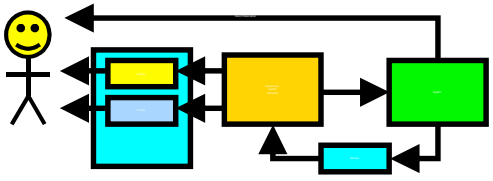
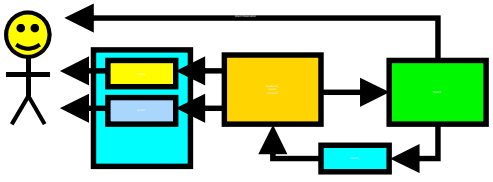


16.422 Workload and Situation Awareness

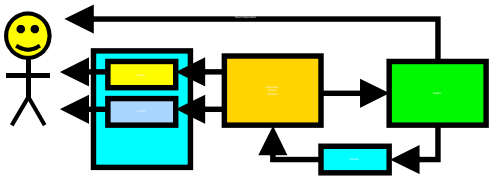
Prof. R. John Hansman

Acknowledgements to Mica Ensley



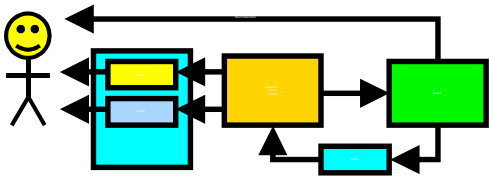
Workload

- What is workload?
- Why is it important?



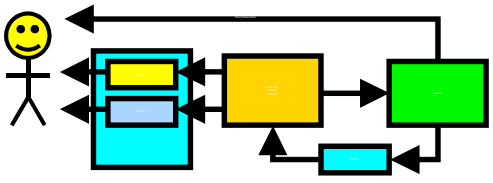
Driving Case: B757/767 2 or 3 person crew ?

- **Prior to 767 somewhat arbitrary break at 100 seats**
  - ❑ DC-9 (2 person crew - pilot, co-pilot)
  - ❑ B-727 (3 person crew - pilot, co-pilot, flight engineer)
- **B-757/767 Designed for 2 person Crew**
  - ❑ Use of automation and simplified systems so minimize systems management
  - ❑ Use of Advanced Cockpit to Increase SA and make primary flight tasks easier
- **Safety concerns raised by Air Line Pilots Association (ALPA)**
  - ❑ Workload
  - ❑ Off Nominal and Emergency Conditions (eg manual pressurization)
  - ❑ Job Protection issues
- **Workload became political and regulatory issue**

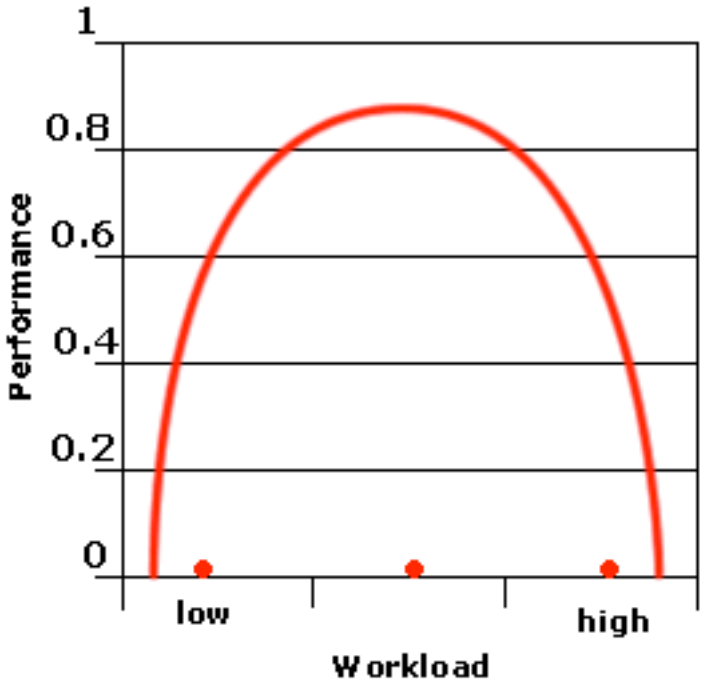


Workload Definitions?

- **Physical Workload**
  - ❑ Traditional view of work for manual labor
  - ❑ Can be measured in physical terms (ergs, joules, ..)
  - ❑ Limited impact of skill to minimize (ie subject variability)
- **“Mental” Workload**
  - ❑ Often not related to physical work
  - ❑ Internal measure difficult to observe
  - ❑ Varies with task difficulty and complexity
  - ❑ Significant subject variability
  - ❑ No real consensus on what it is
  - ❑ Workload is a “dirty” word in Experimental Psychology
- **Activity**
  - ❑ Things that are done
  - ❑ Physical activity easy to measure
- **Taskload**
  - ❑ External measure of tasks which need to be done
  - ❑ Can be weighted for factors such as task difficulty or complexity

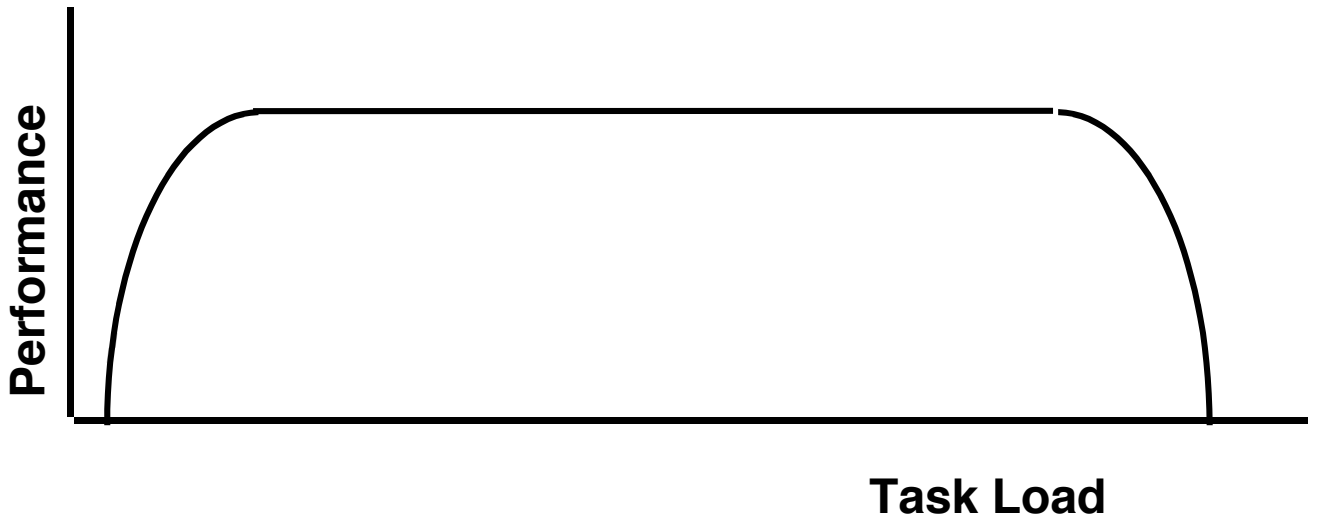


Yerks-Dotson Law

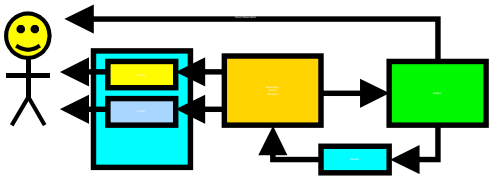


http://www.hf.faa.gov/Webtraining/Cognition/Workload/Mental3.htm

Typical Performance vs. Task Load Curve

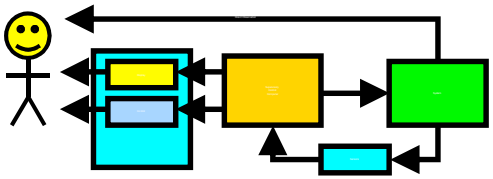


Helicopter Observation of Driver Example



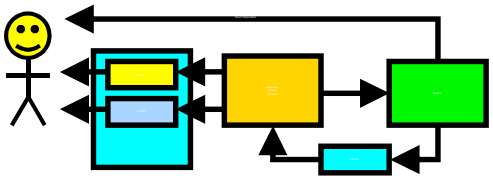
Off Nominal Considerations

- **System design often driven by off-nominal conditions**
  - ❑ Emergencies
  - ❑ System Failures
  - ❑ Failure of the Automation system
- **Secondary task considerations**
- **Cockpit Example**
  - ❑ Emergency diversion
  - ❑ Depressurization



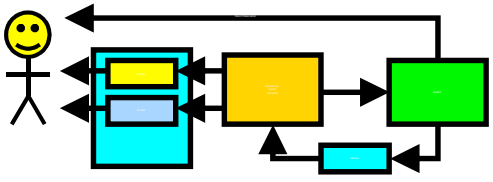
Workload Measurement Approaches

- **Objective Performance Approaches**
  - ❑ Primary Task (Yerks Dodson)
  - ❑ Secondary Task (works well to measure saturation threshold)
    - ◆ Concept of Spare Cognitive Capacity
- **Objective Physiological Measures (weak)**
  - ❑ Heart Rate Variability
  - ❑ Pupil Diameter
  - ❑ EEG P 300
  - ❑ Skin Galvanic Response
  - ❑ New Imaging Methods
- **Subjective Workload Assessment Techniques**
  - ❑ Formal
  - ❑ Direct Query



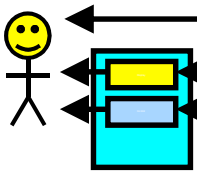
Subjective Assessment Techniques

- Simpson-Sheridan/ Cooper-Harper
- Bedford Scale
- Rate or Perceived Exertion (RPE)
- NASA Task Load Index (TLX)
- Defense Research Agency Workload Scale (DRAWS)
- Malvern Capacity Estimate (MCE)

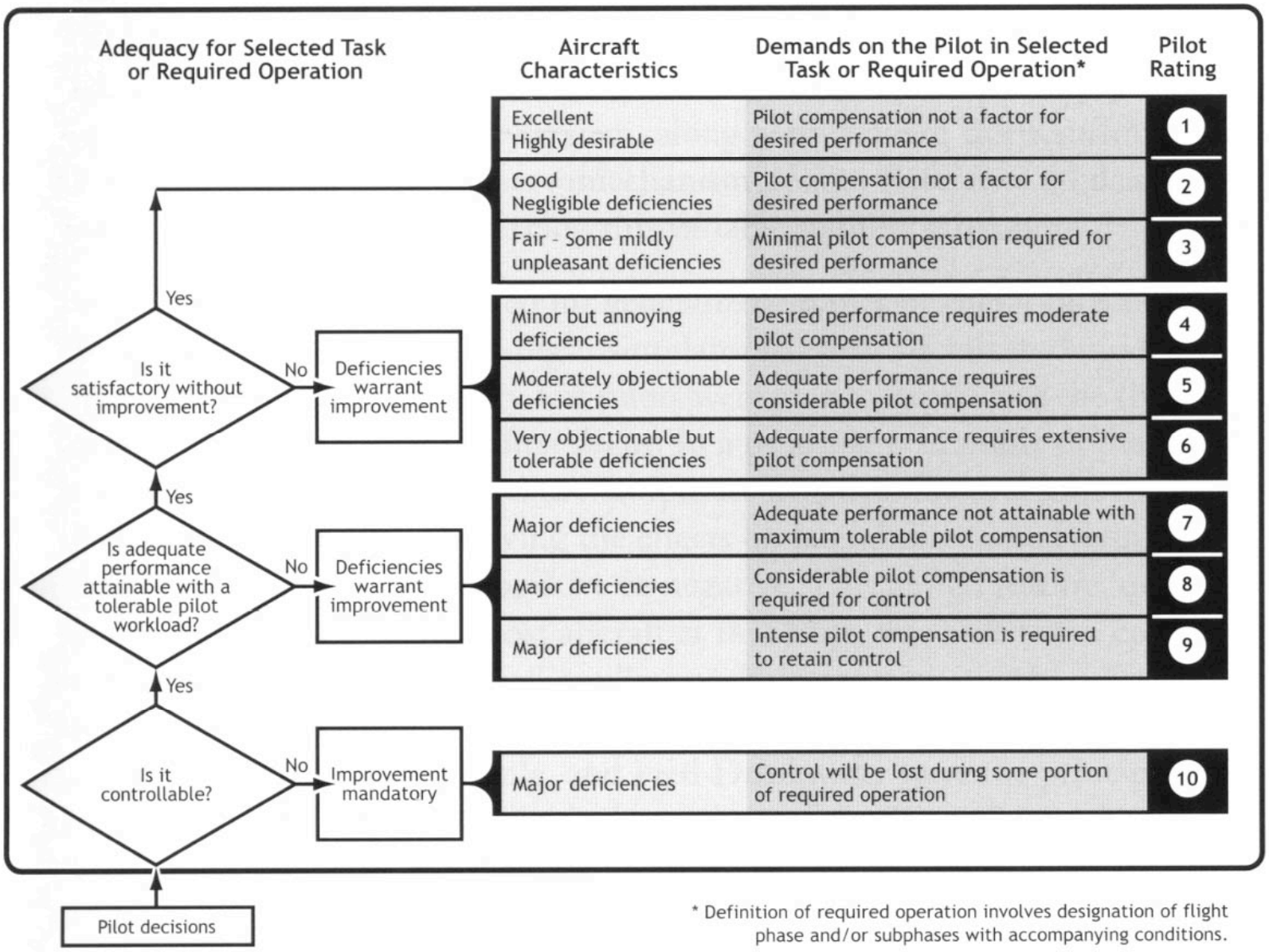


Simpson-Sheridan Scale

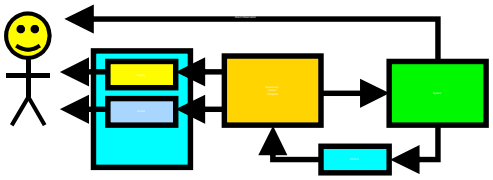
- **Modified Cooper Harper Scale for Workload**



Cooper Harper Handling Qualities Rating Scale



Source: http://history.nasa.gov/SP-3300

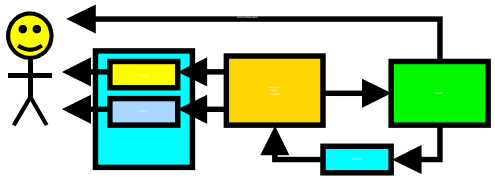


Bedford Scale

- **The Bedford Scale is a uni-dimensional rating scale designed to identify operator's spare mental capacity while completing a task. The single dimension is assessed using a hierarchical decision tree that guides the operator through a ten-point rating scale, each point of which is accompanied by a descriptor of the associated level of workload. It is simple, quick and easy to apply in situ to assess task load in high workload environments, but it does not have a diagnostic capability.**

- **Refs:** Roscoe and Ellis, 199

Source: Eurocontrol http://www.eurocontrol.int/eatmp/hifa/hifa/HIFAdata_tools_workload.html

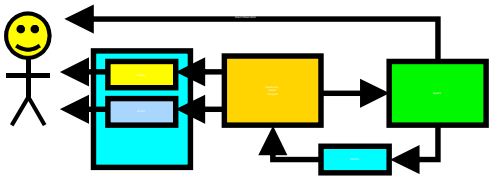


Rate of Perceived Exertion
Borg RPE Scale

- 6 No exertion at all
- 7 Extremely Light
- 8
- 9 Very Light
- 10
- 11 Light
- 12
- 13 Somewhat Hard
- 14
- 15 Hard (Heavy)
- 16
- 17 Very Hard
- 18
- 19 Extremely Hard
- 20 Maximal Exertion

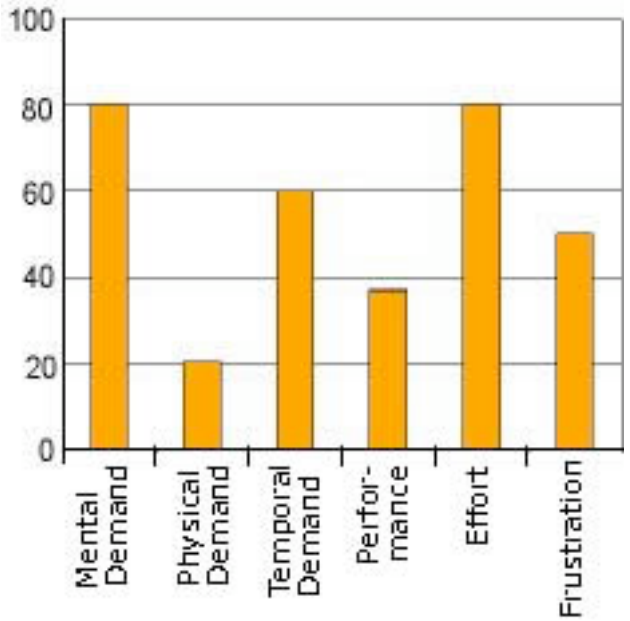
- Borg Rate of Perceived Exertion Scale
- Originally developed for physical workload
- Intended to be ordinal scale
- Modified 0-10 version CR-10

Source: http://dticam.dtic.mil

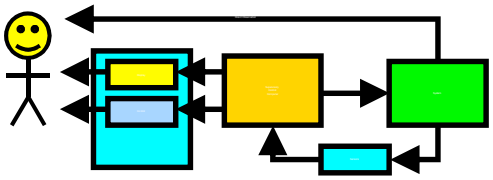


NASA TLX
Task Load Index

- **Sandy Hart**
- **5 Element Structured Subjective Assessment**
- **Individual relative element calibration**
- **Requires Trained Users**
- **Often used but difficult to interpert**



http://www.hf.faa.gov/Webtraining/Cognition/Workload/Mental3.htm

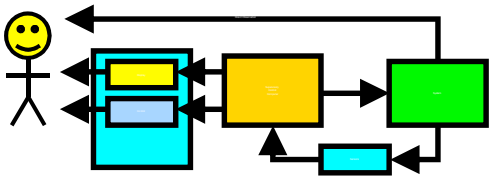


DRAWS

- **DRAWS is a multi-dimensional tool (similar to NASA TLX) used to gain a subjective assessment of workload from operators. The rating scales are input demand (demand from the acquisition of information from external sources), central demand (demand from mental operations), output demand (demand from the responses required by the task), and time pressure (demand from the rate at which tasks must be performed). DRAWS offers ease of data collection and ratings can be obtained during task performance by asking respondent to call out ratings (from 0 to 100) to verbal prompts. This can also provide a workload profile through a task sequence.**

- **Refs:** Farmer et al, 1995; Jordan et al, 1995.

Source: Eurocontrol http://www.eurocontrol.int/eatmp/hifa/hifa/HIFAdata_tools_workload.html

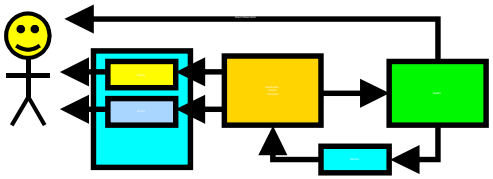


Malvern Capacity Estimate

- MACE is designed as a quick simple and direct measure of maximum capacity. It is designed to provide a direct measure of air traffic controllers' subjective estimates of their own aircraft handling capacity. MACE is applied at the end of a work sequence (e.g., simulation trial) and provides capacity estimates in aircraft per hour. Applications have typically been in simulation environments.

- Refs: Goillau and Kelly, 1996.

Source: Eurocontrol http://www.eurocontrol.int/eatmp/hifa/hifa/HIFAdata_tools_workload.html

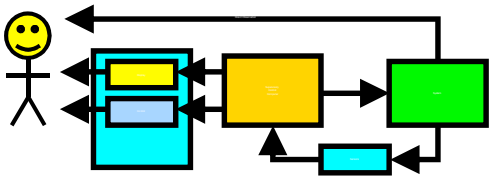


Instant Self Assessment of Workload (ISA)

- **ISA was developed as a tool that an operator could use to estimate their perceived workload during real-time simulations. The operator is prompted at regular intervals to give a rating of 1 to 5 of how busy he is (1 means under-utilized, 5 means excessively busy). These data can be used to compare operators' perceived workload, for example, with and without a particular tool, or between different systems.**

- **Refs:** Jordan, 1992.

Source: Eurocontrol http://www.eurocontrol.int/eatmp/hifa/hifa/HIFAdata_tools_workload.html

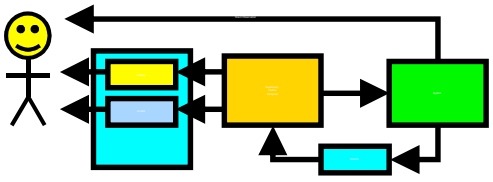


Subjective Workload Assessment Techniques (SWAT)

- SWAT is a subjective scale of workload that can be administered easily in operation situations and is available as a PC-based software tool. It is multi-dimensional tool incorporating factors of temporal load, mental effort and psychological stress. SWAT has two stages: The respondent ranks the levels of the three workload scales in order from the lowest to highest workload prior to the trial, and rates each of the scales during the trial. It was originally designed to assess aircraft cockpit and other crew-station environments to assess the workload associated with the operators' activities.

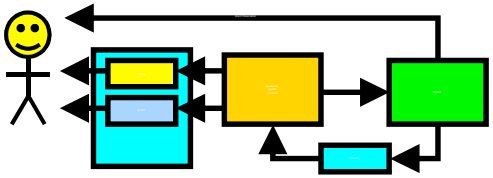
- Refs: Reid and Nygren, 1988; Dean 1997

Source: Eurocontrol http://www.eurocontrol.int/eatmp/hifa/hifa/HIFAdata_tools_workload.html



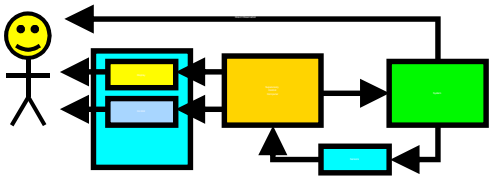
Situation Awareness

- ***Term originally defined for air combat***
- ***Working Definition (Hansman) : Sufficiently detailed mental picture of the vehicle and environment (i.e. world model) to allow the operator to make well-informed (i.e., conditionally correct) decisions.***
- ***Individual SA and Team SA***
- ***Has become an extremely popular and powerful concept***
- ***Mica Endsley: Situation vs Situational Awareness***



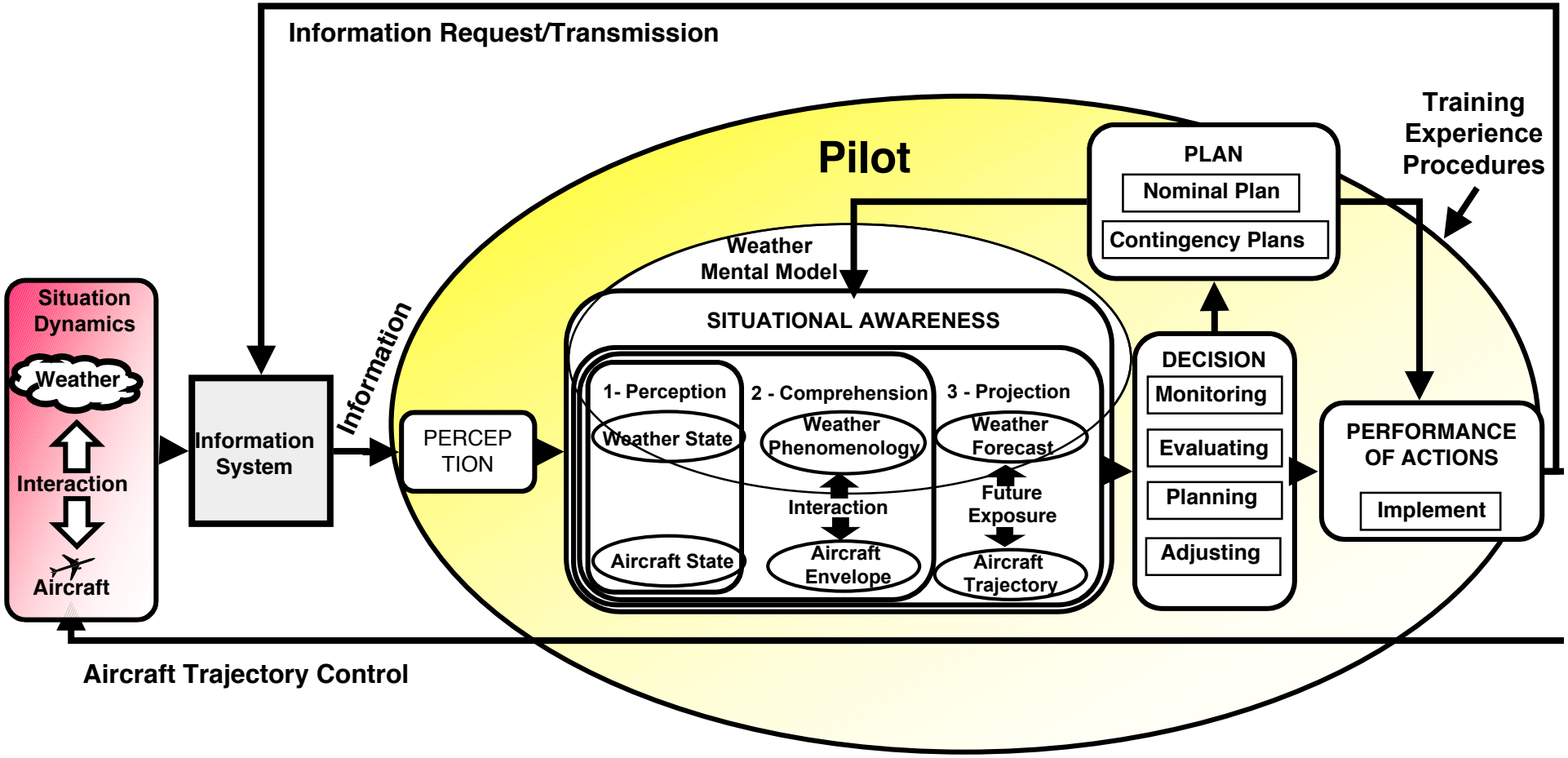
Endsley
Situation Awareness Model

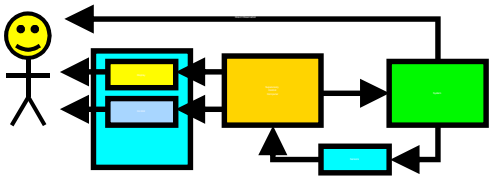
(Image removed due to copyright considerations.)



Model of Pilots' Cognitive Constructs of Information Processing

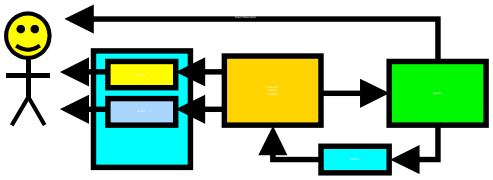
References: Endsley, 1995; Pawlak, 1996; Reynolds *et al., 2002*





Enhancing SA

- **Level 1 - Perception**
  - ❑ Enhanced Perception Systems (eg Enhanced Vision Systems)
  - ❑ Alerting Systems
- **Level 2 - Comprehension**
  - ❑ SA Displays (eg Moving Map Displays, EGPWS)
- **Level 3 - Projection**
  - ❑ Displays
  - ❑ Decision Support Tools



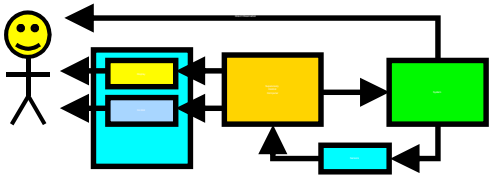
Enhancing SA

- **Level 1 - Perception**
  - ❑ Enhanced Perception Systems (eg Enhanced Vision Systems)
  - ❑ Alerting Systems
- **Level 2 - Comprehension**
  - ❑ SA Displays (eg Moving Map Displays, EGPWS)
- **Level 3 - Projection**
  - ❑ Displays
  - ❑ Decision Support Tools

Enhanced Vision & Synthetic Vision Systems

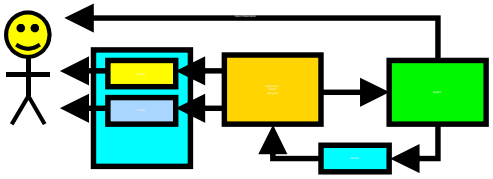
Enhanced Vision

Synthetic Vision



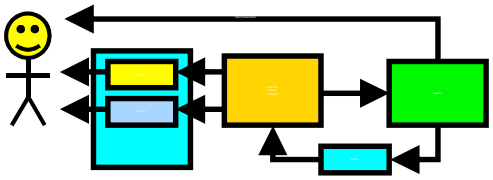
Enhanced Vision

Picture of the outside world created by real-time weather and darkness penetrating on-board sensors (eg. Cameras, FLIR, MMW radar, and weather radar).



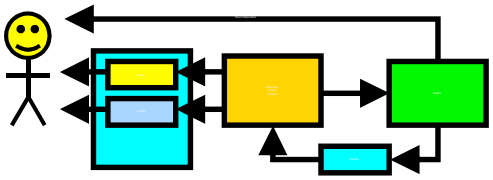
Synthetic Vision

Picture of the outside world created by combining precise navigation position with databases of comprehensive geographic, cultural and tactical information.



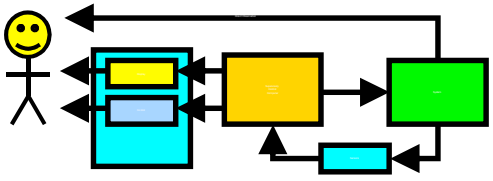
Enhancing SA

- **Level 1 - Perception**
  - ❑ Enhanced Perception Systems (eg Enhanced Vision Systems)
  - ❑ Alerting Systems
- **Level 2 - Comprehension**
  - ❑ SA Displays (eg Moving Map Displays, EGPWS)
- **Level 3 - Projection**
  - ❑ Displays
  - ❑ Decision Support Tools



Enhancing SA

- **Level 1 - Perception**
  - ❑ Enhanced Perception Systems (eg Enhanced Vision Systems)
  - ❑ Alerting Systems
- **Level 2 - Comprehension**
  - ❑ SA Displays (eg Moving Map Displays, EGPWS)
- **Level 3 - Projection**
  - ❑ Displays
  - ❑ Decision Support Tools



New Weather Datalink Products

ARNAV

Avidyne

Bendix/King FAA FISDL

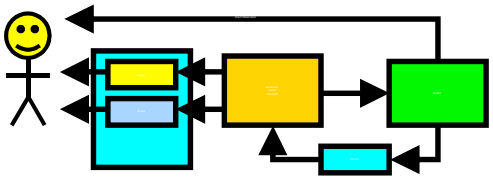
Control Vision

Echo Flight

Garmin

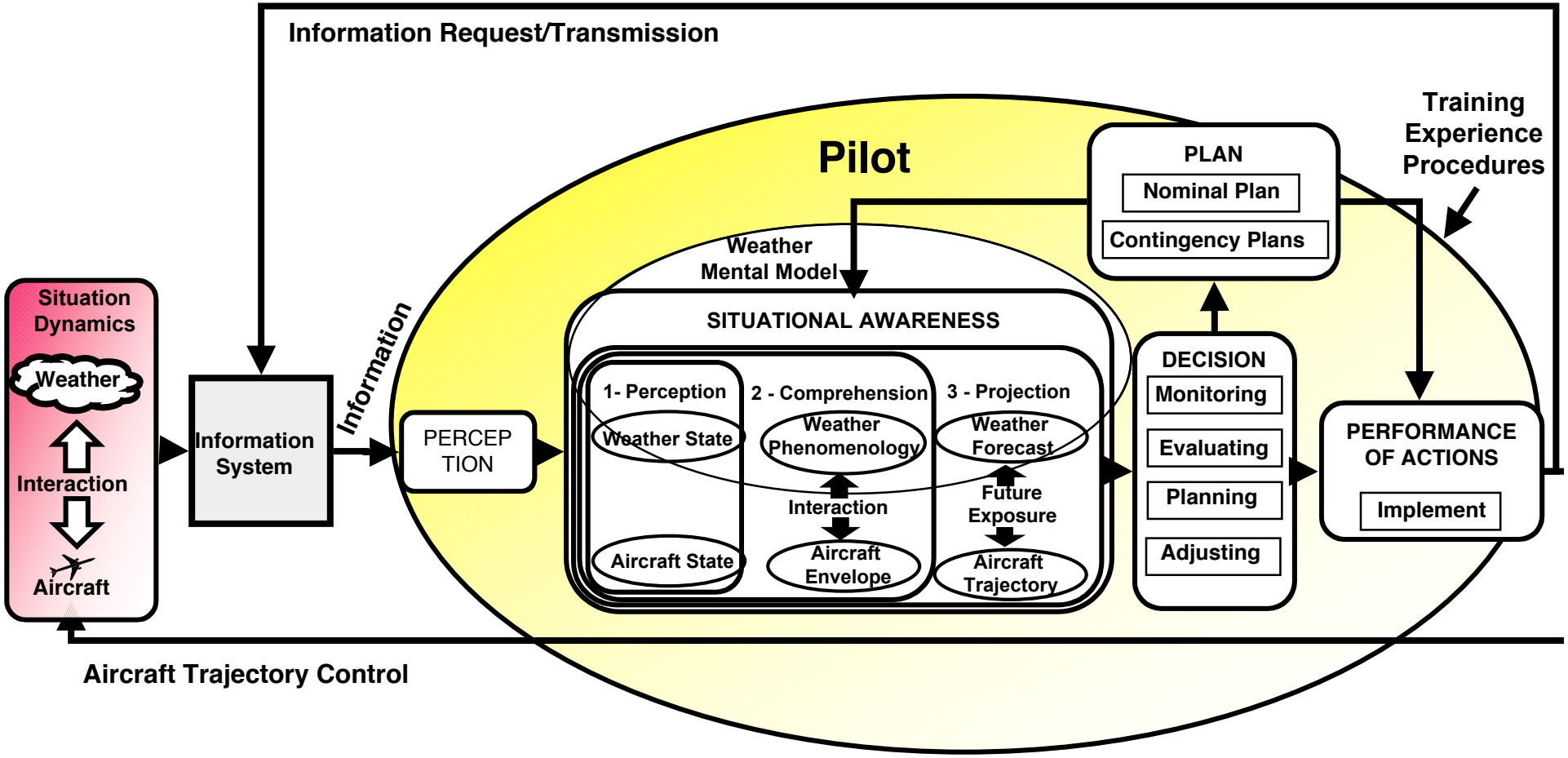
UPS – AirCell

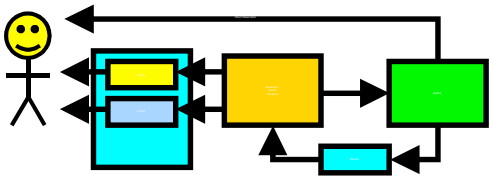
Vigyan



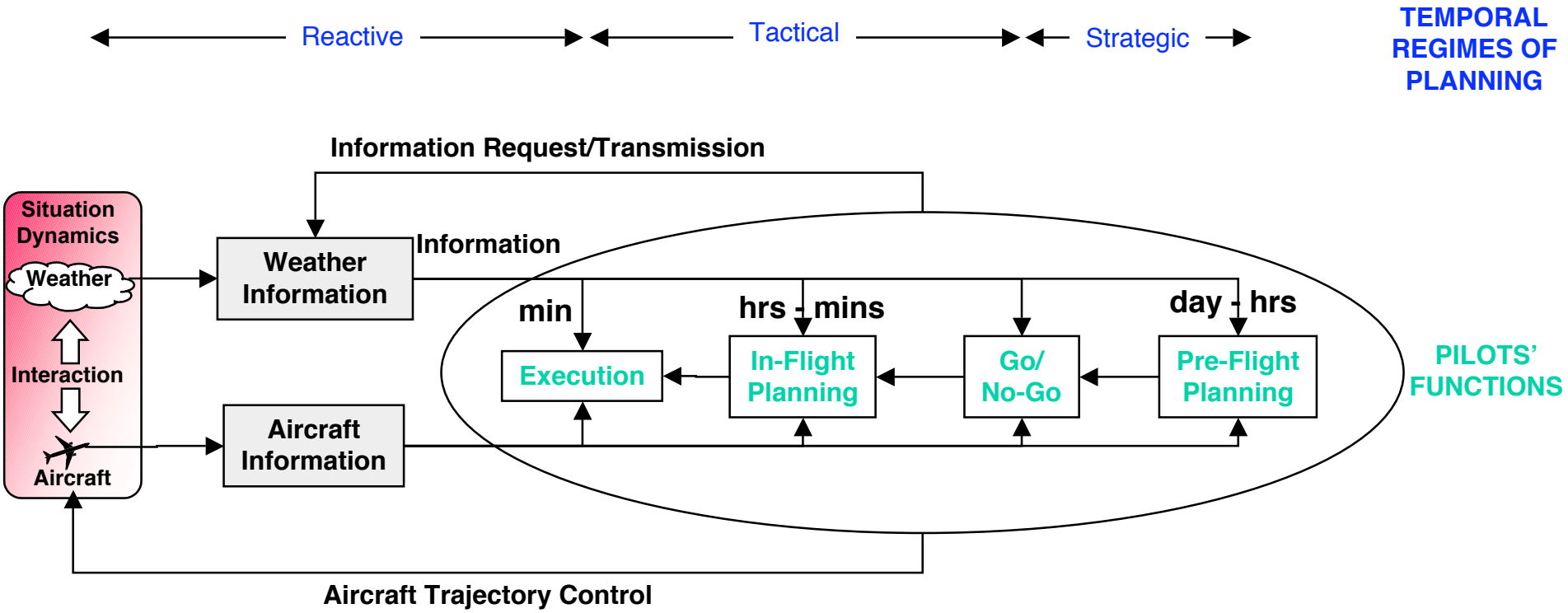
Model of Pilots' Cognitive Constructs of Information Processing

References: Endsley, 1995; Pawlak, 1996; Reynolds *et al., 2002*





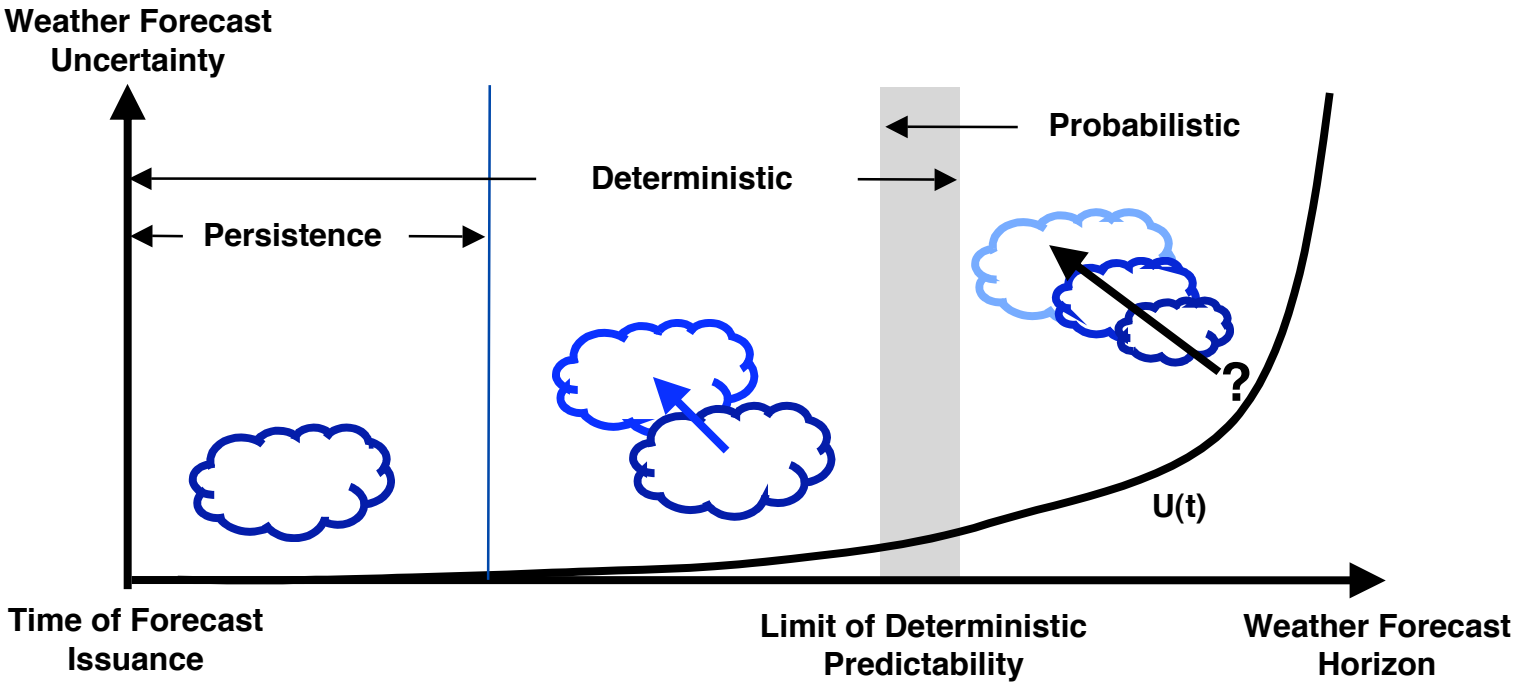
Temporal Representation of Pilots' Functions

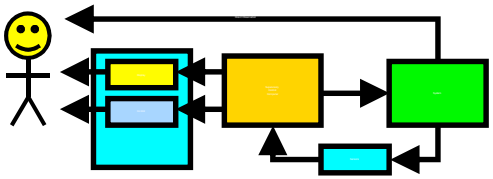


Temporal Regimes of Wx Predictability

Uncertainty Growth with Forecast Horizon

Time constants dependent on:
- Weather phenomena and phenomenology (e.g., convective weather, droplet size distribution, temperature)
- Phase of weather phenomena (e.g., storm initiation versus storm decay)





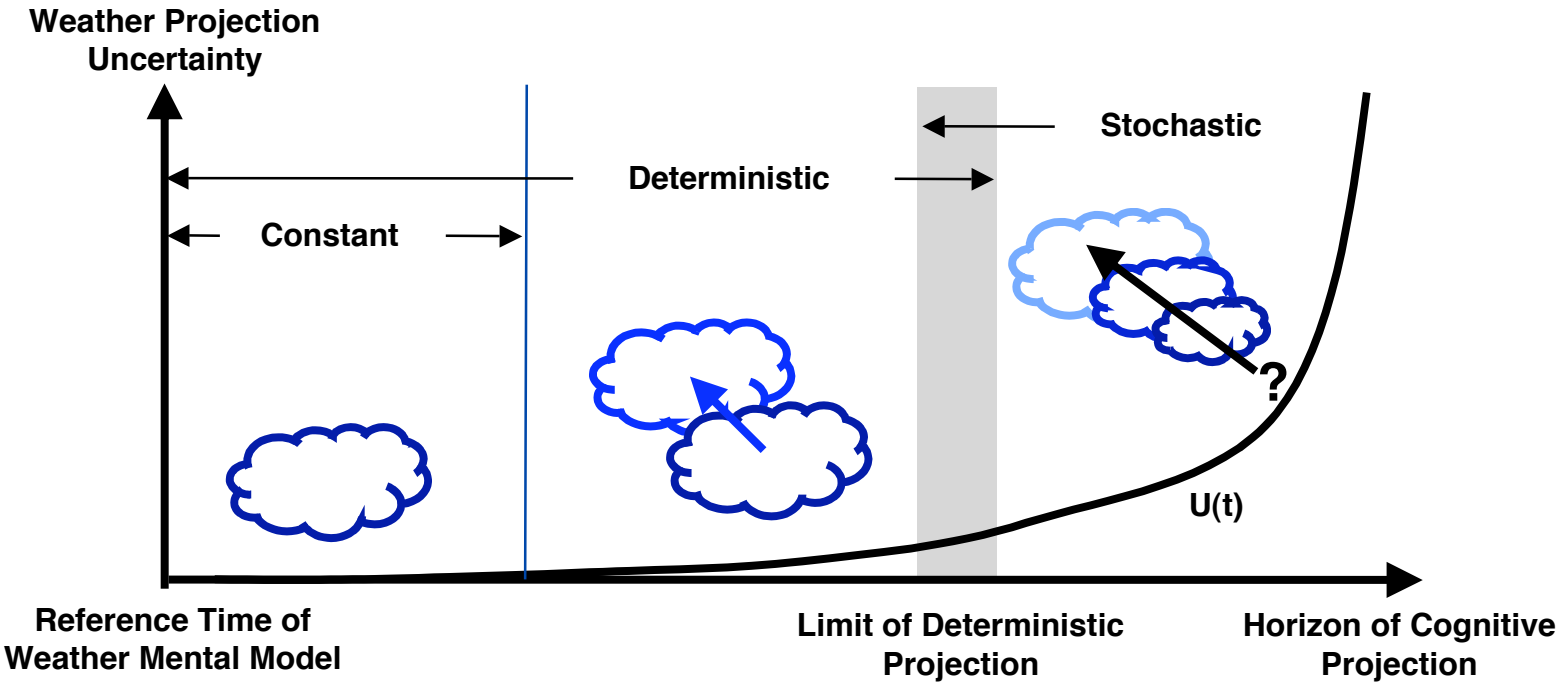
Temporal Regimes of Cognitive Projection

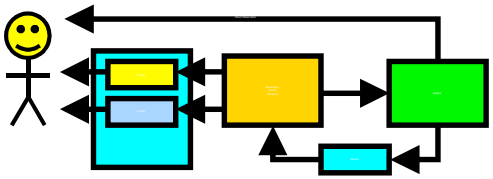
Uncertainty Growth with Horizon of Projection

Weather representation based on observation over a time period where conditions do not significantly change

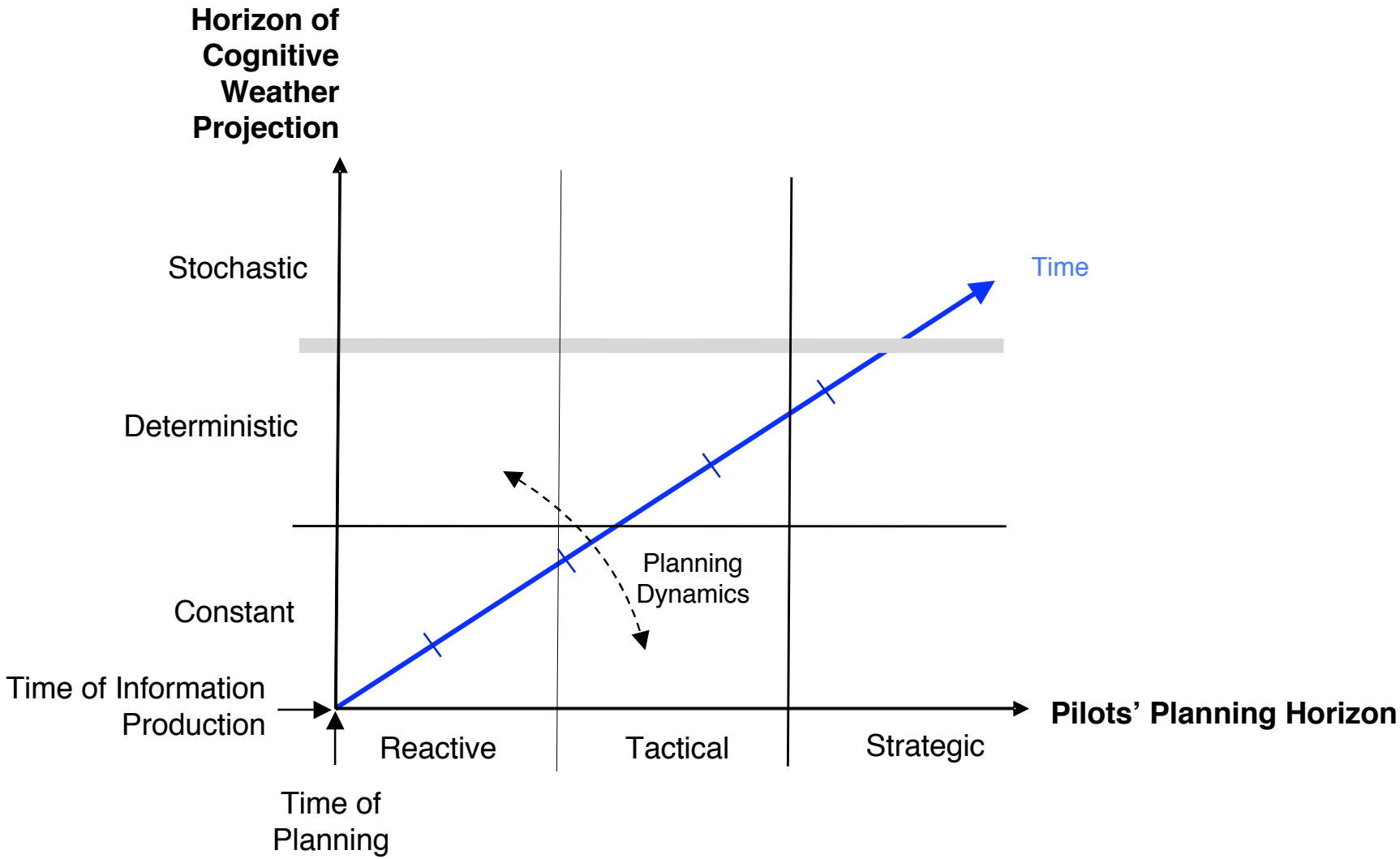
Weather representation based on deterministic forecast of "acceptable" accuracy

Weather representation at time in future beyond "predictability limit"

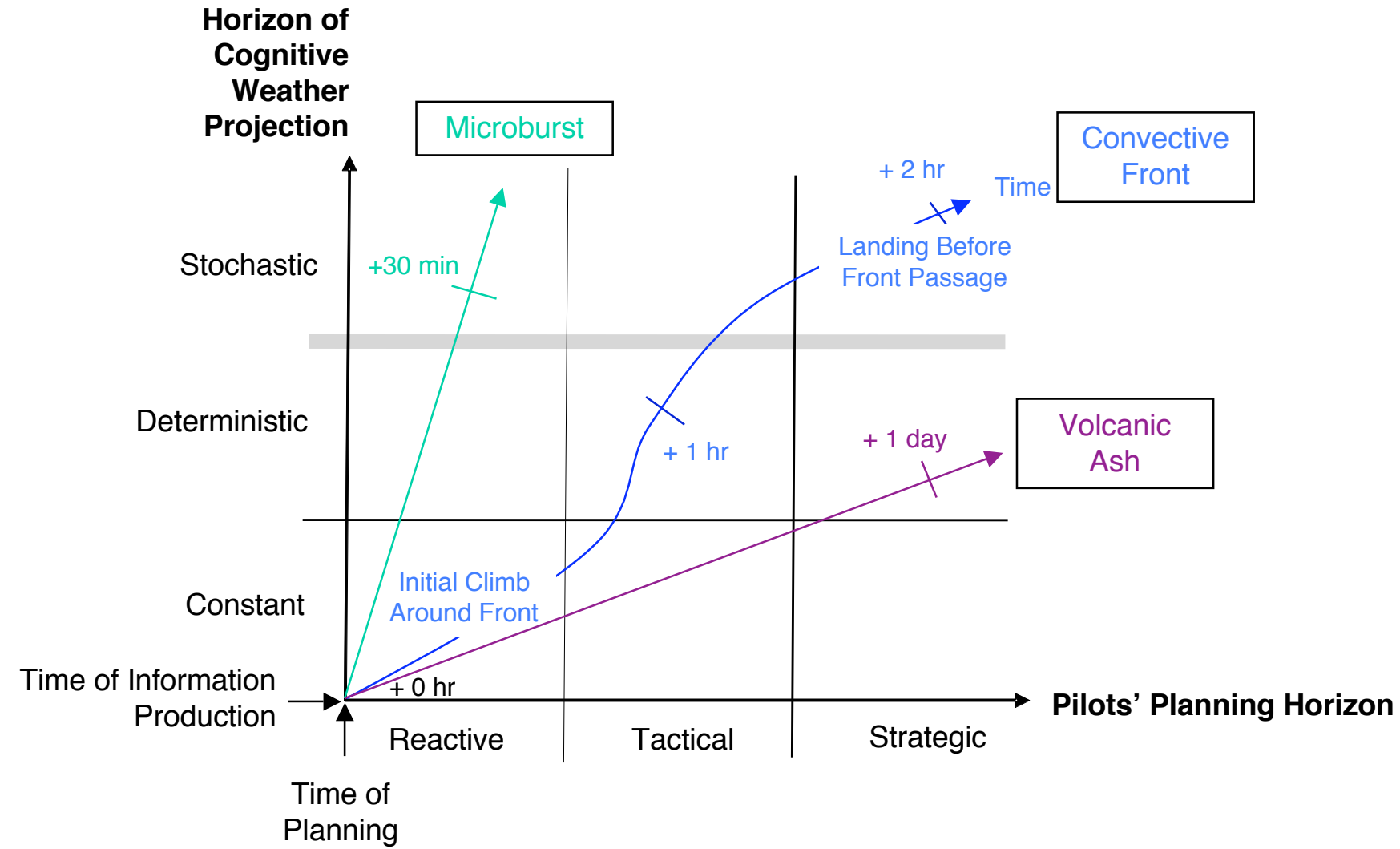


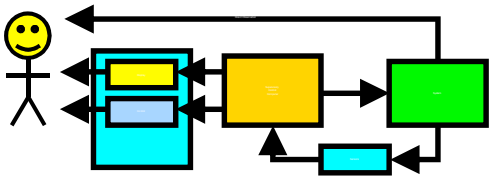


Temporal Framework of Decision-Making Representation of Cognitive Plan



Representation of Cognitive Plan Examples

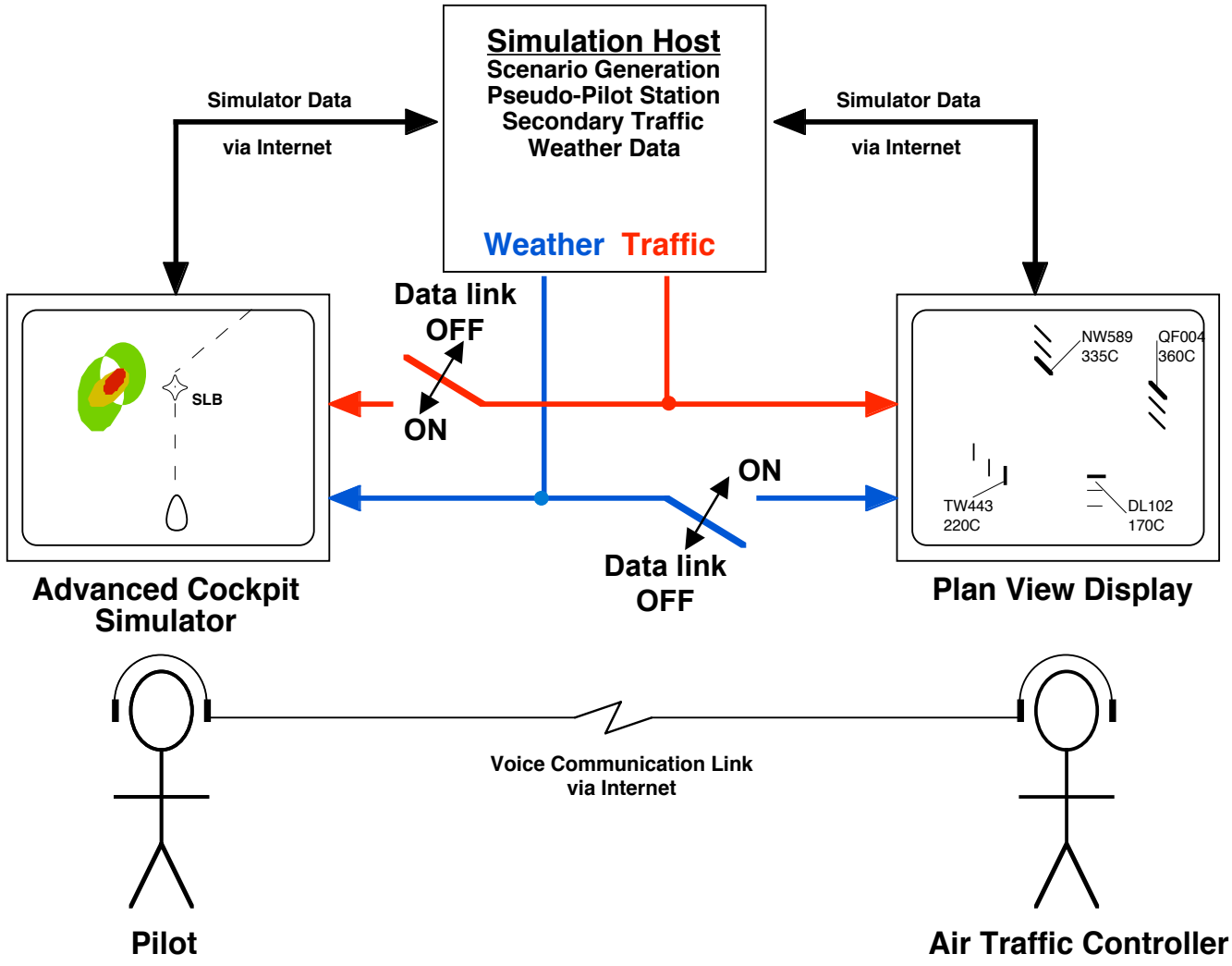




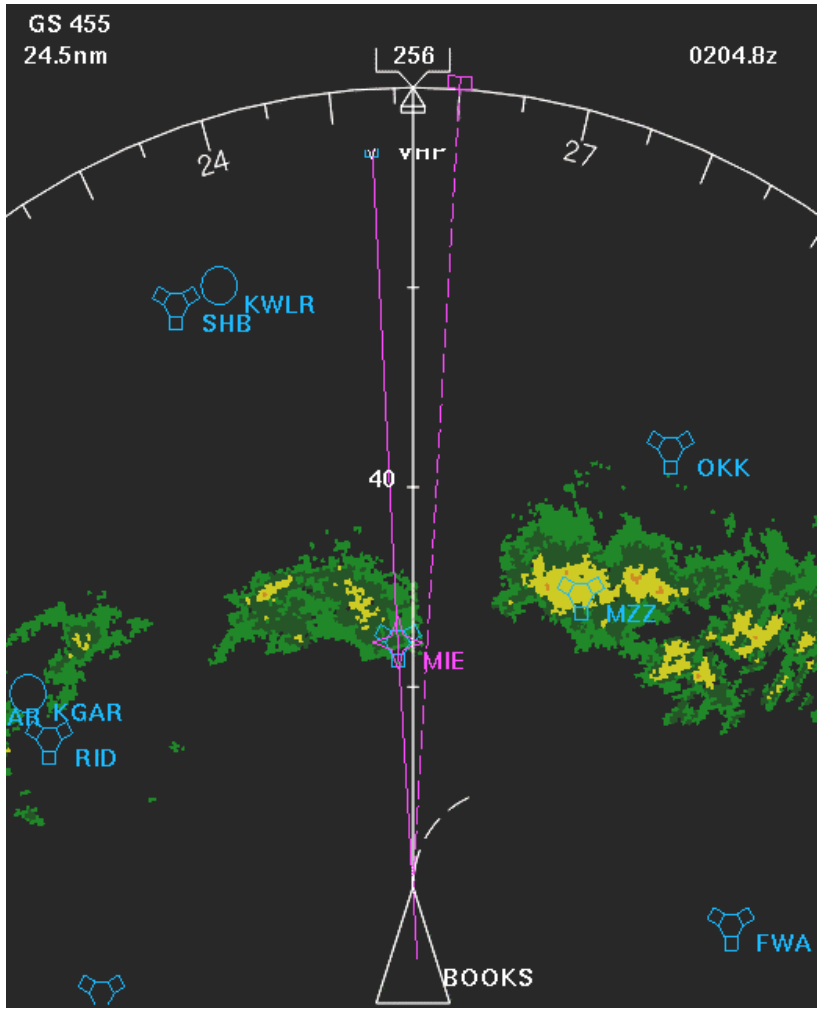
Measurement of Situation Awareness

- **Situation Awareness General Assessment Technique (SAGAT)**
  - ❑ Endsley
  - ❑ Requires interruptions
  - ❑ Invasive (queries may influence subsequent SA)
  - ❑ Time issue
  - ❑ Requires knowledge of required SA elements
    - ◆ Goal Directed Task Analysis
- **Testable Response Approach**
  - ❑ Pritchett and Hansman
  - ❑ Works for scenario based studies
  - ❑ Requires scenarios where differential SA implies differential action

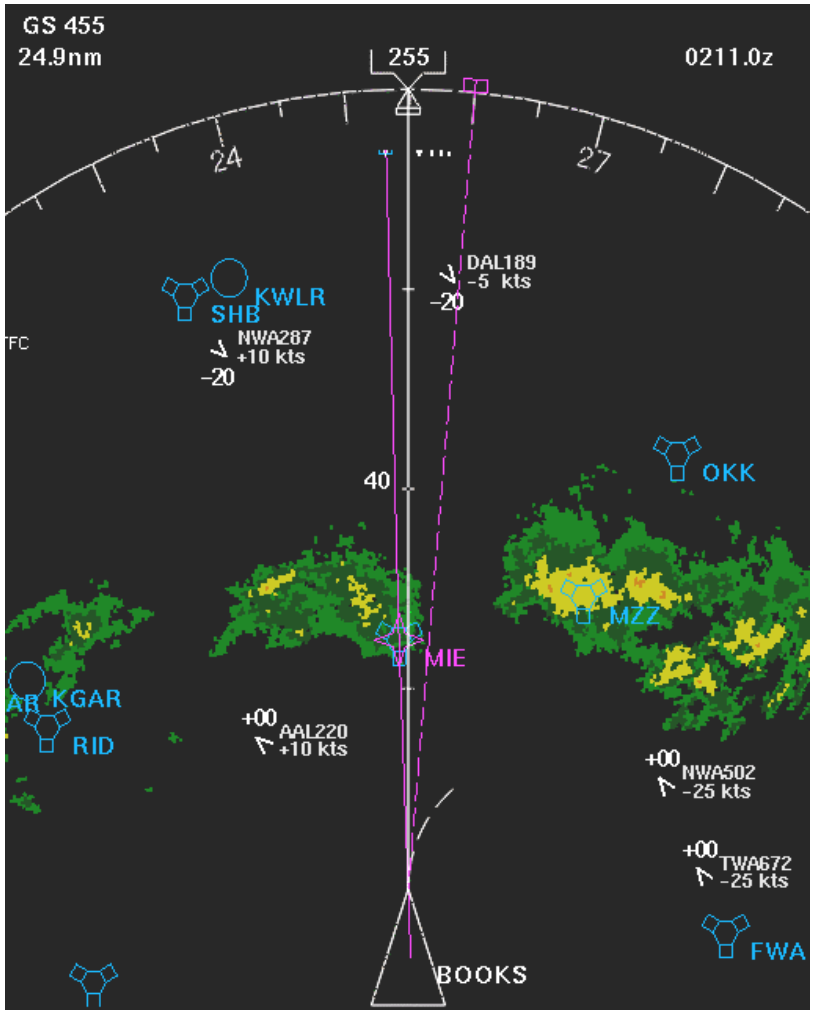
Datalink Shared Information Experiment (Traffic & Weather)



From the Cockpit

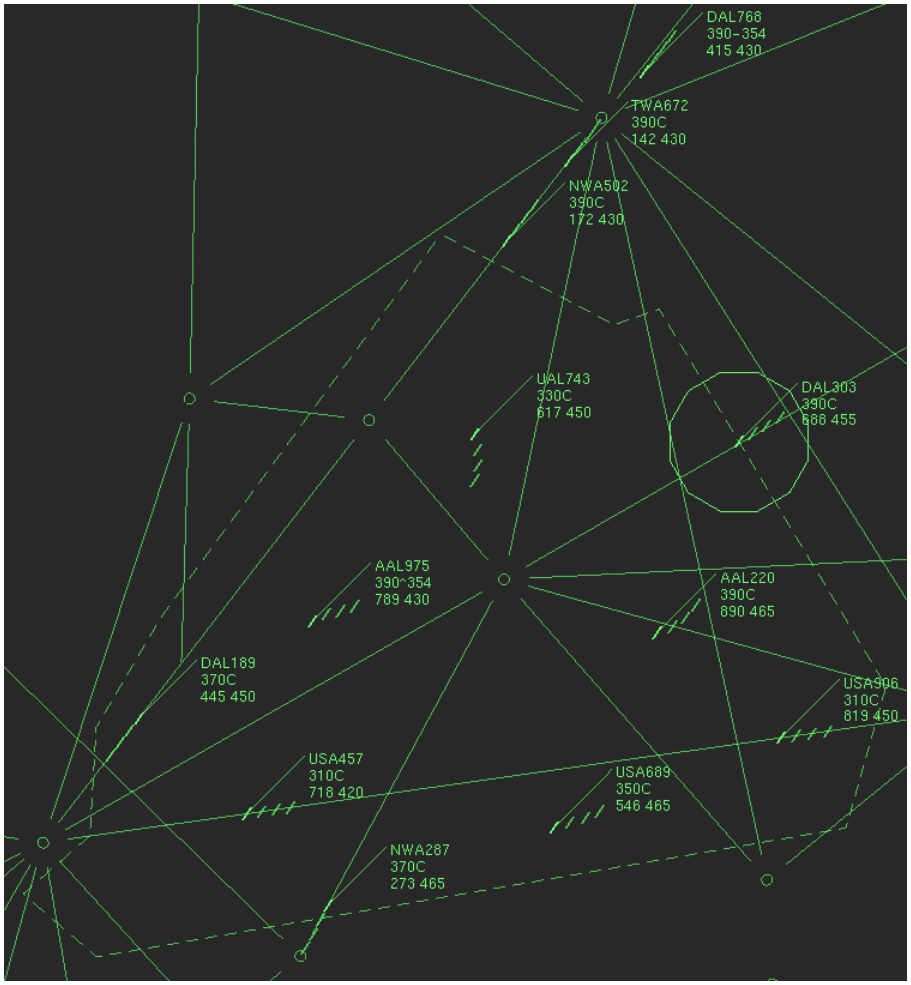


Data link OFF

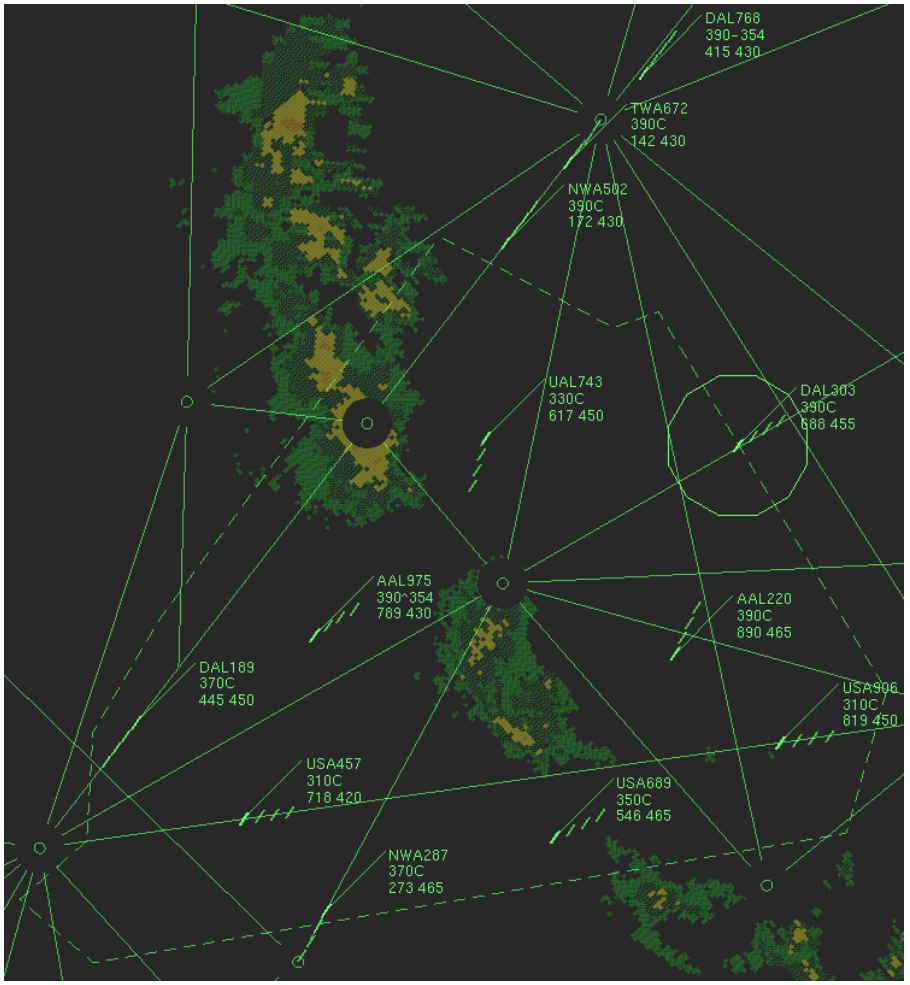


Data link ON

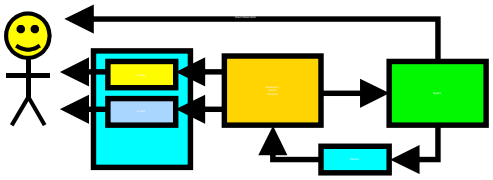
From the ATC Display



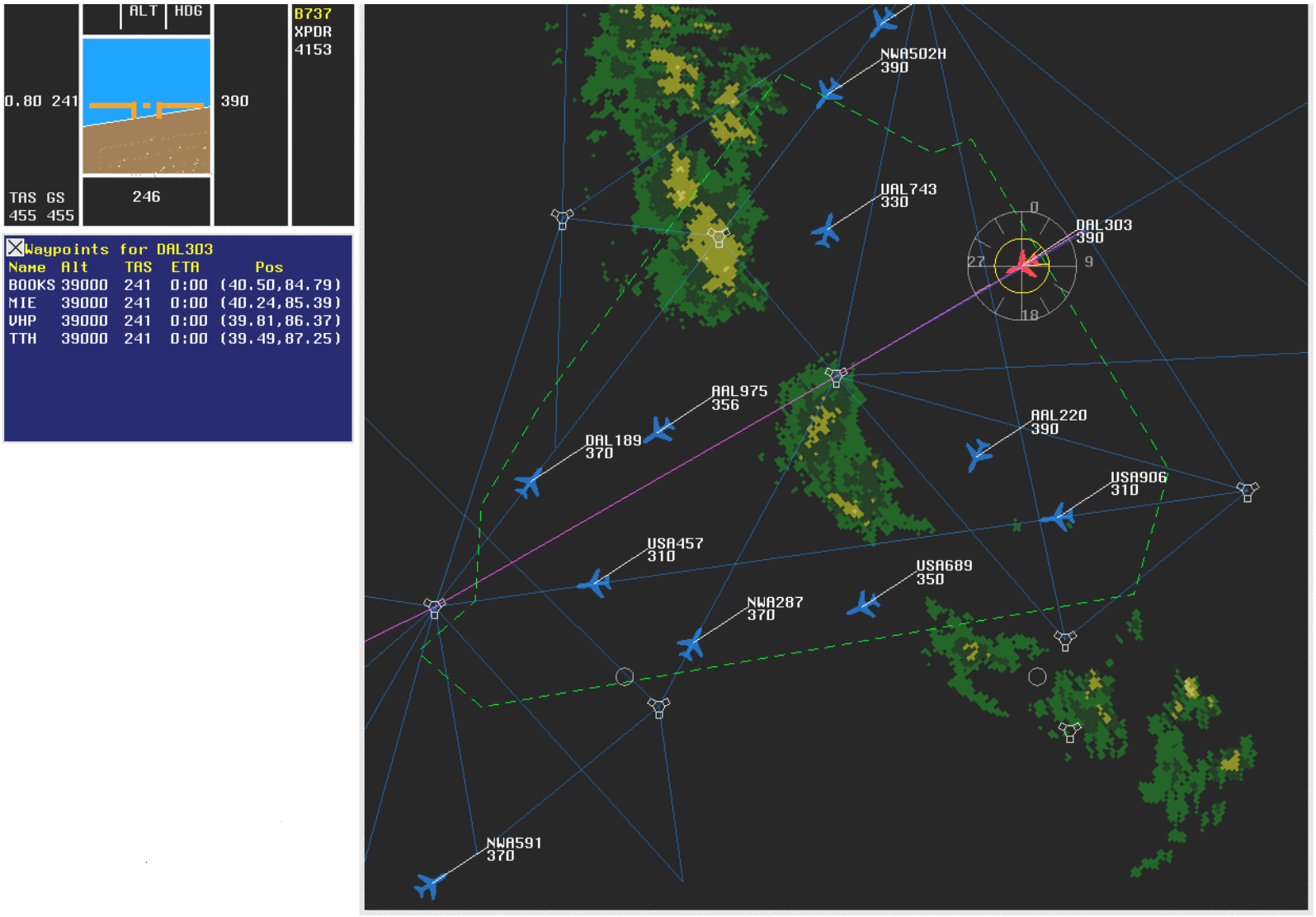
Data link OFF



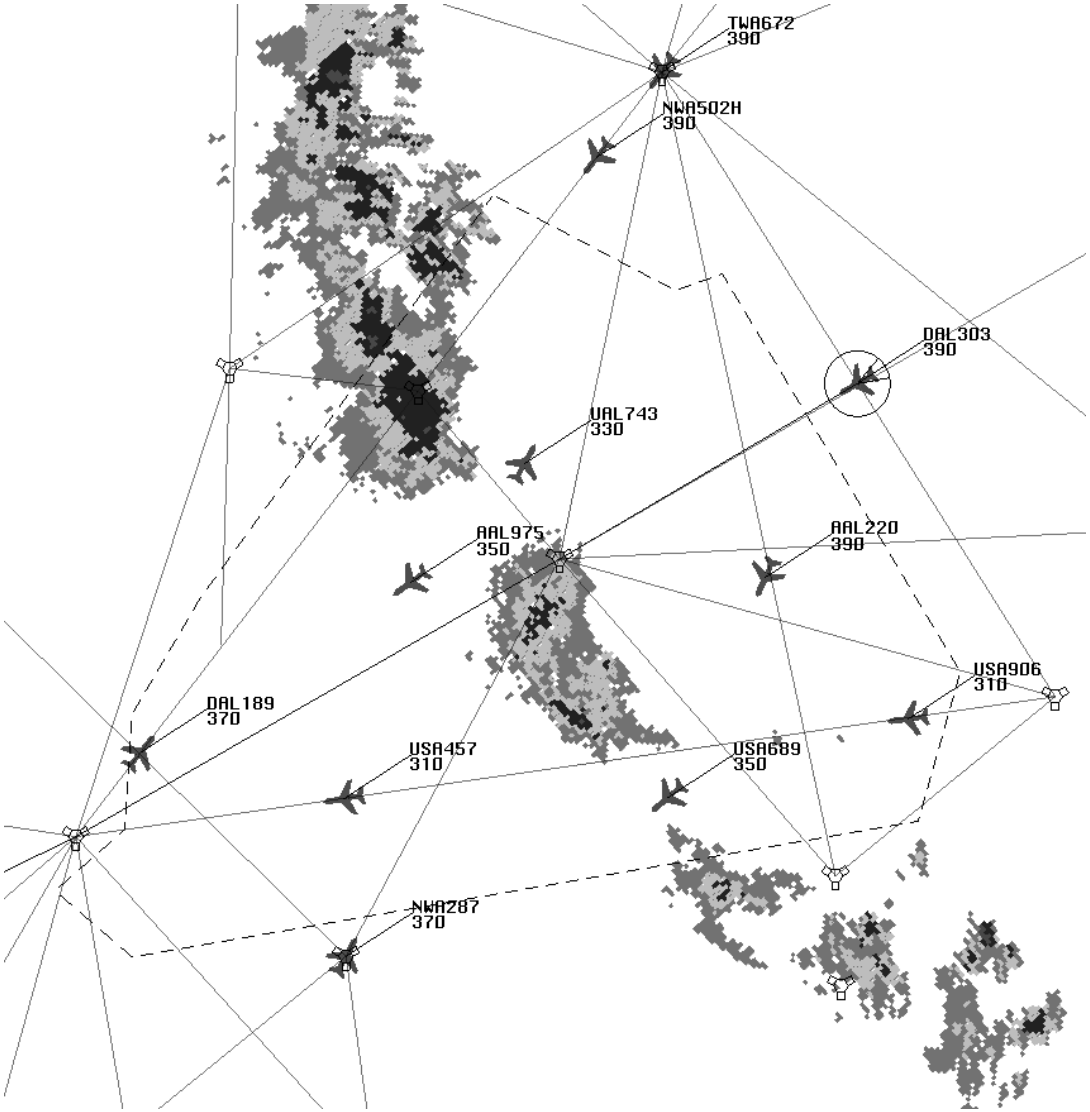
Data link ON



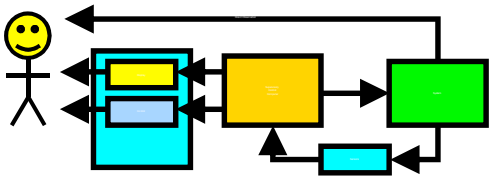
Pseudo-Pilot Station



Example Scenario



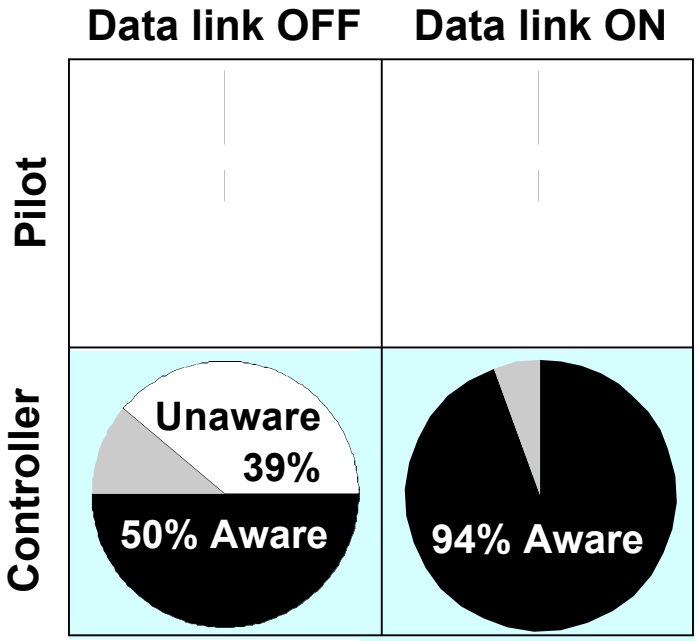
- 12-18 aircraft
- Convective weather
- Performed once **without** the shared information
- Repeated once **with** the shared information
- 6 subjects x 6 runs each = 36 runs total
- ~10 minutes in duration
- Averaged 80-90 voice transmissions per run
- Recorded data:
  - ❑ Situation awareness data
  - ❑ Aircraft trajectories
  - ❑ Voice data
  - ❑ Workload data
  - ❑ Subjective ratings



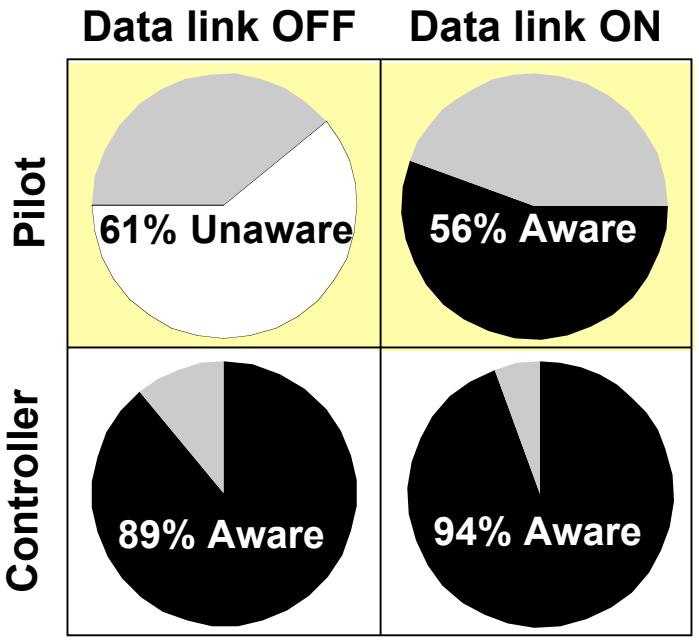
Results: Situation Awareness

- Controllers' situation awareness with respect to weather improves when weather information is shared
- Pilots' situation awareness with respect to traffic improves when traffic information is shared

Weather Situation Awareness

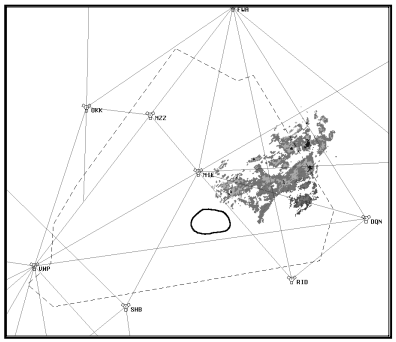
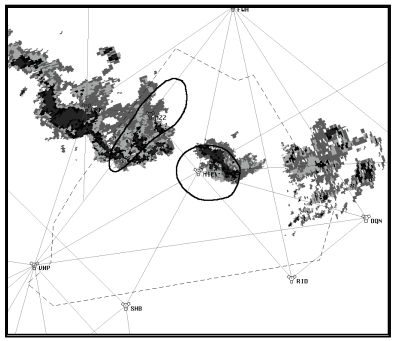
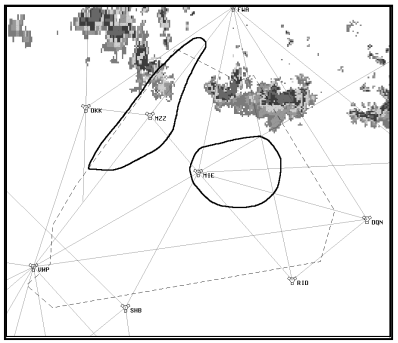
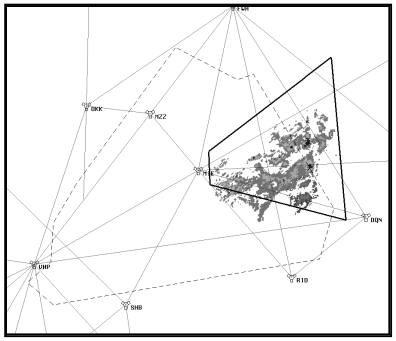
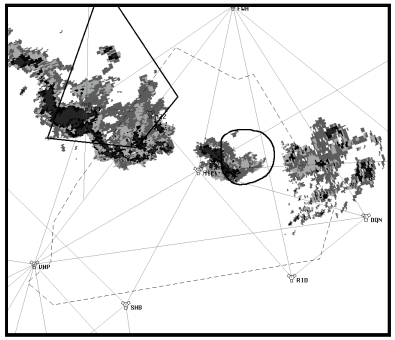
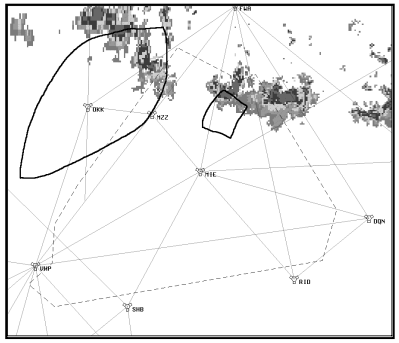
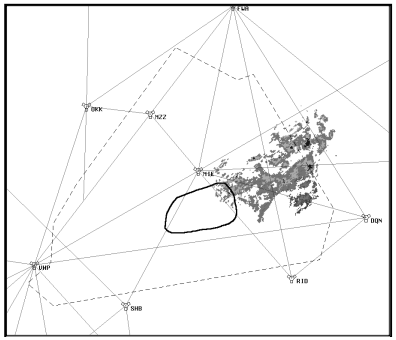
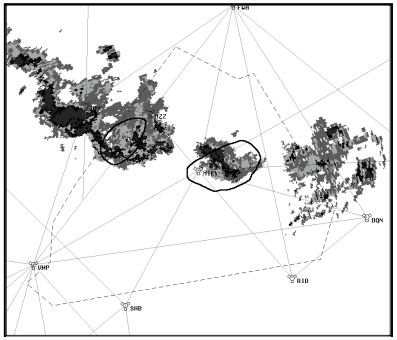
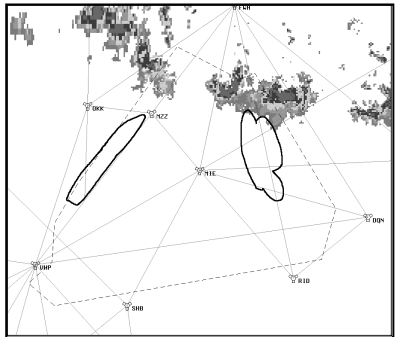


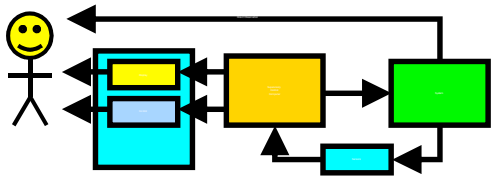
Traffic Situation Awareness



Aware | Ambiguous | Not aware

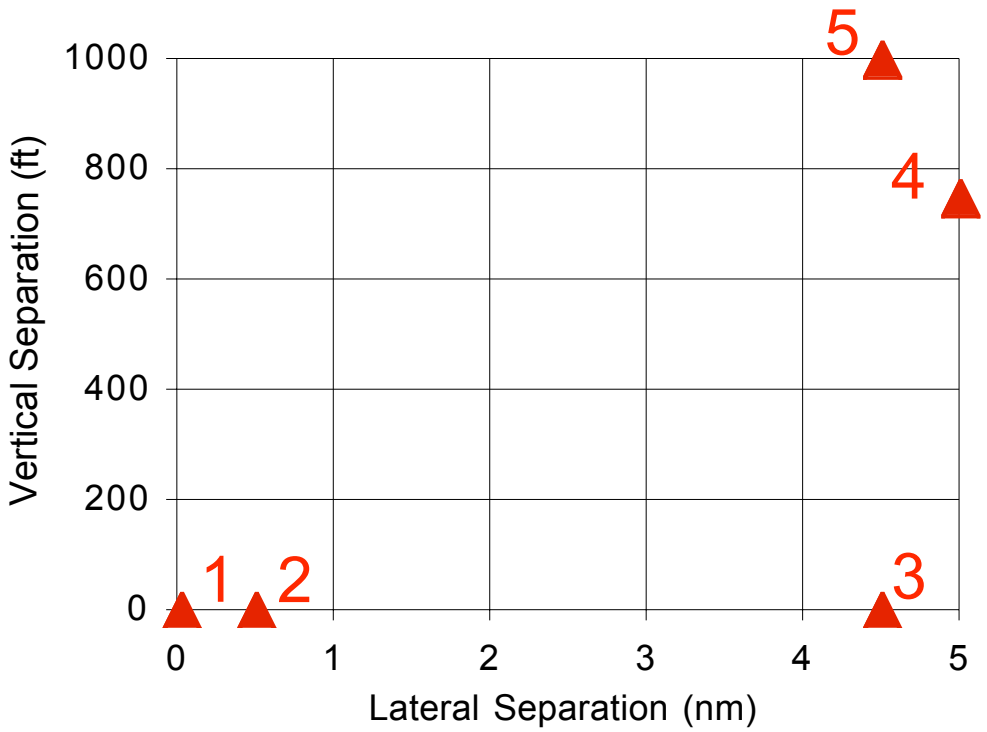
Results: Controllers' Weather Awareness

	Scenario 1	Scenario 2	Scenario 3
Subject 1			
Subject 3			
Subject 5			



Results: Separation Violations

- **5 operational errors observed in 36 scenario runs**
  - ❑ All occurred in the **non-datalinked** configuration



1 Conflict precipitated by a late deviation around weather

2 Several aircraft diverting through same hole in weather

3 A/C not handed off; conflict occurred outside the sector

4 Pilot blundered (turned in wrong direction)

5 Pilot blundered (wrong A/P mode for descent)

Results:
Separation Violations

▲1: total separation < 100 feet