MIT International Center for Air Transportation

Preliminary Design and Evaluation of Portable Electronic Flight Progress Strips

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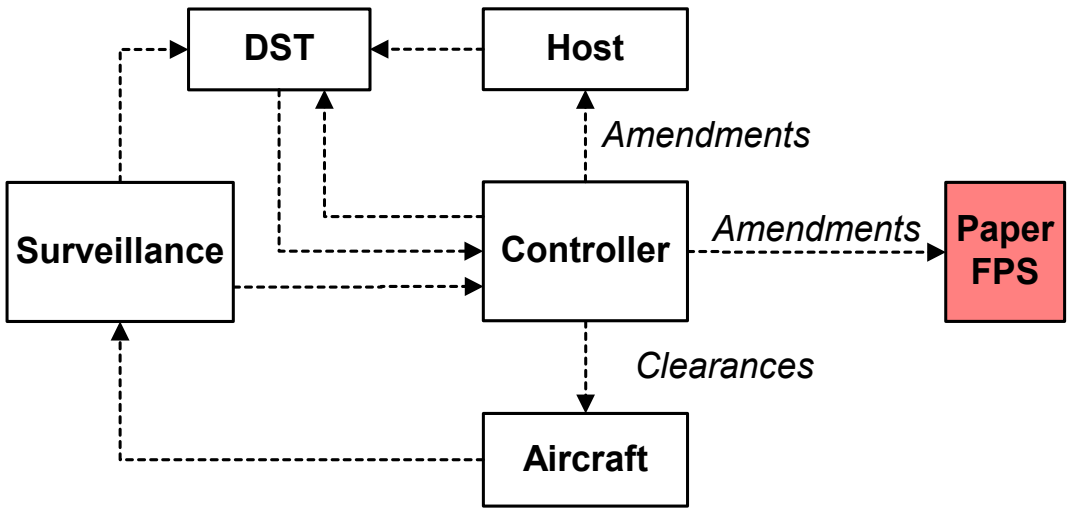
Motivation

- **Two trends in air traffic control observed**
  - ☐ Electronic or stripless systems replacing paper flight progress strips
  - ☐ Increasing number of Decision Support Tools
- **Mostly seen in enroute control environments, fewer cases of implementation in control towers**
- **Many air traffic control Decision Support Tools (DSTs) suffer from poor data input**
- **DSTs in the control tower may increase head-down time**
- **Current technology creates the opportunity to design an electronic flight strip system for the control tower**
  - ☐ Addresses DST interface requirements unique to the tower environment
  - ☐ May solve some DST information deficiencies

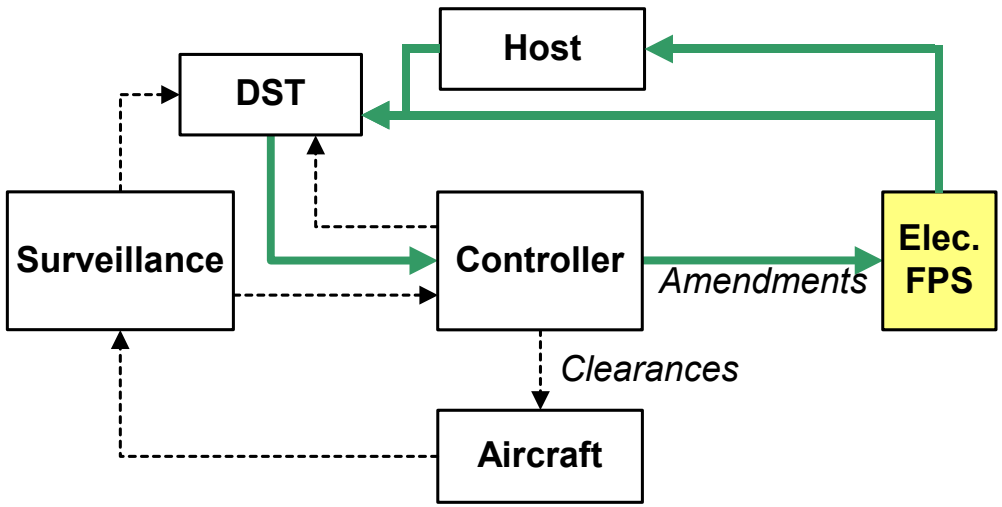
Air Traffic Control with Paper FPS

- **Limited observability of control actions**
  - Voice channel is primary means of disseminating clearances, but surveillance can only infer these indirectly
  - Flight plan amendments are recorded on paper FPS, but there is no way to access this information
  - Amendments can be entered into Host computer via Flight Data Input/Output equipment, but this usually isn't done for tactical changes to the flight plan or when other means of controller coordination exist



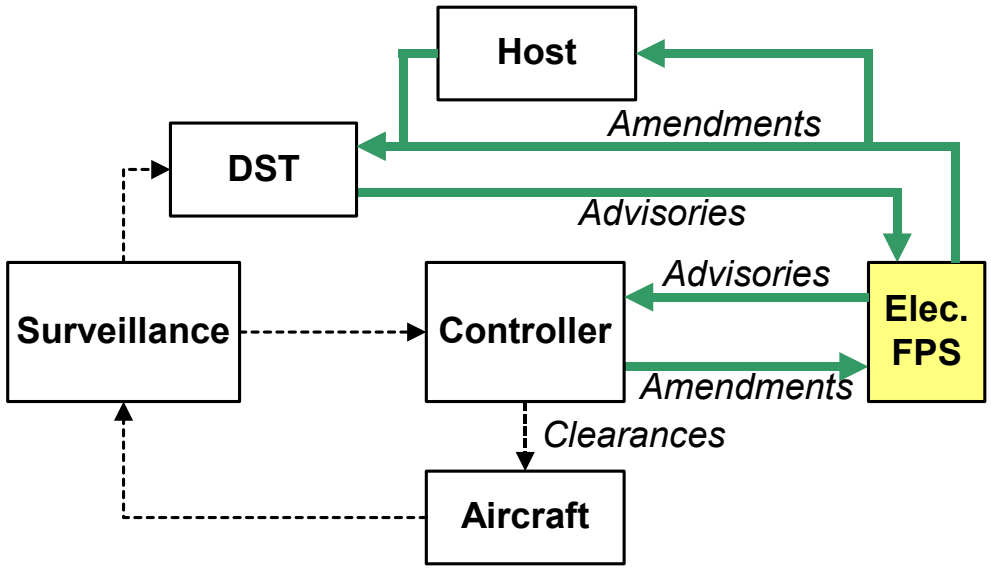
Potential Benefits of an Electronic FPS

- **May increase observability of control actions, integrity of input data for DST**



Potential Benefits of an Electronic FPS (2)

- **Enables flight strip as DST interface**
  - ☐ Potential issue: increased head-down time for DSTs in control tower environment



Need to Retain Benefits of Paper FPS

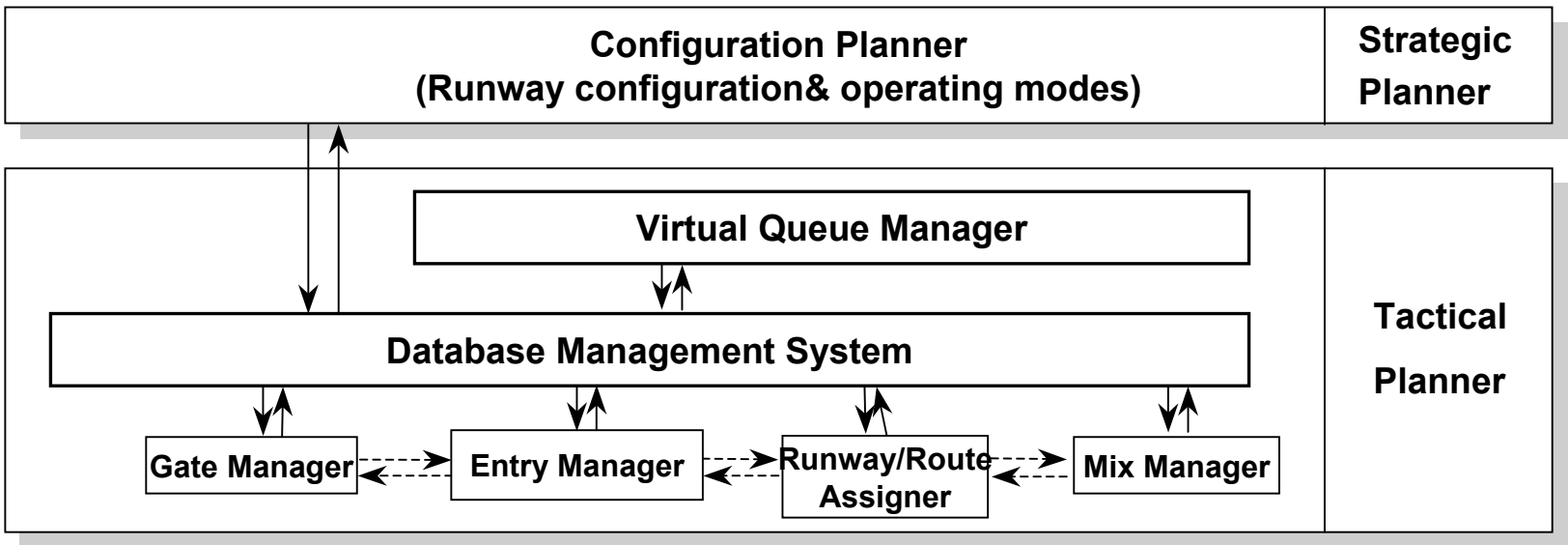
- **Flexibility**
  - Can accommodate differences in annotation methods across facilities and controllers
- **Reliability**
  - Strip printer is only major failure point
  - If strip printer is not working, flight data can be handwritten on FPS
- **Portability**
  - Possession of FPS (holding it or placing it in the strip bay) conveys ownership of a flight
  - FPS can be offset in strip bay to draw attention to a particular flight
  - Intra-facility control transfers performed by physical handoffs
  - Controller out-the-window view and mobility within tower cab preserved
- **Direct interface**
  - Controllers make annotations directly on FPS, instead of using separate input method (e.g. mouse or keyboard)

Portable Electronic FPS Concept

- **A flight progress strip could attempt to combine the benefits of both the paper strip and an electronic strip**
- **To date, most electronic FPS concepts have used a fixed, head-down display, creating an electronic analogue of the strip bay**
  - ☐ May not be appropriate for head-up control tower environment
  - ☐ May not sufficiently replicate human factor benefits of the paper FPS
- **New approach proposed**
  - ☐ Instead of a single display replicating the strip bay, use multiple handheld displays and wireless networking to create electronic analogues of individual flight strips which also act as interfaces to a decision support tool

Example DST Application: Departure Planner

- MIT Departure Planner used as an example case from which to derive DST interface requirements
- Departure planner issues pushback, taxi, and takeoff advisories based on optimal, "virtual" queues along with runway configuration suggestions



Source: Yiannis Anagnostakis

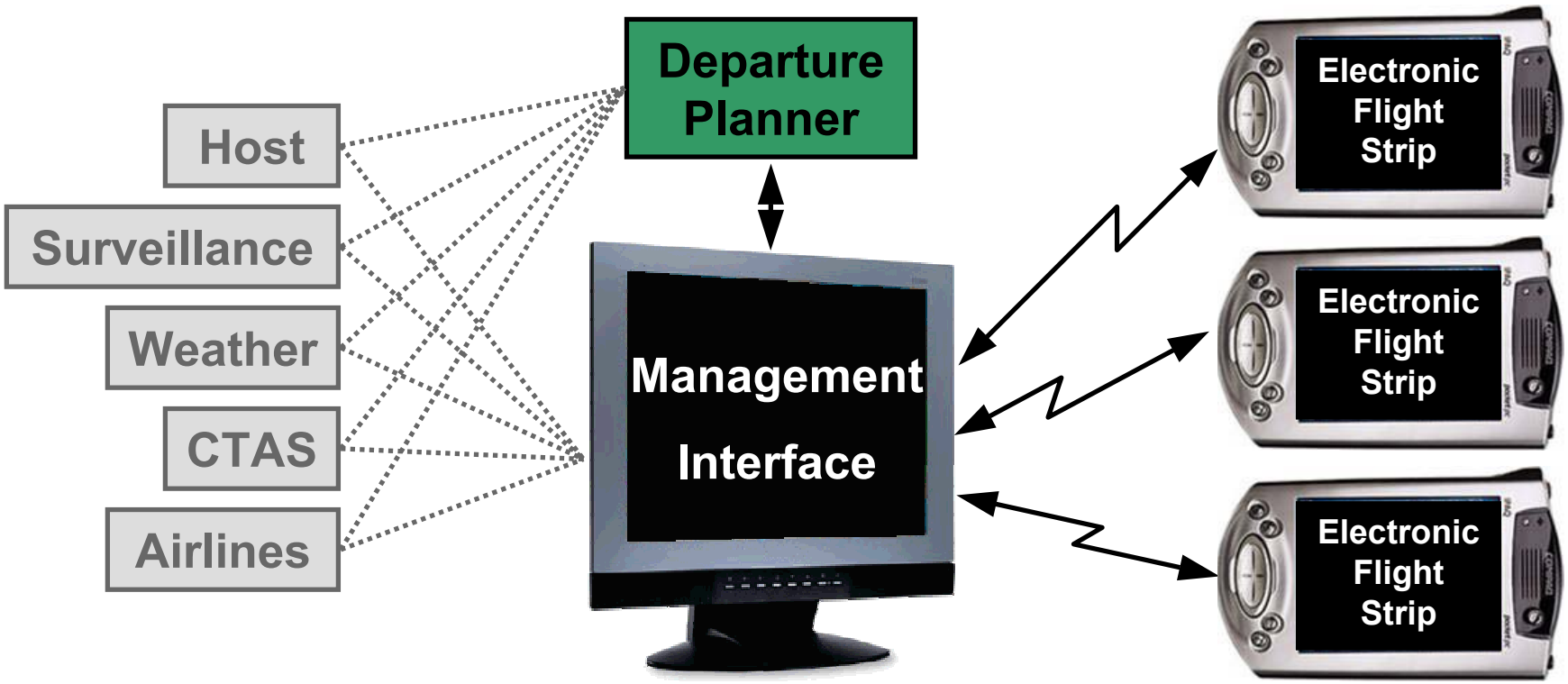
Portable Electronic FPS Requirements Analysis

- **Two major categories of requirements identified**
  - Core FPS functional requirements -- preserving the existing paper strip functionality
    - Display and change aircraft flight data
    - Note departure restrictions
    - Record pushback and takeoff times
  - Departure Planner requirements
    - Display suggested controller actions in the form of aircraft queues (pushback, taxi, takeoff)
    - Input actual departure actions as feedback to the DST (actual times for “ready to push”, pushback, taxi, takeoff)

Architectural Requirements

- **Core FPS and Departure Planner requirements can be organized into two categories**
  - Aircraft-specific information
    - Pushback, taxi, and takeoff times, gate locations, runway assignments
  - Airport-wide information
    - Pushback queues, takeoff queues, runway configurations
- **Portable Electronic FPS is well-suited to showing aircraft-specific information (some Departure Planner inputs already shown on paper FPS)**
- **Airport-wide information more appropriate for centralized interface**
- **The Departure Planner interface should consist of both the Portable Electronic FPS and a centralized management interface**

System Architecture

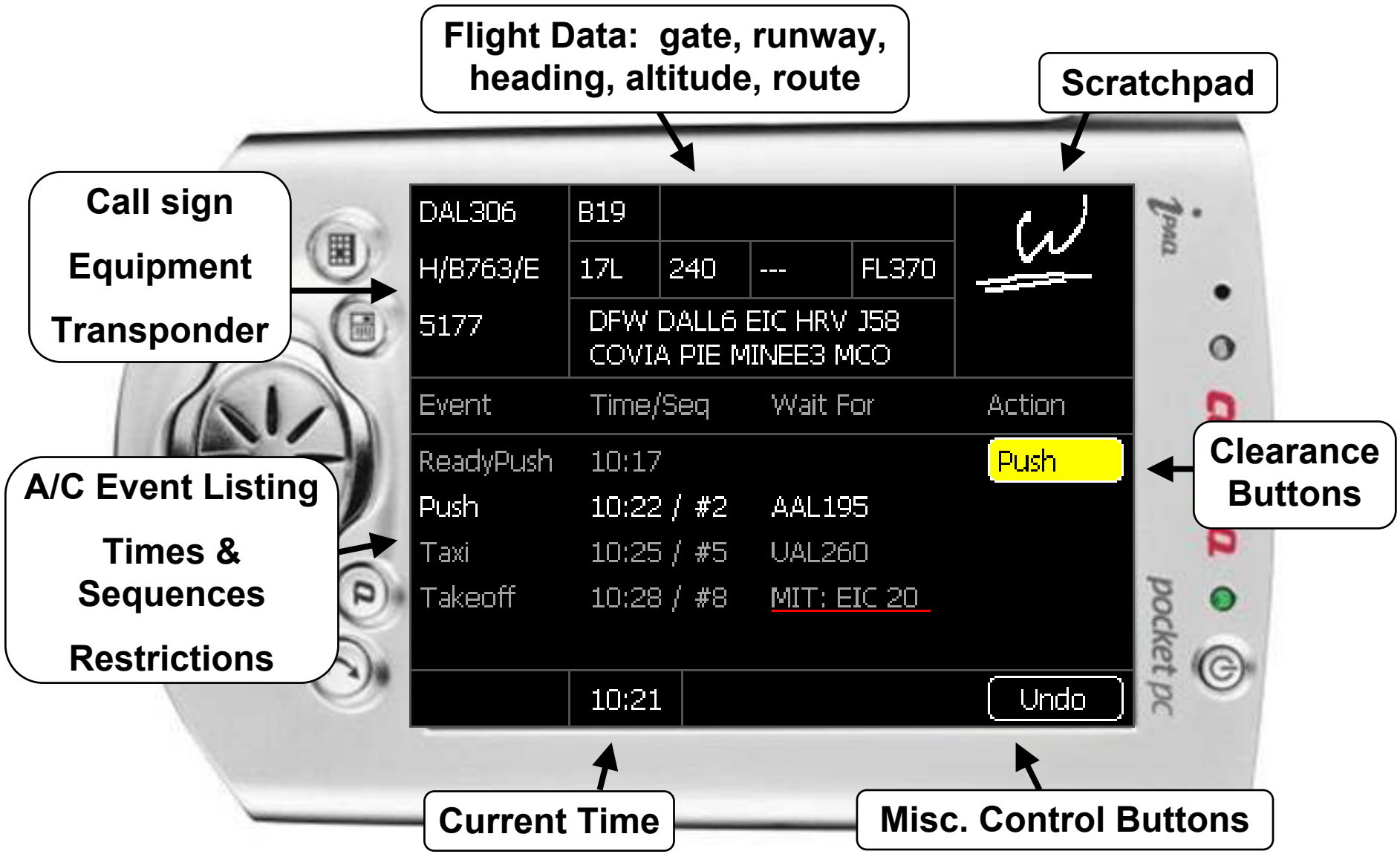


- One electronic device per flight strip

Prototype Hardware

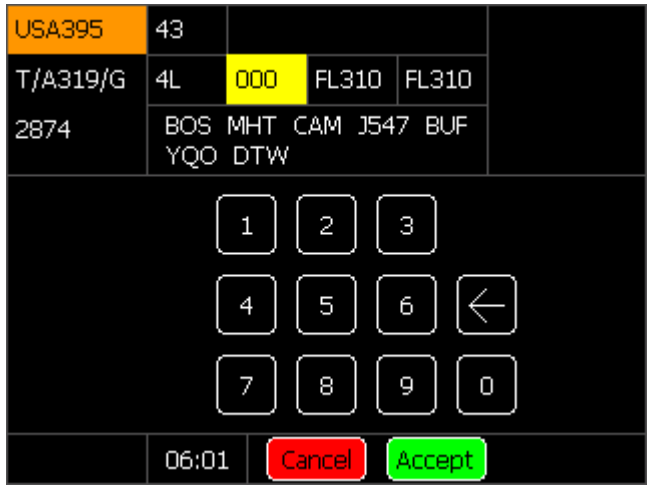
- **Portable Electronic FPS: Compaq iPAQ PDAs**
- **Management Interface: standard desktop computer**
- **iPAQs and desktop communicate via wireless LAN**
- **Hardware not considered appropriate for production system, but has attributes useful for prototyping**
  - ☐ iPAQs reasonably approximate size of paper strips
  - ☐ Straightforward software development environment
  - ☐ Touch-screen for direct input
  - ☐ Easy to add wireless networking capability to the PDAs
- **Assumed that with growth in handheld computing technology, devices will be available for a production system with greater functionality, lower costs, and a customized form factor**

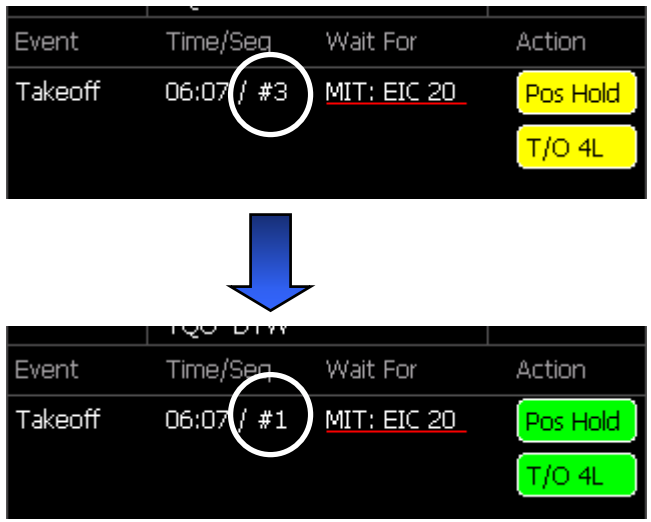
Portable Electronic FPS Display Prototype



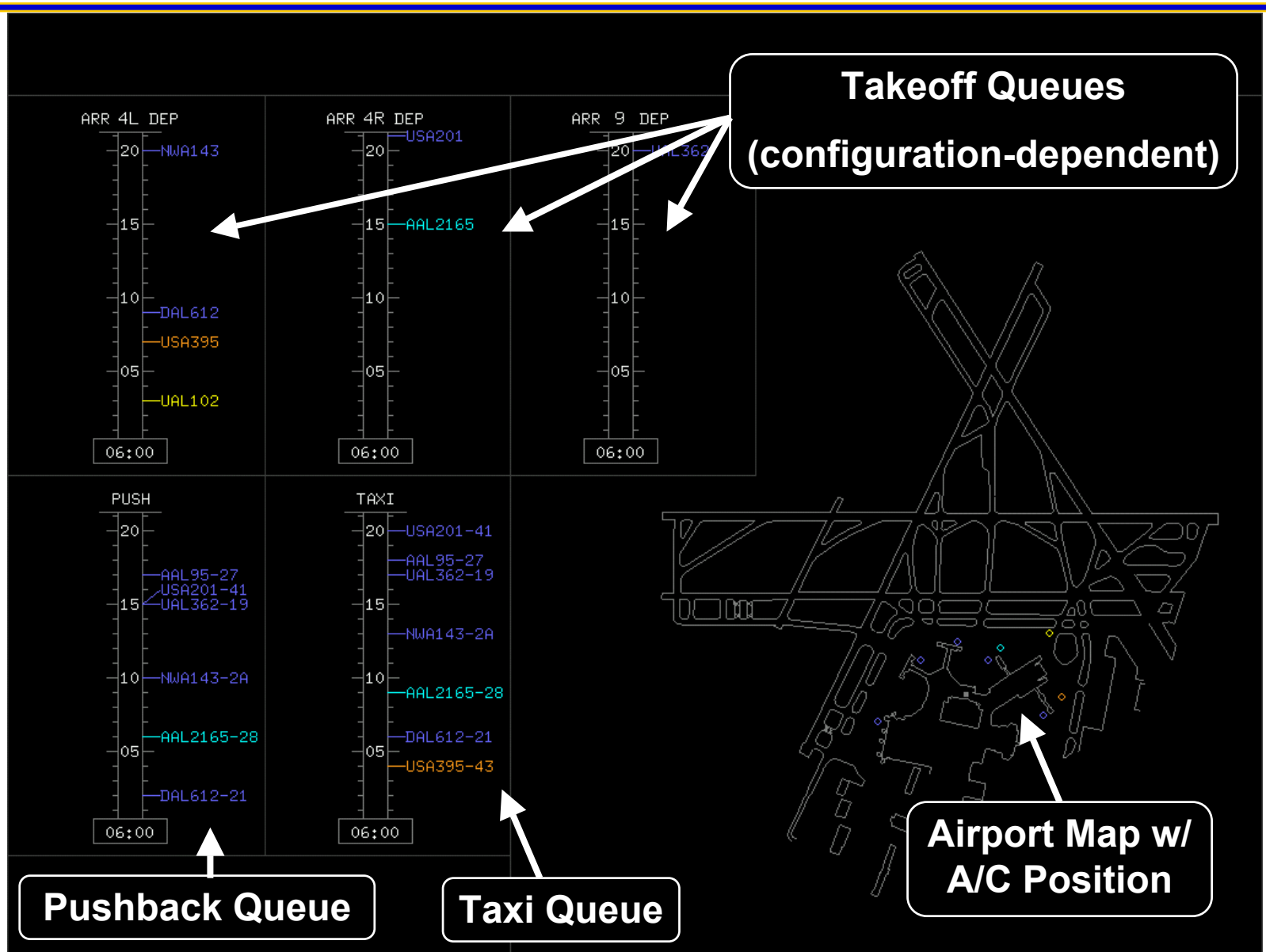
Controller Interaction with Portable Electronic FPS Prototype

- **Possible actions**
  - Modifying flight data fields
  - Issuing clearances
  - Writing free annotations on scratchpad
- **Menu-based changes to flight data**
  - Most fields have a discreet number of possible values
  - Handwriting recognition approach might increase controller workload
- **Clearances issued by tapping color-coded soft buttons, which change based on aircraft state**
  - Eliminates need to write clearance times, as is currently done



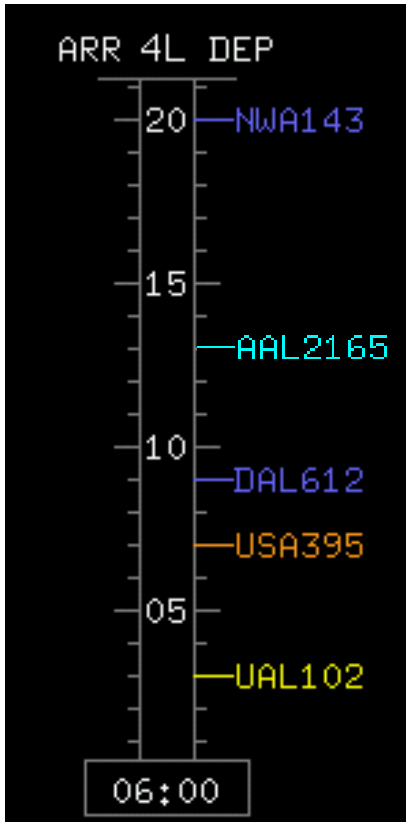


Management Interface Display Prototype
BOS 4L - 4R - 9 Configuration



Management Interface Color Conventions

- **Data tags color-coded based on departure state**
- **Potential issues**
  - ☐ Color conflicts with Portable Electronic FPS
  - ☐ Need for secondary cue (symbology) to indicate departure status



At Gate

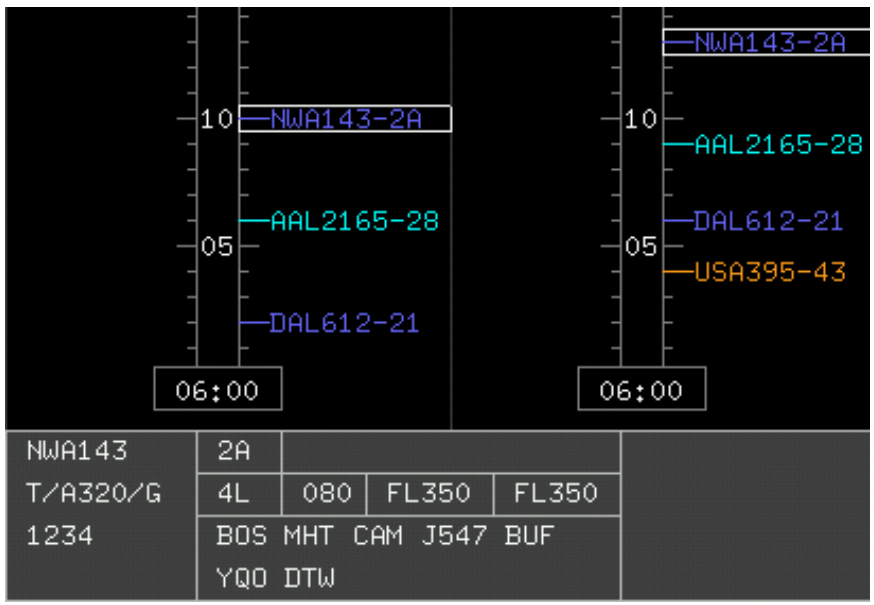
Ready for Pushback

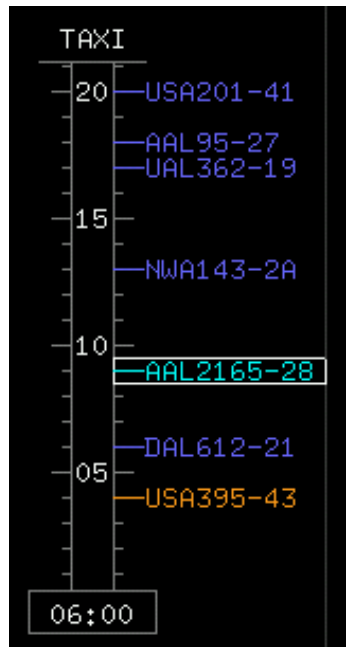
Cleared to Pushback

Cleared to Taxi

Controller Interaction with Management Interface Prototype

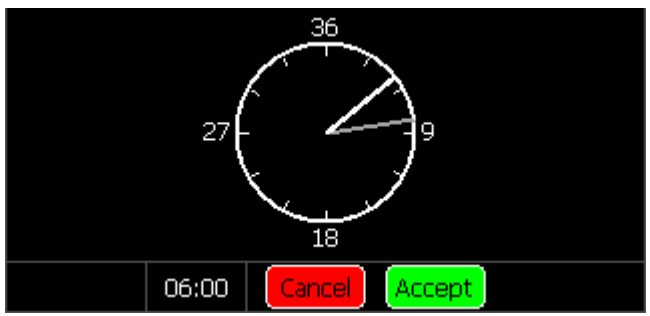
- **Possible actions**
  - Choosing runway configurations
  - Inputting flight restrictions
  - Resequencing aircraft
  - Full route clearances
- **Other uses for management interface**
  - Highlighting aircraft on timelines and airport map
  - Viewing flight data



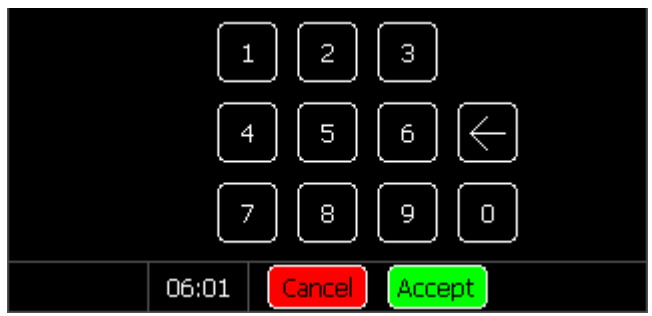


Implementation Issues

- **System**
  - Failure modes
  - Position sensing
- **Hardware**
  - Durability
  - Display readability under different viewing angles and lighting conditions
- **Local adaptation**
- **Display formatting**
  - Absolute time vs. relative time vs. sequence-only
  - Methods for changing flight data
  - Appropriate amount of graphic aids



vs.



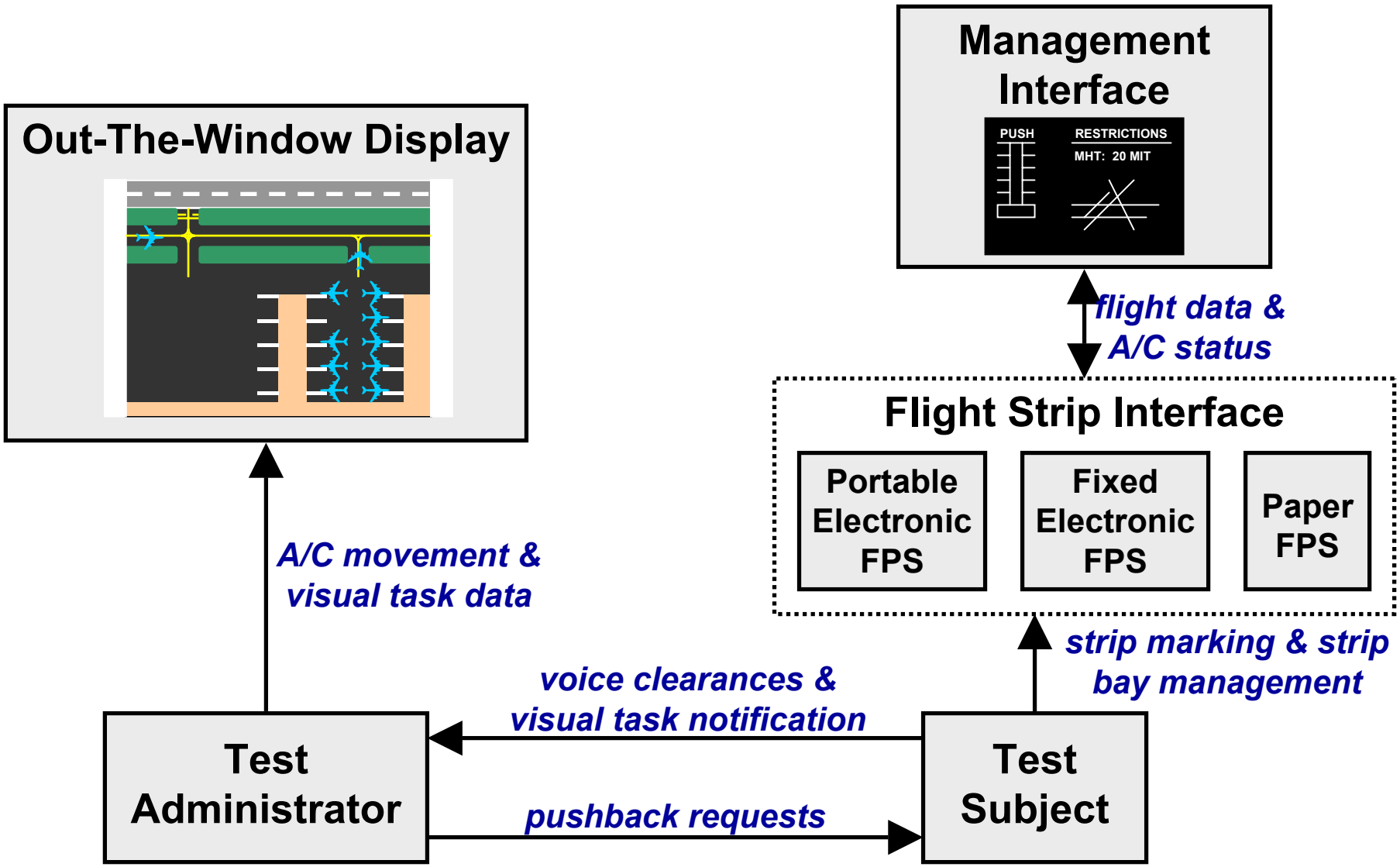
Testing Overview

- **Objective**
  - Characterize differences in controller performance for Portable Electronic FPS vs. a fixed electronic FPS display vs. paper strips
  - Characterize differences in controller performance when given DP advisories vs. no departure advisories
- **Specific questions to be addressed**
  - Is controller workload reduced with DP advisories on the flight strip in addition to a central display?
  - Does the portability of the flight strip decrease workload for the controller?
  - Do interface improvements on the electronic strip decrease workload for the controller?
- **Method**
  - Part-task simulation of pushback controller position using tower controllers from Boston area
  - Controllers must sequence departures while performing a visual task requiring head-up observation

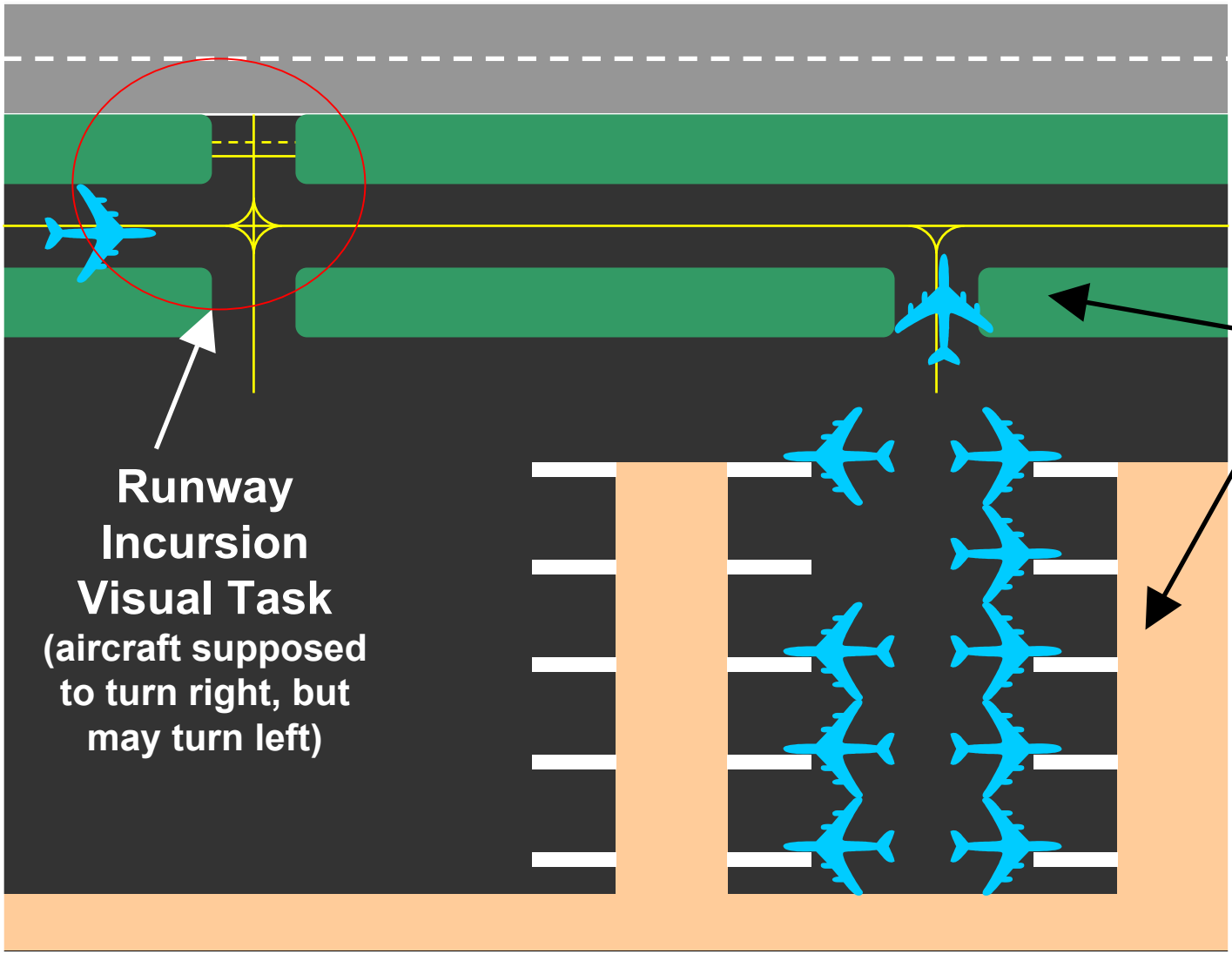
Simulation Tasks

- **Scenario starts with 10 departure aircraft parked at gates, pre-ready-to-push, with flight strips (paper or electronic) in order of proposed departure time**
- **Test subject tasks**
  - Primary
    - Issue pushback voice clearances and perform required strip marking as aircraft announce ready-to-push
    - Order pushbacks to achieve maximum throughput without violating departure constraints
  - Secondary
    - Perform safety-oriented visual task, e.g. catching runway incursions, by looking at projected out-the-window view
- **Test administrator tasks**
  - Act as pilot for all voice communication (notifies controller ready-to-push)
  - Control movement of departure aircraft on out-the-window display
- **Simulation ends when all aircraft have pushback clearance**
- **Resequencing after pushback not modeled**

Simulation Block Diagram



Out-The-Window View



Simulation Scenarios

- **Question 1: Is controller workload reduced with DP advisories on the flight strip?**

Management Interface	*Flight Strip*
w/ push advisories	Portable Electronic w/ push advisories

vs.

Management Interface	*Flight Strip*
w/ push advisories	Portable Electronic w/o push advisories

- **Question 2: Does the portability of the flight strip decrease workload for the controller?**

Management Interface	*Flight Strip*
w/o push advisories	Portable Electronic w/o push advisories

vs.

Management Interface	*Flight Strip*
w/o push advisories	Fixed Electronic w/o push advisories

Simulation Scenarios (2)

- **Question 3: Do interface improvements on the electronic strip decrease workload for the controller?**

Management Interface	*Flight Strip*
w/o push advisories	Portable Electronic w/o push advisories

vs.

Management Interface	*Flight Strip*
w/o push advisories	Paper w/o push advisories

Controller Performance Metrics

- **Visual Task**
  - Ratio of missed or late detections to correct detections of runway incursions (i.e., whether or not controller notices aircraft before hold-short line is crossed)
  - Average delay between time aircraft takes wrong turn and time controller controller notifies aircraft
- **Sequencing Task**
  - Whether or not DP solution is achieved
  - Number of shift constraints violated (downstream constraints will be reflected in throughput measure)
  - Departure throughput (i.e., total time until last aircraft takeoff)
- **Subjective assessment by controllers**