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Human Interface Criteria for Flight Deck Surface Operations Displays

RATIONALE

ARP5898 has been reaffirmed to comply with the SAE five-year review policy.

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1. SCOPE:

Following a number of high-visibility collisions between aircraft on the airport surface, overall taxi operations have been brought under greater scrutiny. In addition, observation of taxi operations and the results of associated research programs have revealed that the efficiency of taxi operations could be significantly improved with available technologies and by applying a human centered design approach. Surface operations displays have been tested in prototype form and a number of manufacturers are moving toward product definition. This document provides guidance on the design of elements, which may be part of surface operations displays whose objectives would be to enhance safety and to improve overall efficiency of aircraft operations on the airport surface. Such efficiency increases should be realized not only in day-to-day operations, but should also be manifested in training for surface operations.

This document sets forth functional and design recommendations concerning the human factors issues and criteria for flight deck display of surface operations information. It is assumed that the system will have a human centered design based on the “lessons learned” from past systems, with simple operation, consistent performance, and intuitive use, without negative transfer of information. The visual and aural characteristics are covered for both the alerting components and surface operations display components. The display system may contain any one or a combination of these components. Although the system functionality assumed for this document exemplifies fixed-wing aircraft implementation, the recommendations do not preclude other aircraft types. The recommendations contained in this document address both near- and far-term technology directed toward providing information used during surface operations, although the present version remains primarily focused on near-term applications. Since this type of document provides only “best practice” recommendations, the guidance is provided in the form of “should” statements as opposed to the “shall” statements that appear in standards and requirements types of documents.

The assumptions about the system that guided and bounded the recommendations contained in this document include:

- The system is a flight-deck-based system displaying surface operations information to the flight crew in visibility conditions down to and including CAT IIIb or under a Surface Movement Guidance and Control System (SMGCS)
- When available, multiple sources of data will be used to provide the flight crew with the best available information
- The system will be capable of worldwide operation
- At least initially, paper and/or electronic versions of the surface charts will still exist and be available to the flight crew
- There will be pilot-in-the-loop/manual involvement in any path changes
- Information will be accessible by appropriate flight crew members

1. (Continued):

- The system will be based on the English language, but other languages may be considered
- The system will be available full time during all ground operations
- Ground operations are defined as the time from the gate to 1000 feet AGL or the departure end of the runway on departure and from 1000 feet AGL to the gate on approach.
- The display function may be stand alone or part of a multi-function display
- Initial design will provide for upgradeability and expansion
- The human interface will be integrated with other display functions and will not interfere with any other flight deck functions
- In-flight planning displays of surface information will be addressed by other standards development efforts focused on electronic charting
- Whenever possible, information will be layered according to pre-selected priorities

The figures in this document are derived from ongoing experimental programs and are used as illustrative samples only.

2. REFERENCES:

The documents listed in 2.1 are referenced for guidance in this document. The documents listed in 2.2 are provided for information purposes only and do not form a part of the recommendations of this document. A bibliography of literature relevant to this document is presented in Section 10.

2.1 Applicable Documents:

2.1.1 SAE Publications: Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

AS264	Instrument and Cockpit lighting for Commercial Transport Aircraft
ARP268	Location and Actuation of Flight Deck Controls for Transport Aircraft
AS425C	Nomenclature and Abbreviations for Use on the Flight Deck
ARP571	Flight Deck Controls and Displays for Communication and Navigation Equipment for Transport Aircraft
ARP1068	Flight Deck Instrumentation, Display Criteria and Associated Controls for Transport Aircraft
ARP1093	Numeral, Letter, and Symbol Dimensions for Aircraft Instrument Displays
ARP1161	Crew Station Lighting - Commercial Aircraft
ARP1782	Photometric and Colorimetric Measurement Procedures for Direct View CRT Displays
ARP1874	Design Objectives for CRT Displays for Part 25 (Transport) Aircraft

2.1.1 (Continued):

ARP4032	Human Engineering Considerations in the Application of Color to Electronic Aircraft Displays
ARP4033	Pilot-System Integration
ARP4101	Core Document, Flight Deck Layout and Facilities
ARP4101/2	Pilot Visibility from the Flight Deck
ARP4102	Core Document, Flight Deck Panels, Controls and Displays
ARP4102/4	Flight Deck Alerting Systems
ARP4102/7	Electronic Displays
ARP4102/7	Appendix A – Electronic Display Symbology for EADI/PFD
ARP4102/7	Appendix B – Electronic Display Symbology for EHSI/ND
ARP4102/7	Appendix C – Electronic Display Symbology for Engine Displays
ARP4105	Abbreviations and Acronyms for Use on the Flight Deck
ARP4107	Aerospace Glossary for Human Factors Engineers
ARP4153	Human Interface Criteria for Collision Avoidance Systems in Transport Aircraft
ARP4256	Design Objectives for Liquid Crystal Displays for Part 25 (Transport) Aircraft
ARP4260	Photometric and Colorimetric Measurement Procedures for Airborne Direct View Flat Panel Displays (when approved)
ARP5364	Human Factors Considerations in the Design of Multifunction Display Systems for Civil Aircraft (draft)
AS8034	Minimum Performance Standards for Airborne Multipurpose Electronic Displays

2.1.2 FAA Publications: Available from Federal Aviation Administration, 800 Independence Avenue, SW, Washington, DC 20591.

FAA-RD-81-38II	Aircraft Alerting System Standardization Study: Volume II Aircraft Alerting System Design Guidelines (Berson, et. al.,1981)
DOT/FAA/PS-89/1	Flight Status Monitor Design Guidelines (Anderson, et. al. 1989)

2.1.3 RTCA Publications: Available from RTCA Inc., 1140 Connecticut Avenue, NW, Suite 1020, Washington, DC 20036.

RTCA/DO-242A	Minimum Aviation System Performance Standards for Automatic Dependent Surveillance Broadcast (ADS-B), (2002)
RTCA/DO-247	The Role of the Global Navigation Satellite System (GNSS) in Supporting Airport Surface Operations, (1999)
RTCA/DO-257	Minimum Operational Performance Standards for the Depiction of Navigation Information on Electronic Maps
RTCA/DO-272	User Requirements for Aerodrome Mapping Information, (2001)

2.2 Regulatory Publications:

Available from Federal Aviation Administration, 800 Independence Avenue, SW, Washington, DC 20591.

FAA AC-23.1309-1A	Equipment, Systems, and Installations in Part 23 Airplane
FAA AC-23.1311-1	Installation of Electronic Display Instrument Systems In Part 23 Airplanes
FAA AC 25-11	Transport Category Airplane Electronic Display Systems
FAA AC-25.1309-1A	System Design Analysis
FAR Part 23	Airworthiness Standards: Normal, Utility, Acrobatic, and Commuter Category Airplanes
FAR Part 25/ JAR Part 25	Airworthiness Standards: Transport Category Airplanes
FAR Part 27	Airworthiness Standards: Transport Category Rotorcraft
TSO-C113	Airborne Multipurpose Electronic Displays

3. GLOSSARY:

3.1 Acronyms and Abbreviations:

AC	Advisory Circular
ADI	Attitude Direction Indicator
ADS-B	Automatic Dependent Surveillance-Broadcast
AGL	Above Ground Level
ARP	Aerospace Recommended Practice (SAE)
ASA	Airborne Separation Assurance
ASSA	Airport Surface Situational Awareness
ATC	Air Traffic Control
ATIS	Automated Terminal Information Service
A/V	Aircraft/Vehicle
CPDLC	Controller Pilot Data Link Communication
EADI	Electronic Attitude Direction Indicator
EFB	Electronic Flight Bag
EHSI	Electronic Horizontal Situation Indicator
EMM	Electronic Moving Map
FAA	Federal Aviation Administration
FAR	Federal Aviation Regulation
FAROA	Final Approach and Runway Occupancy Awareness
FIS-B	Flight Information Service Broadcast
FMS	Flight Management System
FOV	Field of View
GIS	Graphical Information Service
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HDD	Head-Down Display
HMI	Human Machine Interface
HUD	Head-Up Display

3.1 (Continued):

Hz	Hertz
ICAO	International Civil Aviation Organization
IFR	Instrument Flight Rules
ILS	Instrument Landing System
IMC	Instrument Meteorological Conditions
INS	Inertial Navigation System
JAA	Joint Aviation Authority
JAR	Joint Aviation Requirements
MASPS	Minimum Aviation System Performance Standards
MFD	Multi-Functional Display
MSL	Mean Sea Level
ND	Navigation Display
NOTAM	Notice to Airman
PANS-OPS	Procedures for Air Navigation Services – Aircraft Operations
PF	Pilot Flying
PFD	Primary Flight Display
PNF	Pilot Not Flying
PWS	Predictive Windshear System
Rnav	Area Navigation
RNP	Required Navigation Performance
RWS	Reactive Windshear System
SA	Situation(al) Awareness
SMGCS	Surface Movement Guidance and Control System
TAWS	Terrain Awareness Warning System
TCAS	Traffic Alert and Collision Avoidance System
TERPS	Terminal Instrument Approach Procedures
TIS-B	Traffic Information Service Broadcast
VFR	Visual Flight Rules
VMC	Visual Meteorological Conditions

3.2 Definition of Terms:

Absolute Altitude: Aircraft altitude referenced to mean sea level (QNH) - typically referred to as barometric corrected altitude.

Accuracy: A measure of the difference between the reported A/V position as compared to the true position. Accuracy is usually defined in statistical terms of either: (1) a mean (bias) and a variation about the mean as defined by the standard deviation (sigma) or a root mean square (rms) value from the mean. The values given in this document are in terms of the two sigma variation from an assumed zero mean error.

Advisory Alert: Non-normal operational or aircraft system condition that requires flight crew awareness and may require subsequent corrective or compensatory flight crew action.

3.2 (Continued):

Aircraft/Vehicle (A/V): Either (1) a machine or service capable of atmospheric flight, or (2) a vehicle on the airport surface movement area.

Airplane State: The variables required to fully describe the dynamic behavior of an airplane and to predict this behavior into the future. These variables include, speed, flight path vector, attitude (pitch and roll), and horizontal track. Aircraft state is often represented as a state vector, which comprises the minimum number of values required to fully specify the state; from the state vector, related values such as angle of attack, flight path angle and sideslip can be derived.

Airspace: In the most general sense, airspace refers to the atmosphere in which aircraft operate, extending upwards from the surface of the earth. However, the term airspace also commonly denotes the spatial boundaries used to define areas restricted to civilian flight and to subdivide the airspace into areas controllable by individual air traffic controllers. These airspace boundaries add a constraint to aircraft operations by limiting acceptable aircraft flight paths.

Alert: A visual, auditory or tactile stimulus presented to attract the flight crew's attention and convey some information concerning an event/situation.

Aural Alert: Discrete tone/sound used for attention-getting.

Availability: Is the probability that a function is operational and able to perform were it called on.

Barometric Altitude: Geopotential altitude in the earth's atmosphere above mean standard sea level pressure datum plane, measured by a pressure (barometric) altimeter.

Barometric Altitude Error: For a given true barometric pressure, P0, the error is the difference between the transmitted pressure altitude and the altitude determined using a standard temperature and pressure model with P0.

Caution: Non-normal operational or aircraft system conditions that require immediate flight crew awareness and subsequent corrective or compensatory flight crew action.

Certified Reference Point: A point along the longitudinal axis of an aircraft near its centerline located so that all of the extremities of the aircraft are contained within the smallest possible rectangle. The certified navigation point will generally be located in the same place on the same type aircraft. The requirement for a certified navigation center directly supports the cockpit display (airborne/surface) of graphical information. Additionally using a certified navigation point and a limited set of aircraft graphic icons, weight, size, and model information can be accurately displayed.

Closed-Loop Control: Pilot-in-the-loop manual control of the aircraft path.

Clutter: Clutter refers to the negative impact of poorly organized and crowded displays. It generally results in reduced display legibility, and/or in increases in the time needed to locate information on the display.

3.2 (Continued):

Color Value: The attribute of a color that allows it to be classed on a scale from very dark to very light. Note: Brightness is a perception that results from surface luminance and is a property of the object itself and of the light illuminating it.

Conflict: Any situation involving two or more aircraft/ground vehicle, or an aircraft and an airspace, or an aircraft and ground terrain or obstacle, in which the applicable separation minima may be violated.

Conflict Avoidance: A strategic maneuver taken to preclude a conflict.

Conflict Detection: The process of projecting an aircraft's trajectory both spatially and temporally to determine whether it is probable that the applicable separation minimum will not be maintained between the aircraft and another aircraft or vehicle. The level of uncertainty in the projection is reduced with increased knowledge about the situation, including aircraft capabilities, flight plan, short-term intent information, etc.

Conflict Management: Process of detecting and resolving conflicts.

Conflict Probe: An airborne or ground-based system that performs the process of conflict detection.

Conflict Resolution: The process of identifying and or performing a tactical maneuver or a set of maneuvers that are intended to resolve a conflict or potential conflict between the ownship and either (1) another aircraft or vehicle, (2) a given airspace, or (3) terrain.

Conformal: The displaying of symbology (usually on HUDs) that corresponds to the actual spatial position of objects in the forward visual scene.

Criticality: Indication of the hazard safety level associated with a function.

Dedicated Display: A display that has only a single intended function in the flight deck.

Display: Visual, auditory and tactile elements of a system that present information to the operator.

Electronic Flight Bag (EFB). A system comprised of electronic computing and/or communications equipment or systems designed primarily for use in the cockpit/flight deck, and used to display a variety of aviation data or perform a variety of aviation functions. In the past some of these functions were traditionally accomplished using paper references. The scope of EFB system functionality may include various information management applications including datalink and/or databus connectivity. EFB systems may be portable electronic devices, installed systems, or a combination thereof. The physical EFB display(s) may use various technologies, formats, and forms of communication.

Ellipsoid Height (Geodetic Height): The height related to the reference ellipsoid, measured along the ellipsoidal outer normal through the point in question. [ICAO Annex 14]

3.2 (Continued):

Error: (1) An occurrence arising as a result of an incorrect action or decision by personnel operating or maintaining a system. (2) A mistake in specification, design, or implementation.

Event: An occurrence which has its origin distinct from normal aircraft operations, such as atmospheric conditions (e.g. wind gusts, icing, lightning strikes), runway conditions, and non-normal operational or system conditions.

Failure: A loss of function or a malfunction of a system or part thereof.

False Alert: An alert that occurs in a situation for which the system design should not have presented an alert.

Fault: An undesired anomaly in a function or system.

Geoid: The equipotential surface in the gravity field of the Earth which coincides with the undisturbed mean sea level (MSL) extended continuously through the continents. Note: the geoid is irregular in shape because of local gravitational disturbances (wind tides, salinity, current, etc.) and the direction of gravity is perpendicular to the geoid at every point. [ICAO Annex 14]

Guidance: (1)Tactical control task of maneuvering the aircraft along a course or route; (2) information presented to the flight crew which directs them in maneuvering the aircraft along a specific course or route.

Guidelines: Recommendations for complying with regulations and design requirements and objectives.

Hue: The dominant wavelength category which is described by a color term such as red or green (white, gray and black are considered achromatic colors, being differentiable but without perceptible hue).

Independence: (1) A design concept which ensures that a failure of one item does not cause a failure of another item. (2) Separation of responsibilities that assures the accomplishment of objective evaluation.

Integration: (1) The act of causing elements of an item to function together. (2) The act of gathering a number of separate functions within a single implementation.

Isometric View: A method of drawing so that three dimensions are shown not in perspective but in their actual measurements.

Late Alert: An alert that does not provide the flight crew with sufficient time to respond successfully.

Latency: The total system time from the time of sensing information until the information is presented to the flight crew.

3.2 (Continued):

Latency Compensation: Correction of system latency introduced position errors using time synchronized position and velocity information.

Luminance: An objective measure of the effective intensity of light emitted from (or reflected by) a surface. Perceived luminance can also be affected by contrast from adjacent or surrounding colors.

Master Visual Alert: Discrete annunciator used for attention-getting and providing indication of situation urgency.

Missed Alert: From a system operation perspective (i.e., not a human operator perspective),the absence of an alert in a situation for which the system was designed to provide an alert.

Mode: The current selected state of a system that determines which of many possible functions the system will perform at that specific time.

Movement Area: That part of an airport/aerodrome to be used for the take-off, landing and taxiing of aircraft, consisting of the maneuvering area and the apron(s).

Multi-function Display: A display capable of presenting multiple information or control functions.

Navigation: Planning task (short or long term) which involves positional awareness relative to other airport features for the purpose of moving the aircraft from current position to a destination.

Nuisance Alert: An alert that, while occurring as intended in the system design, was not appropriate in the specific situation for which it occurred.

Obstacle: All fixed (whether temporary or permanent) and mobile objects, or parts thereof, that are located on an area intended for the surface movement of aircraft or that extend above a defined surface intended to protect aircraft in flight. [ICAO Annex 14]

Obstruction: Any object that penetrates an obstruction identification surface. Note that this is considered to be a subset of the “Obstacle” definition. [FAA Doc. 405]

Orthographic View: Drawing in which the depicted lines are perpendicular to the plane of projection; a 2D View.

Orthometric Height (or Elevation): Height of a point related to the geoid, generally presented as an MSL elevation. [ICAO Annex 14]

Ownship: The aircraft in which the system is installed and about which the situation mental model is being built.

3.2 (Continued):

Perspective View: A method of drawing used to show the effect of relative distance and position. A perspective view may be either an “inside-out view” (also known as the pilot’s-eye or egocentric view) or an “outside-in view” (also known as –an exocentric view). Both types of perspective drawings assume a given viewing angle, viewing distance, display field of view and point of convergence. In an outside-in view two additional parameters must be assumed: the elevation-viewing angle and the azimuth viewing angle. Manipulation of any of these parameters changes the viewers perception of the display.

Pictorial Information: The presentation of information in a way that creates a graphical and symbolic representation of the entity it is representing.

Plan View: A drawing which shows a horizontal section; drawing plane is shown perpendicular to the line of sight between the eye and the object.

Primary Field of View: (1) head-down – a region that is within 15 degrees of a line running from the pilot’s eye-reference point to the center of the PFD/EADI/ADI; (2) head-up – a region that is within 15 degrees of a line that runs out the window from the pilot’s eye-reference point parallel to the aircraft centerline and 10 degrees down from horizontal.

Primary Flight Display (PFD): An electronic display which provides the basic “T” information (i.e., attitude, airspeed, altitude, and heading) and other information pertinent to navigation and primary control of flight.

Profile View: A display presenting a side-view which depicts elevation or altitude versus range or speed.

Reflectance: The proportion of incident light reflected by a surface.

Reliability: The frequency (probability) that a function will perform as required under specified conditions, without failure, for a specified period of time.

Requirement: An identifiable element of a specification that can be validated and against which an implementation must be verified.

Risk: The frequency (probability) of occurrence and the associated level of hazard.

Saturation: The perception associated with the purity of a color in terms of the wavelengths represented in that color. Saturated colors consist of a narrow band of wavelengths and appear vivid; desaturated colors contain many other wavelengths as well as the dominant wavelength and appear muted.

Separation: (1) Separation exists between two or more aircraft and/or other external hazards when their positions and velocities are in accordance with standards and procedures that have been determined to be appropriate for the operations in which the aircraft are engaged. (2) The maintenance of independence by means of a physical barrier between two hardware components.

3.2 (Continued):

Shared Display: A shared display is multi-function and integrates multiple inputs onto a single display (see MFD). Alternate definition is a display used by more than one crew person.

Situation(al) Awareness: A multidimensional construct that encompasses “the perception of elements in the environment, the comprehension of their meaning, and the projection of their status into the near future” [Endsley, 1990]. For example, for pilots, the multidimensional awareness elements of the environment include, but are not limited to, crew awareness, cabin awareness, aircraft systems awareness, time awareness, spatial awareness, weather/environmental awareness, traffic awareness, and awareness of ATC constraints. Any specific task that the pilot performs will require the application of one or more (usually not all) of these awareness elements.

Sub-System Latency: The various sub-elements that contribute to total system latency. These may include data communication, data processing, control-display latency, graphics rendering, and so on.

Time-Critical Warning: Non-normal operational or aircraft system conditions that require unconditionally immediate corrective or compensatory flight crew action usually involving the flight path of the airplane.

Validation: The determination that the requirements for a function or system are sufficiently correct and complete.

Verification: The evaluation of an implementation to determine that all applicable requirements are met.

Visual Alert: Discrete alphanumeric display or light used to get the attention of the flight crew and transfer some information about situation urgency.

Voice Alert: Auditory property of voice messages that gets the attention of the flight crew and transfers some information about situation urgency.

Voice Message: The information content of a voice alert.

Warning: Non-normal operational or aircraft system condition that requires immediate corrective or compensatory flight crew action conditional upon achieving and maintaining overall airplane safety.

4. SYSTEM FUNCTIONALITY – INTENDED FUNCTIONALITY/POTENTIAL FUNCTIONS:

Several documents have described potential flight deck surface operational concepts/potential functions.

- Minimum Aviation System Performance Standards for Automatic Dependent Surveillance Broadcast (ADS-B) (RTCA DO-242A, 1998)

  a. Enhanced Visual Acquisition of Other Traffic in the VFR Traffic Pattern at Uncontrolled Airports
  b. Runway and Final Approach Occupancy Awareness
  c. Airport Surface Situational Awareness - ASSA (VFR & Night)
  d. Enhanced IMC Airport Surface Operations

- The Role of the Global Navigation Satellite System (GNSS) in Supporting Airport Surface Operations (RTCA, 1999)

  a. Guidance Concept
  b. Surveillance Concept
  c. Control Concept
  d. Routing Concept

- SafeFlight 21 Master Plan (FAA, 2001)

  a. (Pilot) ASSA
  b. Runway and Final Approach and Occupancy Awareness (ADS-B only and ADS-B & TIS-B)

- User Requirements for Aerodrome Mapping Information (RTCA DO-272, 2001)

  a. Charting Information
  b. Surveillance and Conflict (Runway Incursion) Detection and Alerting
  c. Route and Hold-Short Depiction and Deviation Detection and Alerting
  d. Depiction of Digital ATIS
  e. Aerodrome Surface Guidance and Navigation
  f. Resource Management
  g. Training and High Fidelity Simulation
  h. Aerodrome Facility Management
  i. Emergency and Security Services Management
  j. Runway Operations
  k. Notices to Airmen (NOTAM) and Aeronautical Data Overlays
  l. Aerodrome Asset Management: Managing Constraints on the Aerodrome Surface Using Hand-Held Computers
  m. Synthetic Vision

- Minimum Aviation System Performance Standards (MASPS) For Airborne Separation Assurance (ASA) (RTCA, in preparation)

  a. Airport Surface Situational Awareness (ASSA)
  b. Final Approach and Runway Occupancy Awareness (FAROA)
  c. Surface Enhanced Visual Acquisition (SEVA)

4. (Continued):

It is expected that any surface display will start with basic functions such as those that are based on spatial awareness (e.g., airport geographical awareness). As users and developers gain experience and the enabling technology and infrastructure is in place surface displays will move towards more complex uses (e.g., navigational and traffic awareness, guidance concept (surface route overlays), runway status alerting (hold bars and/or runway status indicators)).

As each concept is developed, human factors support will be required to determine the necessary surface map features and functions that address the fundamental questions asked by flight crews during surface operations.

- Where am I?

  - Ownship position with airport map and stationary features

- Where am I relative to my route/destination?

  - Same information as above

- Where am I relative to other moving objects?

  - Same information as above plus traffic information

- What is the status of surfaces (runways, taxiways, other movement areas) in the movement area?

  - Same as above plus status information

- “Will my landing gear stay on the appropriate surface?”

  - Same information as above

Any implementation of a surface map display system should consider the integration and use of individual map functions and features. For example, concepts which allow the pilot to use the display as a supplement to their out-the-window view in support of the visual search task need to consider head-down time. Additionally, surface map features that do not support the intended function of the concepts should not be included. For example, the Airport Surface Situational Awareness concept is intended to provide the flight crew with a surface moving map to aid in general orientation, navigation, and traffic awareness, and is expected to improve SA. The map display is not currently designed to support vehicle guidance and thus the inclusion of information that supports this task may be counter productive. For example, surface map features, such as taxiway centerlines may suggest that the map could be used to support vehicle guidance and therefore should not be included on the display. However, recent studies (Andre, et. al. 1998) suggest that route overlays, which are very similar, were found to be very informative in support of the navigational task.

5. DESIGN OBJECTIVES:

The overall goal of the surface operations displays should be to help the flight crew to accomplish the following tasks:

- Determine ownship current location/position on the airport
- Determine the destination location/position on the airport
- Determine the route(s) to the destination from the current position
- Determine that the current path is the cleared path to the destination
- Determine the ownship location/position relative to the taxiway/runway edges
- Determine position of other aircraft or obstacles of concern
- Determine if ownship is on an active runway
- Determine if ownship is on the cleared runway
- Determine if there is unacceptable positional certainty for intended operation

The control and display equipment for the surface operations display system should apply the basic design objectives called out in ARP571, taking into consideration the functions, their frequency of use and all aircraft operational and environmental conditions so as to:

a. Enhance efficiency (both operational and training) and safety

b. Result in error reduction/mitigation

c. Maximize flight crew traffic and surface spatial awareness

d. Minimize head-down time and increase the productivity of the required head-down time by providing information that is available at a glance

e. Provide consistency of operation for common functions

f. Promote timely and accurate operation

g. Ensure legibility of legends and displays throughout the wide range of flight deck ambient lighting conditions

h. Ensure that system failures do not degrade the operational capability of other systems with which they interact

i. Ensure intelligibility of voice messages throughout the wide range of flight deck ambient noise conditions, concurrent speech messages and other aural signals

j. Provide for information redundancy to assist the flight crew in verification and error detection

k. Minimize nuisance alerts

5. (Continued):

l. Permit flight crew to perform conflict analysis

m. Result in an overall acceptable workload for multi and single pilot operation

n. Provide surface navigation consistent with airborne navigation

o. Provide closed loop local control with the HUD

p. Augment “eyes out of window”

q. Provide a head-down display for navigation, not manual control information, for near term implementation

r. Increase effectiveness and efficiency of communication between crew members and between the crew and controller

s. Minimize language based errors

t. Minimize crew training requirements

u. Present the set of information required to accomplish the flight crew tasks and implement the basic design objectives

The goal of these objectives, though not necessarily presented in order of importance, is to keep associated flight crew workload at a level compatible with current/existing flight crew operation.

6. UTILIZATION PHILOSOPHY:

The utilization philosophy of the system (that is, how it will accomplish its objectives) defines what information the flight crew needs and the way in which the information should be presented. The following paragraphs document a utilization philosophy that addresses the above system objectives.

System design should lend itself to the minimization of pilot errors and should aid the pilot in mitigating the effects of the pilot's own errors, and of errors by other pilots and by air traffic controllers. The kinds of errors that the pilot may make during surface operations, many of which stem from loss of navigational or positional awareness, are as follows (this list is not all-inclusive):

a. Unauthorized entry to runways and taxiways
b. Deviation from the cleared route
c. Taxiway excursion - Aircraft wheels inadvertently depart from the taxi surface
d. Runway overruns or excursions
e. Attempting to land on the wrong runway
f. Landing without clearance or while the runway is still occupied
g. Excessively fast taxi for the existing conditions

6. (Continued):

Close encounters and minor collisions during taxi resulting from poor judgment of clearance distances are not expected to be reduced by this system.

Air traffic controller errors may result in the aircraft's being inadvertently cleared onto runways or perhaps taxiways and putting aircraft at risk. Flight crew traffic awareness facilitated by the surface operations display(s) should help mitigate such errors. This traffic awareness may be a result of a range of techniques as simple as a display of traffic information through more advanced incursion alerting systems.

Although current technology allows for and could be designed to provide the pilot with all the information necessary to taxi safely in conditions of zero visibility, this document recognizes the implications of the necessary supporting infrastructure for such a system. End-to-end system cost would render achievement of a favorable return on investment highly improbable. As a result, this document considers a system that will provide augmentation for conventional eyes-out-of-the-window surface operations especially during low visibility and night operations. This augmentation ranges from provision of simple awareness of orientation and position on the airport to enhancement or synthesis of enough of the visual field to allow taxi operations to continue safely at a rate equivalent to that achievable in day, visual meteorological conditions.

Navigation versus. Control: Foyle et.al. (1996) cited work by Lasswell and Wickens, who in a task analysis of low-visibility taxiing, described the control task as maneuvering the aircraft along a route, and described the task of navigation as maintaining positional awareness relative to the gate and other airport features. They assume that the control task is supported by the out-the-window visual information or through a conformal display, such as a HUD, and the navigation task is supported by a global visual display, such as an heads-down moving map. The design philosophy of a surface display system should be consistent with this distinction between control and navigation. This way, closed-loop manual aircraft control is always conducted with the pilot "eyes out" while viewing conformal symbology, whereas navigation can be supported by a more global heads-down display.

It is envisaged that a head-up display (HUD) will be the only type of display used to provide required closed-loop manual control feedback to the pilot. Full automation of control functions is not postulated. A good deal of research has been carried out on the use of symbology as cues for taxi guidance (Foyle et. al., 1996). In addition, HUD-displayed imagery from forward-looking infrared cameras intended primarily to support low visibility landings has been evaluated for its effectiveness in enhancing pilot vision during surface operations. There are, however, some concerns about the pilot's ability to see beyond raster-based HUD imagery. Both methods are considered in this document along with symbolic guidance cues.

6. (Continued):

A head-down display (HDD) is also likely to be a near term element of surface operations display systems. The HDD should not be designed to provide control guidance during taxi operations since its utilization requires that the pilot's attention be diverted from his primary task of viewing the outside scene. Instead the HDD should be used to support spatial, navigation, traffic, and runway incursion prevention awareness. Given the plethora of information that might be presented on what may be a relatively small display surface, the potential for clutter and information overload is high. HDDs should be designed to give the information necessary for the particular operational function at a glance, thus minimizing head-down time and ensuring that the display provides an overall benefit. In multi-pilot crew aircraft, it may be viable to allow head-down information to be more complex so that the pilot not flying can make full use of available information. Even here, however, if the pilot flying is to make use of the HDD, the version presented to the pilot should minimize head-down time in meeting its functions.

7. CANDIDATE DISPLAY CONCEPTS:

The appropriate display format and information content depends on the intended use and operation of the surface operations display system. Each format and display medium has benefits and limitations. Further research and testing should be performed before implementation. For example, the flight crew's assessment of obstacles or traffic and their required actions has been found to be highly dependent upon the type of display; plan view head-down displays provide the "big" picture and are well suited for strategic information, they do however bring the flight crew's eyes into the flight deck. Head-up presentations are more appropriate for presenting tactical information and keeping the flight crew's eyes focused outside, however, their narrow fields of view provide limited preview of the planned route.

7.1 Graphic Formats:

Graphic display formats may be classified in a number of ways. Among the common ways to classify these formats are: (1) projection technique (i.e., method by which objects in a three dimensional world are mapped onto the two dimensional coordinates of the image); and (2) by point of view presented (the location from which a scene is viewed and direction in which it is viewed). A perspective display is a method of drawing used to show the effect of relative distance and position. A perspective view may be either an "inside-out view" (also known as the pilot's-eye or egocentric view) or an "outside-in view" (also known as an exocentric view). Both types of perspective drawings assume a given viewing angle, viewing distance, display field of view and point of convergence. In an outside-in view two additional parameters must be assumed: the elevation-viewing angle and the azimuth viewing angle. Manipulation of any of these parameters changes the viewers perception of the display. Figures 1and 2 present samples of these two display types. The display format used will determine the functional capabilities of the display system since each format has its own benefits and limitations. Due to the strong impact of graphic display format, research and testing should be performed before settling on any specific implementation.

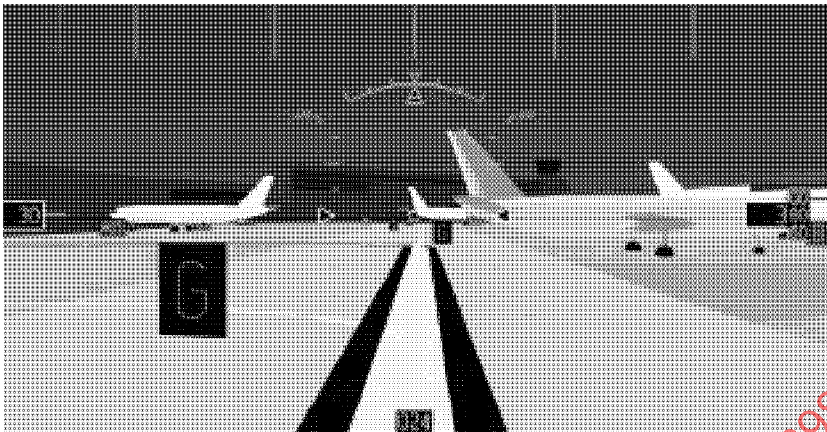

FIGURE 1 - Sample of an Egocentric Surface Display

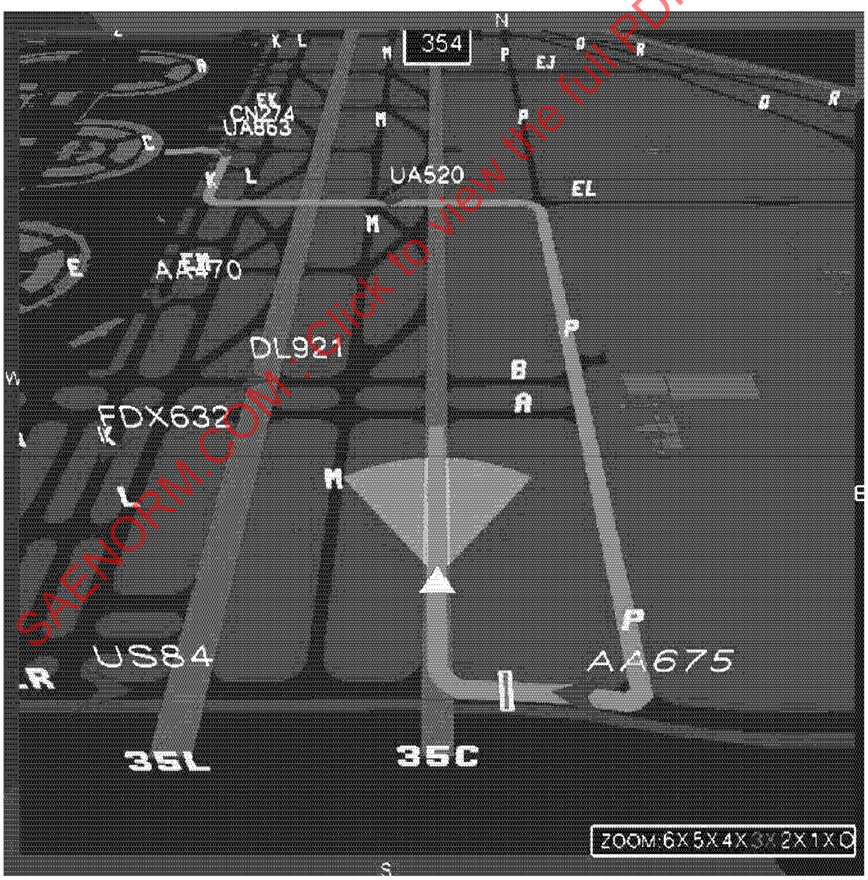

FIGURE 2 - Sample of an Exocentric Surface Display

7.1.1 Graphical Display Elements: For all display concepts, the presentation of ownship position on the display aids the pilot in developing spatial awareness relative to obstacles and the airport environment and assists in tactical operations and strategic planning (Andre, et. al., 1998). Other information elements may be presented as needed. Section 9 identifies other candidate elements and discusses them in detail.

7.1.2 Mode of Information Coding: Flight displays can depict information using methods ranging from literal to abstract. Functions of the surface operations display system should be analyzed to identify the specific information which must pass from the system to the flight crew (display) and that which must flow from the flight crew to the system (control). This analysis should make it possible to decide how to organize and present information to the flight crew (e.g., analog versus digital, literal versus abstract, continuous versus demand driven).

7.1.3 Method of Presentation: Surface operations information may be presented on a HDD and may include data linked and auditory guidance information. It may also be implemented on a HUD. The method of presentation within the flight deck must be appropriate to the pilot's primary scan, surface operations application and flight phase workload. Certain procedures, such as incursion prevention or obstacle avoidance, may require traffic information to be presented on the HUD. With current HUD systems, features will be typically limited to green wire frame objects, and a limited field-of-view. An inherent concern with use of current HUD systems is that the pilot can visually fixate on the HUD and as a result compromise scanning for traffic in the full field of view. As technology emerges it is expected that HUD design will be multi-colored and permit shaded objects which will cover a greater section of the pilots' field-of-view limiting the pilot's ability to see beyond the image which could make this situation worse.

7.2 Alerting and Command Displays:

Visual displays may also serve to provide the flight crew with alerts, which serve to direct the crew's attention to some element of the surface operations situation, or notify the flight crew of non-normal situations. These alerts and potential commanded actions would be generated by an automatic system working in coordination with the surface operations system.

The alerting and command displays may be integrated with a spatial presentation of the airport environment. For example, with a plan or perspective view format and ownship on a short final, a specific aircraft involved in generating a runway incursion alert may also be highlighted. In the far term implementation ownship could be commanded to go around.

7.3 Aural Displays (Indicators):

Candidate concepts may use an aural (voice or tonal, both 2D and 3D) display. This display may replace or supplement graphical displays. Both basic state information about the airport environment and warnings/alerts may be provided. It is possible to present aural displays with current aircraft equipment.

8. FLIGHT DECK INTEGRATION:

Addition of the flight crew interface (controls and displays) and processing unit components of a surface operations displays system into the flight deck should consider a number of factors. These factors include: integrated design versus dedicated design, design consistency, pilot/vehicle integration, flight crew information and alerting requirements, interaction with other aircraft systems, mission and operational requirements and future growth requirements. Also, the surface operations information interaction with the flight crew-related areas of workload, SA, training and procedures must be addressed to satisfy (existing and potentially new) flight deck certification and operational approval requirements. Additional HMI integration techniques should be applied to minimize operator interruptions from other duties. Hands on throttle and tiller concepts should be revisited with respect to surface operations display utilization. PNF duties in relationship to both HUDs and HDDs should be examined. With integrated multifunction or layered displays, issues may arise such as problems with flight crew awareness of the current display mode or status. Testing of these display concepts before implementation is highly recommended. For example, on any particular display space, airport information may not be the only or primary feature. Other pieces of information can be shown, including: various alerting information, weather, terrain, flight path, navigation data, and representations of aircraft state. This combining of functions on a single display may be a function of display-space limitations, or it may instead be convenient for the flight crew, allowing simultaneous consideration of related information, or it may be related to the importance of the information.

8.1 Design Consistency:

8.1.1 Overall Surface Operation Display System Design Consistency: The display of surface operations information should be consistent with the rest of the flight deck in terms of color, standardization, automation, symbology, interaction techniques and operating philosophy (reference FAA AC 25-11).

8.1.2 Alerting System Design Consistency: The standardization fundamentals recommended in the FAA Aircraft Alerting System Standardization Guidelines (reference Berson, et al 1981) should be applied to the surface operations displays and controls to promote a consistent implementation philosophy on the flight deck. For those flight decks that utilize an integrated alerting system, the surface operations information should be integrated into that system. For retrofit applications, the guidelines set forth in the above document should be used.

8.2 Display Integration:

8.2.1 Dedicated Surface Operations Display Design: A dedicated surface operations display concept requires minimal or no integration with the existing avionics system, but instead requires either one or two separate displays. Significant constraints are that space in the flight deck must be available to accommodate the placement of a dedicated display, and any single display be viewable by the flight crew member(s) using the display. This type of approach will typically be used on flight decks with analog avionics or with a federated avionics architecture. The stand-alone approach for these aircraft could use a separate side-mounted (angled) display as shown in Figure 3.

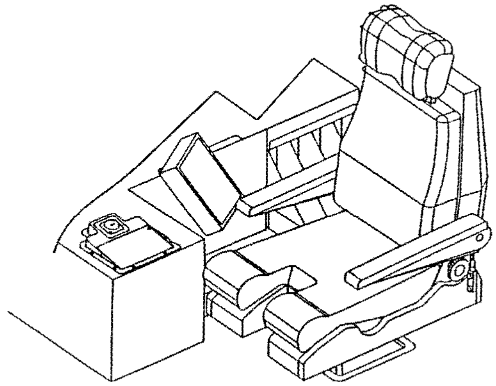

FIGURE 3 - Dedicated System Placement

8.2.2 Shared Displays: As the amount of information available to the flight crew increases, methods of displaying and manipulating that information should be made available. Conventional and hybrid flight decks may require the surface operations display(s) to be shared. Display sharing may be done either by space (e.g., split display, windowed information or overlayed information) or time. Strategies to allow the flight crew to manipulate the shared display of information should be provided. Time-shared displays tend to be useful for independent functions and procedures. Space-shared displays tend to be useful for related or same functions where the need to provide complementary information exists. Display clutter, symbology/font size and increased workload can be an issue for shared displays. The use of time-shared displays may require an alerting function to indicate any change of information on the system(s) not currently being displayed.

8.2.3 Integrated Multifunction Surface Operations Display Design: The glass cockpit provides the potential for functional growth. The glass cockpit is capable of displaying multiple images on the same surface by integrating multiple video/sensor input sources. The integrated surface operations displays approach would require the current avionics system to be equipped with a device that would allow the surface operations graphical and textual information to be displayed separately or on the same surface as other existing images. Interface control should provide the needed selections to the flight crew to manipulate the surface operations information. The glass cockpit permits an integrated design; it does not preclude the possibility of implementing a dedicated system.

8.3 Interaction with Related Flight Deck Systems:

The surface operations displays may often be used in coordination with other systems, driven by closeness of function, mutual benefit, or lack of display space. This section lists some of the systems which may be used in coordination with the surface operations displays.

8.3.1 Alerting and Separation Assurance Systems: When used in conjunction with a surface collision avoidance or runway incursion prevention system, the surface operations displays may provide alerts and command information related to maintaining the separation required for the current application. The surface operations information may be used in coordination with an automatic system for monitoring of conflicts and/or generating suggested or commanded actions to resolve potential conflicts.

Care should be taken that: the alerts appear justified by the presentation of the surface operations information; the nuisance alerts be minimized; and the alerting system attempts to incorporate all the other integrated information.

8.3.2 Autoflight and Flight Management Systems: Current and conceivable future implementations of runway incursion prevention may incorporate information concerning the Autoflight and Flight Management Systems. These systems may contribute information to the surface operations information system to present information about the intentions and future trajectory of ownship directly on the displays.

8.3.3 Data Communication Systems: Forms of datalink and/or broadcast data (e.g., ADS-B, TIS-B, FIS-B, and CPDLC) will most likely become the principal information sources for surface operations display implementations which could provide information elements such as the cleared taxi paths of ownship as well as of other aircraft. As flight crew involvement in decision making about traffic flow increases, the data communication systems will become increasingly linked with the surface operations information.

8.3.4 Flight Management Function: Flight crew interface with the Surface Operations Display System may be different for FMS equipped aircraft. For aircraft equipped with FMS functions in the current avionics, a logical design approach would be the integrated approach. As a result flight crew interaction with the surface operations information may be through the FMS. For aircraft that are not equipped with an FMS system, then a separate navigation source and flight crew interface needs to be retrofitted to supply the necessary navigation information and crew control. For surface operations display, ownship position and velocity data should be consistent, i.e. use the same reference system, as displayed airport data.

8.3.5 Aircraft System Integration: When the surface operations displays are integrated with other aircraft systems, the design should ensure that all data displayed is referenced in the same way and is displayed at the same scale. For example, heading-up oriented data should not be displayed simultaneously with track-up oriented data. One should be converted prior to display. For a second example, if a surface operations display is also displaying weather radar information, the design should not allow the range-scale of the weather data displayed to be different from the range-scale of the airport data that is simultaneously displayed. There should not be separate range controls for different functions such as radar and surface features when they appear on the same display. One control should affect the range setting for both functions when they are both active.

8.3.5 (Continued):

Additional HMI integration techniques to minimize operator interruptions from other duties should be utilized. Hands on throttle and tiller concepts relative to the surface display utilization procedures should be reviewed. Finally, PNF duties in relationship to both HUDs and HDDs should be revisited.

8.3.6 Caution, Warning and Information System: The caution and warning ant information system should give high priority to safety of flight including obstacle/hazard avoidance, visual acquisition, and hazardous weather messages and lower priority to procedural and efficiency of operation messages.

8.3.7 Autopilot/Autothrottle/Flight Director: Hardware and/or software interfaces may be required to provide the flight crew with guidance-based information and control if the runway incursion and surface information system is integrated with the Autoflight system.

8.4 Integration with Mission and Operational Requirements:

8.4.1 Operator Tasks: New flight crew tasks associated with the use and/or operation of the surface operations information system should not adversely affect performance of existing tasks.

8.4.2 Flight Crew and Controller Coordination: In early implementations of the surface displays, the presentation of aircraft traffic could increase the communications between flight crews and ATC. For example, if flight crews had access to flight identifications/call signs and were able to use that information, they could query ATC as to the identification of the traffic to follow. Alternatively, such information might reduce/improve ATC to flight crew communications by eliminating current ambiguities.

Presentation of traffic information in the flight deck potentially increases the propensity of the flight crew to be more actively involved in traffic separation and surface operation management. Also this might require a method for managing the information and procedures new to the flight deck, and might change the role the flight crew is willing to accept in relation to the air traffic controllers and other aircraft. Therefore, before implementing surface operations displays an examination should be made of the need for changes in flight crew and controller coordination procedures especially for alerting situations. It should take into account changes in flight crew and controller operational communications that may arise as the traffic management information becomes more observable by the flight crew.

8.5 Information Requirements:

8.5.1 Data Sources for Surface Operations: Information for presentation on the surface operations display system may be from single or multiple sources. These sources include but are not limited to various data link sources (ADS-B, TIS-B, FIS-B, CPDLC), navigation flight management system, on-board sensors and databases. Some of the potential applications will require figure of merit data for operation. Therefore, a means should be provided to obtain a figure-of-merit for the data and to control the use of the data source.

8.5.2 Data Fusion: Sensor data fusion is the integration or merging of data from multiple sensors to enhance sensor viewing resolution and accuracy and to eliminate multiple presentations of the same data (e.g., fusing of ADS-B and multilateration data). Sensor fusion should be used to assist human decision making by integrating large amounts of sensor data into unambiguous information. Fusion of data from multiple data links may have timing differences as well as identification considerations as data links may not all have the same transmission or update rates.

9. FLIGHT CREW INTERFACE CHARACTERISTICS:

Decisions about the type, number and location of the displays for effective information presentation should be based not only on how the system will be used, but also on the geometry of the flight deck and the available technology. Such variables as flight crew coordination, operational procedures and flight crew complement will dictate the number of displays and have an effect on the design of the display and control components. Displays and controls should be located in positions that are commensurate with criticality of use and crew coordination. They should also be located within appropriate visual angles and reach envelopes and so that there is no sight line interference from the design eye reference point.

A general statement about each of the information elements described in the sections below is that information elements should be clear and unambiguous and should not mislead the flight crew in any way. Although this statement seems straight forward and intuitively obvious it is not always achieved in system design. The clarity and explicit nature of information is both context and content dependent. Care should be used to understand the operational context and the overall content of the information throughout the design process. Performance tests and trade studies should be conducted under operational or simulated operational conditions to validate that the information elements effectively perform their intended function. Performance requirements should be defined before the tests are conducted to serve as evaluation success criteria.

9.1 General Features that Apply to Both Air and Ground Components:

9.1.1 Traffic Information: In general, traffic information can take a variety of forms from situation information to time-critical alerts. The urgency of the information to the flight crew should dictate how the information is presented and controlled. Traffic situation information should be crew selectable and deselectable. The alerting system should only be used to ensure the flight crew's awareness and response to non-normal traffic operations. Alert urgency should be part of the information contained in the alert.

9.1.2 Mapping Information: Current HUD and HDD systems only provide positions relative to airport features. With the introduction of new surface operational procedures such as GNSS approaches and low visibility taxi, airport map displays will need to be geo-referenced to precise, ,two and three-dimensional positions. Mapping data will include horizontal position information described in units referenced to a point that is surveyed in latitude/longitude (WGS-84), for the purpose of displayed data exchange. For all features that require a vertical component, the vertical reference should be orthometric height (MSL) for the purpose of data displays. If surface operations are to be enhanced, precise mapping display data is needed to integrate moving map taxi-guidance functionality with navigation systems. Mapping information should be consistent across all airport representations. An example of the types of map features that have been identified for survey in RTCA DO-272 is presented in Figure 4. It is cautioned that all the identified features may not be appropriate for inclusion in a surface operations display.

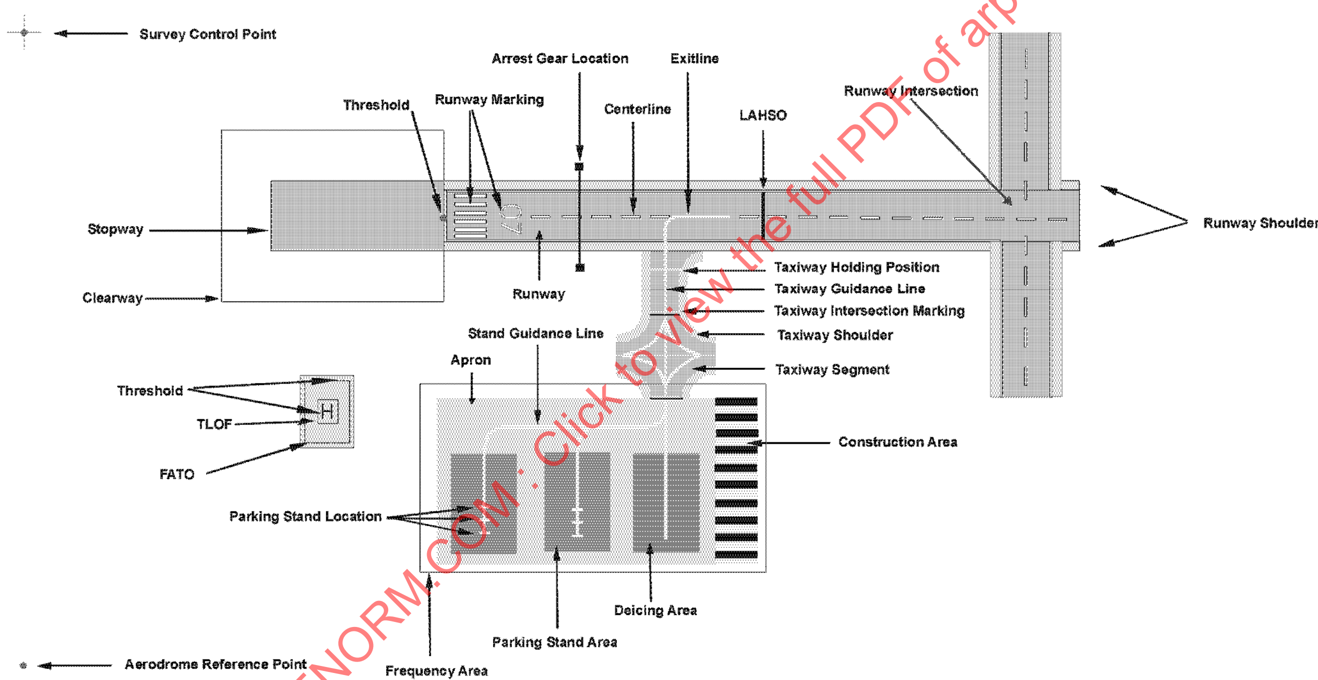

FIGURE 4 - Map Features Identified to be Surveyed in RTCA DO-272

One of the anticipated applications of today’s highly accurate navigation systems is aircraft navigation on the airport surface (see Figure 5). With the advent of GNSS augmentation systems, technology will soon be available to enable aircraft to obtain accurate position information while operating on the airport surface. Related standards are under development by ICAO, EUROCAE NASA and RTCA.

FIGURE 5 - Plan View of Airport Surface Showing Ownship Postion

9.1.2 (Continued):

Despite the capability of technology (e.g., GNSS) to perform the navigation function (i.e., determining position and velocity), for certain applications there must be a means by which this position is relayed to the flight crew (e.g., HUD) so that they can safely move the aircraft from the current position to the desired destination. One approach is by presenting current position to the pilot relative to geographic locations stored in an airport mapping database. These geographic references can be centerlines, runway/taxiway edges, painted markings, and/or obstructions. Using precise navigation data, an accurate database, and a display, the flight crew can determine, in real-time, both lateral and longitudinal track deviations (independent of visual aids).

A complete airport data base for avionics display is composed of a variety of thematic data elements and features; for example, vertical objects, runways, taxiways, and building geometry. The methods employed to collect and handle each data type may differ widely. In addition to display methods, the data types pose different hazards, risks, and informational opportunities to surface and terminal-area navigation applications. Therefore, the spatial or surveyed extent of the display map is defined on an object-by-object basis. Practical methods of data collection employed by industry (vis-à-vis airport surveyors and GIS specialists) are also considered when defining the data base for displays.

9.1.2 (Continued):

Unlike terrain databases, which are typically represented as grid points with associated elevation data, airport databases are typically constructed from a photo-grammetric image that is then converted to vectors and assigned themes and attributes using GIS techniques. This is because of the fact that many important data elements are features and not just elevations. These features are more easily characterized by points, lines, and polygons. Examples include runway edges and hold lines. Airport surface data usually represents regular geometric objects that can be grouped or classified. Examples of classifications that are to be displayed are: runways, taxiways, service roads, localizer antennas, glide slope antennas, buildings, radar sites, radio navigation beacon sites, etc. All of these can be displayed with their own set of attributes, most of which are related to surface horizontal positioning.

9.2 General Visual Display Characteristics and Features:

To reduce duplication, recommendations for those display elements that are the same for head-up and head-down displays are presented in this section. Those recommendations that are directed to a specific display type and application are presented in later sections. The assumptions that, while somewhat general in nature and presented in Section 1, provide the primary focus for the discussion of head-up and head-down displays for surface operations are as follows:

a. Worst case visibility minimums addressed in the document will be SMGCS or Cat IIIb.

b. The system will be surface operations oriented as currently defined by industry which is 1000 feet AGL to the gate on approach and the gate to 1000 feet AGL or the runway end on departure.

c. At least initially, paper and/or electronic versions of the surface charts will still exist and be available to the flight crew.

9.2.1 Common Airborne Display Features:

9.2.1.1 Runway Occupancy Awareness and Alerting: Display of information for existing runway occupancy or potential runway incursion situations should follow existing traffic display conventions and be consistent with the flight deck display philosophy. The meaning of an alert should be immediately apparent and unambiguous to the flight crew. The use of automatic format changes (pop-ups or alerting windows) to display information of immediate concern may be acceptable when data is of a high priority or transient in nature. The automatic display of the alert can be based on range, phase-of-flight, and navigation or communications needs. In the case of existing or potential runway incursion alerting situations, in multiple target environments, the symbol of the traffic causing the alert should be easily identified. The type, priority and meaning of an alert must be clearly indicated to the flight crew and consistent with existing flight deck alerting philosophy. Figure 6 depicts a sample head-up display and head-down runway map with an incursion alert.

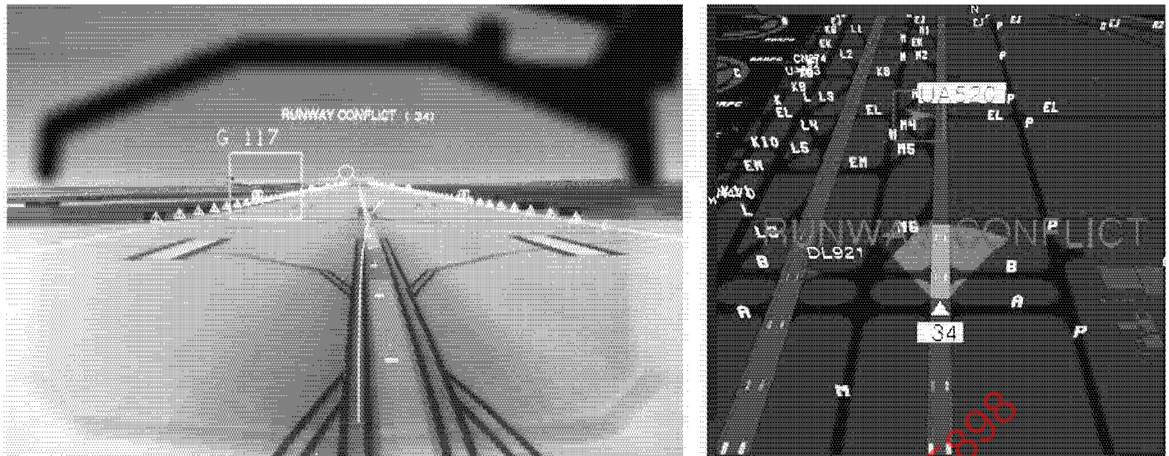

FIGURE 6 - Sample Runway Incursion Alerting Displays

9.2.1.2 Traffic Separation: Alerting to the potential loss of separation with another aircraft/vehicle, horizontal or vertical, is important for all phases of flight operation. Accordingly, during terminal flight operations in the transition to surface movement, the display of other aircraft in close proximity with respect to own aircraft is a practical solution to potential encroachment scenarios. Some sample traffic data might include range references, closure rate, ground speed, aircraft size, and track or heading. Such information could aid in the decision as to whether the runway will be occupied when ownship intends to touch down. However, care should be taken when including data because increased complexity of the display could also hinder the decision making process.

9.2.1.3 Hazard/Obstacles/Structures: Selected meteorological phenomena (e.g., wind shear, wake vortices, snow and ice), terrain, structures, and vehicles may be displayed in a variety of overlay formats. However, the number of layers should not cause confusion or cause clutter or visual obscuration. When information is routinely displayed, accuracy, resolution and integrity of the data attributes may vary according to application; however, the display should not cause distraction, misinterpretation, or conflict with similar information displayed elsewhere on the flight deck. The type of information displayed will vary, depending on the application, and the intended use of the information (information/alert/orientation). Above all, the display should only present the information in a form that assists the flight crew in recognizing hazards, obstacles and structures that are significant to the intended use of the information. Buildings, structures, & obstacles should be displayed in such a manner as to provide information about position, orientation and type.

9.2.1.4 NOTAMs (graphical and text): Display of NOTAM information should be pilot selectable to the degree of detail necessary for conformance to the immediate operation. However, NOTAMs that involve surface movement area closures and added obstructions should be displayed as part of the basic data set requirement for both head-up and head-down. Graphical NOTAM information should be incorporated using overlay techniques that allow for the assessment of priority and validity by flight crews and controllers.

9.2.2 Common Ground Display Features:

9.2.2.1 Runway Occupancy Awareness and Alerting: See 9.1.1.1.

9.2.2.2 Traffic Separation: See 9.1.1.2.

9.2.2.3 Hazard/Obstacles/Structures: See 9.1.1.3.

9.2.2.4 NOTAMs (graphical and text): See 9.1.1.4.

9.2.2.5 Taxi Route/Clearance: Taxi routes should be enterable, modifiable and verifiable in a user-friendly manner, by either data link and/or manual entry. They should be formatted so that they can be augmented through automated taxi route assistance (i.e., intelligent route entry system either through datalink or on-board which will minimize workload by reducing the number of required key strokes, particularly when a re-route is given during the taxi phase). When augmented manual inputs are used, the automated function should not override manual inputs without crew alert or a requirement for crew consent. Taxi routes loaded through a data link should be formatted consistent with onboard systems and should require pilot acknowledgement to execute. The clearances may be in the form of alphanumerics or graphics or both. In order to display the graphical route information, the system must have access to airport layout (reference RTCA DO 272), ownship position and intended route. Pending routes should be clearly distinguished, through some form of coding (e.g., color, highlight, brightness, etc.), from accepted routes. Other useful information could be traffic management information, NOTAMs and general airport surface information. Figure 7 depicts the airport surface with the ownship's taxi path and the active hold lines.

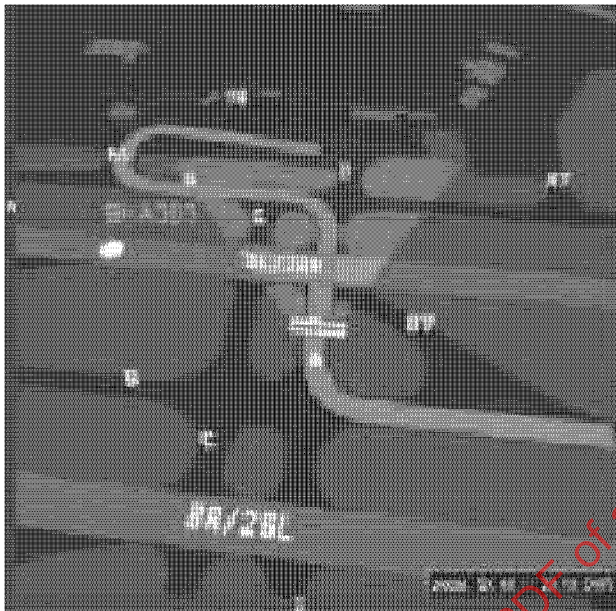

FIGURE 7 - Sample Ownship Cleared Taxi Route With Active Hold Line and Pending Route Beyond the Active Hold Line

9.2.2.6 Hold Lines: Hold lines provide the flight crew important information as to the points to stop prior to crossing a runway or taxiway. Therefore, the hold lines (whether physically painted on the airport surface or generated by the controller) should be depicted on the surface map. More advanced implementation should display the hold short lines such that there is a clear distinction between active and inactive lines. Active hold lines are defined as those hold lines that are in effect for the current clearance (see Figure 7). Inactive hold lines are defined as those that the ownship is cleared to cross. To support runway incursion prevention applications, the system should incorporate alerting and symbology to indicate crossing an active hold line. The relationship of an alert should be immediately apparent and unambiguous to the flight crew. Warning information requiring immediate response by the flight crew should not cause fixation. If overlaying information on a HUD, the display of added information should not interfere with the ability of the flight crew to see and maintain a mental image of the outside scene. Pending routes (that portion of the route beyond the active hold line) should be clearly distinguished, through some form of coding (e.g., color, highlight, brightness, etc.).

9.2.2.7 Edge Lines, Centerlines, and Identifiers: The display of runway, taxiway and ramp edge/edge lines, centerlines and identifiers should provide a clear and uncluttered representation of the proximate airport surface movement area. It should allow visual identification of the outside scene with minimal display clutter. Note that the display of certain elements might not be desirable on the moving map display, to deter its use as a closed-loop manual control display.

9.2.2.8 Trend Information (own and traffic): If trend information is presented, it should show both ownship and traffic (aircraft and vehicles) future trend information for selectable periods in the future (e.g., 20/40/80 seconds) as necessary to show predictive conflicts and it should be de-selectable by the flight crew. The information provided by the display, in conjunction with a surface moving map, may assist the flight crew in predicting the intentions of other aircraft and performance of the ownship.

9.2.2.9 Taxiway, Gate, Ramp, and Runway Labels/Identifiers: Should be marked on displays in such a manner so as not to clutter or obscure the taxi path of the aircraft. It is envisioned that the graphical display of identifiers and labels will be as overlays referenced to and correlated with the appropriate airport reference points. In most visibility conditions, surface navigation display functions, like those mentioned above, would be intended to supplement visual cues. Visual aids such as airfield signs, painted markings, and lights would continue to be used as the primary method of guidance/navigation. This supplemental information would be used by the crew as needed to mitigate any uncertainties associated with guidance presented by the visual aids (e.g., indeterminate sign direction arrows, missing centerline paint, etc.).

9.2.2.10 Taxiways, Ramp, and Runway Markings (centerlines, hold bars, threshold, etc): Should be marked on displays in such a manner as to provide an exact understanding of the aircraft position in relationship to the airport surface movement area constraints. In conditions of good visibility, this is normally done using external visual references such as center lines/lights, runway edge, and taxiway paint markings. In conditions of low visibility or at night, access to sufficient cueing on the primary flight deck display will assist flight crews in maintaining proper path during landing roll out and normal taxi (see Figure 4).

9.2.2.11 Turn Indication: If turning indicators are used they should be displayed in sufficient detail and in a timely manner to augment traditional surface navigation tools (markings, lights, signage and communication). The information provided by the display should show the flight crew how they are conforming to the cleared and intended route of taxi. Suggested turn-off/turn information should be displayed in a subdued manner so as not to subordinate more important information or clutter the display. However, "automatic" de-cluttering, deleting/relocating information, should be avoided. It is assumed that the display of turn-off/turn information will be predicated on the implementation of a "certified reference point" for specific size classes of aircraft (reference RTCA DO242A).

9.2.2.12 Runway Length Remaining: If runway remaining data is routinely displayed, latency, accuracy, resolution, and integrity of the data attributes may vary according to aircraft application.

9.3 Head-Up Displays:

There are potential pitfalls in using HUD for airport surface operations functions (e.g., the narrow field of view only covers a limited percentage of the potential approach angles of encroaching traffic). Additionally, there is a tendency for pilots to adapt a tunnel like view when using the HUD on the surface. For purposes of this document, the following assumptions are generally applicable to use of HUDs in both airborne and surface operations. In addition to what is covered in 9.2, the information presented below is specific to HUD presentations only.

9.3.1 Assumptions:

- The current HUD is monochromatic.
- The development of color will be considered an enhancement and provide a redundant coding capability.
- The development of color symbology, for a HUD system, will be consistent with the considerations for the design of cockpit display systems as described in ARP5364 and with the head-down displays.
- Head-Up display technology will continue to provide SA in such a way that it does not reduce or obscure crew cognizance of the outside scene or cockpit resource management requirements.
- The HUD will only employ a conformal, 3-D perspective display, unless adequate research were to show equivalent performance using other perspectives.

9.3.2 Head-Up Display Airborne Information: General display requirements for HUD in airborne operations usually include display elements such as heading, airspeed, altitude, attitude, rate of climb, flight director guidance, precision landing guidance information, and runway depiction.

9.3.2.1 Runway Occupancy Awareness and Alerting: If overlaying information on a Head-Up display, the added information should not interfere with the ability of the crew to view the outside scene and maintain SA.

9.3.2.2 Traffic Separation: If traffic is displayed on the HUD, an accurate positional depiction of traffic is needed to enable the flight crew to maintain outside scene SA within the FOV of the HUD. Potential requirements might include display of airborne traffic that is of immediate concern to own aircraft operation (for example, FAROA and ASSA operations in the terminal area). Another example would be closely spaced parallel approach operations where both the airborne traffic in close proximity and the surface traffic in and around the intended landing point are of primary concern to own aircraft operation.

9.3.3 Head-Up Display Ground Information:

9.3.3.1 Basic HUD Ground Operation Information: Information such as heading, and ground speed should be displayed in a manner similar to the conventional HUD display:. Other potential operational information elements might include: taxi route, hold lines, runway length remaining, edge lines, centerlines , and identifiers, steering guidance and symbology, trend vector, and imaging sensors.

9.3.3.2 Steering Guidance and Symbology: Steering guidance and symbology should provide sufficient accuracy to ensure that the aircraft remains on the portions of the airport surface approved for airplane operation. This includes nose wheel guidance, and possible ground speed limitations. Therefore, the surveyed database must be accurate enough on an object-by-object basis and have sufficient resolution to permit this operation. Given that the data has been correctly published or otherwise made available by the data originator, the data provider shall issue the updated database as needed (reference RTCA DO-272 and DO-276).

9.3.3.3 Non-Conformal Information: While most of the HUD information should be conformal, some non–conformal information, in support of navigation awareness, may be necessary. For example, the HUD could display, using text, the current taxiway as well as the upcoming taxiway/runway intersection. When presenting non-conformal information, it should be displayed in the outer regions of the HUD FOV and not overlap any near-field conformal symbology.

9.3.3.4 Imaging Sensors: Displayed information derived from imaging sensors should be in conformance with standard HUD symbology. Data derived from imaging sensors should not conflict with other HUD symbology or the flight crew's ability to use visual cues in the outside scene. Sensor displays should be configured in a manner such that flight crews can remove layers or deconflict images easily.

9.3.3.5 Deceleration Cues: If deceleration cueing is used, the display should provide clear and adequate cueing for runway deceleration to allow a safe turn and exit from the runway within the design parameters for taxiing the aircraft. The display should provide sufficient path guidance to allow rollout requirements determination and taxiway turnoff cueing, this may include deceleration cueing.

9.4 Head-Down Displays:

In addition to what is covered in 9.2, the information presented below is specific to HDD presentations only.

9.4.1 Assumptions:

- HDD are most likely to be multicolor and multi-function
- HDD may include graphical and textual information
- HDD provide pilots with a range of selectable information which may not be available on a HUD
- HDD should be used to support awareness and navigation, and not closed-loop manual control

9.4.2 Head-Down Display Airborne Information:

9.4.2.1 Runway Occupancy Awareness and Alerting: The display of information should be easily understood so as to minimize the time that crew attention is focused inside the flight deck.

9.4.2.2 Single Alert Versus Multiple Traffic Alerts: When multiple alerts occur, the most urgent source should be apparent. If overlaying information, the scaling of the information and the display of added information should not interfere with the ability of the crew to gain visual reference to the alert source. All warning and caution alerts should be presented in a redundant manner, in which they are distinguished by at least two unique dimensions (e.g., color and shape).

9.4.2.3 Traffic Awareness: If traffic is displayed on the HDD, it should provide at a minimum an accurate positional depiction of traffic to enable the flight crew to maintain outside scene SA (reference RTCA DO-242A, ADS-B MASPS and DO-XXX, TIS-B MASPS).

9.4.2.4 Surface Traffic: When surface traffic information is displayed, it should not clutter or obscure the underlying display or image. Additionally, the crew should be provided a means to select and deselect surface traffic information when appropriate to a specific application. Deselecting traffic information should not affect the alerting function. Surface traffic should be clearly distinguished from airborne traffic.

9.4.3 Head-Down Display Ground Information:

9.4.3.1 Position Data: The horizontal reference for all displayed position data shall be the WGS-84 ellipsoid. All airport mapping data that includes horizontal position information should be described in units of latitude/longitude for the purpose of displayed data exchange. It is expected that for many applications, display implementation may include conversion to a local coordinate system (e.g. Cartesian) along with at least one geodetic reference point. Data quality should be preserved when performing coordinate system conversion. For all airport mapping data that requires a vertical component, the vertical reference should be orthometric (MSL)height for the purpose of data exchange.

9.4.3.2 Vertical Objects: Vertical objects (e.g., construction cranes, radar towers, tethered balloons) on the airport surface have traditionally been displayed according to Airport/Aerodrome paper charts, PANS-OPS, or FAR. However, emerging surface operations applications may require accuracy that exceeds these previously defined symbology requirements. For example, applications that depend on precision display for surface operations may require that many elements in the movement area be shown at sub-meter accuracy (RTCA DO-272). Initially, these high-accuracy requirements will be imposed upon a region in and around the movement areas. Therefore, when these elements are displayed, the resolution and accuracy should permit the intended function. Rationale for the vertical extent boundary is driven by three considerations: (1) wing-tip and airframe clearance requirements, (2) air-ground (landing) and ground-air (take-off) proximity operations, and (3) helicopter maneuvering operations.

9.4.3.3 Airport Structures: Airport structures is a general term used to describe the airport terminal, tower, hangars, and other miscellaneous buildings on the airport surface. Based on the geometric complexity of these objects, they are not traditionally depicted as a true representation of the object, and in some cases only the corners can be displayed. Future applications, particularly those with regard to efficiency and routing applications, may require detailed models of these geometric elements. Because of constant change in airport structures, the display should show structures that are relevant to the surface operations, or that may serve as important navigation landmarks. The database updates should reflect changes in these relevant structures in a timely manner (reference RTCA DO-272).

9.4.3.4 Non-Movement Area: If the system supports operations in and on non-movement areas, all dynamic (movable) objects, obstacles, hazards and environmental features that affect aircraft operation or safety should be depicted if the information is available.

9.4.3.5 Textual Notes: Alphanumeric information pertaining to the airport (e.g., NOTAMs) should be displayed so as not to hinder or obscure the intended purpose of the display. Additionally, once viewed, text should be de-selectable by the flight crew with a minimum of effort.

9.4.3.6 TERPS Data: For approaching/departing aircraft TERPS data may be displayed, it should be de-selectable to a minimum set of data by the crew.

9.4.3.7 Weight and Wing Span Limit Information: If weight and wingspan information is used to indicated limited movement areas for the ownship the display may include indication of turn radii that are close to or outside the maneuvering limit of ownship. Additionally, taxi weight and surface load bearing capabilities to support ownship configuration may be provided as an overlay feature on a surface map display. There should only be two types of movement area depicted; those the aircraft can taxi on and those that it cannot. The dividing line may be dynamic - in this case with weight change, but in others with clearance from ATC. However, in order to prevent misleading information, if some areas that are not available to taxi due to weight and wing span limitations are presented then all such areas should be presented.

9.4.3.8 Off Airport Features: Terrain and cultural features if available should be clearly displayed when they add to SA, and should be easily de-cluttered.

9.4.3.9 Ramp Demarcations: Ramp edges and identifiers, centerlines, stopping points, should be marked on displays in such a manner as to provide an understanding of the aircraft position in relationship to the airport surface that is clear enough to perform the intended operation.

9.4.3.10 Ownship (location, icon, size): In order to be consistent with airborne navigation displays, the pilot should have the ability to move ownship from off center of the HDD to another position (e.g., the center). In minimum visibility conditions, this will allow the crew to observe conditions other than ahead of the nose of the aircraft (e.g., approaching weather, taxiway congestion, landing airplanes). The ownship location should allow the majority of the view to be in front of the aircraft, while still supporting traffic awareness behind the aircraft. The icon does not need to be true to size, given that the HDD is used to support navigation and not control. If supported by the data, either a generic directional icon can be used (triangle, but not equilateral) or an aircraft icon can be used. The presentation of the ownship relative to the airport surface should be consistent with the actual position (i.e., the nose of the airplane is depicted where it actually is relative to the airport surface). Therefore, the depiction of the nose position will require a translation from the navigation position data. If sensing airplane direction accurately is not supported by the data, a nondirectional icon should be used.

9.4.3.11 Surface Traffic: When surface traffic is displayed, it should not clutter or obscure the underlying display or image. Aircraft within the display field of view should be depicted with an appropriate icon that denotes location and possibly size of the traffic. Additionally, the crew should be provided a means to select and deselect surface traffic when appropriate to a specific application. Deselection could be a function of the significance of the traffic to the ownship position or route. Deselecting traffic should not affect any alerting function. Surface traffic should be clearly distinguished from airborne traffic.

9.4.3.12 Traffic Identifiers/Tags: Traffic identifiers and tags on a display should not obscure each other. The display of tags should be prioritized according to significance to ownship position and route. The accurate depiction of the traffic position will require a translation from the navigation position data. Traffic identifiers/tags should be selectable and deselectable by the flight crew.

9.4.3.13 Display Decluttering: Decluttering should be under flight crew control. Decluttering algorithms should de-clutter in the order of least to most significant information. Proximate and hazardous vehicles and obstacles should be the last to be de-cluttered.

9.4.3.14 Insets: Insets (picture-in-picture) are not generally recommended, but can sometimes be used effectively to present two different views of the same information. For example, a north-up inset can be presented in the corner of a track-up display or a sensor image might be presented in the corner of a display.

9.4.3.15 Track Versus North Up Views: Both views should be supported because they are both usable for different applications. For example, the pilot-flying should normally use a heading-up or track-up display; the pilot-not-flying could select either heading- or north-up for clarification of routing as the flight crews currently do with paper charts. The default view should be the track-up view.

9.4.3.16 Scale/Range Indicator: At a minimum the scale indication should indicate to the flight crew the current selected and active range of the display.