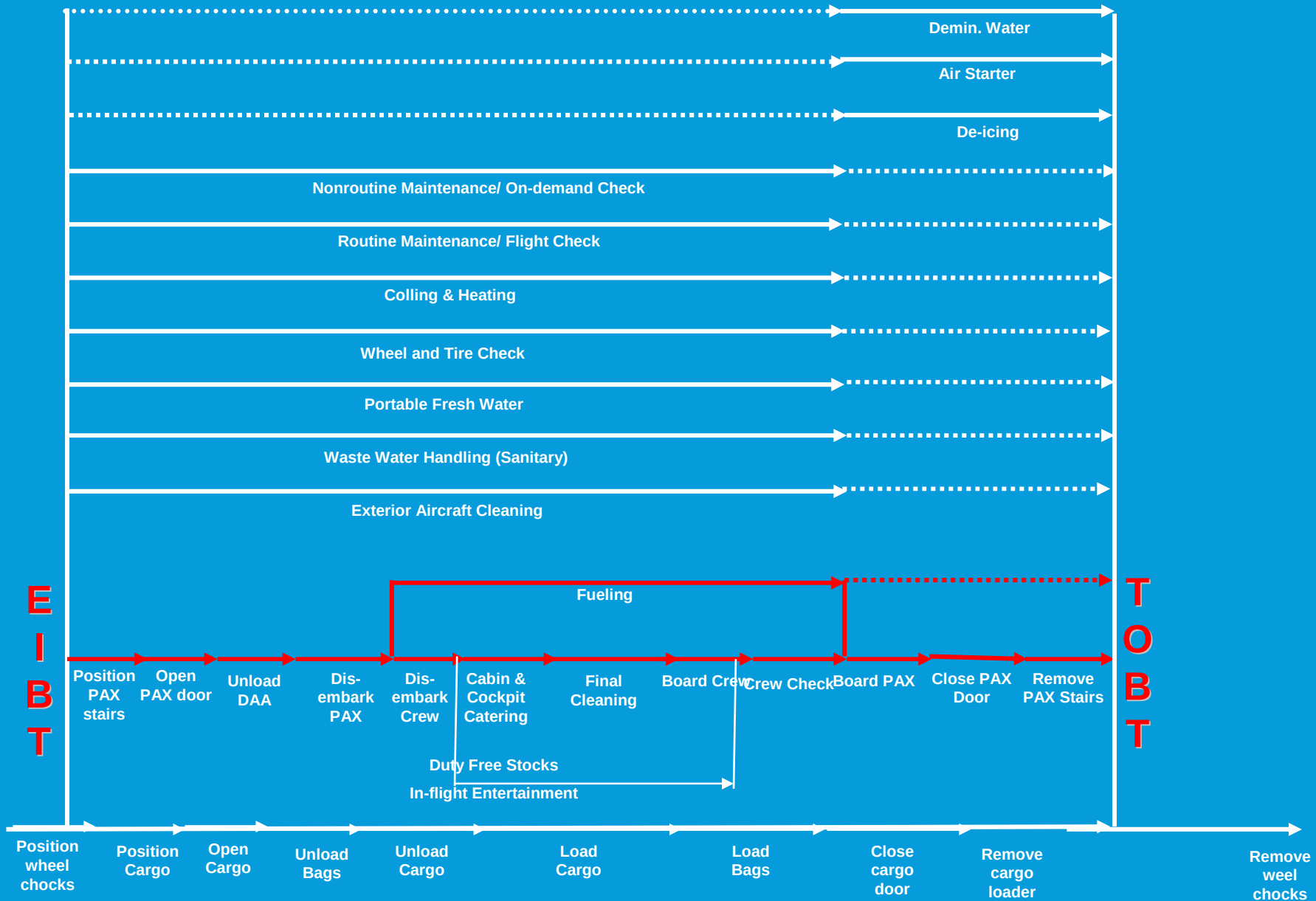
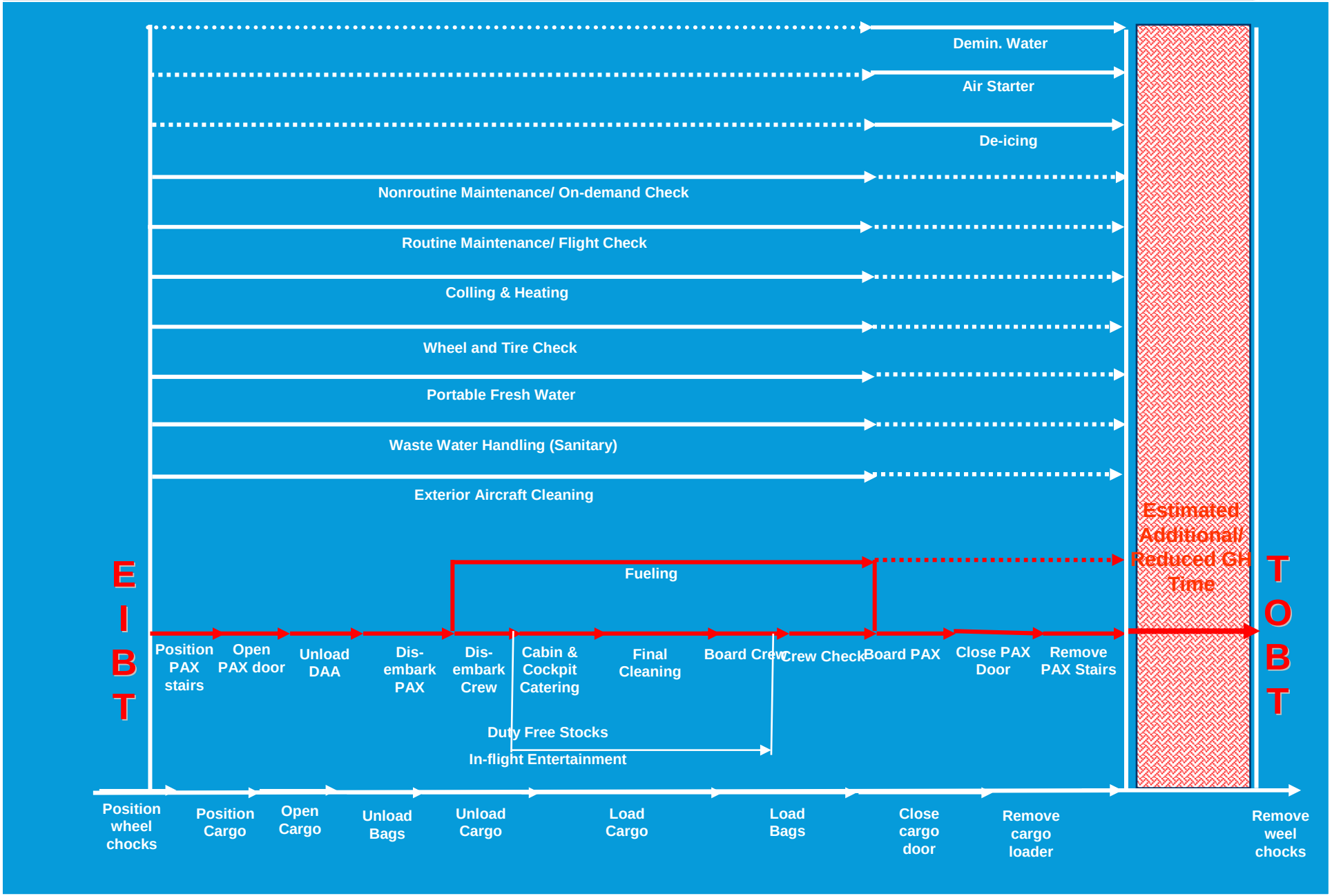
# The A-CDM Turn-Round: Critical Path



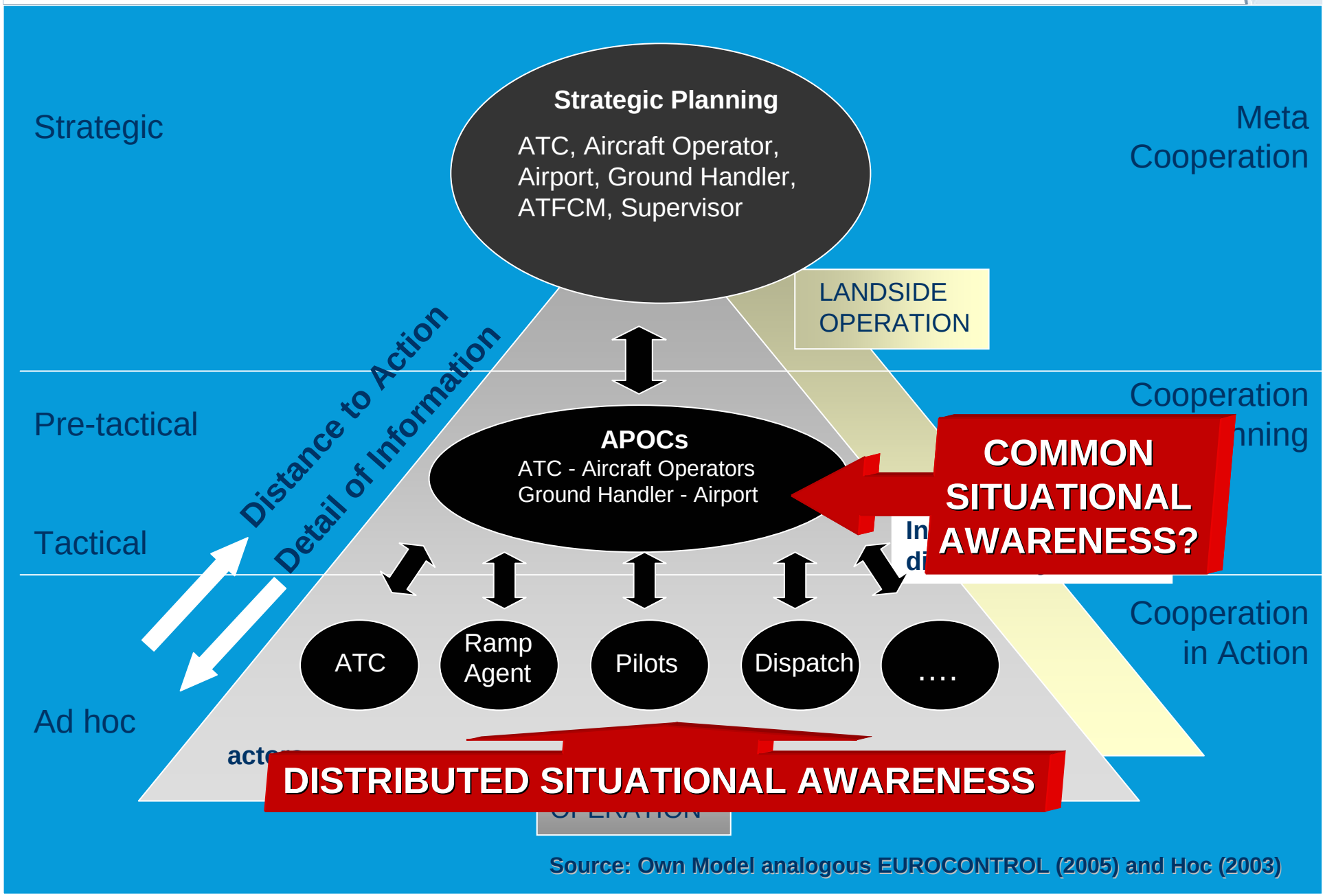
# The A-CDM Turn-Round: Critical Path



# Airport CDM Environment I

- Operational decision making is based on *insufficient quality & flow of information* (observation & own experience)
- Not all airport partners have required *Situational Awareness* for operational decision making

# Airport CDM Environment II




Source: Own Model analogous EUROCONTROL (2005) and Hoc (2003)

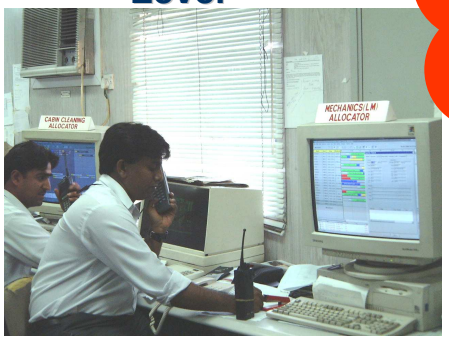
# Airport CDM Environment III

**Cockpit: Action Level**

**INFORMATION SHARING**
- Intermediaries
- Distributed Location

**INFORMATION SYNCHRONISATION**
Distance to Planning/ Action

**APOC: Planning Level**



**Operational Decision Making**

**Safety related Decision Making with Operational Consequences**

**ATC Tower: Action Level**



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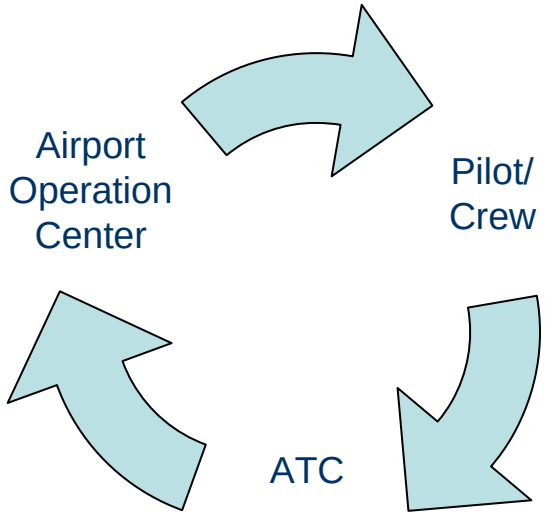
# Project Objective: Improve TOBT Predictability

**Context I: Constraints through Multi-Party Decision Making**

- **Identify *individual (single operator)* goal setting to increase cooperation towards a *common (global)* goal**
- **Understand *HHIs* and *HCIs among operators* to increase cooperation building factors**



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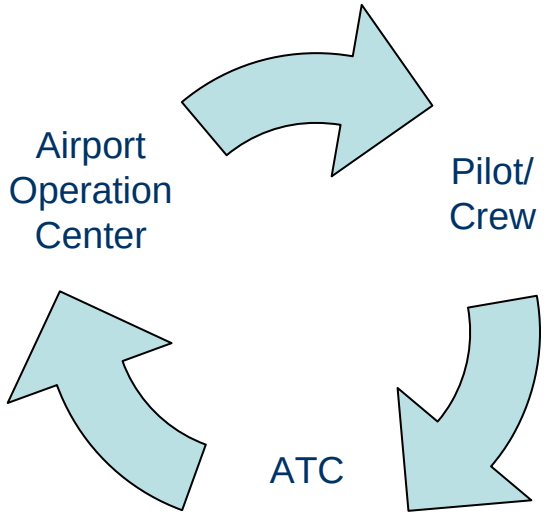
# Project Objective: Improve TOBT Predictability

## Context II: Heterogeneous & Asynchronous Information Sharing

- **Identification of *data/information/ knowledge components* which should be employed to provide situational awareness**
- **Synchronization of information sharing for time critical decisions**



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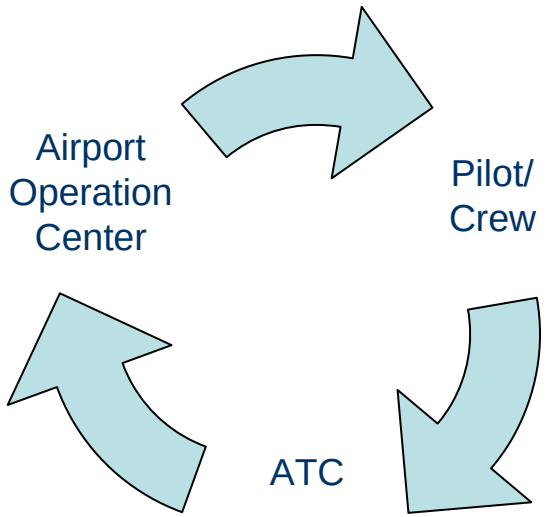
# Project Objective: Improve TOBT Predictability

## Context III: Irregularities through Unanticipated Events

- **Identify *decisions necessary* during unanticipated situations**
- **Understand *which information* is required for decision making and cooperation among partners during these situations**



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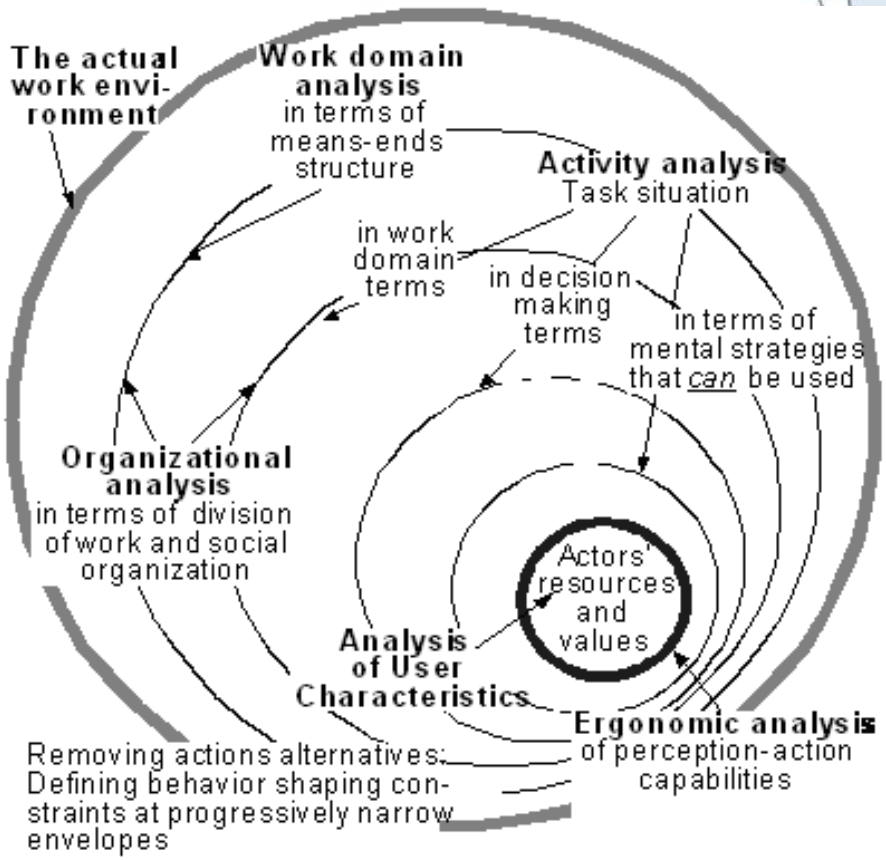
# Applying Cognitive Work Analysis I

- **Analysis, design, and evaluation of complex sociotechnical systems**
- **Contrast to other task analysis: *Formative* approach**
- **Designed to provide *decision support* in an environment with different policies, skill sets and capabilities**



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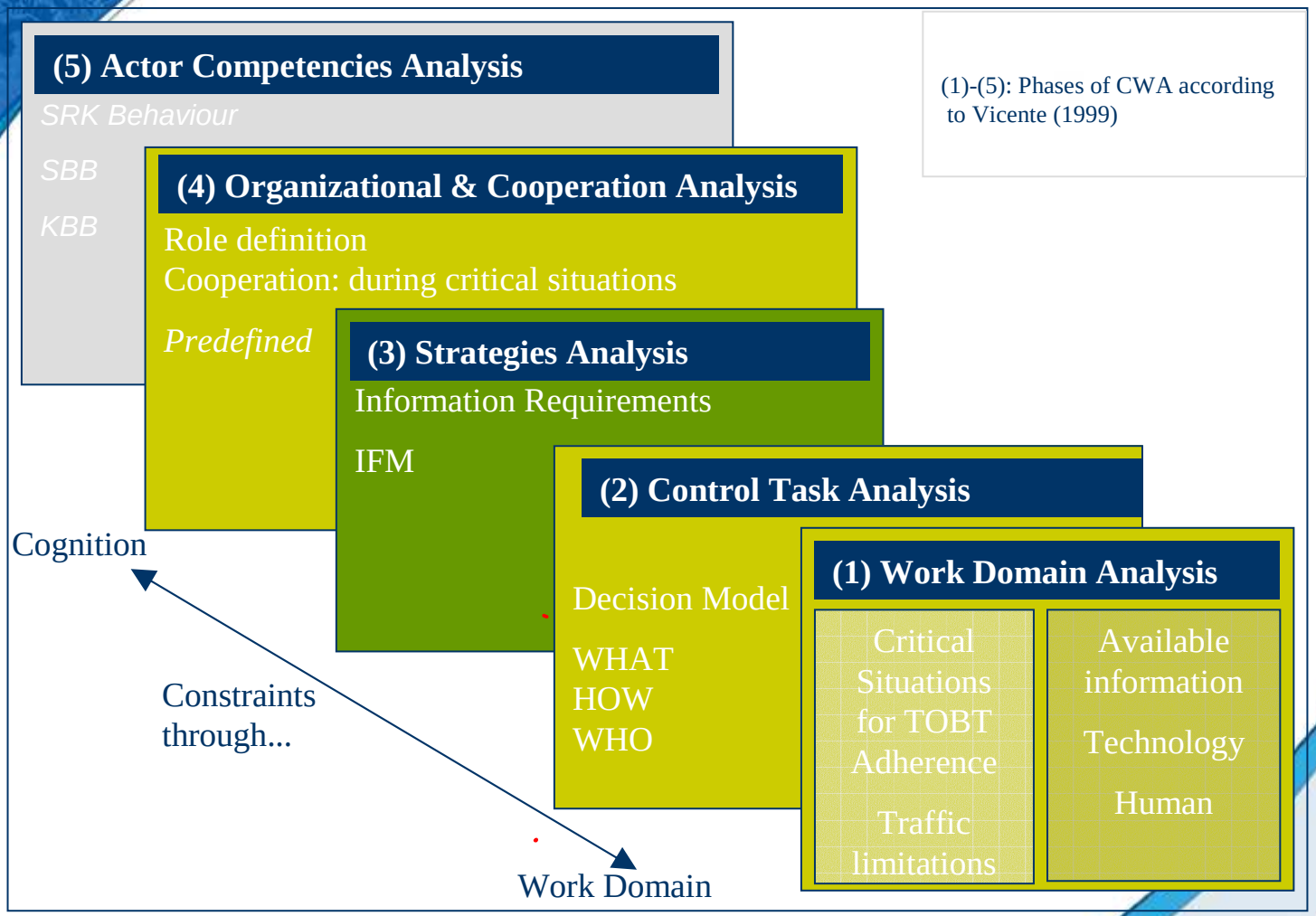
# Applying Cognitive Work Analysis II



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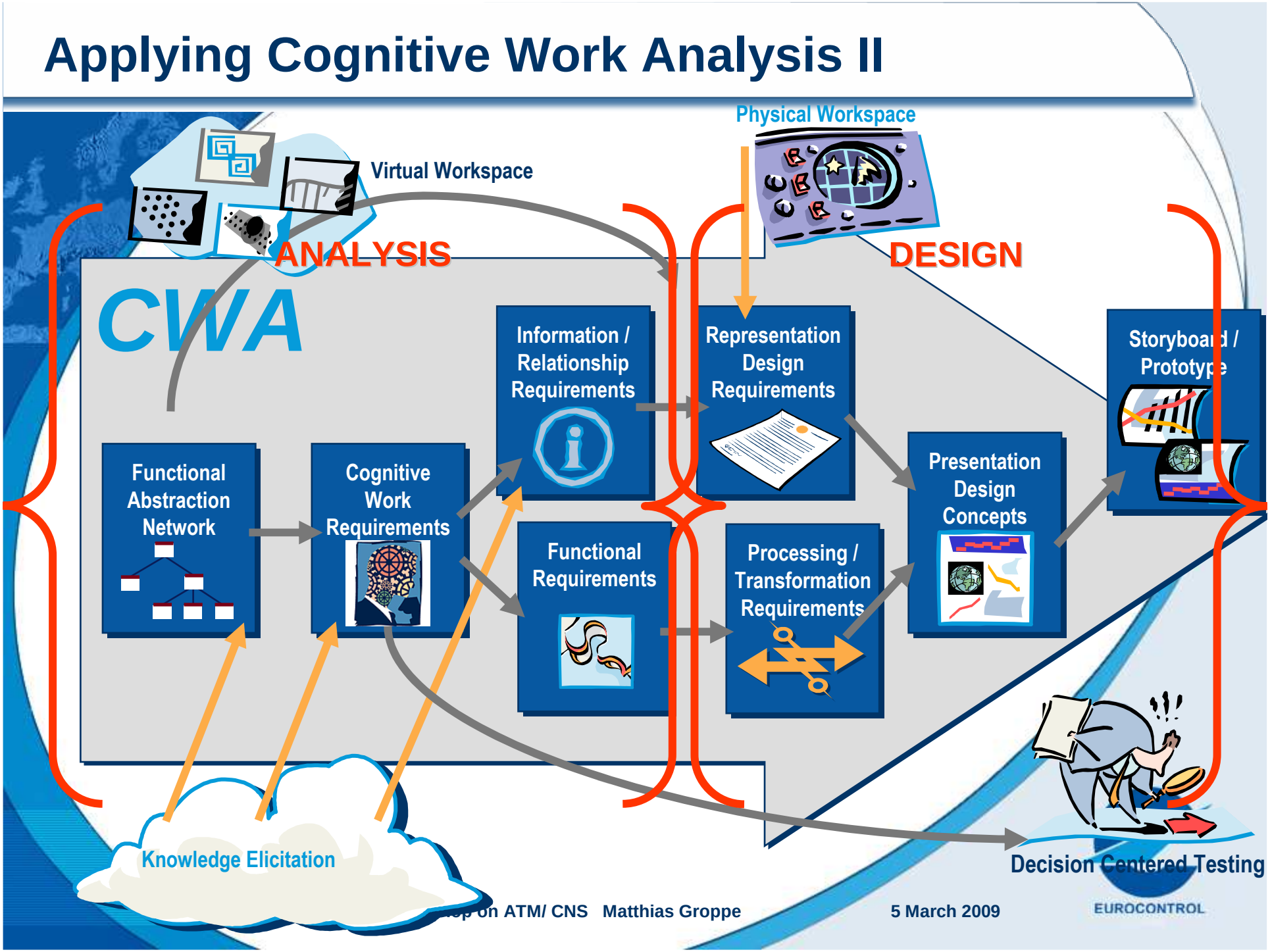
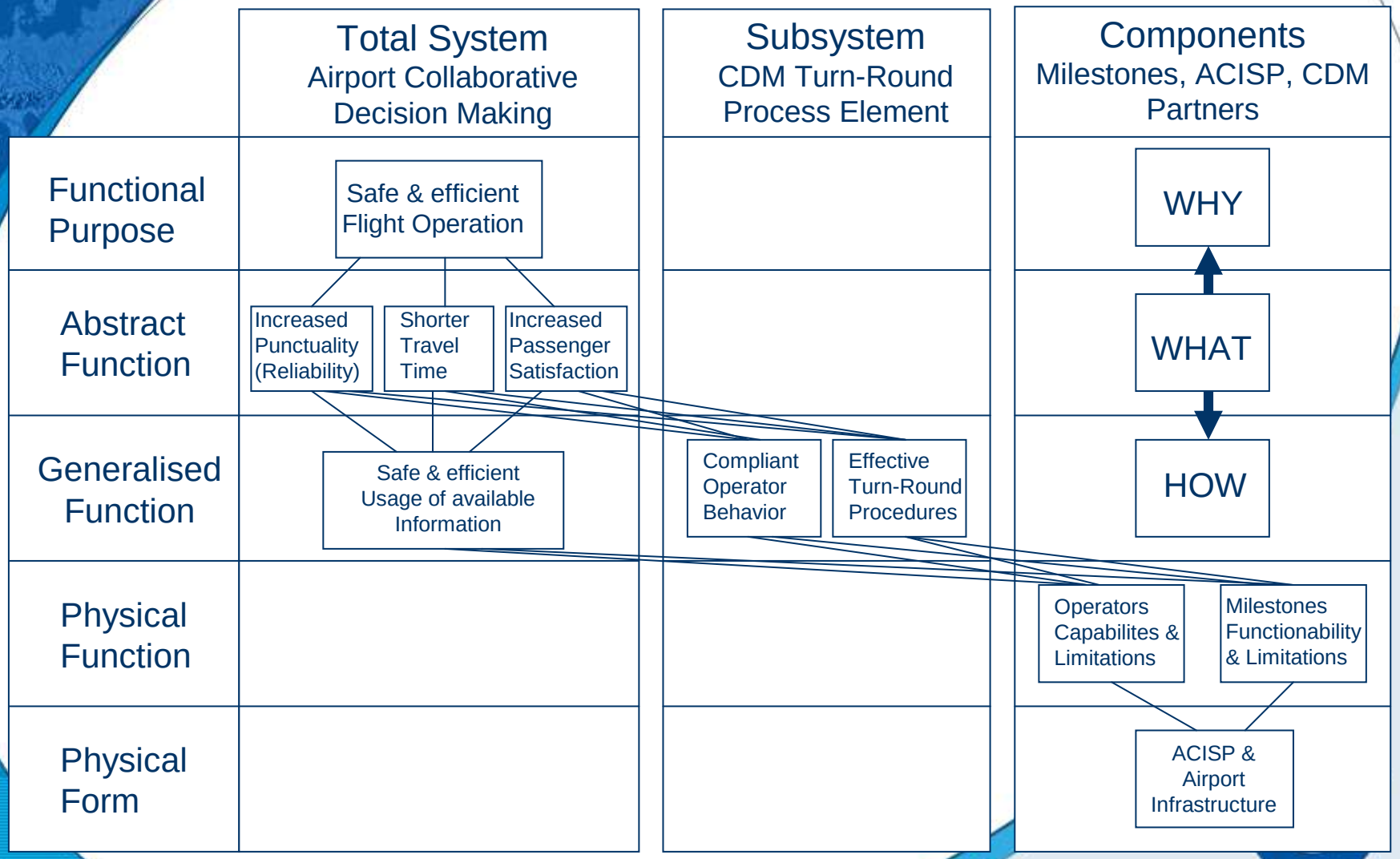
# Applying Cognitive Work Analysis II



# Building the Abstraction-Decomposition Space

| | Total System<br>Airport Collaborative Decision Making | Subsystem<br>CDM Turn-Round Process Element | Components<br>Milestones, ACISP, CDM Partners |
|---|---|---|---|
| Functional Purpose | *Purposes*<br>* Improve work together at an operational level<br>* Efficient and safe daily flight operation with reliable information provision & Common Situational Awareness<br>*External Constraints*<br>* Laws & Regulations by airport, national governement, Europe, IATA, EUROCONTROL, ICAO<br>* Local Standard Operationg Procedures (e.g. due to environmental, airline, airport..) | *Purposes*<br>▪Provide the A-CDM partners with a common situational awareness<br>▪Anticipation of disruptions & expeditious recovery through information sharing among all partners including passengers<br>*External constraints*<br>▪Distributed location between CDM partners and actors<br>▪Laws & Regulations by airport, national governement, Europe, IATA, EUROCONTROL, ICAO | *Purposes*<br>▪Milestones: To provide decision makers with information about flight progress and trigger decision making<br>▪ACISP: To provide information sharing between the Airport CDM Partners<br>▪A-CDM Partner Goals<br>*External Constraints*<br>▪No & design of Milestones, Alert Messages, participating partners |
| Abstract Function | *Criteria*<br>*ATTT<br>*Turn-round compliance (STTT vs ATTT)<br>*TOBT/TSAT Predictability<br>*EIBT Predictability: EIBT vs time<br>*Ready Reaction Time: AOBT - ARDT | *Criteria*<br>▪ATTT<br>▪Turn-round compliance (STTT vs ATTT)<br>▪TOBT/TSAT Predictability<br>▪EIBT Predictability: EIBT vs time<br>▪Ready Reaction Time: AOBT – ARDT | *Milestones*<br>▪CDM Procedure Group Meetings<br>▪Performance Assessments<br>*ACISP & A-CDM Partners*<br>▪User feedback & Performance Assessment |
| Generalised Function | ▪Safe & efficient usage of available resources<br>▪Effective law, regualation, procedure, and policy enforcement<br>▪Redesign of airport operational procedures<br>▪Implementation of CDM functions | ▪Safe & efficient turn-round & flight<br>▪Adherence to CDM procedures<br>▪Efficient implementation of collaborative decisions at action level<br>▪Enforcement of laws, regulations, procedures, policies | *Milestones*<br>▪Data/ Information availability & Practicability of Information<br>*ACISP & A-CDM Partners*<br>▪Physical dynamics of user behaviour |
| Physical Function | ▪Provision of reliable information for all CDM partners<br>▪Collaborative operational decision making<br>▪Increasing Situational Awareness<br>▪A-CDM Information Sharing Platform (ACISP) | ▪Efficient information provision & cooperation between operators & actors<br>▪Distributed Situational Awareness at action level<br>▪Efficient comand & control structure between pretactical & action level of operation | *Milestones*<br>▪Functionalability/capability/limitations & status<br>▪Inform all partners<br>*ACISP & A-CDM Partners*<br>▪Functionalability/capability/limitation<br>▪Establish Situational Awareness |
| Physical Form | ▪IT platforms with operational information sources, eg TOBT/TSAT<br>▪AMAN/DMAN<br>▪Airport Operation Centre (APOC)<br>▪Representative Decision Makers of all partners<br>▪Meteorlogical features, e.g. adverse weather condition | ▪Printed Information/ Data about TOBT/TSAT<br>▪Information Screens for passengers<br>▪Airport Infrastructure & Airspace Structure<br>▪Alert Messages to all CDM partners via the ACISP<br>▪Flight Update Messages (FUMs) | ▪Electronic Data/ Information<br>▪Software Applications<br>▪HMIs, e.g. ACARS, Telefon, Computer<br>▪Computer Network<br>▪Operation Room<br>▪System Operators<br>▪Passengers<br>▪Actors |

# The A-CDM Abstraction-Decomposition Space



# (1) Work Domain Analysis: Mapping Information Requirements I

| | **Total System**<br>Airport Collaborative Decision Making | **Sub-System**<br>CDM Turn-round Process Element | **Component**<br>e.g. Milestones, ACISP, A-CDM Partners |
|---|---|---|---|
| **Functional Purpose** | ▪ **A-CDM Information Sharing**<br>▪ **Common Situational Awareness** | | ▪ Pilots`Goals<br>▪ Safety Level<br>▪ Airport Performance<br>▪ Aircraft Technical Status<br>▪ A-CDM Partner Goals |
| **Abstract Function** | ▪ **ETTT**<br>▪ **Turn-round compliance of Actors involved** | ▪ Milestones 6 until milestone 15<br>▪ Not time & time related data<br>▪ Aircraft operational statu<br>▪ Variable Taxi Time Calculation<br>▪ CDM Complicance Alarms | ▪ Economic Cost of Planned/ Alternative Turn-Round<br>▪ Safety Level<br>▪ Performance and Status of All Participating<br>▪ Aircraft Requirements & Status |
| **Generalised Function** | ▪ **Warnings, e.g. airport policies & local restrictions**<br>▪ **Behavioral recommendations, e.g. taxi time required** | ▪ **TIBT & Stand Information**<br>▪ **Ground Handling Start Delay** | ▪ Physical turn-round control task support<br>▪ Cognitive turn-round control task support<br>▪ Turn-Round Complicance control |
| **Physical Function** | ▪ Operational Information Sharing with Cockpit<br>▪ CDM operating procedures<br>▪ Information Sharing among pariticpating actors<br>▪ A-CDM Information Sharing Platform (ACISP) | ▪ Information about Changes of TIBT & Stand<br>▪ Information about Ground Handling Start Problems<br>▪ Information about Runway changes<br>▪ Information about EOBT/TOBT/CTOT changes<br>▪ Information about scheduled EXOT, if relevant | ▪ **Capability/ Knowledge Level of All Participating**<br>▪ **Availability of Resources** |
| **Physical Form** | ▪ Access to ACISP from cockpit<br>▪ Provision of TOBT/TSAT/TTOT to cockpit<br>▪ Information about Passenger Boarding Time<br>▪ Environmental Condition Information<br>▪ Turn-Round disruptions | | ▪ **Current Component Performance & Status**<br>▪ **Current Airport & Aircraft Condition**<br>▪ **Other A-CDM users location & future movements** |

# Cockpits' Survey: Information Requirements I

| Information Requirement | Information Provided to Pilots | | |
|---|---|---|---|
| | YES | NO | PARTIALLY |
| Information from ACISP | | x | |
| TOBT/ TSAT | x | | |
| ETTT | | x | |
| Turn-Round Compliance of other actors | | x | |
| CTOT | x | | |
| TTOT | | x | |
| Apron Rules & Regulations | x | | |
| Infrastructure related warnings | | | x |
| Behavioral Recommendations | | x | |
| Operational Information | | | x |
| CDM Operating Procedures | x | | |
| Information Sharing among participating actors | | | x |
| Passenger Boarding Time | | x | |
| Environmental Condition Information | x | | |
| Turn-Round Disruptions | | x | |
| Time related Data | | | x |
| Not time related Data | x | | |
| Aircraft Operational Status | x | | |
| Variable Taxi Time Calculation | | x | |
| CDM Compliance Alerts | | x | |
| Target In Block Time | | x | |
| Stand Information | x | | |

| | | | |
|---|---|---|---|
| Ground Handling Start Delay | | x | |
| Runway in Use | x | | |
| EOBT/TOBT/CTOT Compliance alarms | | x | |
| EXOT | | x | |
| Pilots`Goals | x | | |
| Safety Level | | x | |
| Airport Performance | | x | |
| Aircraft Technical Status | x | | |
| A-CDM Partner Goals | | x | |
| Economic Cost of planned/ alternative Turn-Round | | | x |
| Performance & Status of all participating actors | | x | |
| Aircraft Requirements & Status | x | | |
| Physical turn-round control task support | | | x |
| Cognitive turn-round control task support | | x | |
| Turn-Round Compliance control task support | | x | |
| Capability/ Knowledge Level of all participating actors | | x | |
| Available Resources | | x | |
| Current task status in relation to goals | | x | |
| Current component performance & status | | x | |
| Current airport & aircraft condition | | | x |
| Other A-CDM users location & future movements | | x | |

**Source: On-line Cockpits' Survey (2008)**



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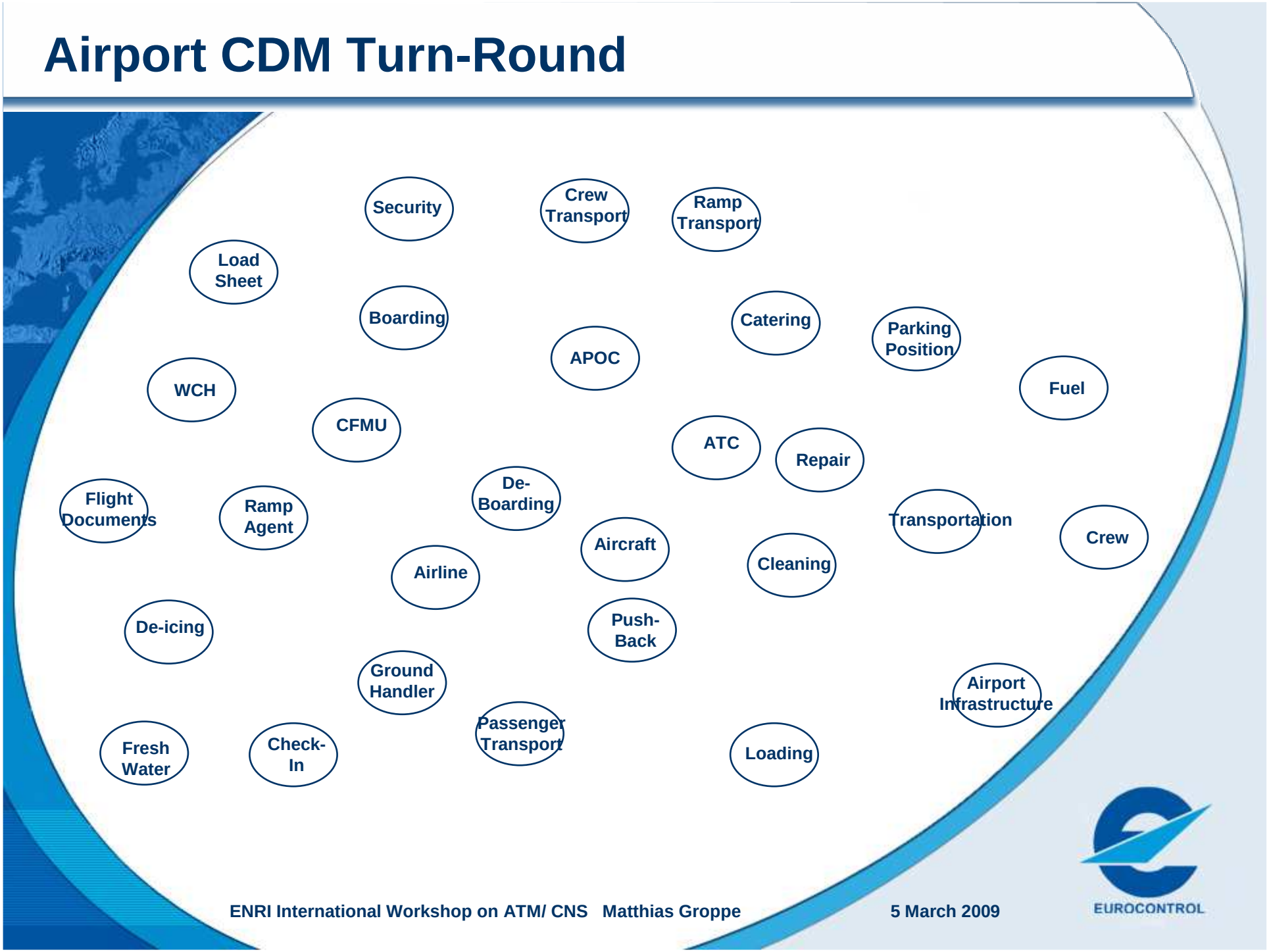
# Airport CDM Turn-Round



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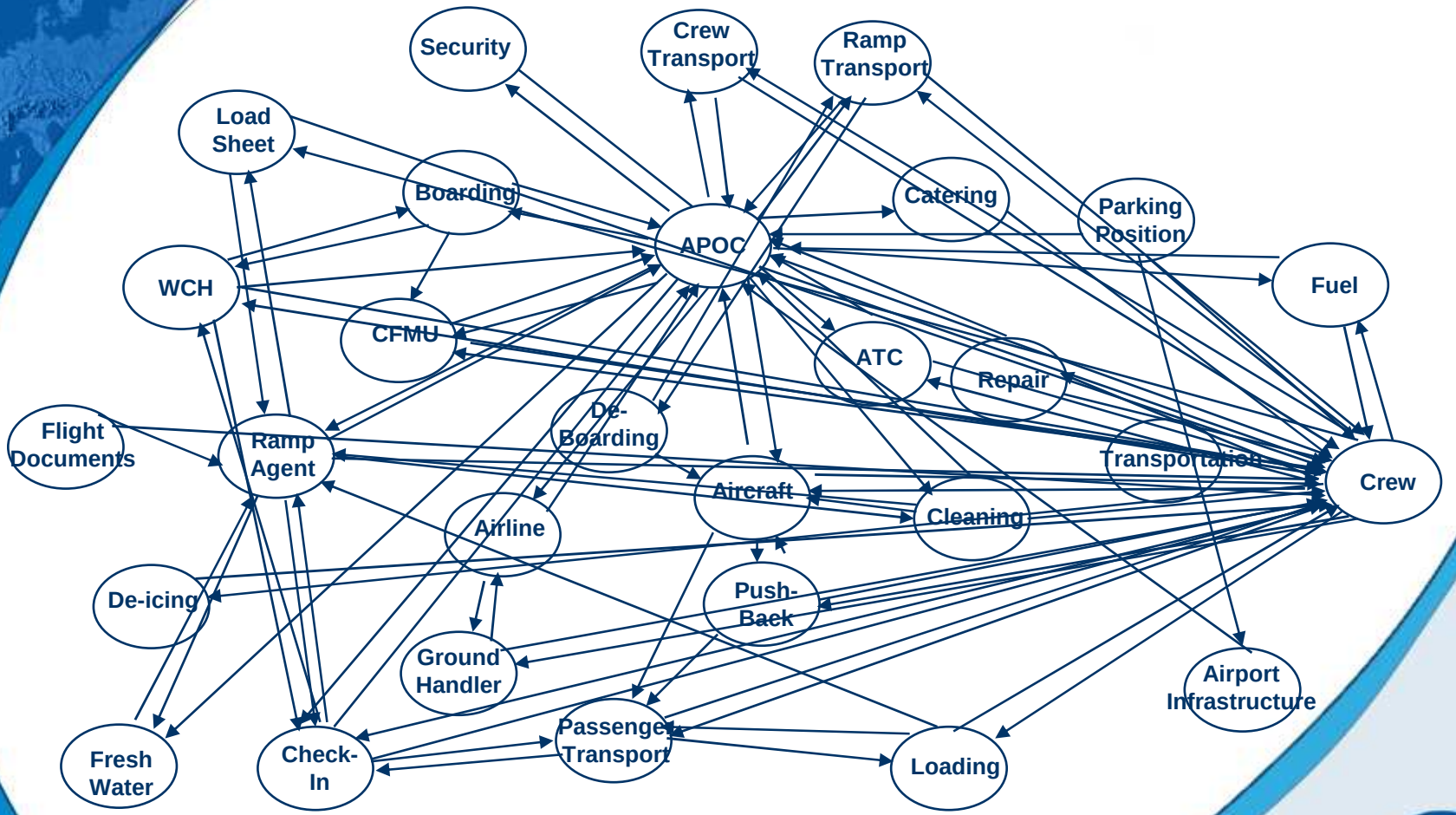
# Airport CDM Turn-Round



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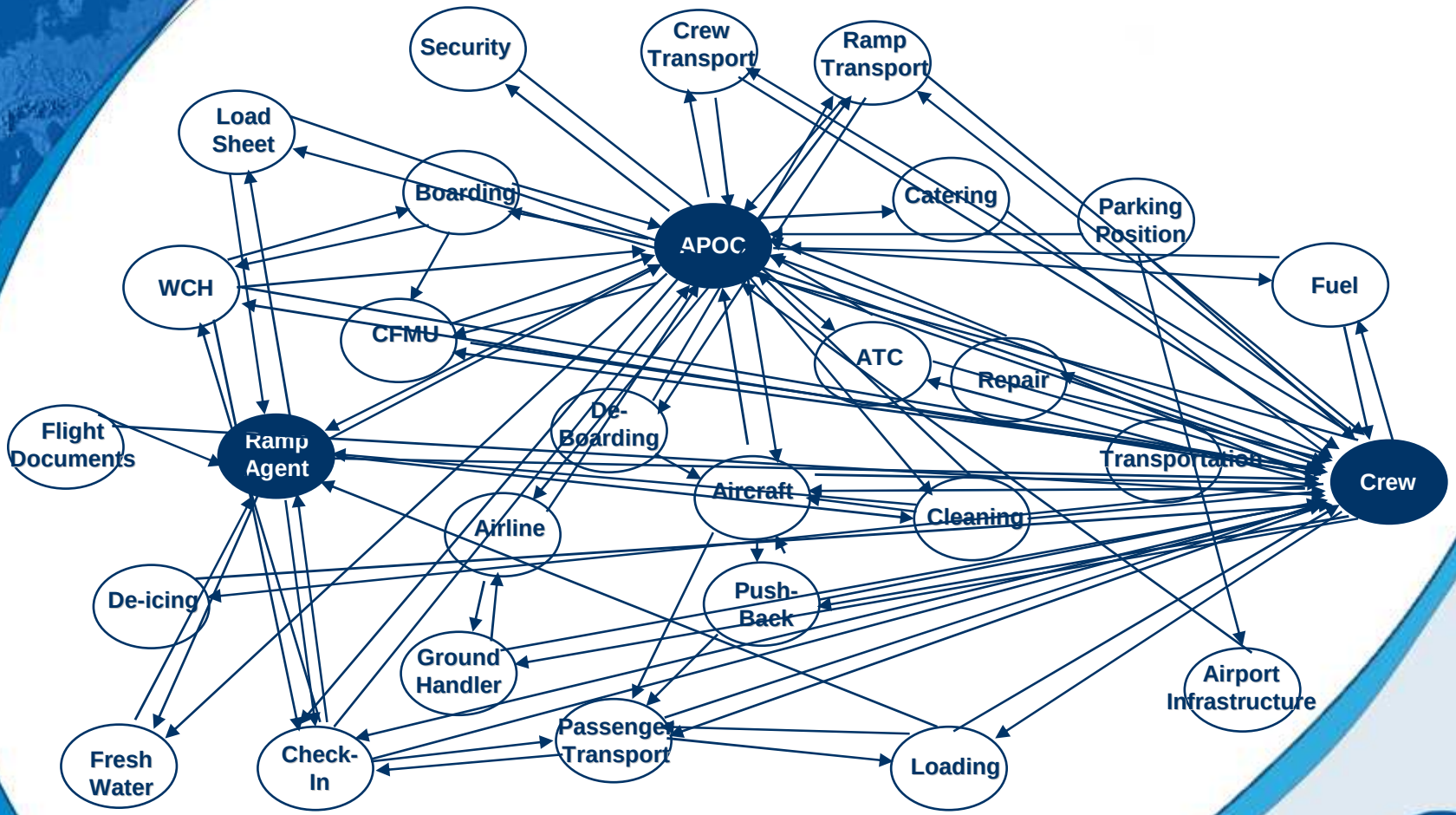
# Airport CDM Turn-Round



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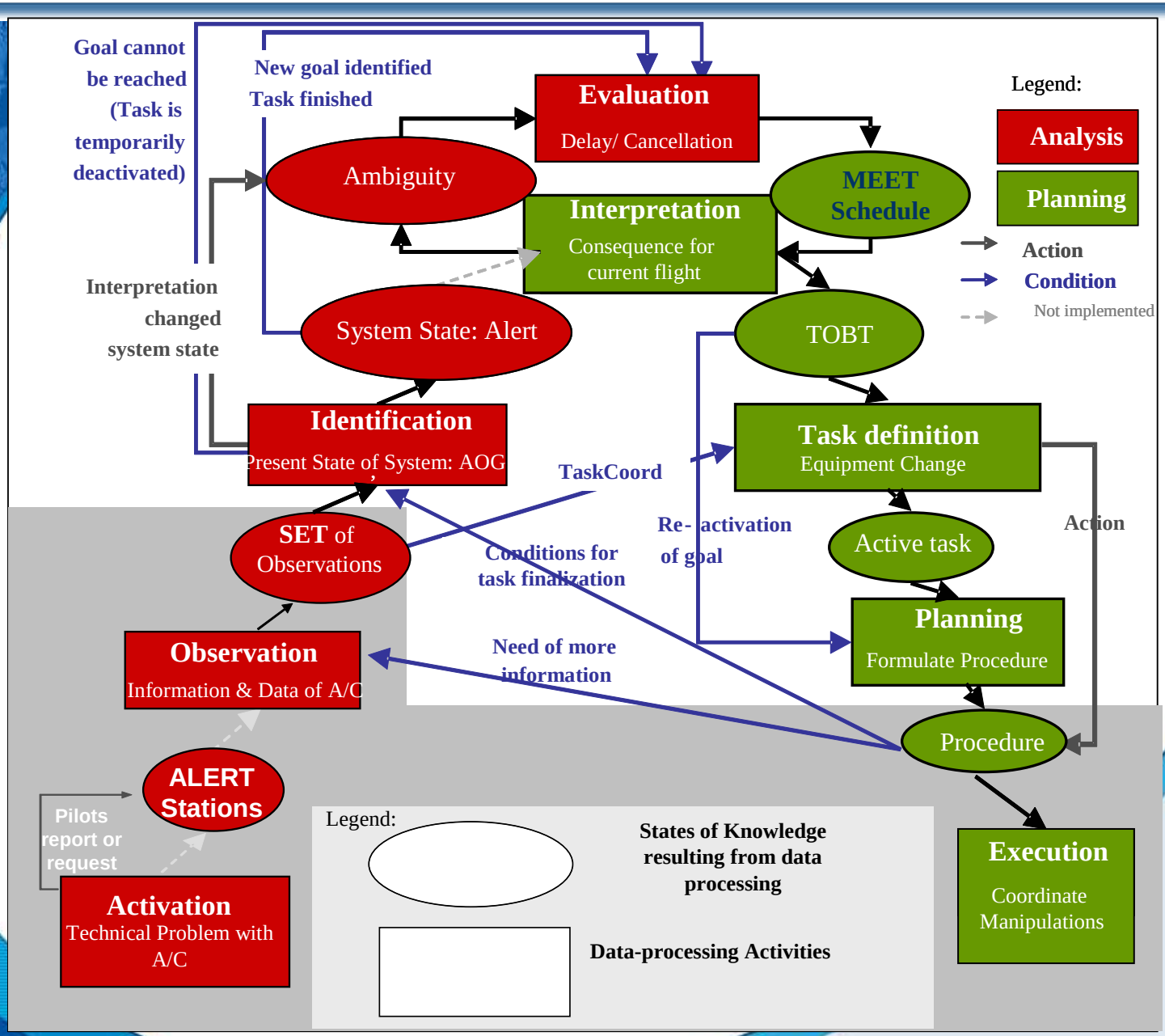
# (2) Control Task Analysis – The Decision Ladder

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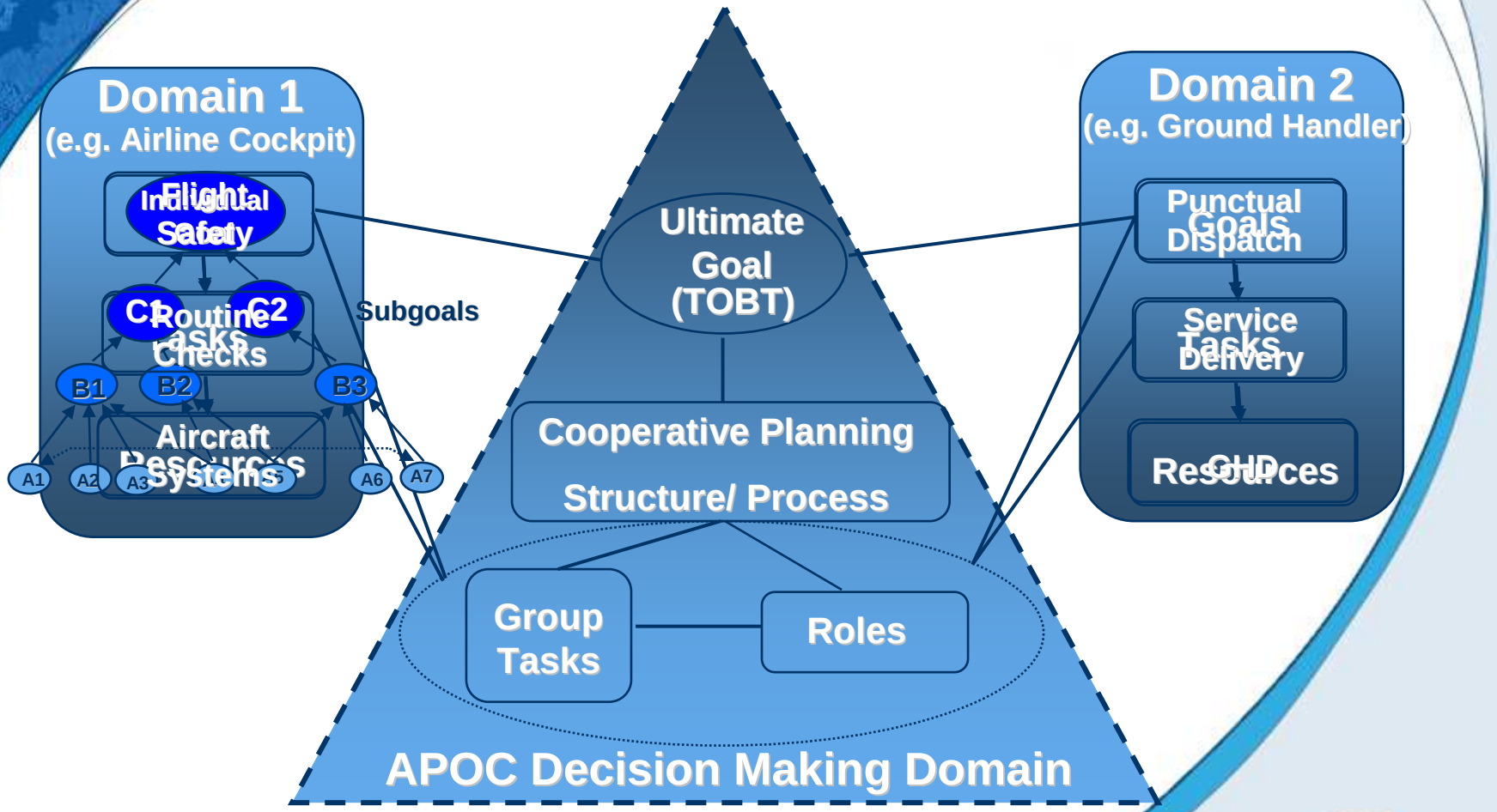
# (3) Strategy Analysis – Goal Complexity I




[2] Own Model analogous Nezamirad (2004)



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# (4) Organizational & Cooperation Analysis

## Classification of Interaction Situations (Ferber,1995)

| Aims/ Interests | Ressources | Abilities | Type of Situation | Category |
|---|---|---|---|---|
| compatible | sufficient | sufficient | Independence | Indifference |
| compatible | sufficient | insufficient | Simple working together | Indifference |
| compatible | insufficient | sufficient | Blockade | Cooperation |
| compatible | insufficient | insufficient | Coordinated collaboration | Cooperation |
| incompatible | sufficient | sufficient | Pure individual competition | Cooperation |
| incompatible | sufficient | insufficient | Pure individual competition | Antagonism |
| incompatible | insufficient | sufficient | Individual resource conflict | Antagonism |
| incompatible | insufficient | insufficient | Collective resource conflict | Antagonism |

**J. Ferber (1995) *Multi-Agent Systems*, Addison-Wesley, Munich**

# Conclusion

- Using Turn-Round Scenarios allows to demonstrate the Applicability of CWA in the A-CDM System Domain
- CWA identifies Information Sharing 'Bottlenecks' and reveals areas for possible Improvements
- CWA allows to draw focus on decision making or conflicting interests
- Can be used to develop a future A-*CDM Decision Support System*



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THANK YOU
Q & A?