Standards for Human-Computer Interaction (HCI) for NextGen High Density Operations

Analysis of Dynamical Properties of

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Outline

1. An Overview: Tasks and HCI
2. NextGen Con-Ops
3. Learning from the Past
4. Flight Metrics for Task Performance
5. Example Calculation
6. Conclusions

HCI

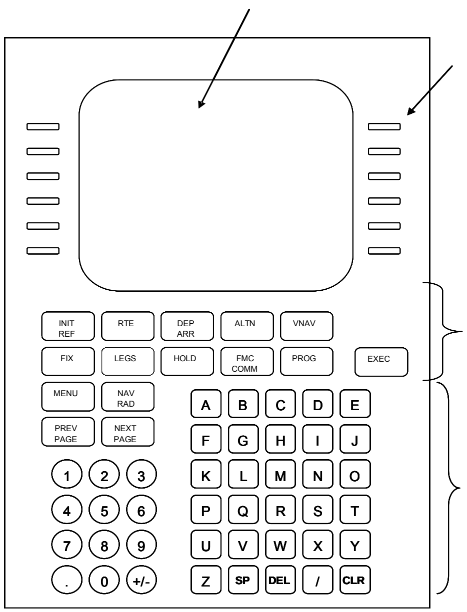
- HCI on flightdeck occurs when flightcrew use automation to complete mission tasks
- Mission tasks are explicit set of tasks required to conduct the mission
  - executing ATC instructions
  - performing checklist items
  - responding to caution/warning messages

Example Tasks

<u>Mission Tasks triggered by ATC</u>:	<u>Mission Tasks triggered by FMS Error Messages</u>:
• "Climb maintain FL 2-2-0" • "Proceed direct to waypoint XXX" • "Intercept course 0-1-4 degrees from present position" • "For weather, you are cleared to offset your current route 20 nautical miles right. Report when clear of the weather" • "Fly heading 180, join the Gordensville 060 degree radial, track the radial inbound to Gordensville" • "Hold west of Boiler on the 270^{O} radial. Right turns. 10 mile legs. Expect further clearance at 0830"	• Diagnose a mismatch in fuel sensors triggered by message FUEL DISAGREE – PROG 2/2 • Diagnose error in automated procedure tuning triggered by message NAV INVALID – TUNE XXXX – • Diagnose flightcrew data entry problems triggered by messages: INVALID ENTRY, NOT IN DATABASE, and INVALID DELETE • Re-enter data required before takeoff triggered by message: TAKEOFF SPEEDS DELETED –

Example Task

MCDU page displays data and accepts *inserted* data



Line Select Keys *insert* data typed into Scratchpad into data field

Mode Keys for *accessing* pages

Apha/numeric keys for data *entry*

1) Id Task as Hold task
2) Decide to use the FMS “LNAV Hold: function
3) Press HOLD Function/Mode Key
4) Press LSK 6L, if a holding pattern is already in the route.
5) Line select waypoint identifier for “Boiler” to scratchpad.
6) Press LSK 6L.
7) Enter the quadrant and the radial into the scratchpad, W/270.
8) Press LSK 2L.
9) Enter the turn direction into the scratchpad, R.
10) Press LSK 3L.
11) Enter the leg distance into the scratchpad,10.
12) Press LSK 5L.
13) Enter expect further clearance time into the scratchpad, 0830.
14) Press LSK 3R.
15) Verify the resulting holding pattern on the ND
16) Press EXECUTE
17) Monitor trajectory for entry and following the Holding pattern

NextGen Con-Ops

Figure 2-6. Elements of a Four-Dimensional Trajectory

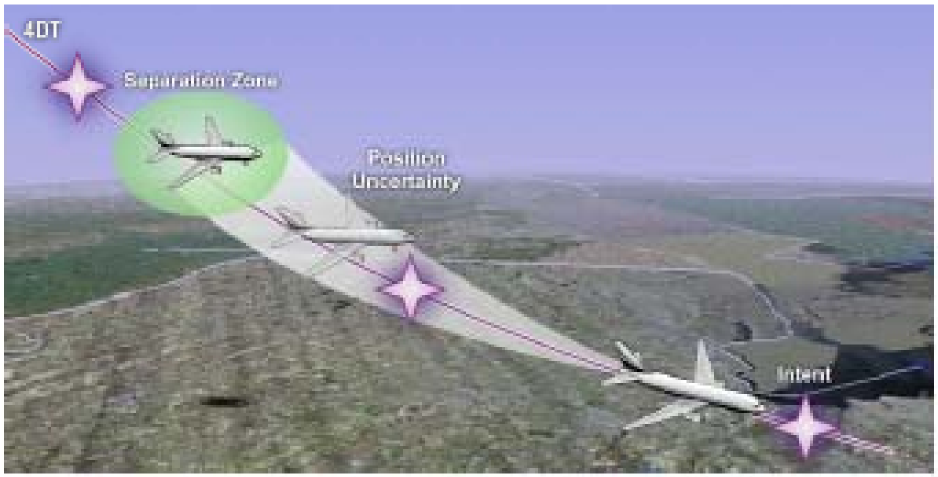


Figure 2-8. Super-Density Arrival/Departure Terminal Operations

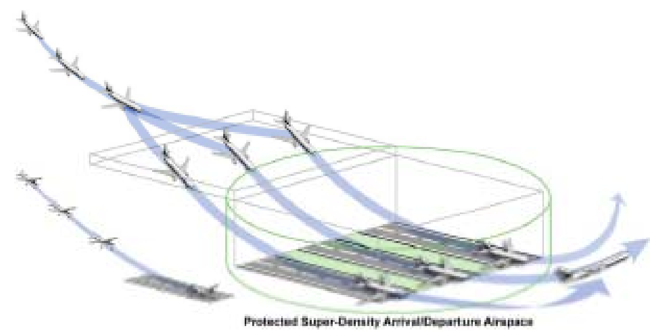
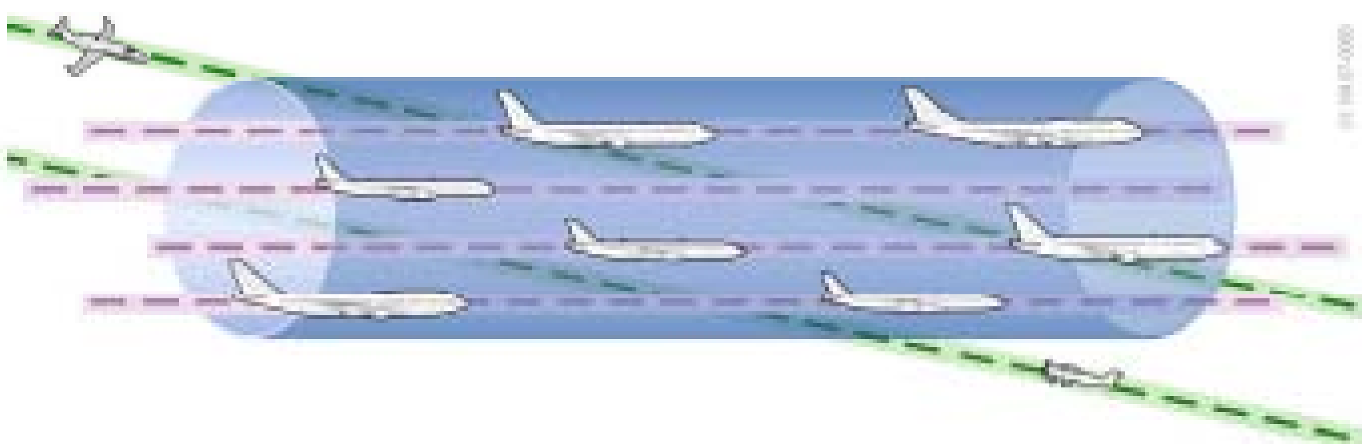


Figure 2-7. Flow Corridors



NextGen Con-Ops

- **More efficient use of the airspace**
  - **Trajectory-based operations**
  - **Reduced separation in high-density airspace**
- **Performance-based Operations**
  - **increased navigation performance**
  - ***increased flight-crew proficiency performing required maneuvers***
    - **in a timely and robust manner**

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What will Change?

- Current Air Traffic Control paradigm
  - flights that do not meet required performance do not lose access to preferential airspace
- NextGen
  - flights that cannot respond to off-nominal situations in a timely manner will be shifted to downgraded airspace
    - experience flight delays
    - extended distance routing

Learning from the Past

- FMS introduced in 1980's
- Researchers documented certification, training, use (or lack of use) of the FMS in revenue service operations
  - Wiener, 1988; BASI, 1999; FAA, 1996; Feary, 1997
- NextGen functions equivalent to FMS upgrade to flightdeck automation in 1980's
- Robust human-computer interaction to ensure seamless operations is not guaranteed
- New practices in the design must be adopted to avoid the pattern of misuse, disuse, and abuse

Unless we do something different, the results will be the same

Flight Metrics for Task (i) Performance

- Excess Costs per Flight =
  FOC(i) * PFtC(i) * ΔFT(i) * ADOC
  - FOC(i) = Frequency of Occurrence
  - PFtC(i) = Probability of Failure to Complete Task i in time ti
  - ΔFT(i) = Additional Flight Time Incurred by Failure to Complete the Task(i)
  - ADOC = Airline Direct Operating Costs

Probability of Failure-to-Complete

- (PFtC(i))
  - Likelihood of task not being completed (within time window)
  - PFtC < 0.3
    - Frequent Task
    - Infrequent Task WITH visual cues for next pilot action
  - PFtC > 0.3
    - Infrequent Task WITHOUT visual cues for next pilot action

Probability of Failure-to-Complete

- "Confusion about the FMS presentation, as is true for use of any computer, is often resolved after *persistent interaction* with it. Thus it is likely that the Captain believed that the confusion he was encountering was related to *his* use of the FMS, and that continued interaction with it would ultimately clarify the situation."
- "He could not be expected to recognize, because it rarely occurs in regular operations, that the fix he was attempting to locate (Tulua VOR) was by this time behind him, and the FMS generated display did not provide sufficient information to the flightcrew that the fix was behind the airplane."
- "… because of the lack of time, the need to perform multiple tasks in the limited time, … his attention thus narrowed to further repeated unsuccessful attempts to locate ULQ [Tulua VOR] through the FMS."

- Peter Ladkin (Cali, Accident Report)

Probability of Failure-to-Complete

- B777 FMS Scratchpad Messages
  - 57% messages
    - No info underlying causes of the message
    - No guidance on subsequent flightcrew actions to respond to message
  - 36% messages will:
    - occur very infrequently
    - exhibit high mission importance
    - not supported by salient visual cues on the interface

Sherry et. al. 2005

Frequency of Occurrence

- Frequent (> once very 5 flights)
- Infrequent (100 < X < 5 flights)
- Very Infrequent (> 100 flights)

Sherry et. al. 2005

Additional Flight Time

- Additional Flight Time Incurred by Failure to Complete the Task I
- Based on Mission Importance
- Flight Critical (+30 mins Δ flight time)
  - must be addressed immediately for continued safe flight
    - error message indicating a mismatch between fuel estimates and actual fuel levels
- Procedure Critical (10 mins Δ flight time)
  - safe flight
  - yield efficiency benefits
    - runway/approach selected in Flightplan is not compatible with the arrival in the flightplan).
- Neither Flight/Procedure Critical (< 1 min Δ flight time)
  - no safety or efficiency implications
  - performed at flightcrew discretion.

Sherry et. al. 2005

FMS Error Messages (B777)

	Frequency			
Mission Impact (estimate of additional flight time if fail to complete the mission task)	Very Infrequent (> 100 flights)	In-frequent (= 20 flights)	Occasional (=5 flights)	All the Time
Flight Critical (+30 mins delay)	2	1	-	-
Procedure Critical (10 mins delay)	24	9	5	1
Not Flight or Procedure Critical (< 1 mins delay)	9	1	13	-

Sherry et. al. 2005

Example Analysis

- Average Flights per Day – 3745
  - 535 aircraft
  - average 7 flights per day
- Average hours utilization per aircraft – 13 hours
- Average flight distance – 630 nautical miles
- Average Direct Operating Cost - $35 per minute
  - Biased by ratio of gate-taxi airborne operations (Bureau of Transportation Statistics)

Example Analysis

	Baseline (Traditional Design Methods)
Daily Total Flight Delays	583 hrs
Daily Total Excess Cost	$1.2M
Annual Total Excess Costs	$447M

Proposed HCI Standards

1. Excess Costs per Flight =

   $FOC(i) * PFtC(i) * \Delta FT(i) * ADOC > \varepsilon$

2. Probability-of-Failure to Complete < Δ
   - Δ adjusted based on frequency of occurrence

3. Label-following meet Semantic Salience standards (see Feary, Blackmon, Polson, John, Kaber, Johnson, Picciano, Sherry)

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