Visual Coding of Status for Technical Operations Systems

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16. Abstract

In order to monitor and control over 30,000 different services and equipment, Technical Operations (TO) specialists must be provided with clear and consistent methods for recognizing status quickly. Without specific guidance on status coding, each new system must come up with a strategy for conveying status information, leading to coding that is inconsistent with other systems and often inconsistent with human factors best practices. The purpose of this document is to promote consistency in the coding of status information used for monitoring and control at TO Service Operations Centers. This report defines the various terms used for status-related events in TO, describes the TO work environment, describes current information displays used by TO, and explains how to use screen real estate to enhance user performance. This document also describes the various methods used to code status and provides explicit recommendations based on Human Factors best practices. If the course of action described in this report is successful, it will promote consistency in the coding of status information across systems. This can reduce the time needed to identify and react to a potential problem, minimizing the potential for outages and decreasing the impact of outages that do occur.

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Executive Summary

Technical Operations (TO) specialists monitor system status through changes in coding on a display. In the past, coding has been developed on a system-by-system basis with each program coming up with coding rules for an individual system. This has led to inconsistent coding schemas across TO systems in an individual work environment. Inconsistent coding between systems prevent the users from transferring knowledge gained from one system to another system.

This paper provides a framework for the development of status coding. If the process described in this paper is successful, it will promote consistency in the coding of status information across systems. This can reduce the time needed to identify and react to a potential problem, minimizing the potential for outages, and decreasing the impact of outages that do occur.

The first steps in developing appropriate status coding are defining what needs to be coded and describing the environments that the coding will be used. Status coding for current systems often are developed without consideration of coding conventions already in use in the existing environment. Generally, each program defines the items to be coded and identifies the coding conventions to be used individually. In this paper, we have defined commonly used status terms so that they can be used consistently across TO systems. Additionally, by providing definitions for these terms, programs that use this document can save the time and money normally allocated to defining these terms.

The environment that it is presented in influences the effectiveness of status coding. Environmental issues that can have an impact include the lighting levels of the room, the distance that the items will be viewed at, the brightness levels of monitors near the new system, and even the age of the TO specialists. Often programs develop coding for a system without a clear idea of the environment in which it will exist because a lack of travel funds, time, or manpower. Although this report does not provide all of the information that may be obtained at a site visit, it provides valuable knowledge about the existing environment that assists developers that do not have the ability to see the environment for themselves. Additionally, it may bring to the attention of developers, items that they may not have considered otherwise.

Finally, this paper defines different coding techniques and provides specific recommendations on how to use these coding techniques appropriately. Some of the specific coding areas that are covered in this paper are: alphanumeric, brightness, flash/blink, highlighting, shape, size, location, and color-coding. The guidelines that are presented here are based on information from the Human Factors Design Standard.

The authors hope that the methods presented in this paper for status coding will promote consistency across TO systems and improve the effectiveness of the coding techniques used in TO systems.

1. INTRODUCTION

Determining how to code status is one of the fundamental challenges in developing Technical Operations (TO) systems. The status of a TO system is an indication of the current operating condition. Examples of status include whether the system is operating as normal, is functioning but not at the optimal level, or is not functioning at all.

Service Operations Centers (SOCs) are the part of the TO organization responsible for systems and services at large Terminal Radar Approach Controls (TRACONs) and Air Route Traffic Control Centers (ARTCCs). TO specialists at SOCs are located on site and directly monitor and control the multiple systems that are necessary for a TRACON or ARTCC to function.

TO specialists at SOCs are often required to determine the status of a system at a glance. This paper presents an approach to the problem of how to address status coding for TO systems by presenting a general procedure and human factors guidelines. A consistent approach and set of human factors guidelines can save programs time and money while promoting consistency which can minimize errors and training time.

TO would like to ensure that human factors best practices are considered in the development of status coding for displays and systems. In order to accomplish this, TO and the Human Factors Division tasked researchers from the NAS Human Factors Group for guidance on the use of status coding for TO systems.

1.1 Background

TO specialists working at SOCs are faced with the problem of how to monitor the status of multiple systems and equipment effectively and efficiently. As they are responsible for more than 30,000 systems, facilities, and equipment that make up the infrastructure of the National Airspace System (NAS), ineffective or inefficient monitoring can have serious implications for the safety and efficiency of the NAS as a whole. Various monitors and displays alert the specialist to the current status through status coding.

Coding is a system of assigning meaning to letters, symbols, or symbol characteristics (such as color, size or brightness). Coding methods in general are used to 1) differentiate classes of information, 2) attract a user's attention to important information, 3) establish relationships between displayed objects, 4) attract a user's attention to potential problems or unusual situations, and 5) indicate changes in the state of a system (Ahlstrom & Longo, 2003). When used effectively, coding can decrease visual search time, drawing user attention to important information and thus permitting the TO specialists to monitor and control NAS systems in a safer and more effective manner.

As new status displays are developed for TO use, questions are raised on how to code effectively. Each program develops its own methods for addressing the problem, leading to a lack of consistency across systems. Although visual aspects of coding such as ensuring appropriate contrast are important, the real problems underlying status coding go beyond what a symbol looks like to include the appropriate mapping of a code to system or equipment conditions.

What the TO specialist needs is a consistent coding scheme that will allow the user to transfer knowledge gained from one system to the interpretation of status coding on another system. This coding scheme must effectively direct the user's attention consistent with the priorities of the tasks.

The information contained in this document is based on what is currently known about human perception and cognition, knowledge gained from research on coding, technical restrictions due to displays and environmental factors, and lessons learned from the use of coding in other environments. This document complements the existing Human Factors Design Standard (HFDS) by tailoring the guidelines and explaining guidelines presented in the HFDS (Ahlstrom & Longo, 2003). This paper includes descriptions on how important status conditions are defined. It discusses how different coding techniques should and should not be used and describes user needs for status coding. If the process described in this paper is successful, it will promote consistency in the coding of status information across systems. This can reduce the time needed to identify and react to a potential problem, minimizing the potential for outages, and decreasing the impact of outages that do occur.

1.2 Purpose

This study promotes consistency in the coding of status information across TO systems. This goal will be achieved by providing human factors guidance, standardized terminology, and a standardized approach to status coding.

1.2.1 A Process for the Application of Status Coding

Consistent status coding goes beyond the application of human factors best practices to individual coding elements of the interface. To truly achieve consistency in status coding, a higher-level approach must be taken. Status coding involves not only how a system looks, but also how it behaves. The approach must include not only the application of good human factors to individual elements, but must also address consistency in assigning status to events and the prioritization of those events based on actions required by the specialists. This will promote consistency in terminology and in how events are assigned to status levels. Defining key TO systems and events is a reasonable first step.

In order to meaningfully map codes of varying perceptual prominence, the definitions must include a specification of how quickly specialists must respond to the event. For any given system, there will be some events that require immediate user attention and others that do not. This is often system-specific, depending on multiple factors such as whether the system itself is critical, whether it is primary or backup, and so on. Events that may require immediate attention in one system, generating an alarm based on the definitions given below, may not require immediate attention for another system, generating an alert based on the definitions given below. Prior to assigning a color, flash rate, or other visual code, the system conditions should be mapped to the appropriate status and associated user action.

Once the research team identified the need for clarity in the definition of system statuses, we compiled a list of events and information that TO specialists might need to be aware of. We based this list on events and information on TO systems in current operational environments. We presented this list to TO specialists for feedback. What we found was that TO specialists often use different terms to describe similar states and statuses.

1.2.2 Impact of Aging on TO Displays

Experiments have demonstrated that as people age the ability to divide attention over multiple on screen tasks diminishes. People in their 20's can perform up to four tasks, especially if the operator is familiar or experienced with some of the tasks. People in their 50's require effort to maintain two tasks simultaneously. Additionally, the ability to maintain attention, even with stimulating tasks, begins to diminish as people age (Vincenzi, Muldoon, & Mouloua, 1997).

With decreasing ability to divide attention, users become increasingly reliant on status codes to attract their attention to items needing attention. Thus, the effective use of status codes to direct user attention becomes increasingly important.

1.2.3 SOC Operating Environment

In order to understand what we are facing in regard to human factors input to the TO work environments, it is helpful to understand what the SOC work environments are like. This section describes TO SOCs.

TO is not a homogeneous environment. Within TO, specialists at Service Operations Centers monitor many systems within a large control room. TO specialists at these facilities use status coding as a primary means of obtaining information while monitoring systems in their domain. There are two general types of SOCs; TRACON SOCs and ARTCC SOCs. The lighting levels and equipment monitored are different for these two types of SOCs.

The TO area is often co-located with Air Traffic operations at ARTCC SOCs. Because they are co-located with Air Traffic operations, the ambient lighting levels are low. The work area is generally small (as little as 400 square feet at some facilities). This workspace contains 35 to 40 CPUs and monitors for the control of up to 25 different computerized systems. The work area also contains hardwired panels and displays of environmental, security, and performance information.

Nearly every ARTCC SOC has at least one wall of computer monitors stacked three high above workstations due to the size limitations of the workspace. Monitor and control of systems information in the middle and upper levels requires standing on a step stool in some cases in order for the shorter personnel to see the information displayed on the upper level of monitors.

Generally, the TRACON SOCs monitor and control fewer computerized systems than the ARTCCs. Specialists in these types of facilities are responsible for 12 to 18 computer systems compared to the 25 to 30 at ARTCCs. SOCs at TRACONs are frequently, but not always co-located with Air Traffic Control operations. In these situations the work area is dark, even darker than the ARTCC SOCs. TRACON SOCs that are separate from the ATC work floor are well lighted. They generally have lighting levels similar to a normal office environment. As in the ARTCCs, there is a substantial amount of information conveyed at TRACON SOCs via hardwired displays. Thus, there is less stacking of monitors and when it is necessary, the stacks are no more than two rows high.

2. DEFINITIONS OF STATUS CONDITIONS

In order to make clear status coding recommendations we begin with a clear explanation of the various terms that are used to represent event status in TO. These explanations will allow us to group like terms. NAS systems are growing increasingly complex and individual systems can have multiple states and statuses associated with numerous events. The interdependencies of the states and statuses often depend on the importance of the system, subsystem or component to the NAS as a whole. For example, it is possible for a system to be in a normal, but off-line state. Additionally, some items may be indicated as an alert in one system but an alarm in another, depending on the particular system. For example, a loss of communications link may trigger an alert for one system but an alarm for another. It is our hope that as systems are developed, the product teams will have these definitions on hand and will be able to use them to guide the coding for individual systems based on these definitions, allowing system developers to attribute a prioritization scheme to system conditions and events while promoting consistency across systems.

Some of the NAS systems are critical to the ability to safely control air traffic, loss of these systems would cause an interruption to air traffic services. To prevent interruption of air traffic services, the NAS is designed to have redundancy for critical systems. Backup systems exist to continue service if primary systems fail. Due to the criticality of the information provided by the systems, it is mandatory that backup systems are available and that specialists are aware of the status of critical backup systems. Backup systems generally provide only a subset of the full system functionality, but allow the critical service to continue uninterrupted.

Developers need to take into account the mapping of different conditions to states and statuses and the human factors best practices for coding. For each system, they need to define what events are critical and what events are non critical with consideration of the states and statuses defined in this document. They also need to consider how states and statuses for a system may interact, for example, if a system is operating in a normal state, but is in an off-line status. Using the definitions provided in this document, system developers can think about how the conditions of a specific system map to the defined states and statuses including what system occurrences require an alarm, an alert, and so on. Once the system conditions are mapped to the definitions provided in this document, the system developer can move to section of the paper where specific recommendations are provided on how to code specific systems conditions. In any program, there will be tradeoffs in which certain guidelines will not be able to be implemented. This paper also provides justification on why the specific coding recommendations are made, so that users can make informed decisions and understand potential consequences of alternatives when faced with coding tradeoffs.

The following tables present definitions of common TO status terms and conditions. These definitions were obtained from FAA documentation, subject matter expert input, and other technical documents like the Standard Terminal Automation System AF Computer-Human Interface (CHI) Thin Spec, the Maintenance Monitoring System Function Key Description, and Maintenance Automation System Subsystem Monitor Control Function technical documentation (Bennett, 2000; Federal Aviation Administration, 1997, 1999, 2000, 2002).

There are only a few primary status conditions found on TO monitor and control status displays. These are defined in Table 1. The status conditions are defined in terms of the immediacy of the action required by the user. Most TO systems have the status of alarm, alert, normal, and unmonitored. Some older systems use the term soft alarm. We recommend dropping the term soft alarm and only using alarm, alert, and unmonitored for the primary status conditions.

Table 1. Definitions of Common TO Status Conditions

Status Conditions	
Alarm	Indicates that the value of a monitored parameter is outside the specified acceptable range. Immediate action is required to avoid impact to NAS operations.
Alert	Indicates that an operational status/condition status of a NAS infrastructure resource in which the resource is still capable of performing it's functions but some aspect of the resource has degraded or failed and the functions may degrade or fail if action is not taken as soon as practicable
Normal	Indicates that a system is operating within its ideal operating range and no action is required.
Soft-alarm	Some parameters may have alarms set to provide an indication that they are approaching an out-of-tolerance condition. These are commonly referenced as soft alarms or maintenance alerts, and have standard values with tolerances/limits defined. Despite the name, a soft alarm is an alert, not an alarm. For consistency, we recommend not using the term soft alarm in TO systems.
Unmonitored/unmanaged/inactive	Not monitored, directed, or controlled. This is a status imposed on the system by the user. A system may be unmonitored, unmanaged, or inactive because: 1) it is awaiting a maintenance action, 2) it is not a system that is currently used, 3) it is being used for training, or similar reasons. Depending on the reason an item is placed in the unmonitor status, specialists may still need to see the status of individual components by drilling down the hierarchy.

In TO systems, an *event* is any occurrence, which may or may not be significant. Specialists usually do not need to have events versus non-events coded as such, but rather need to have specific types of events coded such as alarms, alerts, and so on. Event is usually considered a catchall term and does not require coding in and of itself. An event may include the following:

a) failure of any NAS infrastructure resource,
b) change of operational configuration of any NAS infrastructure resource,
c) any other state change,
d) issuance of any command by NIMS to any NAS infrastructure resource,

e) any action performed directly on a NAS infrastructure resource by an authorized NIMS user while outside of NIMS NOCC, OCC, SOC, and WC physical facilities, or
f) any other occurrence selected by an authorized user for national, regional, or local display and/or retention.

There are many events that can cause a system to go into an alarm or alert status. Some of the events that can cause a system to go into alarm or alert status are listed in Table 2. As seen from the third column in Table 2, whether a condition triggers an alarm or alert status depends heavily on the particular system and the impact that that condition will have on the system and the NAS infrastructure as a whole. It is possible for a system component to have failed but not to have triggered an alarm because the system is not important enough to the NAS infrastructure. Conversely, there are systems where a loss of redundancy will trigger an alarm because the system is so important to the NAS infrastructure that it is critical for operations to have redundancy in that system.

Table 2. Events That Can Lead to an Alarm or Alert Status

Condition	**Description**	**Alarm or alert status**
Abnormal/warning	Indicates that a system is operating within its ideal operating range but there is an aspect of the resource that requires action.	This condition usually triggers an alert.
Failure /failed	Indicates that the cessation of the ability of a system or any of its components to perform a specified function or set of functions. The system is operating outside its acceptable operating range and requires maintenance action. The failed state can be synonymous with unscheduled out of service.	This will usually cause an alarm.
Loss of communications/communication link	Indicates that there is a facility/equipment monitoring or control loss.	A loss of communication link could trigger an alarm or alert depending on the affected item(s) and the particular system.
Loss of diversity	Indicates that there is a loss of backup equipment.	This would generally cause an alert but may cause an alarm depending on the system.
Loss of redundancy	Indicates that primary equipment is out of service (operating on backup/secondary system).	This will usually produce an alarm, but may produce an alert depending on the particular system.

Marginal /degraded status /degraded	Operating outside its ideal operating range but within its acceptable range and requires management action.	This usually triggers an alert.
Nearing certification date	Indicates that a system is nearing its certification date.	This may trigger an alert depending on the system.
Reduced capability	Facility or equipment is still producing data but at a diminished capacity.	This usually triggers an alert.
Scheduled out of service/intentional off-line	This state indicates that a facility, system or piece of equipment is down for an extended period of time or failed by design for preventative maintenance. No immediate specialist action is required. If an item is placed in the unmonitored status for this reason, specialists should still be able to see the status of individual components when they drill down.	Systems that are intentionally off-line or scheduled out of service for an extended time may be placed in the unmonitored status by specialists.
Unknown/indeterminate	Status cannot be determined by the system.	Depending on the system, this could trigger an alarm or an alert.
Unscheduled out of service	A facility is down or failed.	This will usually cause an alarm.

In addition to the status of systems and subsystems, there is additional information related to the status of a system that TO users often need to see at a glance. For example, TO users need to be made aware of the administrative states of systems. These states include the general categories of available, reduced, unavailable and failed. States are often indicated on monitor and control displays by location coding. Some systems have the status on the primary display area and the state on a secondary display area. Each of these categories has subcategories such as on-line and off-line. Table 3 defines additional information that often needs to be coded by TO systems.

Table 3. Additional Information That TO Users Often Need to see at a Glance on Their Status Displays

Acknowledged/unacknowledged	Indicates that a specialist has recognized an event or series of events such as an alarm or alert.
Available	The resource is administratively permitted to perform services for its users. Within this category are: on-line, on-line primary, and on-line standby.
Change in configuration	Indicates that there has been a change of arrangement that the user needs to be made aware of.
Change in status	Indicates that the status of an item has changed.

Failed	The resource has a detected hardware or software failure, has been transitioned off-line by the system, and is awaiting maintenance.
Intentional off-line	A facility is not available by design for preventative maintenance or training. **Maintenance mode**- Indicates that a system is in the maintenance mode. The resource is being readied for maintenance or is being actively tested or repaired. The maintenance mode may be similar to the unmonitored status in that users can choose to unmonitor a piece of equipment to perform maintenance. Whether this needs to be distinguished from an unmonitored or training mode may depend on the specific piece of equipment. **Training mode**- Indicates that a system is in the training mode. The training mode may be similar to the unmonitored status in that users can choose to unmonitor a piece of equipment for training. Whether this needs to be distinguished from an unmonitored or maintenance mode may depend on the specific piece of equipment.
Not Available	The resource is administratively prohibited from performing services for its users. Within this category are: off-line, off-line ready, and intentional off-line.
Off-line	The condition wherein a system resource is not configured for, and is not available for, operational use.
Off-line Ready	The operational status in which a NAS infrastructure resource is ready to support service - it only needs to be loaded with any required operational software or data, have required synchronization performed, and brought on-line to do so. This is often referred to as **hot standby**.
On backup power	Equipment is operational, but some attributes/functionality may be lost or substituted.
On-line	The resource is being used for the providing of NAS services. The condition wherein a system resource is configured for operational use.
On-line Primary	The operational state in which a NAS infrastructure resource is on-line and being used to provide service to the NAS.

On-line Standby	The operational state in which a NAS infrastructure resource is on-line but is a backup to a primary resource. A standby resource is fully capable of supporting the providing of NAS service; all necessary operational software and data have been loaded, and all necessary synchronization has been performed.
Primary or backup system	The NAS infrastructure has a great deal of redundancy built into the system. There are primary and secondary systems for critical NAS functions. Not only does a TO specialist need to know what the condition of a particular system/equipment is, they need to know whether it is the primary or backup system and if the primary system is affected, what the status is of the secondary/backup system and vice versa. Primary or backup system is often indicated in TO systems by either the letter “A” for primary and “B” for backup, or by location coding.
Reduced	Service exists at a level less than normal.

Figure 1 shows an example of the complexity of TO coding. In Figure 1, the green shows the primary system in an active (and presumably normal) state, but doesn’t show the state of the backup or secondary equipment, which could be in an alarm or alert status. An additional complication of this display is that the gray color is often used in other TO systems to indicate unmonitored status. Thus, the first time user of this system may believe that the secondary systems are not monitored. Additionally, the user will not be able to say at a glance whether the secondary system is ready in the case that the primary system fails.

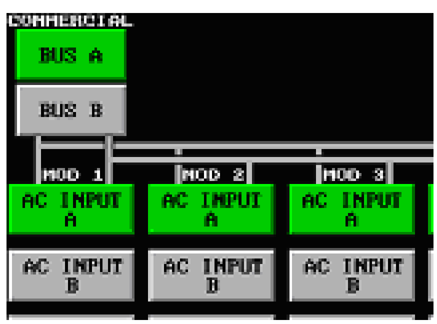

Figure 1. This illustration underscores the complexity of TO codes.

Even more complicated scenarios for system displays are currently being dealt with. With more advanced technology, systems are becoming self-regulating. Imagine a system with a display such as in Figure 1. The primary system exceeds some parameter and goes into an alert status, turning from green to yellow. The user may recognize that there is a change in status because of the change in color. However, or some systems it may be important for the user to be made aware of status changes beyond the change in color. The user may need to indicate that the problem is being addressed, thus there may be a need to show that the alarm or alert has been acknowledged.

Key to appropriate coding of status items is the need for action from the user. The more urgent the need for action, the more perceptually prominent (attention-getting) the code needs to be.

3. ORGANIZATION OF MONITOR

This section provides general guidance on how information should be displayed. TO monitor and control displays are a type of information display. As such, certain general guidelines apply to how the information is presented. Developers should strive to make the layout simple, clear, and consistent. The following recommendations apply to the organization of information on monitor and control displays.

1. In general, the display should be organized so that the user can locate needed information quickly and accurately.
2. The most important information should be placed in the center area of the display.
3. Because people in the United States generally read from top to bottom and left to right, secondary information should be placed at the bottom or right side of the display area.
4. For many monitor and control displays, the area of primary importance is a graphical status display area. This area should be located in the center of the display.
5. Developers should strive to minimize the amount of information in the primary display, consistent with the information needs of the user. If the developer tries to convey too much information in the primary status area, an overabundance of coding will result, minimizing the perceptual prominence of critical items and potentially increasing user workload and reaction time to critical events.

A general convention found in many monitor and control displays is to have two areas, one to display status and another to state and status related messages (see Figure 2). If convention for layout is used, the area that is used to display status should be kept as uncluttered as possible, with only the minimal amount of coding. This area should be used for things that require immediate user attention. If too many codes are used in this area, perceptual prominence of the codes will be minimized and the coding will lose some of its attention getting properties. Location coding, shape or symbol coding, color-coding and line coding can be used in the status area to convey different aspects of status.

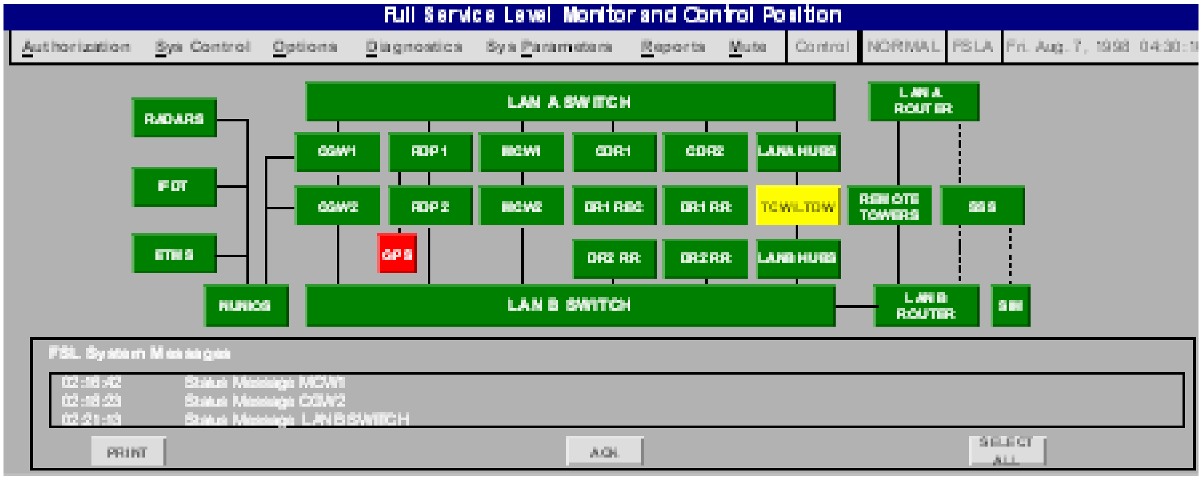

Figure 2. TO system display showing primary status area (colored rectangles) and secondary area (white text below primary status area).

Secondary or additional information can be put in a secondary area (this area is called different things by different systems- one system calls it system messages, another calls it event list). The researchers recommend that the list scroll to show the most recent events, but the system should have a rule that prohibits unacknowledged alerts and alarms from scrolling out of view. Researchers also recommend that the users be given a way to acknowledge a single event or multiple events. The secondary area should not mix routine messages with the alarm and alert messages. Mixing other text into the list adds clutter and can make it more difficult to find the important messages. In some current systems, the routine messages can force the important alerts off of the screen.

Designing effective status displays means successfully balancing attention allocation between the primary task of the user and notification of new items needing attention without disrupting access to other necessary information. The information display must allow the desired amount of attention getting to make the user aware of the situation without undesired distraction. It must allow for the user to take the appropriate action and facilitate gains in the comprehension of the situation. Users requirements depend on the specific situation and the context surrounding the situation. There is a range of presentation options with different attention-getting abilities.

4. APPLYING STATUS CODES TO SYSTEM CONDITIONS AND EVENTS

Status information is conveyed to the user through various coding techniques. Coding is a system of assigning meanings to symbols, colors, and so on, to represent information. Coding can be used to differentiate items of information, call a user's attention to important information; unusual situations, or potential problems that require user notice; or indicate changes in the state of a system (Ahlstrom & Longo, 2003). It can also be used to differentiate categories of data, particularly if a user must distinguish the data included in the categories rapidly and if the data items are distributed in an irregular way on the display. Over the years, research has lead to the development of guidelines for the use of coding. This section provides an overview of guidelines as they pertain to status coding.

The following guidance applies independently of the specific coding method that is used.

1. Coding techniques that have strong attention-getting qualities (for example, color and flashing) should be used sparingly and judiciously. Overuse of coding can reduce or eliminate the intended effect of the coding, particularly for the codes that have higher attention-getting abilities.
2. The coding conventions that are used should be applied consistently throughout an application and related applications. This is particularly important in a work environment such as TO, where the users may interact with multiple systems and be exposed to multiple different status displays.
3. Although special codes should be avoided where possible, it may be the case that the user needs related to a system require a special code. If a code is assigned a special meaning in a display, the meaning should be defined at the bottom of the display
4. In order to maintain consistency, individual users should not be able to change the status codes mapped to different system states and conditions (Ahlstrom & Longo, 2003).
5. Systems designers must avoid the temptation to use coding for decorative purposes. In other words, when codes are used, they should be for functional, not decorative, purposes and meaningful, rather than arbitrary.

Next, we present guidance related to specific coding methods. For each specific coding method, we define the method and provide guidelines related to the use of that specific coding technique. Although the number of different types of coding is almost boundless, we focus only on the methods that may the have most significance for TO use.

4.1 Alphanumeric Coding

Alphanumeric codes refer to the use of letters or numbers to represent information. An example is the use of “M” or “F” to indicate male or female. Figure 3 shows an example of how alphanumeric coding is used in one TO system.

1. Alphanumeric codes should be meaningful rather than arbitrary.
2. Alphanumeric coding does not have the attention-getting ability of other means of coding and thus should not be the sole means of drawing attention to an item.
3. Alphanumeric codes should use either upper case or lower case letters, used consistently.

   The justification behind using all capital letters is to maximize the size of the text display to meet legibility height requirements (a capital R is larger than a small r), but there is no clear evidence that favors the use of all capital letters over capitalizing the first letter for speed of recognition (there is also no evidence that this is detrimental). TO systems are likely to use acronyms for systems being monitored. The letters in these acronyms will necessarily all be capitalized. For consistency, it makes sense to use all capital letters in text boxes if some of the labels will be in all capital letters due to acronym use (Ahlstrom & Muldoon, 2002).

4. If lower case letters are used, it is important to attend to size to make sure they are legible. For maximum legibility, the character height of the text, depending on viewing distance, should be between 20 and 22 minutes of arc, or, at minimum, 16 minutes of arc.
5. If the codes include both letters and number, the letters should be grouped together and the numbers should be grouped together rather than interspersing letters and numbers.
6. If both numbers and letters are used in a label or text pushbutton, it is important that the letters and numbers are easily distinguished. Some numbers and letters used in labels are easily confusable, such as “Z” and “2” or “O” and “0”.
7. The use of “O” and “I” should be avoided in arbitrary codes.
8. Punctuation should be avoided in alphanumeric codes.
9. In general, when alphanumeric characters are used, it is recommended to limit the number of random alphanumeric characters in a string.
10. If the large groups of characters must be used, it is recommended to break down the characters into smaller or more meaningful groups (e.g., creating groups of three to four characters or grouping letters with letters and numbers with numbers).
11. Arbitrary codes or codes that are to be recalled by the users should have no more than five characters.
12. Numeric codes should be limited to seven numbers.
13. Alphanumeric codes could be used for secondary information such as whether a system is primary or backup or whether a system is long term out of service for maintenance or training (Ahlstrom & Longo, 2003).

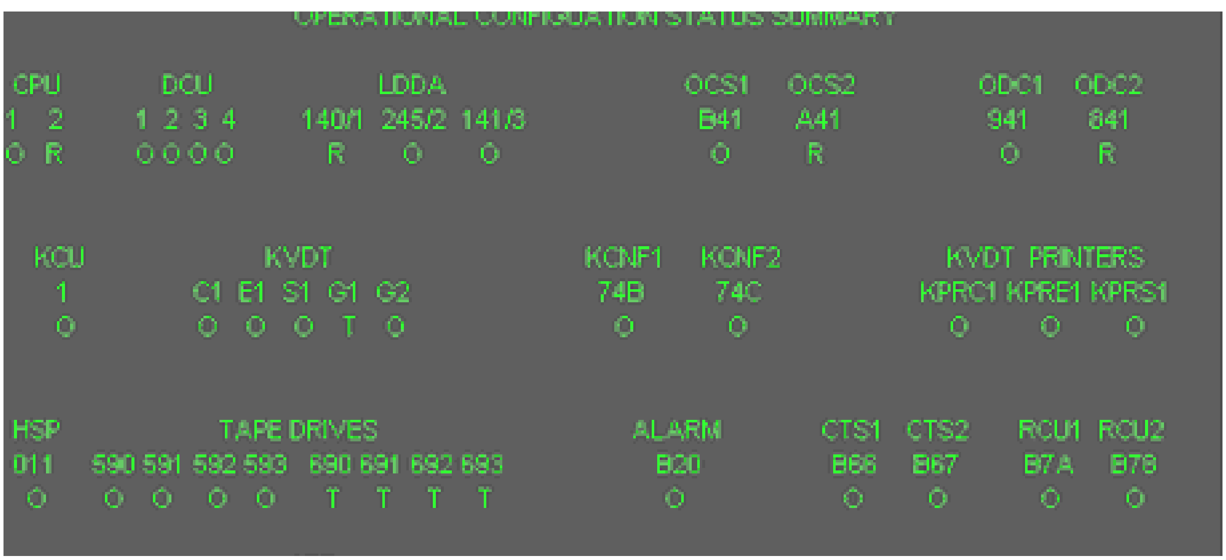

Figure 3. Examples of alphanumeric codes (“O” for operational, “R” for redundant, & “T” for test) used on a TO system.

4.2 Brightness Coding

Brightness coding differentiates individual items by the intensity of the items.

1. If there are too many different brightness levels, it can be difficult for users to distinguish between the levels. Therefore, when brightness coding is used, the number of brightness levels should not exceed three, with two levels as optimal.
2. The brighter of the two levels should be used to code the more critical item, with the luminance levels differing by a ratio of 2:1.
3. Brightness coding should have a consistent meaning throughout an application and related applications (Ahlstrom & Longo, 2003).

4.3 Flash or Blink Coding

Flash coding can be used as a means to draw attention to a symbol, effectively reducing the search time (Van Orden, DiVita, & Shim, 1993). Although individual flash rates carry little absolute meaning, flash rates can carry relative meaning, with a faster flash rate indicating more urgency than a slower flash rate (Wagner, Snyder, Dutra & Dolan, 1997).

1. Only a small area of the screen should flash or blink at any one time.
2. If text must use flash coding (e.g., the text boxes used for many displays), the flash rate should be 1/3 to 1 Hz with an on/off cycle of 70%.
3. Because of its high attention getting abilities, flash coding should only be used to indicate a situation with an urgent need for user attention or on a cursor for indicating the active location for data entry (blinking cursor).
4. Too many flashing items could have the effect of distracting the users (Ahlstrom & Longo, 2003).

4.4 Highlighting

Highlighting usually refers to varying the brightness of an item or reversing the polarity of an item. Highlighting can be helpful in drawing the user's attention to an item; however, it can also have a negative effect if an item other than the target necessary for the task is highlighted (Fisher & Tan, 1989).

1. When highlighting is used on dark backgrounds, the highlighting should be white with dark text.
2. When highlighting is used on light backgrounds, the highlighting should be dark with white text.
3. Overall, the size and number of areas highlighted should be minimized.
4. If reverse video (brightness inversion) is used to draw the user's attention to an item, it should return to normal after the user has responded or when it no longer has meaning. Reverse video should be used in moderation because it can reduce legibility (Ahlstrom & Longo, 2003).

4.5 Line Coding

Line coding in TO status displays is used to indicate association between elements, as shown in Figure 4. A broken line can indicate a break in connectivity between systems.

1. If there are different classes of connectivity such as primary and secondary or stronger and weaker, the primary or stronger connection should be indicated by a thicker line.
2. Line coding should be used consistently within a system and between related systems.
3. No more than three levels of line coding should be used (Ahlstrom & Longo, 2003).

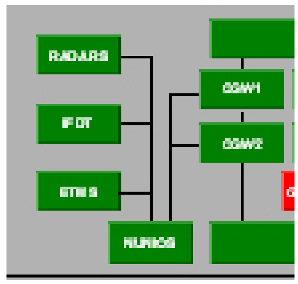

Figure 4. Line coding used on a monitor and control display showing association between elements.

4.6 Shape Coding

Shapes can be used to code items into categories, but only if it is important for the users to distinguish between those categories of items. The use of shape coding facilitates the recognition of warnings and can help support the user's ability to discriminate between categories of icons (Riley, Cochran, & Ballard, 1982).

1. Where geometric shape coding is used and each shape is required to be identified without reference to any other, the number of shapes in the set should ideally be five and not normally exceed fifteen (Ahlstrom & Longo, 2003). With increasing numbers of shapes, the learning time increases and the ability to recall the meaning decreases (Wagner, Snyder, Dutra, & Dolan, 1997).
2. Screen resolution should be adequate to differentiate the different shapes under realistic operational conditions.
3. It should be verified with users that the shape coding used by these systems enhances the information, but it is not critical to the task for users to identify each of these shapes individually.
4. Shapes should be clearly discernable from one another, avoiding similar geometric forms (Wagner et al., 1997).

The information conveyed by shapes is often influenced by conventional meanings (called population stereotypes). For example, an equilateral triangle on its point is a preferred shape for a warning sign (Boff & Lincoln, 1988), and an octagon is commonly associated with "stop" in the United States. Other population stereotypes may be specific to a particular operational environment. It is important that the designer consider the population stereotypes associated with shapes as part of the design process.

When using shape coding, it is important to test for the recognition of the codes. Simple shapes can be misperceived depending on the background they are presented against. Figure 5 shows an example of how the gestalt or grouping of the figure with a surrounding shape code induced unwanted effects in one display. Airplanes with a square around them were used to indicate one type of compliance status, while airplanes with a diamond around them were used to indicate another type of compliance status. When shown the diamonds and squares in isolation, the users had no problem in distinguishing the two shapes from one another, but shown together with the airplane symbols on a display as in Figure 5, it was difficult to differentiate the two shapes because of the gestalt grouping of the shape with the icon it surrounds.

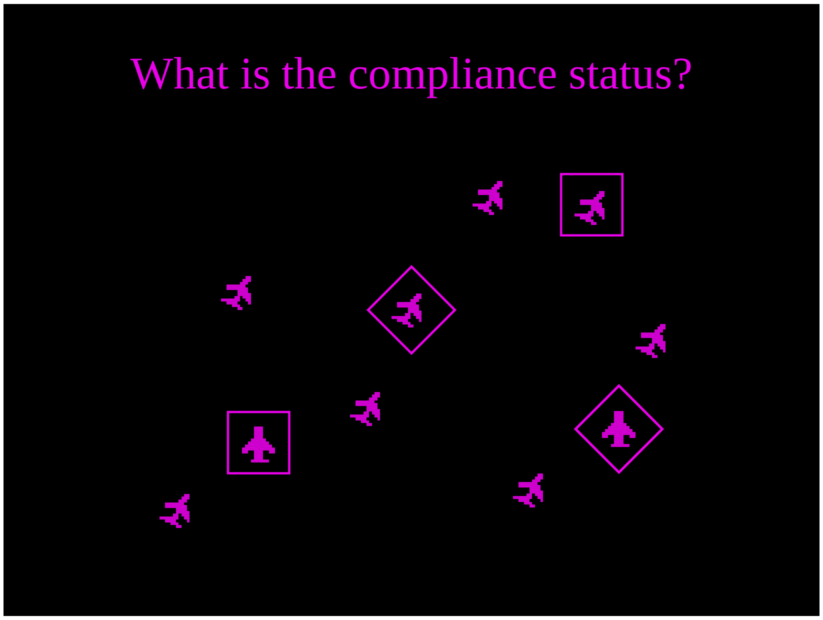

Figure 5. Shape coding used to distinguish compliance status.

4.7 Size Coding

Generally size coding should be used only if there is a low density of items on the screen and should be limited to only two to three sizes (Ahlstrom & Longo, 2003). When size coding is used, the larger sized object should be associated with greater importance than the smaller sized object and should be 1.5 times the height of the next smaller object.

4.8 Spatial (Location) Coding

Spatial coding, sometimes referred to as location coding, can provide a logical organization to information in a display. It can be used as an analogy to physical space or to group related items (Ahlstrom & Longo, 2003).

1. Spatial coding should be used consistently within a system and across related systems.
2. If it is used to indicate importance, the most important items should receive the most prominent position. The most prominent position can be considered either the center of the screen, or the top left. As most users in the United States read from a left to right and top to bottom pattern, scanning of information is likely to begin at the top left and move in the same pattern as reading. For a list of information, the most prominent position would be at the top of the list. We recommend that display layouts have the most important information in the center of the display, with minimal clutter in this area (Ahlstrom & Longo).
3. We recommend that items be logically grouped in a way that is meaningful to the users, such as location coding that maps physical space or a layout that links or groups related items. For example, location coding could be used for indication of primary or backup system as in Figure 6.

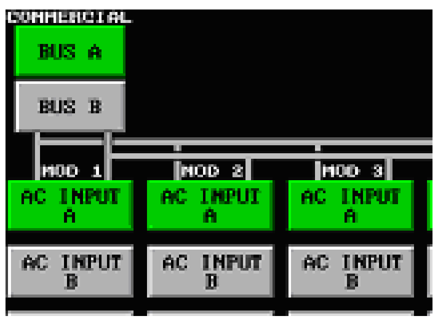

Figure 6. Location coding used together with alphanumeric coding on a TO system to indicate primary (higher location, letter A) and backup system (lower location, letter B).

4.9 Symbol Coding

Symbol coding uses visual symbols or icons to represent status information to the users. Symbols in TO status displays indicate whether an item has been acknowledged or not. In one system, acknowledged items are indicated by a check mark symbol, in another system unacknowledged items are indicated with an arrow symbol.

Although symbol coding is not a common means of conveying status, previous research (Ahlstrom & Muldoon, 2002) found that some TO systems do display status with symbols. As shown in Figure 7, the Digital Voice Recording System (DVRS) incorporates the image of a bell filled yellow to denote an alarm and additional symbols to represent when audio is 'Detected', when a particular communication channel is being 'Recorded', and which channel is being 'Monitored'. Another system, the Maintenance Automation System Software (MASS) utilizes single letter text in different case and colors to represent status with a checkmarks over the Alarm (Red capital "A") and Alert (Yellow lower case "a") symbols to indicate items that are acknowledged by the specialist.

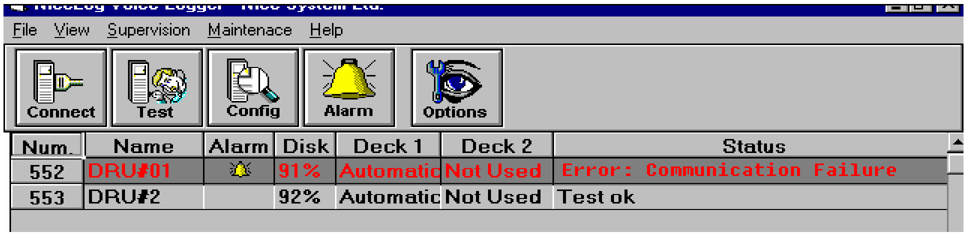

Figure 7. DVRS screen showing an alarm.

4.10 Color Coding

One of the primary means of status coding for TO systems is through the use of color. Although whole books have been written on the use of color for displays (see Arend, 2004; Cardosi & Hannon, 1999 for additional information on color), we will present some general considerations for the use of color for coding.

1. In general, color should be used to augment a user's understanding of the information being presented, to attach specific meaning to a portion of text or a symbol, to direct a user's attention to something (highlighting critical elements), to reduce clutter, to identify and classify information, to indicate changes in status, as a formatting aid, and to enhance legibility.
2. Colors shall be used consistently within a screen, within an application, and across a set of applications (Ahlstrom & Longo, 2003).

When used appropriately, color can be helpful in decreasing response time and aiding visual search for information, particularly in dense displays, if the user knows the color of the target (Kopala, Refsing, Calhoun, & Herron, 1983). When the user knows the target color, the search time depends on the number of symbols the same color as the target. If the user does not know the color of the target, however, search for targets in multicolored displays are longer. In general, search times increase as the number of items on the display increase. Color-coding provides the most benefit with increased display densities. At high densities color-coding is much more effective than shape, numeric, and symbolic coding but only slightly more effective than these methods at low densities. Care must be taken to ensure that the coding is consistent with the user tasks and that color is not overused as a coding method. Task-irrelevant use of color or using more than seven colors can cause performance decrements (Green, & Anderson, 1956).

Although color is the preferred coding method to facilitate visual search, if the primary focus of the user task is recognition rather than search, numeric coding may be superior to color-coding. Hitt (1961) found that numeral coding and color-coding were the two superior coding methods for five different operator tasks (identify, locate, count, compare, and verify) but when greater emphasis was placed on recognition of symbols, numeric coding was superior to color-coding.

Color can also promote user satisfaction. Users often express a preference for color as a coding method, even in the instances when it does not improve their performance. This is often a two edged sword in that users may request that the designers use color even if it is not appropriate for the application and may hinder performance.

As color has strong attention getting qualities, directing visual search and also has strong population stereotypes associated with it we recommend that color be used as a primary coding mechanism to convey status.

4.10.1 How Many Colors Should Be Used?

While there is no universally agreed upon upper limit for the number of colors to use on a display.

1. However, it is agreed that color should be used conservatively and only if it facilitates user understanding or performance.
2. In general, the total number of colors used for coding should not exceed four for a single alphanumeric screen and seven for a set of related screens (Ahlstrom & Longo, 2003); however, the maximum number recommended tends to be highly task-specific. Chapanis and Halsey (1956) have found that only ten steps in hue can be recognized. However, up to 30 combinations of hue, saturation, and brightness can be reliably recognized on an absolute basis (Bishop & Crook, 1960). For example, no more than six distinct colors should be used if the user must perform visual search based on color discrimination (Ahlstrom & Longo; Wagner, Snyder, Dutra, & Dolan, 1997).

4.10.2 What Meanings Should Be Assigned to Different Colors?

1. Many colors have well established meanings, called population stereotypes, such as red for error or failure and yellow for marginal conditions. These meanings should be retained if possible, limiting one meaning per color.
2. According to conventional associations, red should be used to indicate conditions such as no-go, error, failure, alarm, or malfunction.
3. Flashing red should only be used to indicate emergency requiring immediate action to avert personnel injury or equipment damage.
4. Yellow should be used to indicate marginal conditions, caution, or alert.
5. Green should be used to indicate that it is OK to proceed, normal, satisfactory, or within tolerance status.
6. White shall indicate alternative functions or system conditions that do not have operability or safety implications.
7. Blue should be only used for advisory items.
8. If the use of color does not follow well-established meanings or if a color is used for which there is no conventional association, a color key should be readily accessible for the user (Ahlstrom & Longo, 2003).

What are the established meanings for color in TO? Human factors researchers are often told by programs that assigning colors to particular conditions is common sense, yet colors are often assigned inconsistently across systems or inappropriately within a system (see Figure 8). One study looked at TO population stereotypes related to color (FAA, 2004). Researchers wanted to know what stereotypes were already associated with coding conventions in the TO population. To gain insight into these stereotypes, researchers analyzed survey data from 23 TO specialists. The specialists were asked to identify the colors they would associate with five facility status levels (in service/operating normal, out of service, soft alarm, or caution alarm, extended planned out of service), three service status levels (available, unavailable and reduced service), and four NAS impact levels (no impact, critical, moderate, and minor impact).

The users were fairly consistent with conventional associations with their assignment of colors to different terms, yet there was not complete agreement across specialists for any of the items. All but one specialist (96%) said that when the facility status was normal (in-service and operating) it should be given a green color. All but one specialist said that an out of service facility status should be coded as red. The same level of agreement was not found for the other three facility status conditions that they were asked about. Twelve specialists said that loss of redundancy should be coded yellow, nine said orange, and the remainder said blue. Eight specialists said that a soft alarm (caution) should be coded as yellow, seven said orange, and six said blue, with a few leaving this answer blank. Finally, thirteen of the specialists said that extended planned out of service should be blue, with three specialists responding that it should be coded orange, three responding yellow, and one red. All of the specialists agreed that a status level of available should be coded as green, and all but one (who responded orange) agreed that unavailable should be coded as red. The overwhelming majority (14) said that reduced service should be coded as yellow with 7 of the specialists saying that it should be coded as orange. For coding NAS impact, the majority of specialists said that "No impact" should be coded green, critical impact should be coded red, moderate impact should be coded as orange, and minor impact as yellow.

The use of the colors that were most consistent with the population stereotypes were as follows:

1. Normal status should be indicated by green and no flashing.
2. Alarm status should be indicated by red for acknowledged alarms, flashing red for unacknowledged alarms.
3. Item that are unmonitored, unmanaged, inactive, out of service for a long term, or intentionally taken off-line, should be coded as gray at the topmost level to indicate that the user can ignore these items.

   The reason why scheduled out of service or intentional off-line status should not be coded in red is because red should be reserved for items needing immediate user attention. If gray is unavailable as a color choice, blue would be a secondary choice for coding this item. However, the user should still be able to drill down and see the status colors associated with subsystem and component status. If the system is taken off-line for maintenance or training, it may be beneficial to indicate this by a letter code rather than a color code.
4. Alert status, in most cases, an alert should be coded as yellow. Orange should only be used if it is absolutely necessary to differentiate an additional level.

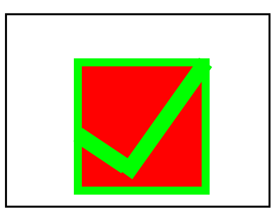

Figure 8. Misuse of color-coding. Green indicates go or normal, a checkmark indicates ok or acknowledged, but red indicates stop or not normal.

4.10.3 Considerations When Using Color As A Coding Method

The use of color as a coding method can be complicated. Decisions need to be made on how many colors to use and what colors to use. This is confounded by the fact that the perceived color can be influenced by many factors such as the color of the background, the size of the stimulus, and the viewing angle. Further complicating matters is the fact that the perception of color may vary depending on age and individual color deficiencies. Because not all of the population perceives color the same due to color deficiencies, and ambient lighting and other nearby colors can influence the perception of color, color should be used as a redundant coding technique only (Ahlstrom & Longo, 2003; Wagner, Snyder, Dutra, & Dolan, 1997).

The trichromatic theory of color vision proposes that color vision is based on three different types of color receptors that have three different spectral sensitivities (red, green and blue). These different receptors react differently to the wavelengths of light coming into the eye to result in the perception of color. Individuals that are missing or have deficiencies in certain of these receptors perceive colors differently. These individuals may have difficulty in discriminating between certain colors. Highly saturated colors in particular can be difficult for color deficient people to differentiate, particularly saturated red (ANSI, 1988). For this reason, color should be used as a redundant coding method. For example, people who cannot distinguish between hues of red and green could use differences in brightness to provide a clue to the color (color and brightness normally co-vary).

Even individuals who have normal color vision will sometimes misperceive the color of an item. Perception of the color depends not only on the spectral composition of the light source, but also on the brightness of the light source, the size of the image, the location in the field of view (central vs. peripheral), the color of the background, and the ambient illumination conditions.

Simultaneous color contrast will cause a gray material surrounded by red to appear greenish, while the same gray material surrounded by blue will appear yellowish (Yung & Armington, 1975). When a symbol color is surrounded by another color, the symbol color tends to shift in appearance toward the complementary color of the background. This may be lessoned by edging the tones with black or white lines (Taylor, 1984). The color of the stimulus may be misperceived depending on the color of the background. One study looked at the classification of colors against different colored backgrounds and found that the largest shifts in appearance and largest deviations occurred for red and blue backgrounds (McFadden, Kaufmann, & Janzen, 1994). Consequently those authors recommend avoiding these particularly in low ambient environment backgrounds. They found a lack of strong chromatic induction effects when the test and background were widely separated in the chromaticity diagram. The highest degree of confusion was between pink and purple. With a red surround, certain hues were labeled purple, but with a blue surround the same hues were labeled pink. These are near the boundaries of the color region, leading to the recommendation that colors that must be reliably classified should not be located near the boundaries of the color region based on CIE charts.

The perception of color differences is also influenced by the size of the image. Color discrimination is impaired for smaller symbol or character sizes. Smaller objects tend to appear less saturated and may appear to shift in hue relative to larger objects. Called small field tritanopia, this effect causes green-yellow objects to appear white, objects above 575 nm to appear yellow-red, and objects below 575 nm to appear blue-green. (Kinney & Huey, 1990; Silverstein & Merrifield, 1985) As the size of colored stimuli become smaller, they lose their color in this order, blue, red then green (Kinney & Culhane, 1978; DeMars, 1975; Reynolds, 1990). Blue images of less than 15 minutes of arc will appear achromatic (Reynolds). Cyan and yellow are difficult to distinguish for symbols less than 30 minutes of arc (Reynolds). Therefore, users should not have to discriminate small areas based on color alone (Ahlstrom & Longo, 2003).

Color-coding can be effected by the visual field location of the stimulus. The widest field of view and shortest response times are for white stimuli, with the narrowest field of view and longest response times for red. In general, peripheral vision is poor for detecting targets, especially if small. One study found that people had more difficulty in finding red and blue targets than white targets when viewed off axis on a LCD screen, but not for a CRT display (Hollands, Parker, McFadden, & Boothby, 2002).

Changing the intensity of colors can change the way that the color is perceived. Increasing the intensity of colors will cause colors with dominant wavelengths above 510 nm to shift toward yellow, and those with dominant wavelengths below 510 nm to shift toward blue (Walraven 1985). Differences in luminance will result in differences the conspicuousness of the object. Perceptually, this can result in the brighter items being perceived as more important than the less bright items (Reynolds, 1994).

4.10.4 What Colors Should I Use When Color-Coding Text?

The contrast between a symbol and background or text and background should be sufficient to enhance color perception, perceived image resolution, and ensure readability of text (Ahlstrom & Longo, 2003). Certain color combinations should be avoided as seen in Table 1. Pure blue should also be avoided as can be difficult to read or resolve if it is presented on small objects, text, or thin lines because of a lack of blue sensitive cones necessary for resolving fine details (ANSI, 1988). Blue can also be problematic for older adults, especially in combination with shades of yellow (Dyck, Gee, & Smither, 1998). One study found that correct identification of aircraft call signs at nighttime viewing from ten feet away was only 67% when the text was green compared to over 80% correct for yellow, white and red (Federal Aviation Administration, 2002). Lippert and Snyder (1986) found that legibility was enhanced when either characters or background of red or magenta hues were employed. They found that chromatic contrast maintained reading performance even independent of luminance contrast. However, another study found that color did not matter to readability as long as the text contrast remained the same (Krebs, Xing, & Ahumada, 2002).

As coding of state often is represented with a red, yellow, or green background, a different color of text may be necessary depending on the color of the background. For example, with a green background, white text may be the most legible; however, white text is not appropriate for a yellow background. The readability of the text should be verified with representative users at viewing distances consistent with normal operations. Additionally, when color is used to indicate status change, a box or shape adjacent to or surrounding the text should change color, instead of the text itself.

Table 4. Color Combinations to Avoid

Yellow text on white background	Magenta text on a black background
Red text on a black background	Magenta text on a green background
Blue text on black background	Yellow text on a green background
Green text on a white background	Yellow text on a purple background
Saturated yellow and green	Saturated blue and green
Saturated red and green	Saturated red and blue

As seen in Table 4, the authors recommend avoiding highly saturated colors from different parts of the visual spectrum. Highly saturated colors, particularly from different parts of the spectrum (e.g., saturated red and blue and saturated red and green) can cause unwanted visual effects, when used near each other particularly when viewed on a relatively plain background (Ahlstrom & Longo, 2003). This is because the hues are focused on at different distances when viewed on relatively plain backgrounds (Taylor, 1984).

In general, thicker strokes are needed for lighter backgrounds because the surround eats into the symbol. On darker backgrounds the symbol eats into the surround (the halo effect), enlarging bright symbols. Bright lines on dark background thus appear thicker than dark lines on light backgrounds (Pawlak, 1986; Taylor, 1984).

4.10.5 How Does the Choice of Background Influence the Coding I Use?

Positive polarity (light backgrounds with dark symbols or text) has the advantage of suppressing reflections. However, with positive polarity, refresh rates must be high enough to suppress noticeable flicker (100 Hz should eliminate flicker for most populations). Most modern computer display monitors have refresh rates of 100 Hz or greater. Advantages of having positive polarity displays include better visual acuity, increased depth of focus, better color discrimination (allowing more colors to be used), less reflections and accommodation. Although it is not clear from the literature whether there is improvement in text legibility with positive displays, positive displays have shown a significant improvement in performance (Pawlak, 1986; Radl, 1983; Bauer & Cavonius, 1980, Reynolds, 1994), with fewer errors.

With negative polarity displays, ambient lighting has to be low to minimize reflections, this will cause a lower visual acuity and less depth of focus (due to a larger pupil size). It may also impact accommodation Walraven (1988). Negative displays (black backgrounds) are sometimes recommended for giving the best color discrimination on CRT displays (Haeusing (1976); Krebs, Xing, & Ahumada (2002)).

Gray background can be a reasonable compromise between the two alternatives. Jacobsen (1986) found that a gray background was better than a black background for learning and remembering color-coded information. However, a gray background can cause a decrease in contrast, so it should be tested in realistic environments (Walraven, 1988).

The decision on whether to use a black, white, or gray background should also take into consideration other things in the environment that the user must look at, such as other displays. It is undesirable to have displays vastly differ in brightness so that the pupil must change substantially when the user looks from one to another display (Hopkin, 1982). Additionally, if there is a large difference in adaptation levels between a display and other fixation points such as keyboard, and so on, it is possible that there may be loss of performance or discomfort. Response times to targets are significantly greater after being exposed to a pretest pattern of brighter luminance (Rupp & Taylor, 1986).

4.10.6 Ambient Lighting Effects of Color Use

Some TO environments are co-located with Air Traffic operations, especially at ARTCC SOC facilities. These environments tend to be dimly lit. Conversely, TRACON SOCs are often dimly lit and have direct control of their lighting. The TRACON SOCs tend to adjust lighting to levels similar to that of a normal office environment. Additionally, information on TO systems may be viewed from different angles or distances depending on the facility. Environmental factors such as this need to be considered in designing coding for TO systems.

The chromaticity of colors as well as the luminance contrast changes as a function of ambient illumination (Silverstein, 1987). Colors shift in hue and become desaturated under higher ambient illumination (Volbrecht , Aposhyan, & Werner, 1988; Walraven, 1985).

Ambient illumination can effect response times. At lower luminance levels, response times are shorter to wavelengths in the blue green spectrum. With high ambient illumination, response times to red are faster than for either green or yellow targets (Boff & Lincoln, 1988).

At low levels of ambient illumination, symbol luminance must be reduced to maintain dark adaptation, but if reduced (to less than 3 cd/m^2), colors cannot be reliably differentiated (Boff & Lincoln, 1988).

5. CONCLUSIONS

This document contains many different guidelines for the creation of status coding displays. In general, we recommend that system designers strive for consistency within a display and across displays both in how the system looks and how it behaves. The application of the guidelines within this document will help the developers achieve this consistency. We recommend mapping specific system states and conditions to the definitions provided in this document. We also recommend using the coding guidelines provided in the document for specific interface elements. In general, the status displays should emphasize important information, deemphasize unimportant information, should not hide or obscure information and should make the status conditions distinct from one another. Specific recommendations are contained within the body of this document.

The process recommended in this document is different than the process often used by system developers because it stresses that system status should be defined by the need for action on the part of the user. Designers should hold on to this fundamental tenet as coding is assigned to system conditions.

A summary of the process is as follows:

1. System states and conditions should be mapped to the definitions provided in section 2 of this document.

2. A prioritization scheme should be applied using the definitions given in section 2 of this document.
3. Events which require immediate action to avoid impact to NAS operations should be given an alarm status consistent with the definitions in section 2.
4. Coding should be applied to match the priority of the event or condition consistent with the guidelines provided in the body of this document. For example, alarms which have high priority, should be assigned coding that has the highest perceptual prominence (red or flashing red).

The information in this document is meant to provide guidance on the development of status coding for TO displays. However, the application of these guidelines does not guarantee an effective system. It is always important to take into consideration the specific needs of the users that will be using a system and the specific environment that a system will be in. Although this document will save time and money by allowing the decision makers to bound their choices and will promote consistency across interfaces by defining key terms and recommending coding choices for particular items, ultimately, the project leaders will need to work with qualified human factors experts and system users to determine what coding strategies are applicable for a given situation. Final coding decisions should be tested with representative users using representative tasks in a realistic work environment to ensure maximum benefits.

This paper has focused on improving the detection of system conditions that require user action. The goal is for conditions that require user action to be mapped appropriately to system status and states and coded so that items in need of the most immediate attention are given the highest perceptual prominence on the display. Improving detection of system status is only one part of the human factors solution related to developing status displays. Displays must be designed not only to facilitate detection of abnormal conditions, but should also ensure that the users arrive at a correct understanding of the state including the understanding of the correct action to take when responding to the status indicator (Mumaw, Clark, & Sikora, 2002). A status indicator can change for various reasons, leading to different actions by the specialists. A better understanding of the actions taken in response to status indicators can further improve status displays by enhancing user understanding; however, this is beyond the scope of the current effort.

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Acronyms

AF	Airway Facilities
ARTCC	Air Route Traffic Control Center
CHI	Computer-Human Interface
DVRS	Digital Voice Recording System
FAA	Federal Aviation Administration
HFDS	Human Factors Design Standard
MASS	Maintenance Automation System Software
NAS	National Airspace System
SOC	Service Operations Center
TO	Technical Operations
TRACON	Terminal Radar Approach Control