Guidelines for Information Display Characteristics for eVTOL Pilot Interfaces

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Background – What is Urban Air Mobility?

- eVTOL-based air taxis/ air cargo operations, envisioned to have simplified displays with potential reduction for pilot training.

- eVTOL manufacturers include traditional aviation companies and pilot interfaces (e.g., Garmin G1000); but also new entrants and novel display concepts that deviate from traditional displays.

- New entrants would benefit from guidance regarding FAA certification requirements.

- Purpose of this effort: Identify human factors (HF) language in FAA eVTOL certification documents specific to the pilot interface; map to HF constructs and measures in the literature.

Source: IEEE Spectrum

Methods

Phase 1: HF Certification Requirements Analysis (Namukasa et al., 2023; Accepted to HFES 2023)

1. Analyzed published Special Airworthiness Certification documents for eVTOL aircraft.

2. Identified relevant HF language mentioned in the documents.

3. Defined and interpreted the HF language meaning based on other FAA documentation, mapped to HF constructs and associated measures

Phase 2: Aviation Display Characteristics Literature Review

1. Determined keywords, databases.

2. Identified 152 articles.

3. Reviewed abstracts, filtered 84 relevant articles.

4. Reviewed the relevant articles and extracted 6 HF categories of display characteristics.

5. Coded relevant articles.

6. Extracted/developed 33 display guidelines

Phase 3: Mapping of HF Constructs To Guidelines

1. Reviewed guidelines against the HF constructs relevant for eVTOL certification.

2. Mapped display guidelines to HF constructs that could be leveraged to meet certification requirements.

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Phase 1 Outcomes

HF Construct	Definition (Namukasa et al., 2023; Accepted to HFES 2023)
Excessive Alertness	Refers to attention/vigilance required to attend to, detect changes in, and respond to multiple sources of information that supersedes typical levels required to complete the flying tasks. .
Excessive Mental Fatigue	Not having the mental capacity to perform duties due to extended exposure to physical and mental workload.
Error Minimization	Reducing design-induced errors by ensuring error-prone facets of the system are designed out or enhancing pilot recovery from errors.
Monitoring	Systematic observation and interpretation of the current state of the aircraft/environment through the information presented on the flight deck.
Excessive Concentration	Refers to the pilots' need to focus increased attention on one task reducing the ability to multitask when required, creating the potential for cognitive or attentional tunneling.
Distraction	Any situation or event that diverts attention away from critical tasks.
Discernability	Ability to perceive and interpret sensory information to make decisions.
Workload	How much physical and cognitive work a pilot must do versus the resources they have available to perform a specified task.

Phase 2 & 3 Outcomes

Guideline Categories	HF Constructs								
	Excessive Alertness	Excessive Mental Fatigue	Error Minimization	Monitoring	Excessive Concentration	Distraction	Discernability	Workload	Total Guidelines
Clutter	2	1	0	1	0	1	0	3	4
Color	0	2	4	1	0	1	8	1	9
Eccentricity	1	0	0	3	1	2	0	0	3
Display Format & Consistency	1	1	3	2	1	0	4	4	8
Symbology	0	0	1	2	0	0	4	2	5
Overlaid Information	0	0	0	2	2	1	4	0	4
Total Guidelines	4	4	8	11	4	5	20	10	**33**

Extracted or developed 33 guidelines that were related to the 8 HF constructs and 6 guideline categories.

Discernability Guidelines

Color…

- …should not be used as the sole means of discerning task essential information.

- …in background must not affect the interpretation of overlaid information.

- …when used to convey meaning, must not have multiple meanings.

- …coding should be used with no more than 6 color codes on a display.

- …must have adequate contrast between fore colors and background colors.

- …meanings must follow conventions:
  - Red and yellow/amber should be reserved for alerting functions only.
  - Do not use pure blue for text, small symbols, as a background color, or for important information.

- …use should avoid these color combinations:
  - Saturated red and blue, saturated red and green, saturated blue and green.
  - Saturated yellow and green, yellow on purple, yellow on green, yellow on white, magenta on green, magenta on black.

- …should be viewable in day and night conditions.

Discernability Guidelines Contd.

Format, Consistency, and Clutter

- Use consistent media throughout a display (e.g., use of audio to alert about nearby traffic).

- Use consistent position of data labels for navigation, traffic, airplane system, and other information.

- Use display features that are discernable and legible.

- Use graphical elements only if they add useful information or reduce access/interpretation time.

- Clearly and unambiguously indicate weather source and associated altitude for weather information.

- Synthetic/Enhanced Vision Systems (SVS/EVS) information should not obscure critical flight information.

Monitoring Guidelines

Eccentricity

- Critical information should not exceed a horizontal eccentricity greater than 10 to 15 degrees.

- For high eccentricity, increase/change: stimulus size, contrast, orientation, spatial frequency.

Format, Consistency and Clutter

- Use consistent layout of primary flight data and components across all displays.

- Menus should not obscure primary flight information.

- Place related information in close proximity.

- Place symbols and associated information (e.g., traffic and their relative position) in close proximity.

- Symbols that represent physical objects should accurately represent the objects' characteristics (e.g., SVS depicting ground infrastructure or terrain).

Color

- …meanings must follow conventions:
    - Use red and yellow/amber for alerts.
    - Use green for normal operations.
    - Other colors can be used for advisory information.

Workload Guidelines

Consistency and Format

- The interaction format should be consistent with user conventions, data entry requirements, and other similar displays.

- Use consistent position of data labels for navigation, traffic, airplane system, and other information .

- The information format should be directly usable without requiring any mental conversion.

- Use graphical elements only if they add useful information or reduce access/interpretation time.

Clutter and Color

- Limit the quantity of information so as the display isn't perceived as visually dense.

- Place related information in close spatial proximity.

- Provide means to manually remove clutter.

- Do not use more than six color for color-coding displayed information.

Symbology

- Information that related to a symbology should appear in the same general location.

- Only use directional symbols when applicable.

Error Minimization Guidelines

Consistency & format

- Use consistent media throughout a display (e.g., ATIS information, traffic information)

- The interaction format should be consistent with user conventions, data entry requirements, and other similar displays.

- Use consistent position of data labels for navigation, traffic, airplane system, and other information.

Color

- When colors are assigned a meaning, each color should have one meaning.

- Ensure that there is adequate contrast between colors and background colors.

- Color shouldn't be used as the sole means of distinguishing task essential information.

- Avoid using saturated red and blue, saturated red and green, saturated blue and green, saturated yellow and green, yellow on purple, yellow on green, yellow on white, magenta on green, magenta on black to present information.

Symbology

- The shape, dynamics, and other symbol characteristics should be consistent across all the displays.

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Concentration Guidelines

Overlaid information

- Background color should not affect the interpretation of overlaid information.

- When using synthetic vision system (SVS), Enhanced vision system (EVS), ensure that the synthetic image or information is not obscuring critical flight information.

Consistency & format

- Use display features that are discernable and legible.

Eccentricity

- Critical information should not exceed a horizontal eccentricity greater than 10 to 15 degrees.

Distraction Guidelines

Overlaid information

- Synthetic/Enhanced Vision Systems (SVS/EVS) information should not obscure critical flight information.

Eccentricity

- Critical information should not exceed a horizontal eccentricity greater than 10 to 15 degrees.

Clutter

- Only required information should be displayed to avoid clutter on the pilot interface.

Color

- Bright, highly saturated colors should be avoided and when used only for critical and temporary information, so they are not visually distracting.

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Excessive Alertness Guidelines

Consistency & Format

- Display layout of individual display components and primary flight data arrangement should be consistent across all displays.

Eccentricity

- For high eccentricity, increase/change: stimulus size, contrast, orientation, spatial frequency.

Clutter

- Display only required information to avoid clutter to avoid clutter.

- Limit the quantity of information so as the display isn't perceived as visually dense.

Mental Fatigue Guidelines

Consistency & Format

- The information format should be directly usable without requiring any mental conversion.

Clutter

- Provide means to manually remove clutter.

Color

- Colors should be viewable in day and night conditions.
- Do not use pure blue for text, small symbols, as a background color, or for important information.

Conclusions and Future Work

- Based on the analysis of eVTOL certification documents and literature, most relevant guidelines were identified that can be leverage to better understand the influence of HF constructs on the eVTOL's pilot ability to safely conduct the flights.

Future Work

- Create mock-ups of eVTOL pilot interface with different variation of information presentation for experimental evaluation

- Develop operational scenarios to test eVTOL pilot interfaces using a flight simulator.

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