Evolution of an Integrated Aircraft Alerting and Notification System for Conditions Outside the Aircraft *

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Abstract - *This paper discusses the evolution of the Alerting and Notification of Conditions Outside the Aircraft (ANCOA) concept, based on an integrated alerting framework. The development of ANCOA was prompted by the alert proliferation and the lack of alert standardization as independent alerting systems for conditions outside the aircraft (e.g. TCAS, EGPWS) are introduced onto the flightdeck. These separate alerting systems, each using different alerting and display philosophies to present information to the crew, have no integrated standard protocol for prioritizing and organizing the information to reduce the demands on pilot attention and information processing. In response, a framework that integrated, organized, prioritized, and displayed information from new flightdeck alerting systems was developed. ANCOA exemplifies the framework by integrating information from independent alerting systems to enable multiple alerts to be prioritized and de-conflicted, in order to support prompt and appropriate responses to adverse conditions based on good situation awareness.*

Keywords: Alerting, Flight Deck

1 Introduction

Beginning in the mid-1970s when the Ground Proximity Warning System (GPWS) was first introduced, flight safety has vastly improved. Hazard warning systems such as GPWS and Traffic Collision Avoidance Systems (TCAS) provide advanced warnings to the crew concerning hazardous conditions to be avoided. The crew is informed of the impending flight hazard (e.g., terrain, traffic) through visual and aural displays. Additional systems that warn of hazards, such as predictive wind shear, wake vortices, and clear air turbulence, continue to be added or soon will be added to the flight deck. One cause for concern is the sheer number of systems continues to grow. These alerting systems are separate, independent units manufactured by a variety of avionics suppliers, each using different alerting and display philosophies to present information to the crew. Just as the Engine Indicating and Crew Alerting System (EICAS) integrated warnings for systems for *internal* to the aircraft in the early 1980s [1], there is a current thrust to do the same for those systems that detect and warn of conditions *external* to the aircraft.

Alerting and Notification of Conditions Outside the Aircraft (ANCOA) concept was developed as a means to present alerting and notification information of conditions external to the aircraft. TCAS and EGPWS are two examples of separate systems and are aimed at very specific external conditions. There are two obvious voids in today's aircraft alerting system, both specific to conditions outside the aircraft: (1) the lack of integration among external condition alerting systems, and (2) the lack of strategic information to provide pilots with the resources and time to prepare for or avoid emerging situations.

The lack of integration among external condition alerting systems gives rise to two issues: (1) alert proliferation and (2) conflicting and contradictory information. Similar issues arose in the early 1970s, an emergency on the flight deck meant that the crew was inundated with visual/aural alerts attempting to direct their attention to the nature of the problem. On the L-1011, alone, almost 800 visual alerting functions were designed to inform the pilot of developing adverse conditions [1]. The introduction of integrated caution and warning systems onto the flight deck, such as Boeing's Engine Indicating and Crew Alerting System (EICAS) solved the alert proliferation problem for conditions inside the aircraft. However, a similar situation is arising from separate systems that alert the crew to conditions outside the aircraft. These alerting systems warn of time-critical terrain (e.g., EGPWS), traffic (e.g., TCAS), or various weather phenomena (e.g., reactive and predictive wind shear). Other independent alerting systems are under development, including clear air turbulence and wake vortices. ADS-B will extend the range of traffic alerts and various electronic communication links are beginning to allow much more information to reach the crew from ground sources, but with no integrated standard protocol for prioritizing and organizing the information to reduce the demands on pilot attention and information processing. Again, these alerting systems are separate, independent units manufactured by a variety of avionics suppliers, each using different alerting and display philosophies to present information to the crew.

The problem of conflicting or contradictory information is best described, in Figure 1, by an actual incident reported to NASA Aviation Safety and Reporting System (ASRS).

> Upon departure from LaGuardia on runway 13, whitestone climb, passing approximately 1000 ft agl, a TCASII traffic advisory (TA) 'traffic, traffic' sounded. At the time we were in instrument meteorological conditions. Immediately after that a resolution advisory (RA), 'reduce vertical speed,' came on with the TCASII target superimposed on our aircraft symbol. We began reducing our climb when an RA 'descend, descend' sounded with a vertical speed command of greater than 2000 fpm annunciated. The target was still directly on top of us with its relative altitude displayed. We immediately commenced our descent and exited the clouds at 900 ft agl at which time a GPWS warning came on saying 'too low, terrain.' By this time speed had built up to 280 knots. I then decided it was better to take a chance on hitting another airplane versus the sure thing of colliding with the ground, and directed the first officer to resume the climb and departure while I turned the transponder to TA only. At this time ATC gave us a new heading and altitude and I reported the TCASII RA maneuver. All this time either a TA, RA or GPWS warning had been going on and for a while 'descend, descend' and 'too low, terrain' were being broadcast simultaneously. The cockpit indeed was a cacophony of bells, whistles and flashing lights. (*abbreviations were spelled out and nonessential text was added for readable*; ASRS ACCESSION NUMBER: 403254)

Figure 1. ASRS incident report.

As described in the incident, the crew was receiving valid but opposing alerts from the TCAS and GPWS systems. In this time-critical, stressful situation, the pilots had to decide on their own which alert would take precedence and the appropriate action to take. Indeed this decision was made even more difficult by the blaring bells and whistles. Each system was designed with its own goals and objectives. Since the systems are separate and independent they do not have a common framework to share intent. Without a means to integrate and prioritize information, pilots are left on their own to de-conflict the alerts.

The second void identified with today's aircraft alerting systems was the lack of integrated strategic information for predictive situation awareness and planning ahead. The authors reasoned that if the crew is adequately informed of developing conditions many potential cautions and warnings can be avoided all together. Noticeably absent among the abundance of information provided on the flight deck is the availability of strategic information for look-ahead prediction, planning, and situation awareness. Though pilots are briefed about an hour prior to their planned departure concerning forecasts, advisories, and expected delays, in a dynamic environment, conditions are continually changing. Pilots generally have access to real-time tactical weather information from their weather radar systems and by looking out the windscreen. For up-to-date strategic information, pilots rely on supplemental information from the Automated Flight Service Station (AFSS) briefing facilities, communications with ATC, dispatch, and the 'party line,' by which pilots overhear other pilots reporting current conditions [3]. The only problem is that the information is presented verbally or textually and therefore needs to be processed, integrated, and visualized by the crew to understand the relevance to their current flight plan.

In response to these issues, we have developed the Alerting and Notification of Conditions Outside the Aircraft (ANCOA) concept. This concept is based on the application of human-centered guidelines and the development of a consistent philosophy for designing the components of an aural and visual alerting system. Key aspects of the concept are: (1) the ability to de-conflict currently separate alerts such as TCAS and EGPWS; (2) categorization (weather, traffic, ground, other) and prioritization (time-critical, tactical and strategic) of alerts to reduce pilot information processing requirements; (3) directional, multidimensional aural cueing to allow quick "pre-processing" of the condition (this aids in time-critical responses and in deciding the priority of the alerted condition relative to the on-going task); and (4) integrated graphic presentation of conditions external to the aircraft to support better situation awareness. ANCOA integrates information from independent alerting systems enabling multiple alerts of external conditions to be prioritized and de-conflicted before presentation to the crew. The goal was to support prompt, appropriate responses to adverse conditions based on good situation awareness.

2 ANCOA

The Alerting and Notification of Conditions Outside the Aircraft (ANCOA) concept proposed here creates an integrated alerting and notification system that assures that pilots are aware of, and informed about, environmental and other important conditions external to the aircraft. It integrates current alerting systems for external conditions, and provides integrated alerting for information transmitted from the ground, much of which is strategic in nature. Finally, it provides supporting information for external situation awareness in an integrated graphical format.

2.1 ANCOA Philosophy

ANCOA development followed human-centered design philosophy. This philosophy was applied to the look and feel of the alerting system as well as the processing requirements. Figure 2 illustrates the functional requirements of ANCOA. These requirements are largely sequential in nature given an alerting situation. ANCOA utilizes aural and visual information to aid the pilot in performing each of these functions. The remainder of this section will describe issues related to each of the functional requirements of the ANCOA concept.

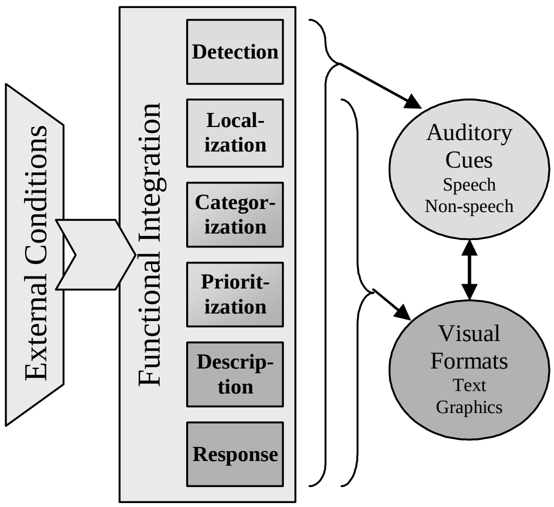

Figure 2. Functional Requirements

Detection. A pilot cannot respond to a situation that he or she does not know about, and so the detection by the pilot of anomalous conditions is the first responsibility of an effective alerting system. In the ANCOA concept, this function is best supported by an aural cue. Research has shown that the ability of an observer to detect a signal can be substantially improved if an aural warning is presented versus situations in which an aural warning is absent [3]. Aural information about the environment can be processed independently of the direction of the pilot's gaze. In the ANCOA concept, a second parameter, location, is used to aid in pilot detection of alerts. The location of the sound in space can play a significant role in detection. To the degree that sounds can be spatially separated in an environment, the potential for masking (i.e., the impact of one sound on the perception of another sound) can be significantly reduced, making the alerts more readily detectable.

Localization. The external flight environment is a spatial one in which events are occurring at different locations in space. Often times, this location information is critical to the pilot and the decisions he or she will ultimately make. In traditional aviation alerting systems, auditory information has not typically had a meaningful directional component. An interesting methodology for providing location information to a pilot is through the use of directional sound, via "spatial auditory displays[1]." With this type of aural display a pilot can perceive "virtual" sounds that can originate from arbitrary azimuth angles, elevations, and distances relative to the listener. Such displays allow ANCOA to take advantage of the natural orienting mechanism of the human auditory system. If an aural alert emanated from the specific location of the threat relative to the pilot of the aircraft (say, for instance, from the direction of another aircraft that is dangerously close), the pilot's response would be to immediately look in that direction, see the threat, and make an evasive maneuver. In this scenario, it has been postulated that the pilot would initiate the maneuver more quickly since he or she would not have to localize the other aircraft via visual displays on the flightdeck before reacting. This can be especially important during time-critical situations. This localization, through the aural cue, is a key function of the ANCOA alerting system.

Categorization. There are literally thousands of separate potential conditions that merit an alert. To avoid processing and information overload, and to help pilots to understand the general nature of the alert more quickly, ANCOA defines four high-level categories of "outside-the-aircraft information": traffic, terrain, weather, and a mission category, which includes information from a variety of sources (e.g., ATC, dispatch, Notices to Airmen - NOTAMS). In the ANCOA concept, unique aural and visual representations are used to aid the pilot in differentiating these categories. Providing high level categorization in the aural cue is another innovative aspect of ANCOA.

Prioritization. All failure conditions are not equal. Some conditions may require an immediate response while others may be less critical in nature. Several factors play an important role in determining the criticality of a condition: time to response, certainty of the information, and level of threat to the aircraft and mission. Existing Caution and Warning Systems (CAWS) like EICAS have a prioritization schema: warnings, cautions and advisories. ANCOA, somewhat similarly, has three categories: (1) Time-Critical, (2) Tactical, and (3) Strategic. These categories are roughly equivalent to the warning, caution and advisory categories used in EICAS, but are defined somewhat differently because of the different nature of internal and external conditions.

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[1] The use of the term " display" in reference to audition may seem somewhat unnatural; the term is most often associated with the *visual* display of information. However, a display is simply the "presentation of information to *any of the five senses*" (Stokes, Wickens, and Kite, 1990, italics added). Therefore, displays can be visual, auditory, tactile, olfactory, or gustatory (taste).

A time-critical alert is for conditions that demand a response within 60 seconds, When a time-critical situation arises, the crew is presented with a correlated aural/visual alert that is designed to quickly direct their attention to the nature and location of the threat and also to command the pilot on what actions to take to evade the threat. Tactical alerts, on the other hand, have less urgency than time-critical alerts, but still require the pilot's attention to the situation, and have a high probability of requiring pilot response in the near future. These alerts are concerned with problems that may affect the mission within 10 minutes, such as weather in the immediate vicinity, or conditions that may be further away in time but are certain and can be responded to immediately, such as a closed runway or faulty equipment. The philosophy behind strategic alerts for ANCOA is probably the most innovative inclusion to the alerting concept. These alerts address problems that are at least 10 minutes away and those that are probabilistic, such as, a weather cell that is near the destination that is moving away from the airport or pilot reports of wind shear. While this strategic information is important to the overall situation awareness of the crew for planning and informed decisions, the notification system for strategic information must be designed such that the crew does not have their current tasks interrupted, or be overloaded with new information. Therefore, we have developed subtle, yet informative, aural and visual alerts that will allow the crew to decide whether or not they will address the situation then, or at a latter time, depending on their current workload.

Description. Time permitting, a pilot's ability to determine a course of action is greatly enhanced by a deeper understanding of the nature of the condition. Thus a description of the condition can facilitate better decision making by the pilot. In the ANCOA concept, this information can range from a single spoken and visually displayed word indicating traffic in a time-critical situation, for example, to a fairly detailed combination of graphic and textual description of a weather cell over the destination airport for a strategic situation.

Response. A pilot may or may not have time to determine a response to an alert. Depending on the criticality of the situation and the pilot's understanding of the situation, an alerting system may have to provide pilots with direction of the appropriate response to take. This is especially important in time-critical situations where pilots have little time to consider options. In the ANCOA concept, we have included commanded information, both aurally and visually, for these situations. This information takes the form of simple voice commands and visual icons to aid the pilot in rapid decision making.

3 Implementation Prototype

Honeywell Laboratories has developed a conceptual design of the Alerting and Notification of Conditions Outside the Aircraft (ANCOA) [4][2]. ANCOA provides for the systematic integration of these independent alerting systems that integrate, prioritize, and deconflict alerts for conditions outside the aircraft. This system is based on the application of human-centered guidelines and the development of a consistent philosophy for designing the components of an aural and visual alerting system. This philosophy was applied to the look and feel of the alerting system as well as the processing requirements.

3.1 Prioritization Scheme

For the ANCOA concept, time-critical alerts are concerned with problems that lie within a 60-second time window. When a time-critical situation arises, the crew is presented with a correlated aural/visual alert that is designed to quickly direct their attention to the nature and location of the threat and also to command the pilot on what actions to take to evade the threat. The first 30 seconds of a time-critical alert is known as the time-critical lite condition. In this phase, a time-critical alert is initiated however a response is not commanded.

Tactical alerts, on the other hand, have less urgency than time-critical alerts, but still require the pilot's attention to the situation, and have a high probability of requiring pilot response in the near future. These alerts are concerned with problems that may affect the mission within 10 minutes, such as weather in the immediate vicinity, or conditions that may be further away in time but are certain and can be responded to immediately, such as a closed runway or faulty equipment. In our concept we use a repeating non-verbal aural alert to inform the crew that there is a tactical situation. In addition to the aural alert, corresponding visual information is provided to the crew that describes the nature of the alert in more detail.

Strategic alerts address problems that are some time minutes away and those that are probabilistic, such as, a weather cell that is near the destination that is moving away from the airport or pilot reports of wind shear. While this strategic information is important to the overall situation awareness of the crew for planning and informed decisions, the notification system for strategic information must be designed such that the crew does not have their current tasks interrupted, or be overloaded with new information. Therefore, we have developed subtle, yet informative, aural and visual alerts that will allow the crew to decide whether or not they will address the situation then, or at a latter time, depending on their current workload.

3.2 Categorization Scheme

ANCOA defines four major categories of information for alerting, listed with examples in Table 1. In the ANCOA concept, unique aural and visual representations are used to aid the pilot in differentiating these categories. Providing high level categorization in the aural cue is another innovative aspect of ANCOA.

Table 1. Category descriptions and examples.

Category	Description	Examples
Traffic	Any alerts due to other vehicles, on the ground or in the air	TCAS, RIPS
Terrain	Ground conflicts	GPWS, EGPWS
Weather	On Board and datalink-based systems that convey weather information and weather-related alerts	Lightning, Windshear, Hail, Turbulence, Convective radar, Icing,
Mission	Any constraints that affects the mission, i.e. flight plan, airports, route	Gate changes, airport conditions, scheduling constraints, flight planning

Category information is incorporated into visual alerts via an icon next to each message in the Message area. Category information is embedded into aural alerts as well. Time-critical alerts contain the name of the category in the voice message. Tactical and Strategic alerts are separated into four distinct “earcons” (distinct aural sounds), one for each category.

3.3 Aural 3D Sound

For the ANCOA concept, we are using a second parameter to aid in pilot detection of alerts, that is, location. The location of the sound in space can play a significant role in detection. To the degree that sounds can be spatially separated in an environment, the potential for masking (i.e., the impact of one sound on the perception of another sound) can be significantly reduced, thereby making the alerts more readily detectable. To this end, we are placing aural alerts at calculated locations on the flight deck to aid in drawing the pilot's attention to the alerts.

For the purposes of ANCOA, we used aural cues to help provide an immediate knowledge to the pilot of what the priority of the alert was as well as the category of the particular condition. We used aural signals to indicate priority by varying certain acoustic characteristics as well as the spatial location of the auditory event. In addition, we designed the alerts such that the pilot would immediately know to which category an alert was referring simply based on the characteristics of the sound. For example, we employed an increasing frequency sweep signal (a "whooping" sound) as our terrain alert. We chose these signal characteristics to mimic the signal configuration of existing GPWS systems since the "whoop, whoop" signal is a readily recognized by pilots to signify situations related to terrain. Similarly, we used a "horn-like" signal to indicate traffic. Inherent in the signal is a mapping onto a real-world event (a car horn). We intended to have this mapping aid the pilot in immediately understanding that the alert is related to traffic simply based on the aural characteristics of the signal.

Time critical alerts are annunciated via voice to distinguish its priority. Alerts sound from the direction of the threat to convey location information. If a response is associated with the alert, it emanates from the direction of the commanded maneuver. Category information is explicitly conveyed via the voice message. The messages repeat until acknowledged by the crew. When an alert has been resolved, an additional single aural message is played to make the crew aware of this fact.

Tactical alerts are annunciated via a tone or chime. The sound emanates from the ND/MAESA display in order to direct crew attention to more information associated with the alert. There are four distinct types of sounds, one for each category. Thus a tactical alert aural cue embeds category information. The messages repeat until acknowledged by the crew.

Strategic alerts emanate from the outboard side of the pilot not flying, in order to not distract the crew if they are engaged in higher priority tasks. It is single sound that does not require acknowledgement. The sound is one of the same four used for tactical alerts, one for each category. Thus a strategic alert aural cue embeds category information.

3.4 Navigational Display

Honeywell Laboratories’ previous implementation of ANCOA involved a stand alone system entitled the Message Alert and External Situation Awareness (MAESA) Display[4]. This display was the primary area for displaying time-critical, tactical, and strategic messages to the pilot visually. The display was used as a situation awareness, planning, and collaborative decision-making tool that allowed pilots to view any flight phase and overlay information from multiple sources to gain an understanding of the current and future flight environments. Upon consultation with a major flight deck integrator, it was determined that a stand alone system was not desirable, but rather the information previously available on the MAESA display should be incorporated onto the NAV display[2]. Realizing this is a valid constraint, the current conceptual design incorporates the previous MAESA features onto a ND.

The ND/MAESA display, illustrated in Figure 3, can be divided into five parts: (1) Display Filter Controls (upper left), (2) Display Area (upper center), (3) Message Area (right), (4)Vertical Profile Display and Range Controls (lower center), and (5) Range Controls (lower left)

Figure 3. Integrated Alerting on a NAV Display

3.4.1 Display filter buttons

The Display Filter Controls allow the pilot control of what information is displayed on the Map Display. The Map Display displays four types of information: weather, traffic, terrain, and flight planning information.

Subcategories of information are available in each category, accessible by pressing the arrow next to each button. Within each of the four categories: (1) Weather: convective weather, icing, turbulence, winds, wind shear, hail, lightning and volcanic ash.; (2) Terrain: relative and absolute terrain; (3) Traffic: TCAS symbology, traffic congestion, RIPS; and (4) Flight Planning Map: waypoints, airports, airways, SUA, destination airport

Any of the four categories of information can be displayed alone or in conjunction with any other category of information. A pilot can select and de-select the information categories depending on the information that he or she needs to gain a good sense of the situation.

3.4.2 Map display

The Map Display integrates iconic representations of objects in the world (traffic, weather, terrain) and navigation information (flight plan, airports, waypoints). There are two viewpoints: 1) egocentric, where the top-down, representation of the world is in reference to ownship and the aircraft is at the center of the display, and 2) exocentric, a world representation where the pilot can navigate to any area by using the arrows to pan in any of the eight directions. The A/C Center button will return the Map Display to the Egocentric View if it is in Exocentric View.

The Map Display shown in Figure 3 depicts an egocentric view, where the aircraft is in the center of the display, and the map moves relative to the airplane. A second view, called the Exocentric View, renders a portion of the map without the constraint of the airplane being centered on the display. The display switches to the exocentric view automatically when one of the eight direction buttons (located at the center and corners of each edge of the Map Display) is pressed.

Pressing a button causes the viewable area of the map to move in that direction. The unit of movement will be equal to the range displayed on the heading dial. When the Map Display is in the Exocentric View, the heading dial disappears. The airplane icon remains, but moves when the map is moved. The range circle remains in its fixed location on the screen.

3.4.3 Message area

The right quarter of the display is the message alert region where text alerts are displayed and prioritized into time-critical, tactical and strategic categories. The message area is divided into three parts and each part is represented as a tab. The three tabs are:

- "ALRT": Time-Critical (red) and Tactical (yellow) messages in this pane,
- "MSG": Strategic (cyan) messages in this pane, and
- "LOG": History log, where time-stamped messages appear,

where only one group is visible at any time. Pilots navigate between groups by pressing the appropriate tab at the top of the display.

In the ALRT pane, all time-critical alerts appear at the top of the message area, followed by the tactical alert. Time-critical alerts are displayed in red, tactical alerts are displayed in amber. Similar to EICAS, new messages appear at the top of the list. The MSG pane contains all the strategic alerts, sorted by arrival time. Strategic alerts are in cyan (for new messages). The messages include alerts of threatening traffic, terrain, and weather conditions. Other available information includes the reporting of NOTAMs, PIREPS (pilot reports) and ATIS reports that are relevant to the flight.

Message Detail Box. The pilot can scroll through the messages and select a message by clicking on it. Selecting a message links the message to the Message Detail Box. There is a dedicated area at in the lower portion of the Message Area that contains the message details. Selecting a message not only highlights the corresponding icon on the Map Display (if one exists) but also populates the Message Detail box with the "long" version of the message and any of its details. Such details might include trend information, the age and certainty of the information, forecast information, or the source of the alert information.

Sorting Messages By Priority. Similar to EICAS, new messages appear at the top of the list. In the ALRT group, time-critical alerts appear at the top of the Message Area, followed by the tactical alerts. Thus an incoming tactical message would appear at the top of the tactical list, just below the last time-critical message. Strategic notifications are listed separating under the MSG tab in chronological order.

3.4.4 Vertical profile display

The conceptual design for the Vertical Profile Display (VPD) involves both display and control functions. The VPD displays the vertical profile of the flight plan, and the aircraft's current position within the flight plan. The VPD indicates the flight plan by drawing a magenta line starting from takeoff, through cruise, and ending at landing. A (white) triangle depicts the airplane. One can advance along the flight path by pressing the arrow keys at the start or end of the flight plan. The white box indicates the portion of the flight plan that is currently visible in the top-down map display area. Zooming in and out will decrease and increase the size of the white box. The VPD can also be used to show terrain, weather, and traffic along the flight path.

3.5 Primary Flight Display

The ANCOA PFD begins with all of the functionality of a conventional primary flight display. The main components consist of: mode annunciations, an airspeed tape with target bugs, altitude tape with target bugs, a vertical speed indicator with target bugs, roll indicator, pitch ladder, heading, radio altimeter, horizon line, and a flight path vector. The flight path vector, when combined with the terrain, will provide the crew with the trajectory preview to ensure clearance of the terrain. Each of these components may be modified in order to annunciate the presence of an immediate threat or response to that threat. The primary flight display is reserved for the highest priority, time-critical alerts only.

When deciding on what features to incorporate onto the PFD, one must consider the tasks that are supported by the display. First and foremost, the PFD should support accurate guidance your flight path via manual control of the pilot flying. With the addition of terrain, the PFD should allow recognition of terrain features and the location where the separation between flight path and terrain may be compromised. Additionally, the PFD should allow the recognition of terrain features where a future conflict between ownship and terrain may arise. With these constraints in mind, we developed an alerting scheme around the PFD.

The PFD is reserved for the presentation of the highest priority alerts only. It is assumed that in time-critical situations the pilot flying's attention is on the PFD, the main display that supports his/her current aviate task. The time-critical hazard is identified with a symbol and/or a label. For instance, a terrain warning would display "TERRAIN" and the terrain with the highest threat to the aircraft would be highlighted. Table 2 gives examples of how hazards are represented on the PFD.

Table 2. PFD hazard alerts.

Hazard Type	**Alert Label**	**PFD Symbology**
Terrain	TERRAIN	Peak painted red; flash
Traffic	TRAFFIC	Red circle around threat; caged when out of FFOV
Turbulence	TURB	Turbulence message
Wind shear	WNDSHR	Wind shear message

3.6 Master Caution and Warning Annunciation

The conventional Master Caution and Warning annunciation panel was modified to incorporate ANCOA's additional features. Below are some of the main features of the modifications and their purposes.

There are two sets of buttons, one for each pilot. Each set has three buttons: red for time-critical alerts, amber for tactical alerts, and blue for strategic alerts, providing a redundant means of informing the pilot of the priority of an alert. Pressing one button turns off the corresponding button on the other set, and inhibits the aural portion of the alert to allow the crew to have some level of control over the aural alerts. The Master-Caution button behave in the following manner: (1) **Time-critical**: top red button light blinks for 5 seconds and then stays on continuously. An associated aural alert sounds. Pressing this button turns off the light and the aural alert. No other alarms will sound while a T/C alarm is still active. (2) **Tactical**: middle amber button light blinks for 5 seconds and then stays on continuously. An associated aural alert sounds. Pressing this button turns off the light and the aural alert; and (3) **Strategic**: bottom blue light is displayed continuously, and accompanied by a single aural alert. Pressing this button turns off the light. Addition of the strategic alerting light modifies the existing panel, and is included as a reminder to the pilot of impending conditions in case the subtle cue was missed.

4 Alerting Functionality

Throughout establishing the philosophy and implementing the alerting scheme, there was a concerted effort to balance alerting the flight crew to a hazardous situation and distracting them with alerts that were too loud, too long, and beyond their usefulness. In the implementation of ANCOA we chose to:

- Provide a visual component to the alert to capture the crew's attention

- Allow the pilot to silence the aural component to the alerts, however,

- Maintain some portion of the visual component until the conflict is resolved.

For instance, as a new alert is issued, the flight crew can silence that alert by pressing the Master Caution and Warning button. However, the text message and the graphical depiction, if any, remains available until the conflict is resolved or the situation no longer exists. The absence of the visual message is feedback to the pilot that the situation has been resolved, which is particularly important in the time-critical and tactical situations. A 'clear of [alert]' is also announced in time-critical situations. Another benefit is the mere visual presence of a strategic message also serves as a reminder to the flight crew of the availability of information if they chose to ignore the initial notification.

It is vitally important that the crew's attention is focused on the most important task at hand. An integrated alerting system must be aware of phase of flight and the flight crew's current task in order to avoid directing their attention to a less critical task. In the implementation of ANCOA, we chose to:

- Make strategic aural alerts noninvasive by having a single, non-repeating tone presented on the outboard side of the pilot not flight and

- Inhibit non-time-critical alerts during critical phases of flight.

Another important component to directing the crew's attention is signifying the highest priority task. Sometimes this involves inhibiting alerts during the critical phases of flight such as take-off and landing so that the crew can continue the task at hand without interruption and other times this requires a prioritization of multiple alerts to ensure that the crew responds to the most pressing situation. To this end, in the implementation of ANCOA, we chose to:

- Present only one aural alert at a time

- Avoid conflicts in alerts by only aurally presenting the highest priority alert, though the visual aspect of all alerts would be available, and

- Establish a clear alert precedence within category scheme. in order to avoid conflicts within a priority level.

Finally, we thought it was important to track the history or changes in the alert as a condition becomes more or less hazardous to the mission. Therefore, in the implementation of ANCOA, we chose to:

- Track changes in alert priority status, so that as an existing alert condition changes such that its priority changes, a new alert is generated.

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