

# Computational Assessment of Different Air-Ground Function Allocations

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# Designing Transformative NextGen Concepts of Operation

Big question in design: Who does what?

- ✧ New functions can be assigned to the aircraft (e.g., Flightdeck Interval Management)
- ✧ New functions can be assigned to the ground (e.g., Communicating autopilot targets via CPDLC)

**We need to evaluate radically new function allocations early in design**

# Terminology

- ❖ **Autonomy:** Functions that an agent can perform independently
- ❖ **Authority:** Functions agent is asked to perform
- ❖ **Responsibility:** Which outcomes will an agent be accountable for
- ❖ **Function allocation:** Assigning agents with the authority and/or responsibility for functions

# Coherence of a Function Allocation

Coherence is a qualitative measure of a function allocation:

## ❖ Coherent function allocation

- ✧ Groups together related actions
- ✧ Groups together actions using the same information
- ✧ Assigns these groups (functions) to agents

## ❖ Incoherent function allocation

- ✧ Requires different agents to perform interleaved actions
  - Need to wait on each other
  - Need to coordinate and transfer information

# Emergence

In concepts of operation with multiple, interacting agents:

- ❖ High level performance can emerge
  - ✧ Eg: Traffic stream emerges out of individual aircraft
- ❖ Demands on individual agents can emerge
  - ✧ Eg: When speed change is required to maintain position in stream

# Computational Simulation of Concepts of Operation

Early in design, can simulate different function allocations to:

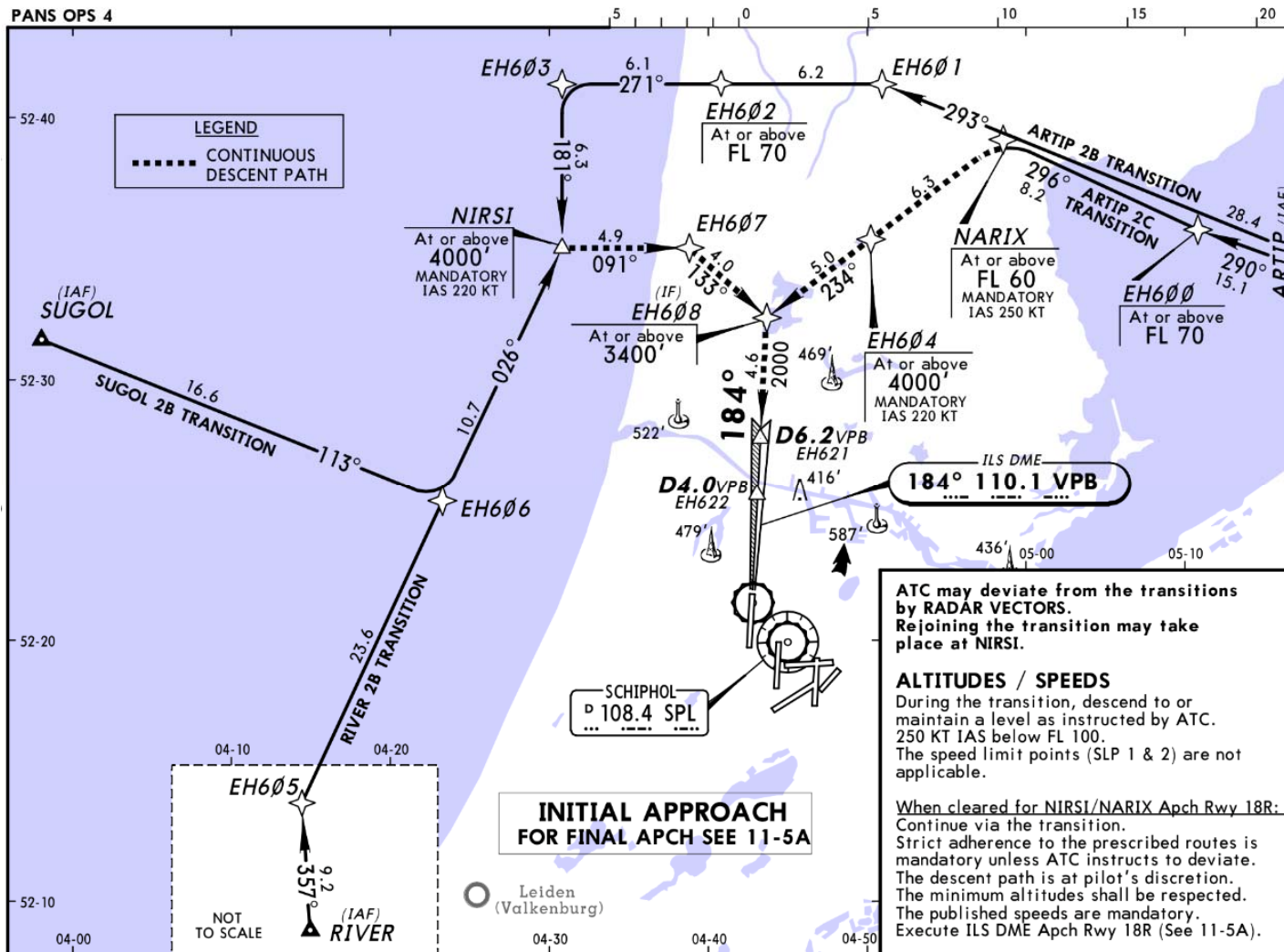
- ✧ Predict overall system performance
- ✧ Predict which functions each agent will need to complete, and when
- ✧ Predict what information each agent will need, and when
- ✧ Predict what information needs to be transferred, and when
- ✧ Identify monitoring required by authority-responsibility mismatches

# Simulation Framework: Work Models that Compute (WMC)

- ❖ Concepts of operation described by the work they require
  - ✧ Functions
  - ✧ Detailed actions comprising the functions
- ❖ Work modeled outside the agents
  - ✧ During simulation, actions allocated to agents

**Different function allocations can be created between  
– or dynamically within – simulation runs**

# Case Study

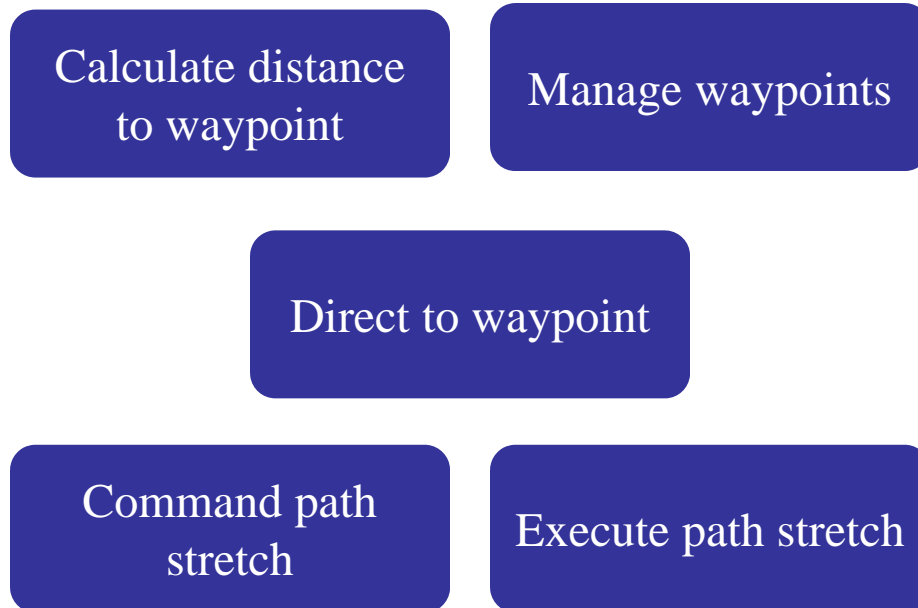




# WMC Setup

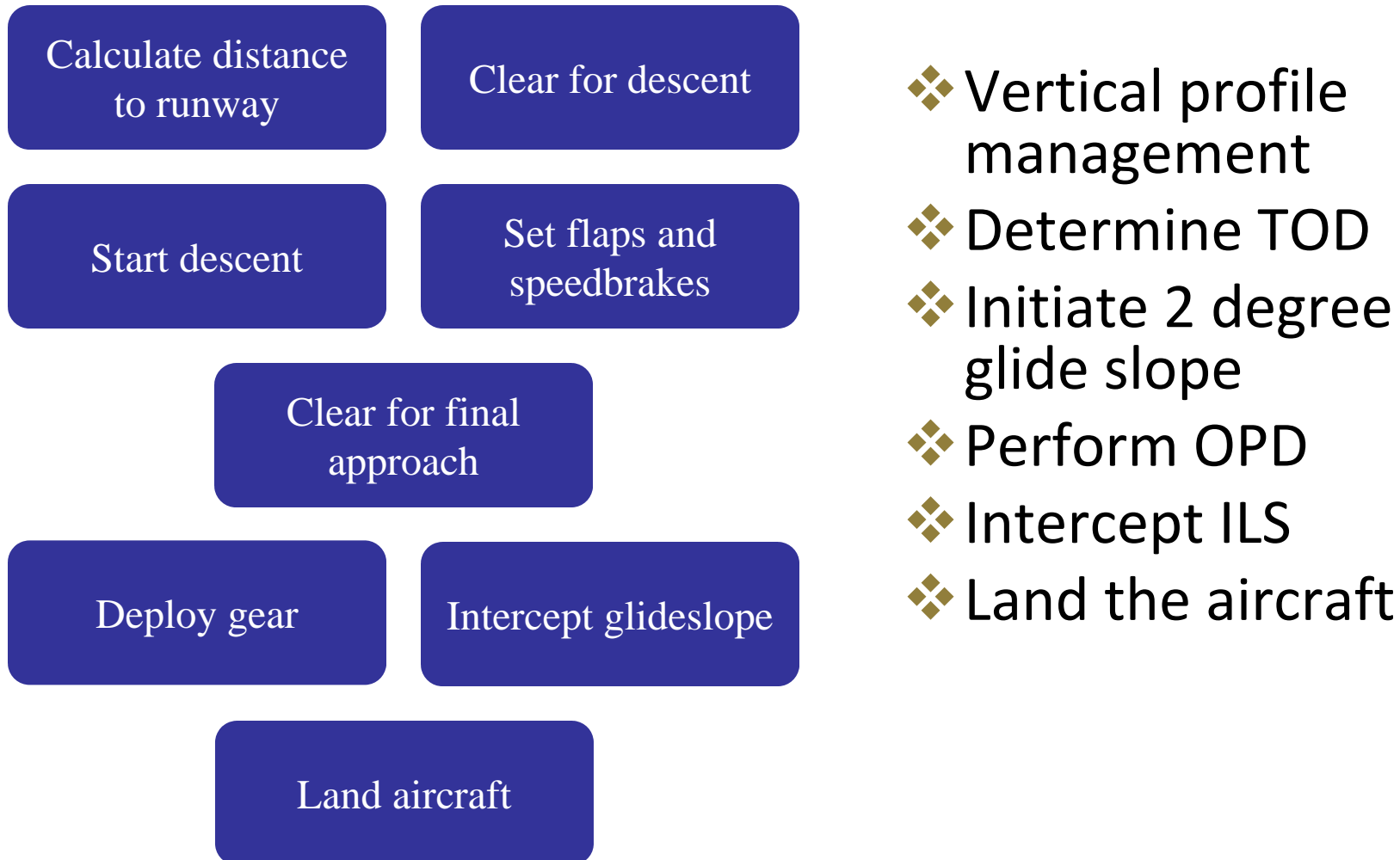
- ❖ (Perfect) agents:
  - ✧ 3x flight crew
  - ✧ 1x air traffic controller
- ❖ Work modeled through actions
- ❖ Actions are linked to agents in two modes:
  - ✧ Authority
  - ✧ Responsibility

# WMC Setup



- ❖ Lateral profile management
- ❖ Set a target waypoint
- ❖ Control heading to direct aircraft to target waypoint
- ❖ Command a response maneuver
- ❖ Execute either fanning or trombone maneuver

# WMC Setup



# WMC Setup

Calculate distance  
to merge point

Determine arrival  
sequence at merge  
point

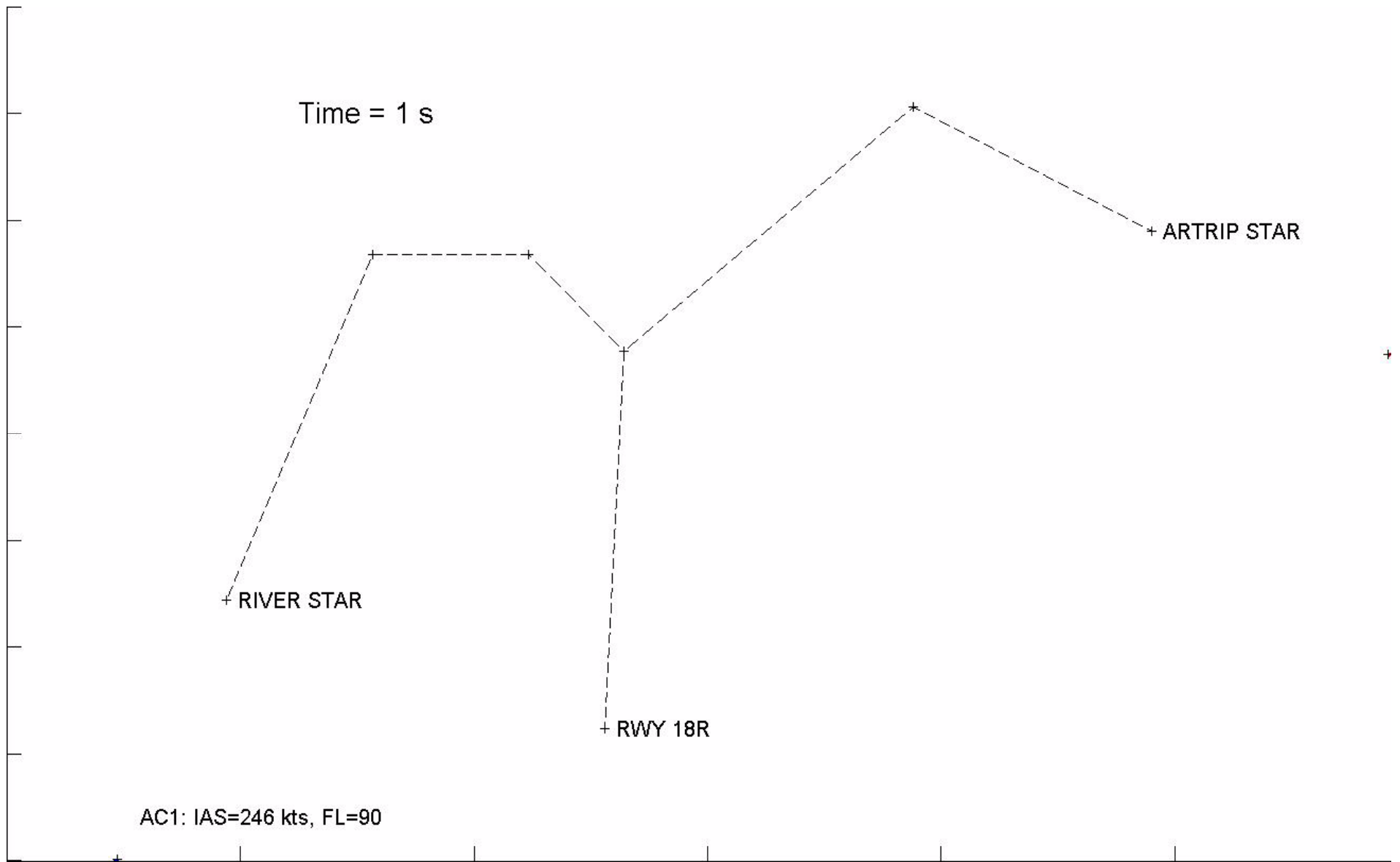
Assign lead aircraft

Command OPD  
speeds

Calculate IM  
airspeed

Set airspeed

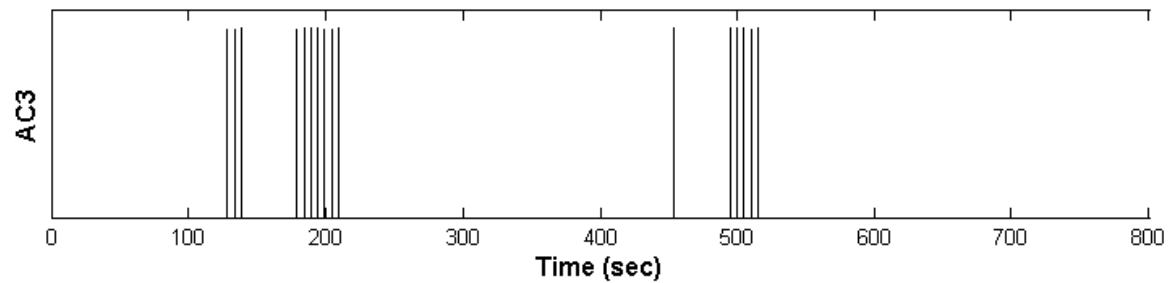
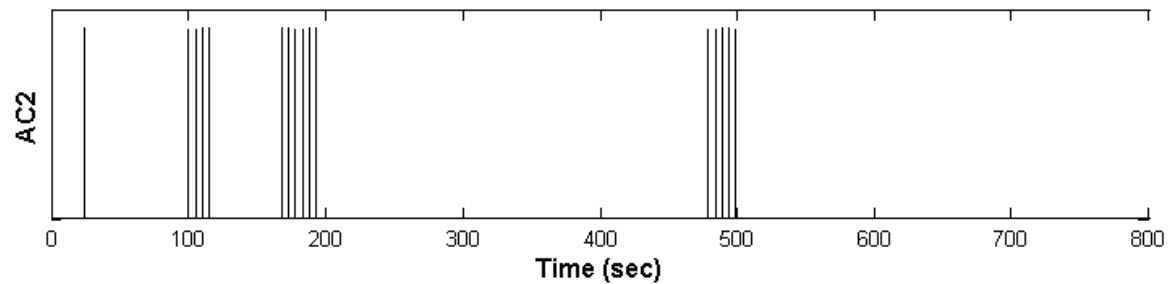
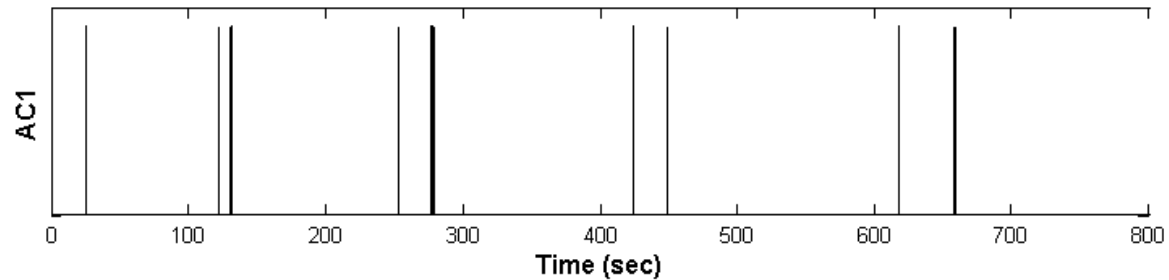
- ❖ Speed management
- ❖ Calculate distances to merge and determine arrival sequence
- ❖ Assign a lead aircraft
- ❖ Maintain separation



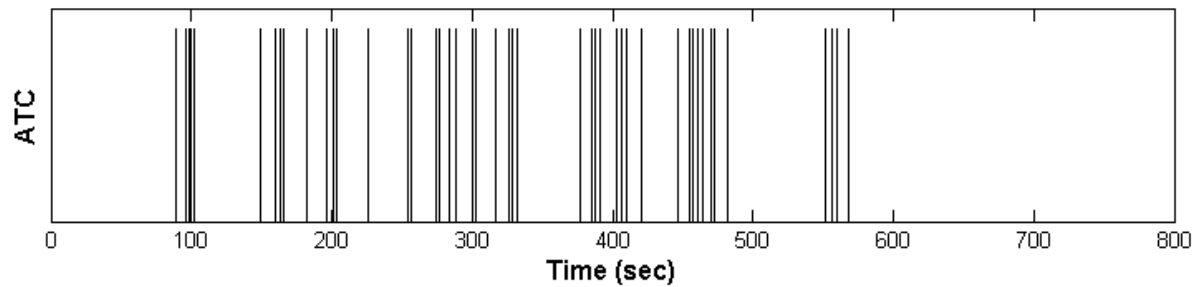
# Function Allocation Matrix

Functions	Authority allocations (AA)					Responsibility allocations (RA)					Incoherent Allocation
	1	2	3	4	5	1	2	3	4	5	
Vertical profile	G	A	A	A	A	G	A	A	A	A	No Ground
A/C config mgmt	G	A	A	A	A	G	A	A	A	A	No ground
Lateral control	G	A	A	A	A	G	A	A	A	A	50% Ground
Speed control	G	G	A	A	A	G	G	A	A	A	100% Ground
Lateral profile	G	G	G	A	A	G	G	G	A	A	No Ground
Vertical profile	G	G	G	G	A	G	G	G	G	A	75% Ground
Speed mgmt	G	G	G	G	A	G	G	G	G	A	No Ground
Non-nominal situation mgmt	G	G	G	G	A	G	G	G	G	A	75% Ground

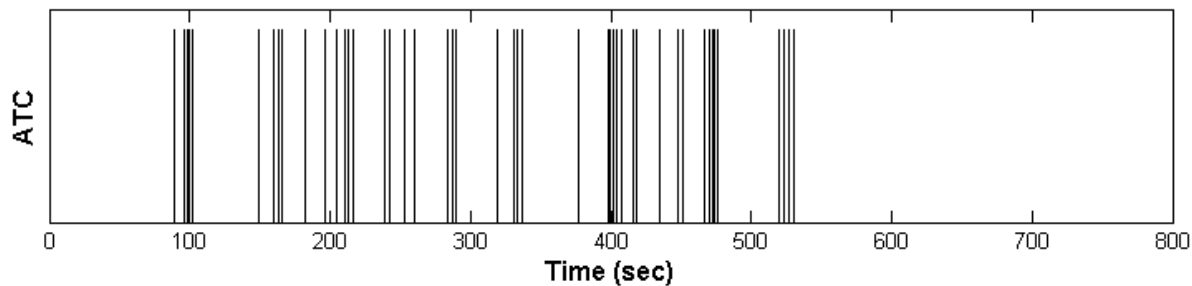
# Action Time Traces FA4



# Action Time Traces FA6



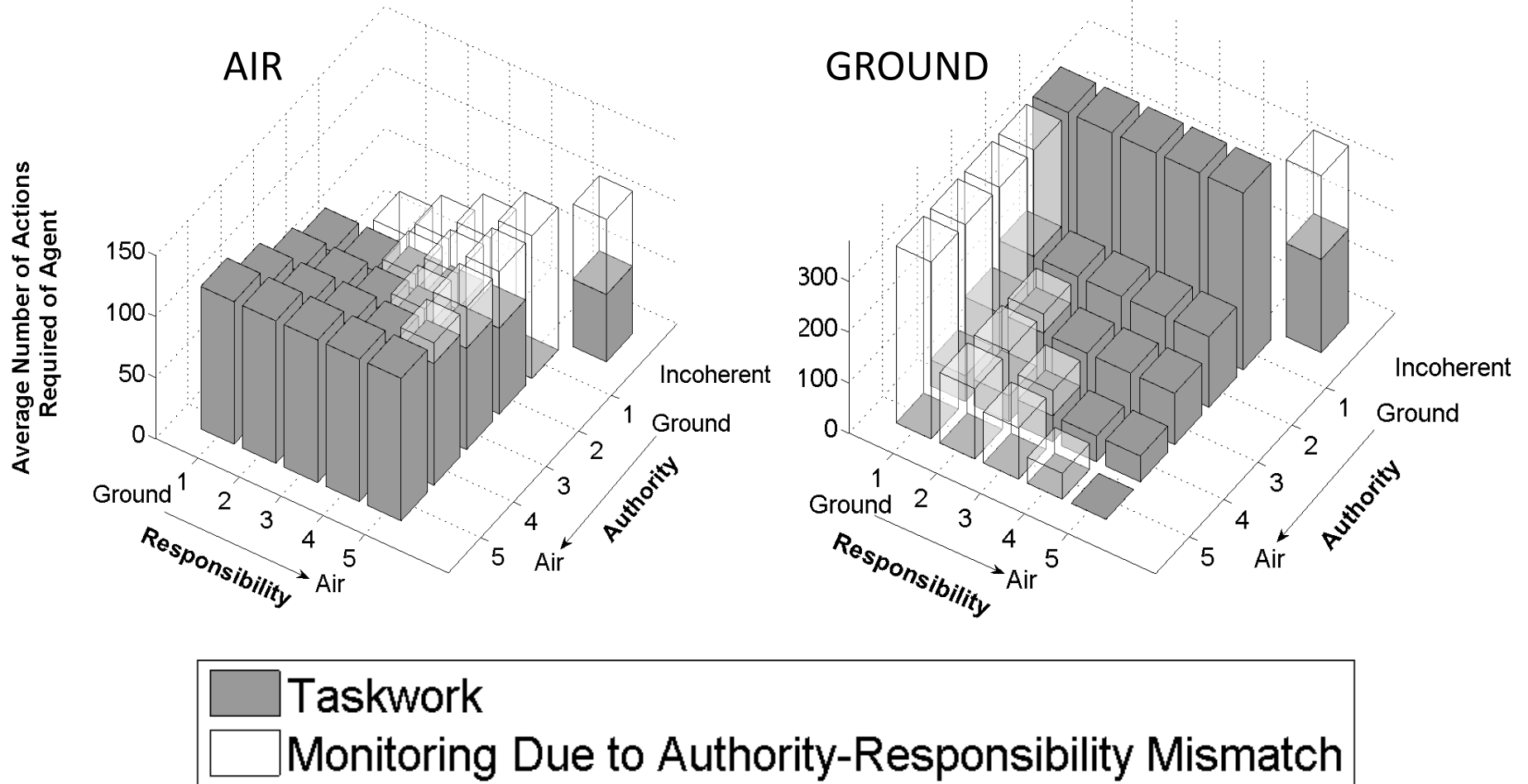
Nominal scenario



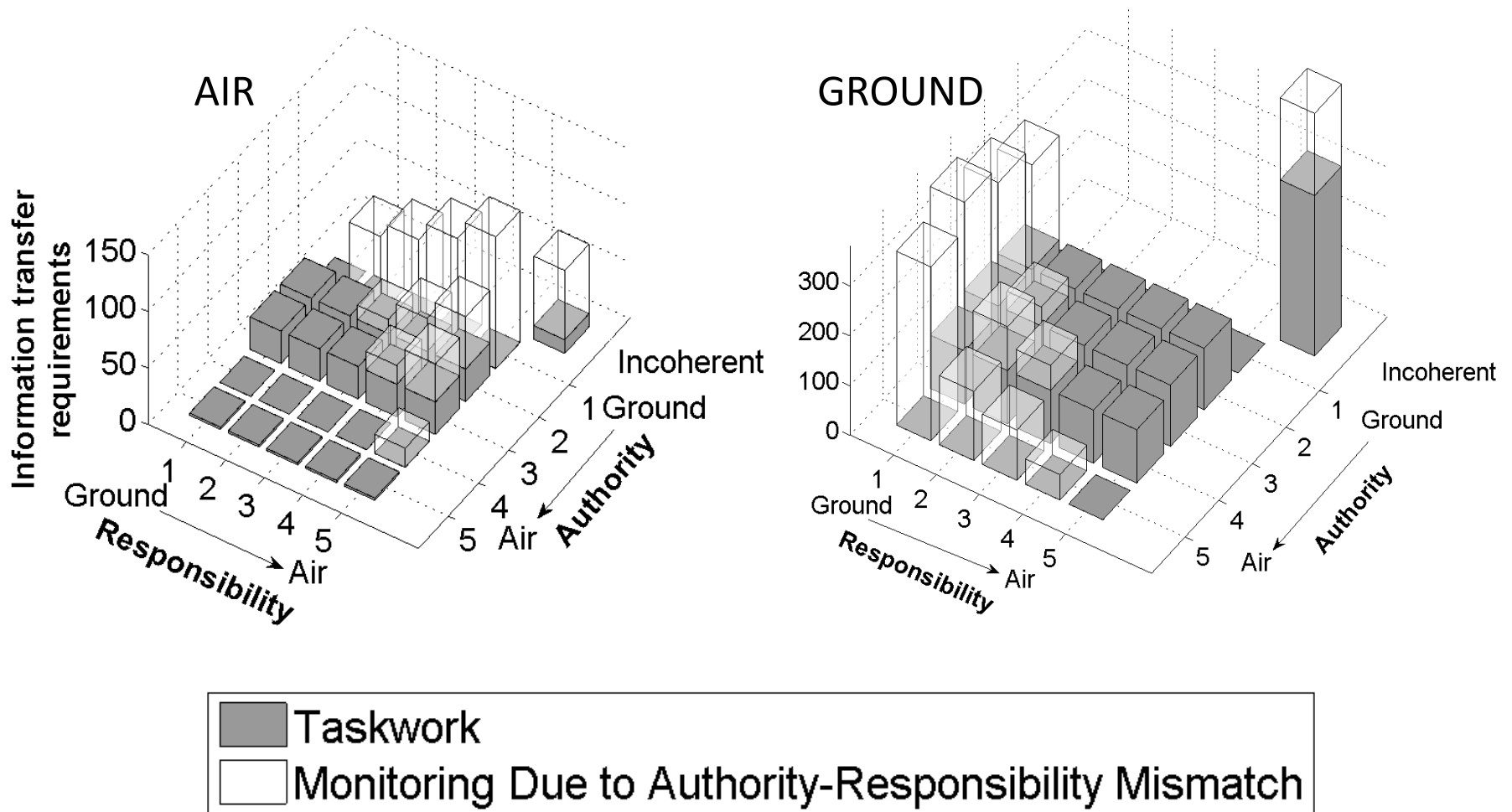
Off-nominal scenario



# Aggregate Number of Actions



# Aggregate Information Requirement



# Summary

- ❖ We can simulate concepts of operation early in design
  - ✧ Simple case study here scales to larger analyses
- ❖ Can identify problems in the inherent function allocation
  - ✧ Static function allocation
  - ✧ Can also examine dynamic function allocation and delegation

**Helps identify and design-out human factors concerns with taskload and information**

# Further Extensions

- ❖ Here focused on ‘early-on design’
  - ✧ Because agents executed actions perfectly, results reflect concept of operation and function allocation
  - ✧ Ought to design-out such problems before detailed design of technology, training, procedures and interfaces
- ❖ Can then progressively incorporate more detail
  - ✧ Different methods of performing same function
    - Depending on which agent executes the work
    - Depending on immediate taskload of agent
  - ✧ Verifiable aspects of human performance
    - Taskload limits
    - Response Time

# Further Extensions

- ❖ Models of communication between agents
  - ✧ Latency/duration/delay
  - ✧ Drop-out or communication error rates
  - ✧ Cost per bit of communication

# Thank You!

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Thank you

