Understanding a Pilot's Tasks

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The safety of today's commercial aircraft is less dependent on the basic airmanship skills of the pilot than on the optimization of the representation of the information provided to the pilot. The advancement of computer technology was the impetus for transforming the steam gauges of the 1960s Boeing 727 into the glass cockpit of today's Boeing 777. A current flight deck might include such items as an electronic map, a threat collision and avoidance system, or a head-up display (HUD). A display designers' task is to mitigate the proliferation of information in the cockpit by transforming the abundant data into comprehensive but intelligible displays. Understanding the information requirements of the tasks, cognitive and perceptual capabilities of the pilot, and the contingencies imposed by the environment is an essential part of designing displays that will help to ensure the safety of our airways.

A common categorization of the modern commercial pilot's tasks is to segment the tasks by four general objectives: aviate, navigate, communicate, and manage systems (Jonsson and Ricks, 1995). The nature of the pilot's task is: "to *aviate* (control the airplane's path), *navigate* (direct the airplane from its origin to its destination), and *communicate* (provide data and requests and receive instructions and information), and, increasingly in modern aircraft, to *manage* the resources available" (Billings, 1997, p. 16; italics in original). This prioritization of the pilot's responsibilities allows a designer to gain an intuitive understanding of the relative importance of the information sources that support the individual tasks. To aviate, the pilot needs all the information that will support his or her ability to maintain lift of the aircraft. In navigation, the pilot needs to be aware the aircraft's position in relation to the desired trajectory (Theunissen, 1997). While the aviation portion of the pilot's task is intuitively more important than navigation, HUDs, in particular, are dedicated to support the navigation task.

The navigation task essentially consists of two spatial tasks: global awareness and local guidance. Global awareness is a general cognizance of the broad region surrounding one's aircraft. This information would include representations of potential threats to the safety of the aircraft, such as other aircraft, mountains, and hazardous weather. Local guidance is a closed-loop task where control inputs are made to minimize the deviations from the intended flight path (Olmos, Liang, and Wickens, 1997). The primary function of a HUD is to support the local guidance portion of the navigation task. Of particular relevance to this thesis is the most demanding aspect of the pilot's flight - the final phases of flight, which includes landing (Wasik, 1997). During final approach and landing, the pilot must exercise precise control of the aircraft to maintain the desired course. A thorough understanding of a pilot's informational needs is required to fully support the pilot in local guidance.

Information (Task) Requirements

Before a display can be designed for functionality and appearance, the question of what should be displayed must be answered. Theunissen (1997) has mapped out the design process for developing a man-machine interface. Whether a new system is being created or design guidelines are being developed, the first stage of the process is determining the task requirements. These task requirements will establish the data that should be observable to the user. Subsequent evaluation of the design concept will

depend on how well it relates to the pre-determined task requirements and task performance.

Once the individual requirements have been determined, presentation of the information can be used to guide the observer's attention to the successfully complete the tasks. Clay (1993) provides a good example of using several methods to identify the cognitive issues and information requirements for the display design of electronic instrument approach charts. She reviewed the literature, examined manuals, reviewed the current designs, interviewed pilots, performed a cognitive task analysis of the instrument approach task, and rode jumpseat while pilots performed instrument landings. Several factors were established to affect the pilot's task of flying an instrument approach. The current charts were so cluttered with information that it was necessary to determine what basic information was needed to conduct the task. Though pilots generally express a preference for displaying all of the information, experiments have indicated that a core group of information elements can be identified as the most important for the task. One of the outcomes of the study was a list of core information requirement items.

Clay noted that although pilots might not use all of the information all the time, they generally still want it to be available. A suitable balance must be established between providing enough data to support a good mental model of the situation and limiting the symbology to essential task-relevant information. A particular concern for HUD designs is that the symbology presentation can obscure the pilot's view of the far domain environment. Considering that HUDs provide redundant information to head-down displays, it is essential to determine the basic HUD information requirements solely for the task at hand and remove less critical items.

The Survey

In order to establish the information needs, a survey was developed to determine the pilot information requirements for the final four phases of flight – approach for landing above 500 feet agl (above ground level), final approach below 500 feet agl, roll out and turnoff, and taxi operations. A set of 50 information sources was assembled from NASA contractor reports and pilot interviews (McGuire, Zich, Goins, Erickson, Dwyer, Cody, and Rouse, 1991; Alter and Regal, 1992). The information sources were organized according to the four basic piloting responsibilities: aviate, navigate, communicate, and manage systems. The survey was distributed via the internet to a mailgroup consisting of professional pilots, researchers, academics, and engineers. See Appendix A1. Commercial and corporate pilots were asked to respond to the relative importance of each of items of the information requirements survey. The survey was created in an attempt to reveal the rudimentary information requirements irrespective of the flight conditions, type of aircraft, type of approach (i.e., instrument or visual), available avionics displays, etc. The relative importance of each item was to be established in a two ways. First, an information item would be considered important if it were referenced relatively frequently. Second, the item's importance would also be determined by the criticality of the item to the safety of the flight. For instance, wind shear may be a relatively infrequent occurrence but knowledge of its existence is critical to the safety of the mission. For each phase of flight, the pilots determined whether the information was of high, medium, or low importance for each of the four phases of flight.

Fourteen pilots responded via the internet. The pilot population consisted of six captains, six first officers, one second officer and one retired commercial pilot. The average age range was between 41-45 years of age and all respondents were male. The mean number of flight hours was 9730.8, which ranged from 3500 hours to over 15,000 hours. The pilots were current in a wide variety of aircraft including a Piper Aztec, Cessna 402, Cessna 172, DA900, B737-300/400/500, B747-400, B757, B767, F-100, MD88, and an MD11.

A summary of the findings is presented in Table 1 below. The table is a compilation of information that was classified as medium-high or high importance on average. The information items are listed in order of perceived importance with a ranking of one being the highest (all ties are listed with the same ranking). Note the clear division between the information needed for the final approach and landing portions of flight, on the one hand, and the ROTO and taxi portions, on the other, particularly in the aviate category. Many more of the flight control parameters (i.e., pitch, roll) need to be available during the final approach phases. This information then becomes irrelevant (or clutter) once ground operations commence. All information listed in the aviate and navigate categories of flight responsibilities will be included as symbology on a head-up display for further experimentation. This information will ensure that the tasks of the individual phases of flight are supported. The survey provided an opportunity to identify that information deemed irrelevant by highly experienced commercial pilots and subsequently removed from the display.

Approach (down to 500')	Final approach (below 500')	ROTO	Taxi
Aviate	**Aviate**	**Aviate**	**Aviate**
1 Altitude	1 Airspeed	1 Ground speed	1 Heading
2 Airspeed	2 Energy Management	2 Heading	2 Ground speed
3 Heading	3 Altitude		
4 Bank	4 Vertical Velocity		
5 Pitch	5 Pitch		
6 Energy Management	6 Heading		
7 Vertical Velocity	6 Bank		
8 Roll	7 Roll		
Navigate	**Navigate**	**Navigate**	**Navigate**
1 Location (along flight path)	1 Wind shear	1 Signage	1 Taxiway location
2 Feet above ground	1 Feet above ground	2 Taxiway location	1 Signage
3 Final approach guidance	1 Final approach guidance	3 Runway/taxiway conditions	2 Gate information
4 Glide slope	2 Location (along	4 Ground traffic	3 Ground traffic

5 Arrival procedures 6 Air Traffic 7 Wind shear 7 Terrain 8 Ground traffic 9 Distance to touchdown 9 Missed approach guidance 10 Wake vortex 11 Wind	flight path) 2 Glide slope 3 Wind 3 Missed approach guidance 4 Runway/taxiway conditions 4 Visibility (wx) 5 Distance to touchdown 6 Terrain 6 Wake vortex 7 Ground traffic 8 Wind shear 9 Horizon	5 Visibility (wx) 6 Air traffic 7 Location (along track)	3 Runway/taxiway conditions 4 Air traffic 5 Location (along track) 6 Visibility (wx)
Communicate	**Communicate**	**Communicate**	**Communicate**
1 Cockpit communication 2 Wind shear alert 3 Approach clearance 4 Runway conditions 4 Landing clearance	1 Wind shear alert 2 Cockpit communication 3 Landing clearance 4 Runway conditions 5 Approach clearance	1 Runway conditions 1 Cockpit communication	1 Gate information 2 Cockpit communication 3 Cabin communication
Manage Systems	**Manage Systems**	**Manage Systems**	**Manage Systems**
1 Landing gear 2 Flaps 3 Thrust 4 Engine and systems warning indications	1 Flaps 1 Landing gear 2 Thrust 3 Brakes	1 Brakes 2 Lights 3 Thrust 4 Engine parameters	1 Brakes 2 Lights 3 Thrust

Table 1. Summary of information requirement survey results

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Appendix A1. Information Requirements Survey

AIRCRAFT LANDING INFORMATION NEEDS SURVEY

Necessary Information

While your responses to the questionnaire will remain strictly confidential, we need to track user responses and to eliminate accidental duplicate submissions. We also need some basic demographic information. We will send you, if desired, results of the questionnaire when they are available.

Your questionnaire responses can not be included in the analysis without the demographic information.

Your e-mail address (if applicable):

Please send me questionnaire results*: Yes / No*

Provide mailing address if you did not include an e-mail address above:

DEMOGRAPHICS

Age: Gender: *M / F*

Current seat position:

Type Ratings:

Aircraft current in:

Approximate total flight hours:

Survey Instructions

To the best of your knowledge and understanding, please consider the importance of each of the 50 items listed below. Relative importance can be determined in a couple of ways. First, an information item would be considered important if it is referenced relatively frequently. Second, how critical the item is to the safety of the flight can also determine the item's importance. For instance, wind shear may be a relatively infrequent occurrence but knowledge of its existence is critical to the safety of the mission. Four phases of flight will be considered (Approach down to 500' agl, Final approach below 500' agl, Roll out and Turnoff (ROTO), and Taxi). For each phase of flight please fill in your selection with an 'H' for high, 'M' for medium, or 'L' for low. Items marked N/A are not applicable to the particular phases of flight and therefore should not be answered. An item marked "High" would be information you would continually seek from the instruments or would be considered critical to the safety of the flight. An item marked "Low" would be

something that you would reference relatively infrequently during the flight phase or would be considered a nonessential information source.

The survey is separated into four columns. In order to keep a consistent mental picture of the individual flight phases, it is recommended that you complete an entire column of information needs before moving on to the next flight phase. In other words, complete all item responses for the Approach phase and then move on to the Final Approach phase. If a particular information source is unclear, please leave the selection blank. To submit your responses, please mail your responses to the address listed at the end of the survey.

The Survey

Scenario: Consider that you are the Captain of a commercial airliner (or corporate aircraft) and you are the pilot flying. Remember to consider the Approach phase only down to 500' agl and the Final Approach for flight below 500' agl.

Information Source/Needs	Approach (to 500')	Final (< 500')	ROTO	Taxi
AVIATE				
Path guidance				
1. Heading (lateral)	1.	1.	1.	1.
2. Altitude (vertical)	2.	2.	2. N/A	2. N/A
3. Airspeed	3.	3.	3. N/A	3. N/A
4. Ground speed	4.	4.	4.	4.
5. Vertical Velocity	5.	5.	5. N/A	5. N/A
6. Roll	6.	6.	6. N/A	6. N/A
7. Pitch	7.	7.	7. N/A	7. N/A
8. Bank	8.	8.	8. N/A	8. N/A
9. Yaw	9.	9.	9. N/A	9. N/A
10. Energy Management (engine out/ wind shear)	10.	10.	10.	10.
NAVIGATE				
Environment: Air				
11. Visibility (WX)	11.	11.	11.	11.
12. Wind	12.	12.	12.	12.
13. Wake vortex	13.	13.	13. N/A	13.N/A
14. Wind shear	14.	14.	14. N/A	14.N/A
15. Traffic (obstacles)	15.	15.	15.	15.
Environment: Ground				
16. Terrain	16.	16.	16.	16.

17. Traffic (obstacles)	17.	17.	17.	17.
18. Horizon	18.	18.	18.	18.
19. Runway/taxiway conditions	19.	19.	19.	19.
20. Taxiway location	20.	20.	20.	20.
21. Gate Information	21.	21.	21.	21.
22. Signage (Runway/taxiway)	22.	22.	22.	22.
Awareness				
23. Position (lat/long)	23.	23.	23.	23.
24. Location (along desired flight path or track)	24.	24.	24.	24.
25. Location of cardinal directions (N,S,E,W)	25.	25.	25.	25.
26. Glide slope	26.	26.	26. N/A	26.N/A
27. Temporal (time awareness)	27.	27.	27.	27.
28. Distance to Touchdown	28.	28.	28. N/A	28.N/A
29. Feet above the ground	29.	29.	29. N/A	29.N/A
Procedures				
30. Arrival	30.	30.	30. N/A	30.N/A
31. Final approach guidance	31.	31.	31. N/A	31.N/A
32. Missed approach guidance	32.	32.	32. N/A	32.N/A
COMMUNICATE				
ATC - Approach				
33. Approach Clearance	33.	33.	33. N/A	33.N/A
34. Airspeed request	34.	34.	34. N/A	34.N/A
ATC - Tower				
35. Landing clearance	35.	35.	35. N/A	35.N/A
36. Airspeed request	36.	36.	36. N/A	36.N/A
37. Runway conditions	37.	37.	37.	37.
38. Wind shear alert	38.	38.	38. N/A	38.N/A
39. Gate information	39.	39.	39.	39.
Crew				
40. Cockpit crew	40.	40.	40.	40.
41. Cabin crew	41.	41.	41.	41.
42. Passengers	42.	42.	42.	42.

MANAGE SYSTEMS				
43. Engine parameters	43.	43.	43.	43.
44. Thrust (NI or EPR)	44.	44.	44.	44.
Main Equipment				
45. Flaps position	45.	45.	45.	45.
46. Landing gear position	46.	46.	46.	46.
47. Engine and Systems warning Indications	47.	47.	47.	47.
48. Flight control position (rudder/ spoilers)	48.	48.	48.	48.
49. Lights	49.	49.	49.	49.
50. Brakes	50.	50.	50.	50.

Please examine your responses to make sure you have completed all items. When completed, please mail your responses to the address below. Thank you for your participation.

Please respond by MAY 31, 1997 to ensure that your responses are included in the final analysis.

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