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Information Display Protocol

Kim M. Cardosi, Ph.D., DOT/Volpe Center
Caroline Donohoe, DOT/Volpe Center
Ben Willems, Human Factors Team – Atlantic City, AJP-6110
Hal Albert, Ph.D., Human Solutions, Inc.
Gregory Anderson, Ph.D., Human Solutions, Inc.
Jennifer M. Chen, Human Solutions, Inc.
Elizabeth D. Murphy, Ph.D., Human Solutions, Inc.
Raquelle Carter, TASC, Inc.
Robert Felbinger, AEROTEC

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16. Abstract

Objective: Human Factors Engineers and air traffic control Subject Matter Experts (SMEs) from the Federal Aviation Administration (FAA) developed a protocol to support in decisions on how to present needed information on the en route controller's visual displays. The protocol provides guidance for determining the criticality of the information and uses this criticality to determine where and how the information should be displayed. **Background:** Human Factors Engineers and air traffic control SMEs developed and validated the protocol with current and upcoming FAA Next Generation Air Transportation System informational items and scenarios. **Application:** The model provides a systematic method for integrating the informational needs of controllers and supports the decision process for designing air traffic control displays.

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Executive Summary

The Federal Aviation Administration is developing many of the programs that will provide Next Generation Air Transportation System (NextGen) services independently. Each Program Office develops its own requirements, and it assumes that the function of the data block (if not the entire situation display) is to enable the most efficient functioning of its specific program and applications. The human factors and display system engineers charged with Computer-Human Interface (CHI) integration have the burden of integrating various program-specific information requirements.

We developed the Information Display Protocol to aid in decisions on how to present needed information on the En Route Controller's visual displays. The protocol provides guidance for determining the criticality of the information and uses the rated criticality of the information item to help determine where and how we should display the information to the controller. Specifically, the protocol assigns each informational item to one of four criticality categories: extremely high, high, medium, or low. The protocol provides guidance on three distinct design dimensions for displaying information: location, level, and emphasis. Human Factors Engineers and air traffic control Subject Matter Experts developed and validated the protocol with current and anticipated NextGen items and scenarios. The model provides a systematic method for integrating the informational needs of controllers and supports the decision process for the design of the air traffic control CHI.

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INTRODUCTION

The programs that will provide Next Generation Air Transportation System (NextGen) services (e.g., Data Communications, Automatic Dependent Surveillance-Broadcast [ADS-B], Tailored Arrivals, and so forth) are in various stages of development and implementation. Consequently, their user-interface requirements for components and applications continue to evolve. We know some of the information requirements, such as state indicators and alerts, but we expect that other requirements will be added, deleted, or changed as functions continue to be refined.

Programs that are functionally independent (such as Data Communications and ADS-B) are developed independently. Each program defines its information display requirements independently of other programs. Each program assumes that the function of the data block (if not the entire situation display) is to enable the most efficient implementation of its specific program and applications. The integration of various information requirements becomes the responsibility of those charged with the task of Computer-Human Interface (CHI) integration.

Purpose

The purpose of this work was to develop a protocol to aid in decisions on how to present needed information on the en route controller's visual displays. The expected users of the protocol are those involved in CHI integration, such as system developers, hardware designers, and human factors specialists. A critical underlying assumption of the protocol is that there is an operational need to present the information to the controller. The judgment as to whether there is an operational need to present the information should be based on the results of an in-depth task analysis. In the absence of a task analysis, structured interviews of Subject Matter Experts (SMEs) will determine whether the information is needed for controller tasks.

For information that the system needs to present to the controller, the protocol provides a rationale for determining whether the information merits display on the "priciest" part of the display (the aircraft representation) or elsewhere. It also provides guidance as to whether the system should continuously display information, make information available with a single control action (such as a click or dwell), or make information available at a lower display level. Use of the tool will help (a) provide consistency among decision-makers on how to present information to the controller, (b) provide a systematic approach to dealing with constant and increasing competition for data block real estate, and (c) document the decision-making process. The output of the use of the Information Display Protocol should be the input for the interface design.

Assumptions

To include information on the Air Traffic Control (ATC) displays we make several assumptions. The six critical assumptions for the interface design are as follows:

1. There is an operational need to present the information to the controller.
2. Any information item can be present in more than one display location. For example, if the Information Display Protocol recommends that an information item should be visible on Level 1: Always Present, *at a minimum*, the information should be visible on Level 1; but this does not restrict placement of that information item at lower levels as well.

3. How and when the controller will use the information is the necessary foundation for determining how the system should present the information. Therefore, one cannot apply the protocol without context-dependent sketches of the situations in which the information will be needed. A context-dependent sketch of the situation should include which positions are working (e.g., Is there a Data [D]-side controller?) and which systems (e.g., conflict probe, data link) are active.
4. The same information item may fall into different criticality levels, display locations, and emphasis depending on how and when a controller needs the information.
5. Importance of information corresponds with location, with the most important information presented in the aircraft representation, the moderately important information presented on the situation display outside of the aircraft representation, and the least important information presented on the auxiliary display.
6. Decision-makers have relevant ATC experience. Because of their subject matter expertise, at least one such Air Traffic Controller must be included in the decision-making group when applying the protocol to information items and scenarios. These controllers must be carefully selected based on their skill sets.

Protocol Description

The protocol provides guidance on several dimensions of information display design: location, level, and emphasis. Table 1 shows a summary of the display design dimensions and the categories within each dimension.

Table 1. Information Display Protocol Dimensions

Display Dimension	Dimension Categories
Location	Primary – Aircraft representation (ACR)
	Secondary – On situation display but not on ACR
	Tertiary – Auxiliary display
Level	Level 1 – No actions needed to access (Always present)
	Level 2 – One action needed to access
	Level 3 – Two actions needed to access
Emphasis	Emphasis 0 – Subdued
	Emphasis 1 – Normal
	Emphasis 2 – Highlighted
	Emphasis 3 – Alerting

A general rule of thumb is that the ease of information retrieval should be proportional to the frequency and urgency of the information. The protocol assumes that more important information should be located in the primary area of the display (i.e., the aircraft representation), and as the information criticality decreases, information should be placed on the secondary area of the display (i.e., on the situation display but not on the aircraft representation), and then on the tertiary area (i.e., on an auxiliary display). Display Level and Display Emphasis have similar importance hierarchies that are related to ease of access. The order of importance from high to low for Display Location is aircraft representation, situation display, and auxiliary display. The order of importance from high to low for Display Level is Level 1, Level 2, and Level 3.

Criticality levels. Six questions are provided to guide an informed group of decision-makers in determining a criticality category for each information item.

1. Is this information an indicator of a critical safety alert or other emergency information?
2. Is this information needed to contact aircraft or communicate with pilots?
3. Does this information affect the controller's current plan for aircraft?
4. Does this information affect the controller's future plan for aircraft?
5. Is this supplemental aircraft, airspace, or weather information that is not continuously needed?
6. Is this contextual or background information that supports the use of higher levels of information?

If the first question is answered with "Yes," the information item is assigned to the Extremely High-criticality category; if the second or third question is answered with "Yes," the information item is assigned to the High-criticality category; if the fourth or fifth question is answered with "Yes," the information item is assigned to the Medium-criticality category; and if the sixth question is answered with "Yes," the information item is assigned to the Low-criticality category. Based on the assigned criticality, the protocol provides guidance on how the information should be displayed along the three design dimensions: location, level, and emphasis. A graphical representation of the protocol is provided in the Appendix.

Display location. In the current scheme, the aircraft representation is the most important component of the display. It should contain all of the critical information necessary for the controller to perform time-critical tasks and to maintain situation awareness only. Data on a display can either be information or clutter. When needed to perform a task, data items presented in the right format and at the right time convey information. Data that are not needed create clutter and make it more difficult to locate information needed to perform a task. For these reasons, this protocol for information display is based on characteristics of the information and of the task. As with all display designs, the goal is to ensure that information is present when it is needed and that information does not contribute to display clutter when it is not needed. The logic the protocol follows is intuitive, and it has been empirically demonstrated that data blocks designed with the most relevant information in upper layers reduce the time controllers need to accomplish tasks (Cummings, Tsonis, & Rader, 2008). With so many competing display demands, however, tradeoffs must be made with respect to information availability.

Display level. We can define ease of access to data by the number of steps or the time it takes to find the data. The most important data must be available at the highest layer of the display (Level 1), requiring no more than eye movements to locate and read the information. No display control actions are necessary to access information at Level 1—the information is displayed continuously, unless a window is activated that may briefly obscure it. For example, data pertinent to creating a plan, but not required to be visible at all times, would be available one layer down (Level 2), requiring a single action (such as a dwell or a click) to display the data in the aircraft representation. Information that is integrally linked in content should be logically linked in presentation so that information is found where it is expected. For example, Data Communications information (such as message history) may be layered under the Data Communications indicator.

Display emphasis. Emphasis categories should be chosen based on aircraft state for aircraft-specific information. Aircraft state is defined in the controller's perspective and takes into consideration owned versus unowned aircraft, immediacy of action required for controlling owned aircraft, and aircraft location with respect to the controller's assigned sector boundaries. The following statements about aircraft state are thought or spoken in first-person singular in the controller's perspective and are tied to the four emphasis categories:

- **Emphasis 0 = Subdued Presentation** (below normal)
  Aircraft is outside my sector and not predicted to enter my sector.
- **Emphasis 1 = Normal Presentation**
  Aircraft is outside my sector but predicted to enter my sector.
  Aircraft is under my control and no immediate action is needed.
- **Emphasis 2 = Highlighted Presentation**
  Aircraft is under my control and action is needed.
- **Emphasis 3 = Alerting Presentation**
  Aircraft is in conflict-alert or other alert status.

For non-aircraft-specific information, normal presentation (Emphasis 1) should be used for all Medium-criticality information and for any Low-criticality information presented on an auxiliary display. Subdued presentation (Emphasis 0) should be used for any Low-criticality information presented on the main situation display.

For this version of the Information Display Protocol, only luminance (brightness) levels are used to code for emphasis. The model will continue to be worked to see if other types of emphasis (e.g., color, font size) need to be included in the Information Display Protocol. If brightness levels cannot be used because of unintended effects, we will need to identify other viable emphasis techniques. The protocol is expected to evolve even further as it is applied to additional scenarios.

Decision Tree

The "decision tree" is a graphical representation of the Information Display Protocol. The purpose of the decision tree is to guide decision makers through the process needed to determine the display location, level, and emphasis of information items. A draft of the decision tree (Version 2.0) is provided in the Appendix section of this report.

Decision guidance. Specific guidance is provided at "decision points" within the decision tree. The decision points are represented by diamond shapes, which occur at the top and the middle of the decision tree. The decision points in the middle of the tree are guided by the data element's frequency of use, intrinsic linkage to the main aircraft representation, and use for comparing and sorting aircraft attributes.

Data elements. If a data element is frequently used for tasks in the primary display or track area, the design should provide controllers with access to that data from the aircraft representation (at a minimum). If a data element is linked intrinsically to other data elements already present in the aircraft representation, the design should make that data element accessible through the aircraft representation. A fictitious example is the Exit Flight Level (XFL) for a particular aircraft based on letters of agreement (LOAs) or standard operating procedures (SOPs). Because this altitude constraint data element is linked to the aircraft and to its current altitude, it should be accessible from the aircraft representation (e.g., with a click or dwell on the current altitude).

If the data element is used to compare attributes of an aircraft, or to sort a set of aircraft, that data element would be best presented in a list or view (i.e., in the secondary display area). For example, although the metering delay countdown time may be presented on the main aircraft representation, the arrival sequence may be better presented in a list or view, because it groups a set of aircraft and shows the sequence of these aircraft. This type of processing would be more time-consuming for the controller if the information were only represented in the track areas of the individual aircraft. The following four questions are associated with each diamond shape that is located in the middle of the decision tree.

1. Is this information used frequently?
2. Is this information linked to data already in the aircraft representation?
3. Is this information used for comparing multiple aircraft attributes?
4. Is this information used for sorting a set of aircraft?

The answers to these questions help determine which pathway needs to be taken from the decision point. If one or more of the questions are answered with "Yes," then place the information item in the more prominent Display Location or Level. If all of the questions are answered with "No," then place the information item in the less prominent Display Location or Display Level.

METHOD

We developed the protocol in the following steps. First, we created a method for classifying data into different levels of criticality (Display Classification Characteristics). Next, we matched the criticality of the data to how it should be displayed (based on known human factors principles). For example, information that is not continuously used should not be continuously displayed in the controller's central focus of attention. Such information should be displayed on a peripheral display (that is, off to the side) or by layering the information under what is always present. The nature of the controller's task determines whether the information is displayed on a peripheral display or layered under the primary display, as well as how many levels below the primary display it should appear. These decisions can only be made in a holistic manner once all of the display requirements have been identified. As a final step in its development, the protocol was applied to sample scenarios to ensure face validity (i.e., the protocol generated the results that were deemed operationally acceptable to the Post-Release 3 [PR3] En Route Automation Modernization [ERAM] CHI Team).

Application to NextGen Scenarios

Sample NextGen scenarios were run through the protocol during a series of meetings with Human Factors Engineers and ATC SMEs, and the design outcomes were recorded. The PR3 ERAM CHI Team was a critical component of the development and validation of the protocol. The following examples show the process and results of running NextGen information items, with accompanying sketches through the protocol. The examples provided in the Extremely High-Criticality Scenario subsection and the Low-Criticality Scenario subsection demonstrate that the outcome may vary depending on the details of the scenario.

All examples are from a meeting at the Federal Aviation Administration (FAA) William J. Hughes Technical Center (WJHTC) on February 15-17, 2011, involving members of the PR3 ERAM CHI Team, FAA System Engineering, WJHTC, and Human Solutions, Inc. The protocol has undergone several minor modifications during its development, so the current wording of the criticality-determining questions differs somewhat from what it was originally. The following questions were used during the February 15-17, 2011, working meeting.

1. Is this information an indicator of a critical safety alert or other emergency information?
2. Is this information needed to contact aircraft or communicate with pilots?
3. Is this information needed to identify or change the aircraft trajectory (i.e., altitude, speed, heading, and route)?
4. Is this supplemental aircraft, airspace, or weather information that is not continuously needed?
5. Is this contextual or background information that supports the use of higher levels of information?

If the first question was answered with "Yes," the information item was assigned to the Extremely High-criticality category; if the second or third question was answered with "Yes," the information item was assigned to the High-criticality category; if the fourth question was answered with "Yes," the information item was assigned to the Medium-criticality category; and if the fifth question was answered with "Yes," the information item was assigned to the Low-criticality category.

Because the protocol has evolved since the meeting in February 2011, the examples provided in this section do not represent the final decisions of the parties involved. The decisions made in the following examples need to be revisited by applying the final version of the protocol.

Extremely high-criticality scenario. This example is an extremely high-criticality scenario. The example covers ADS-B service degradation in a low-altitude sector that has a mix of radar and ADS-B coverage.

- **Information item:** ADS-B service degradation
- **Sketch:** Controller is working a low-altitude sector. ERAM uses a mix of radar and ADS-B to process and display aircraft surveillance data. All aircraft are currently separated by at least 5 miles. An ADS-B service degradation occurs.
- **Question 1 answer:** Yes
    - Criticality: Extremely High
    - Display Dimensions: Show information on aircraft representation. (Note: In the current system, upon loss of surveillance data, a target symbol changes to a pound sign. However, this subtle state change is likely to be inadequate to attract the controller's attention to this safety-related event. This points to the need for careful coding as well as placement.)

High-criticality scenario. This example is a high-criticality scenario. The example covers receipt of a Data Communication (Data Comm) message in a high-altitude sector.

- **Information item:** Receipt of Data Comm message from a pilot, other controllers, or Traffic Flow Management (TFM).
- **Sketch:** Controller is working a high-altitude sector. All aircraft are currently separated by at least 5 miles. The Data Comm Ground System detects receipt of a pilot-initiated downlink (PID) requesting a lower altitude. (Note: This sketch reflects routine downlinks or messages from external sources. Clearance would be automatically probed before viewed by the controller.)
- **Question 1 answer:** No
- **Question 2 answer:** No
- **Question 3 answer:** Yes
    - Criticality: High
    - Display Dimensions: Show information on Level 1 of aircraft representation.

Medium-criticality scenario. This example is a medium-criticality scenario. The example covers an open Data Comm uplink in a high-altitude sector.

- **Information item:** Data Comm open uplink
- **Sketch:** Controller is working a high-altitude sector. One controller is assigned to the sector and is controlling several Data Comm equipped and voice-only aircraft. All aircraft are currently separated by at least 5 miles. The controller has uplinked a clearance to an aircraft and is waiting for a pilot response. (Note: This sketch reflects routine Data Comm operation.)
- **Question 1 answer:** No
- **Question 2 answer:** No
- **Question 3 answer:** No
- **Question 4 answer:** Yes
    - Criticality: Medium
    - Display Dimensions: If information is frequently used, display at Level 2 or 3 of the aircraft representation. (Controller must take action to view the state of the open uplink.)

Low-criticality scenario. This example is a low-criticality scenario. The example covers an indication of ADS-B service outage in a low-altitude sector.

- **Information item:** Indicator of ADS-B service outage
- **Sketch:** Controller is working a low-altitude sector. ERAM uses a mix of radar and ADS-B to process and display aircraft surveillance data. All aircraft are currently separated by at least 5 miles. An ADS-B service outage occurs. Surveillance data is lost on ADS-B equipped aircraft operating within an area with radar coverage.

- **Question 1 answer:** No
- **Question 2 answer:** No
- **Question 3 answer:** No
- **Question 4 answer:** No
- **Question 5 answer:** Yes
    - Criticality: Low
    - Display Dimensions: If information is frequently used, display on the situation display. If information is infrequently used, display on an auxiliary display.

Recording Decisions

The process and results of running data elements through the protocol should be recorded. Based on meetings at the FAA WJHTC with the PR3 ERAM CHI Team, a recording method was developed. Although the recording method may change as the protocol evolves, the following information should be recorded for each data element.

- Data Item (e.g., Callsign)
- Sketch (e.g., Traffic situation and complexity)
- Criticality Level (Extremely High, High, Medium, or Low)
- Frequency (High or Low)
- Display Location (Primary, Secondary, or Tertiary)
- Display Level (Level 1, 2, or 3)
- Emphasis (Emphasis 0, 1, 2, or 3)
- SME Comments
- Requirement for Automation

Automation Requirements

Ideally, the automation should anticipate when data elements are needed for the next task and either display the data or signal its availability (depending on the data and the task) to the controller. An example in the current environment is the transition from a limited to a full data block when a handoff takes place. Another example may be showing conflict trajectories, or proposed resolutions, when a controller hovers on a conflict probe indicator.

Additional Considerations

Currently, fly-out menus on the Radar (R)-side rarely provide additional task-relevant data. An exception is the flight plan altitude in an altitude fly-out menu on an aircraft with a temporary altitude. Fly-out menus on the D-side have additional task-relevant data—the route menu being an extreme example. The route menu seems to be more of a template disguised as a fly-out menu. Proposed capabilities will change this drastically. Fly-out menus for Data Communications (ministatus fly-out menu showing requests and outgoing messages), probed menus (potentially showing probe status for altitudes, routes, headings, or speeds), conflict resolution advisories (showing probed status as well as a proposed resolution), and others will provide more information. As a result, the sequence of controller actions may change as new information becomes available.

The execution of an ATC task typically consists of (a) the creation (when the situation is new and no prepackaged solution is available) or retrieval of a plan (when the solution is recognized), (b) the transmission of the necessary clearance or coordination, and (c) the update to the system through a data entry. To access the additional data, controllers may first have to start a data-entry task while formulating a plan instead of following their current process. Results from applying the Information Display Protocol can help to identify situations that require changes to the interface (or automated support) to minimize interruption of controller tasks.

CONCLUSION

During the February 2011 meeting with the PR3 ERAM CHI Team, the Information Display Protocol was found to be a systematic and structured method for making decisions on how and where information should be placed on the en route controller's visual displays. The protocol has been reviewed and approved by the PR3 ERAM CHI Team, air traffic controller SMEs, and Human Factors Engineers. Further refinement of the model may be necessary as NextGen programs and information requirements evolve.

REFERENCE

Cummings, M. L., Tsonis, C., & Rader, A. (2008). The impact of multi-layered data blocks on controller performance. *Air Traffic Control Quarterly, 16*(2).

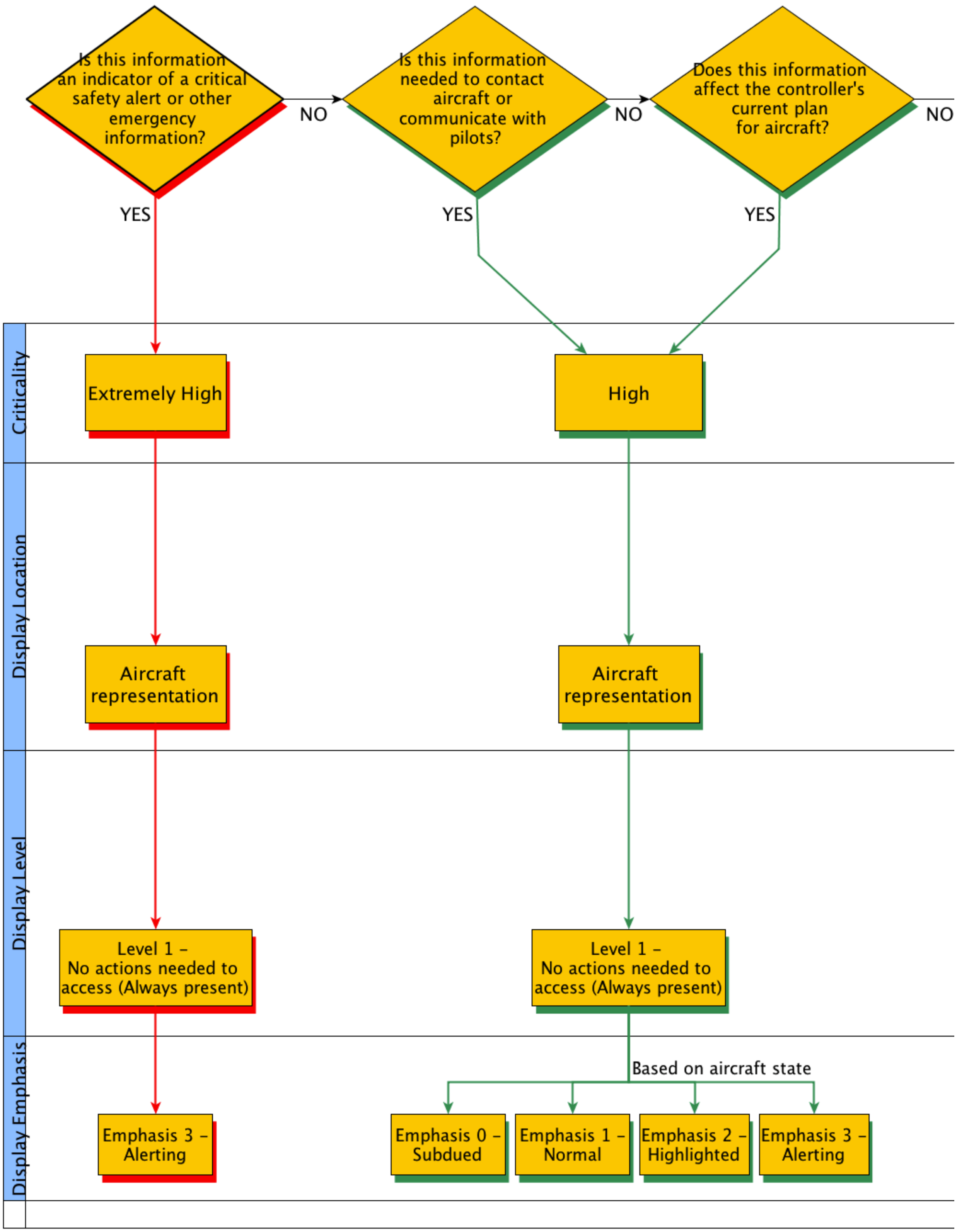
ACRONYMS

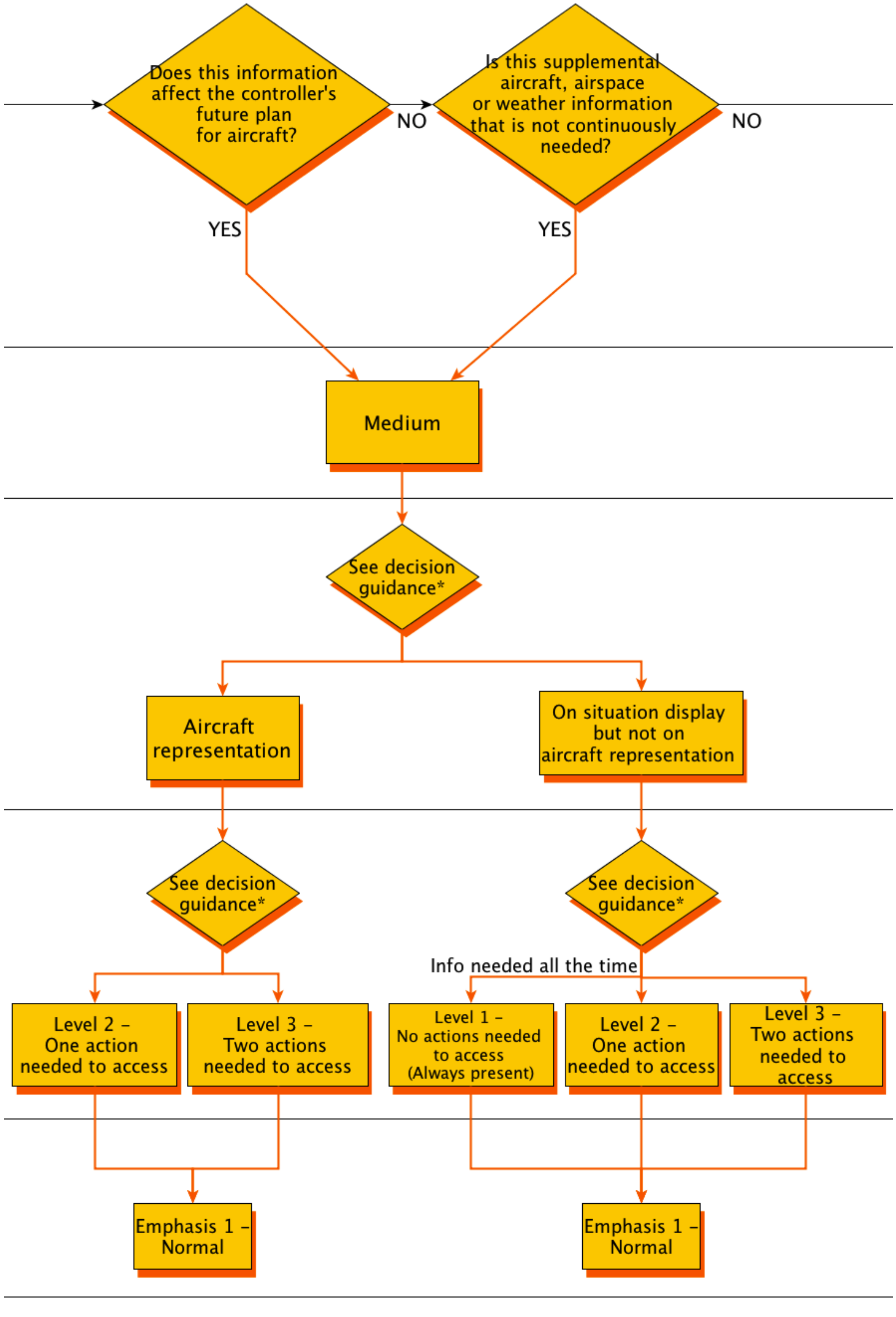
ADS-B	Automatic Dependent Surveillance-Broadcast
AJP	NextGen and Operational Planning Services
CHI	Computer-Human Interface
Data Comm	Data Communications
D-side	Data-side
ERAM	En Route Automation Modernization
FAA	Federal Aviation Administration
NextGen	Next Generation Air Transportation System
PID	Pilot-Initiated Downlink
PR3	Post-Release 3
R-side	Radar-side
SME	Subject Matter Expert
TFM	Traffic Flow Management
WJHTC	William J. Hughes Technical Center

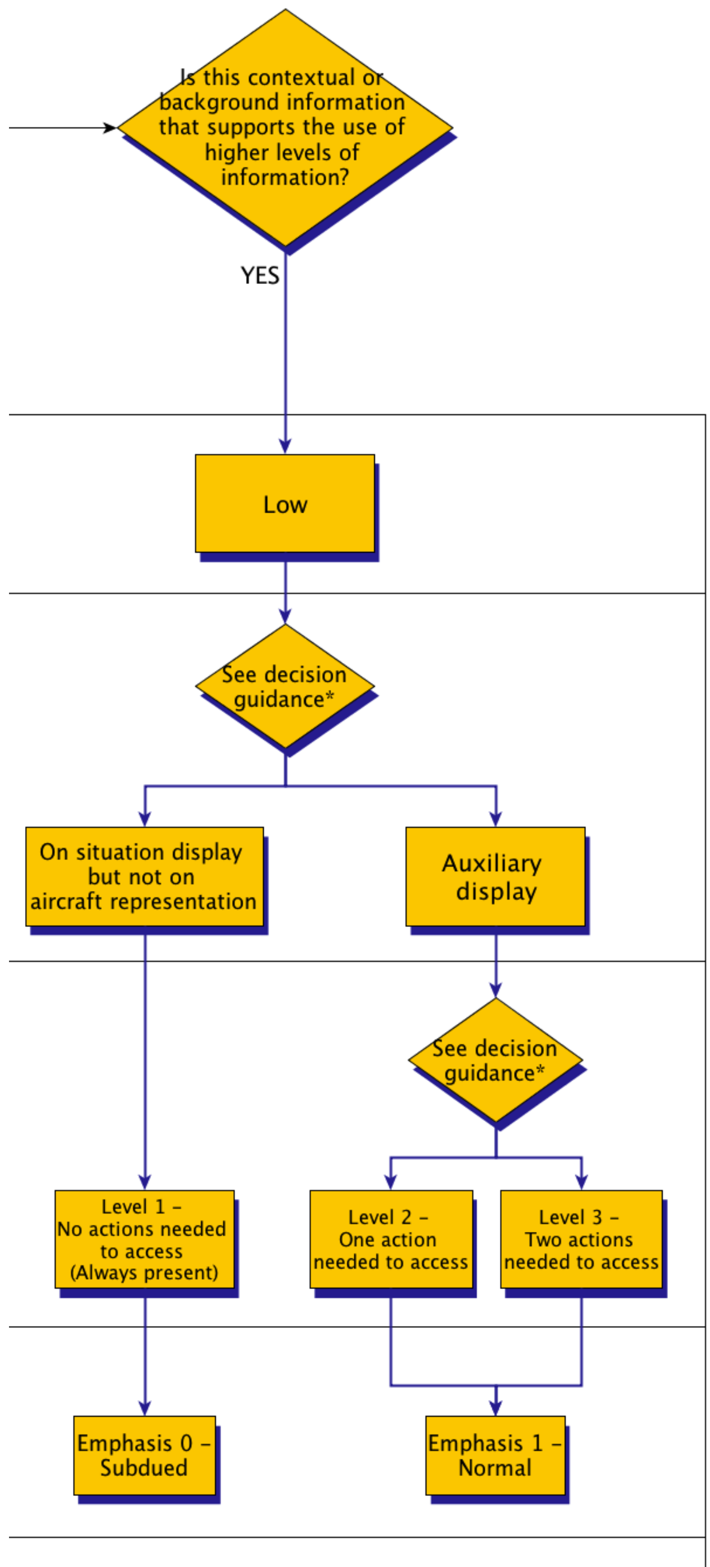
Appendix:

Information Display Protocol Decision Tree (Version 2.0)

Information Display Protocol Decision Tree (Version 2.0)




Does this information affect the controller's future plan for aircraft?
NO
Is this supplemental aircraft, airspace or weather information that is not continuously needed?
NO
YES
YES
Medium
See decision guidance*
Aircraft representation
On situation display but not on aircraft representation
See decision guidance*
See decision guidance*
Info needed all the time
Level 2 – One action needed to access
Level 3 – Two actions needed to access
Level 1 – No actions needed to access (Always present)
Level 2 – One action needed to access
Level 3 – Two actions needed to access
Emphasis 1 – Normal
Emphasis 1 – Normal


Is this contextual or background information that supports the use of higher levels of information?
YES
Low
See decision guidance*
On situation display but not on aircraft representation
Auxiliary display
See decision guidance*
Level 1 – No actions needed to access (Always present)
Level 2 – One action needed to access
Level 3 – Two actions needed to access
Emphasis 0 – Subdued
Emphasis 1 – Normal

* Decision Guidance

If you answer YES to one or more of the following questions, place the information item in the more prominent Display Location/Level.

If you answer NO to all questions, place the information item in the less prominent Display Location/Level. (For further explanation on how to use this decision guidance, see the full document.)

- Is this information used frequently?
- Is this information linked to data already in the aircraft representation?
- Is this information used for comparing multiple aircraft attributes?
- Is this information used for sorting a set of aircraft?

Order of Prominence for Display Location & Level

Display Location Prominence (high to low)

1. Aircraft Representation
2. Situation Display
3. Auxiliary Display

Display Level Prominence (high to low)

1. Level 1
2. Level 2
3. Level 3