Appendix G

Tradeoff Scenarios (Non-Varying Characteristics)

Explanation: The following characteristics were found to exist in a tradeoff relationship with other characteristics. However, these characteristics are unique in that they do not fit the definition of a characteristic used thus far in this analysis. Until this point, we have examined characteristics that vary from a desirable to and undesirable state. However, characteristics such as those listed below were also included in the analysis in order to cover all aspects of the "Machine" category. For example, the characteristic "Display Size" may have undesirable and desirable states, but the research provided in this analysis does not answer the question "Which display size is most favorable". Because we cannot examine a tradeoff relationship containing this characteristic using the previous method, the possible tradeoff relationships containing these characteristics were looked at in a more general sense. It was simply asked, "What problems or tradeoffs, if any, can be expected when this characteristic of the system is involved?"

Non-Varying Characteristics that were involved in tradeoff relationships include the following:

Auditory vs. visual warning
Display size
FOV currently depicted on the SVS display
Color of symbols/text
Color of terrain
Pictorial scene information density

1.) Difficulty of approach/landing/Display size

For this analysis, it was assumed that the SVS may have three possible display sizes (757 EADI 5 x 5.25 inch, 777 PFD 6.4 x 6.4 inch, and rectangular flat-panel 8 x 10 inch). It is possible that the display size chosen could have positive and/or negative consequences, especially because the possible display sizes are of very limited space. The approach/landing phase of flight could therefore become more or less difficult for the PF depending on the SVS display size that is employed. For example, on a very small display, visual warning text may be too small for the pilot to easily notice, read, and interpret. Also, terrain detail may be lost in smaller displays, and the FOV choices able to be selected may be limited.

Despite these concerns, research conducted by Comstock, Glaab, Prinzel, and Elliot (2000) suggests that small display sizes, though not necessarily preferred by pilots, do not appear to produce performance deficits when raw horizontal and vertical guidance information is present. However, there is some evidence from pilot preference data that very small display sizes have the effect of making the aircraft appear lower to the ground than it actually is (Beringer (2000), Williams (2000), Willshire, Latorella & Glaab (2000)). This could be detrimental to the approach/landing phase of flight, and more research needs to be conducted to determine if this is in fact an issue that needs to be taken into account.

Tradeoff Scenarios (Non-Varying Characteristics)

2.) Difficulty of approach/landing/Auditory vs. visual warning

It is presumed that the SVS will provide some type of warning when the aircraft is in danger of impacting terrain. This warning has the potential to be auditory, visual, or both. The type of warning presented has the potential to make the approach/landing phase of flight more or less difficult for the pilot depending on the type of warning used and the degree to which the pilot can easily understand this warning. Typically, auditory warnings are seen as beneficial because of their omnidirectional format (Wickens, 1998). In other words, they can be heard regardless of what the pilot is doing or where he/she is directing their attention. Obviously, a number of factors should be taken into account when deciding which type of warning the SVS should present.

An auditory warning can be used if:

- The display is highly cluttered, and the pilot may not see a visual warning
- The pilot is experiencing a high level of mental workload
- The pilot is not devoting a significant amount of attention to the SVS
    - This could result from a lack of trust in the SVS, an inaccurate machine model, a very high or low degree of self-confidence, a high degree of display cross-checking, etc.
- The color used for a visual warning does not have high contrast with the background used in the display

A visual warning can be used if:

- The display has a low degree of clutter, and the pilot can easily see a visual warning
- The pilot is experiencing a low level of mental workload
- There is a high level of noise in the cockpit
- The pilot is devoting a significant amount of attention to the SVS
- The colors of symbols and text used in the warning have an adequate degree of contrast with the background colors used in the display
- The visual warning is in a prominent place on the display
- The text of the warning is easily interpretable, and is large enough to be quickly noticed
- The text conveys to that pilot that there is a serious problem that must be taken seriously, so the pilot does not ignore the warning

3.) Difficulty of approach/landing/ FOV currently depicted on the SVS display

For the current analysis, it was assumed that FOV was selectable by the pilot from four possible choices. The FOV currently displayed during the approach/landing phase of flight has the potential to make the approach/landing more or less difficult for the pilot. Research conducted by Comstock, Glaab, Prinzel, and Elliot (2000) suggests that pilots prefer having the FOV be selectable, and also prefer to have the FOV larger at higher altitudes, and smaller as they got closer to the runway in an approach.

Tradeoff Scenarios (Non-Varying Characteristics)

This suggests that FOV may have an impact on the difficulty of the approach/landing phase of flight. Further research needs to be conducted to investigate if various FOV's affect pilot error in this phase of flight. If this is the case, then pilots should be trained on what FOV to select for various phases of flight when using the SVS display.

4.) Auditory vs. visual warning/Intuitiveness/usability of the SVS

As mentioned previously, the type of warning presented to the pilot can affect how intuitive or usable the SVS is for that individual. Various types of warnings are preferable under different circumstances. Auditory displays will be more intuitive if they warning is presented at the correct decibel level, is presented when there is a low level of noise in the cockpit, is presented in a clear tone, is presented understandably, and is presented in a way that conveys the degree of severity to the pilot. Visual warnings will be more intuitive if they are presented in large enough text that they can be easily seen by the PF, are presented in a color that contrasts adequately with the background color of the display, are in a prominent place on the display, and if they are presented in a way that conveys the severity of the present situation.

5.) Color of symbols/text/Color of terrain

This relationship merely suggests that the color of symbols and text should have adequate contrast with the colors used for the terrain displayed on the SVS display. This relationship is not meant to suggest that certain colors are more appropriate, but that the relationship between various colors used in the display should be taken into account.

6.) Color of symbols/text/Intuitiveness/usability of the SVS

Based on a large body of previous research it is obvious that the type and amount of colors used in a display can influence it intuitiveness and usability for the pilot (Christ, 1975). There is evidence that the color used for warnings, or for special symbols should be unique to that symbol or text in order to aid in easy identification. Colors for the same or similar attributes of the display should also remain consistent throughout the system, and the number of colors used should be kept in check, since a large array of colors can cause confusion, and contrast problems between elements.

7.) Color of symbols/text/Pictorial scene information density

This relationship suggests that the colors of symbols and text that will be overlaid on the terrain background should be different and have an adequate degree of contrast with this background. This is not meant to suggest that certain colors are more appropriate or intuitive, but that this relationship should be considered.

Tradeoff Scenarios (Non-Varying Characteristics)

8.) Color of terrain/Intuitiveness/usability of the SVS
Pictorial scene information density/Intuitiveness/usability of the SVS

These two potential tradeoff relationships were grouped because it was determined that the characteristics “Color of terrain” and “Pictorial scene information density” produced the same entries in the matrix, and can therefore be examined together. This is not to say that the characteristics are the same, but that they affect and are effected by other system components in similar ways.

The prototypical SVS considered for this analysis was assumed to have three possible types of terrain rendering (pictorial scene information density). The SVS may have a photo-realistic terrain display, a less detailed terrain texture display, or a wire-frame rendering of terrain. It was not the aim of this analysis to determine which type of pictorial scene information density would produce the least amount of error and would be the most intuitive and usable to the pilot. However, this relationship suggests that the type of rendering chosen has a great impact on the system and has the potential to influence the usability of the display. Further research should be conducted in order to determine which type of rendering is best for use in the SVS.

9.) Degree of display clutter/Degree of overlay with PFD data/Pictorial scene information density

This potential tradeoff relationship suggests that certain types of pictorial scene information density may allow for more or less overlaid information to be presented on the SVS. For example, a photo-realistic display may have significantly more graphics than a wire-frame rendering. This type of terrain rendering may therefore allow for less information to be overlaid on it, since it may be difficult to easily see that information because of the clutter produced. This should be taken into consideration when choosing the type of terrain rendering to be used in the SVS. A detailed, visually appealing display may not always be the best choice if many symbols, text, PFD data, etc. need to be overlaid on top of this terrain background.

10.) Display size/FOV currently depicted on the SVS display

This tradeoff relationship represents the possibility that small display sizes may limit the FOV that can be selected by the pilot. Or, if the FOV choices are not limited, there is still the possibility that the largest FOV would produce very small graphic representations on a small display. The interaction between these two characteristics needs to be considered when designing the SVS display since both were found to have a significant impact on the system.

Appendix G

Tradeoff Scenarios (Non-Varying Characteristics)

11.) Display size/Intuitiveness/usability of the SVS

Display size has the potential to influence how intuitive or usable the SVS is to the pilot. Small display sizes may have terrain renderings or symbols and text that are perceptually difficult to interpret. This can therefore influence the difficulty of the approach/landing for the pilot. Please see the tradeoff relationship “Difficulty of approach/landing/Display size” mentioned above for a more detailed explanation.