Shipboard Automatic Identification System Displays

Meeting the Needs of Mariners

JOCELYN N. SANDS

A shipboard automatic identification system (AIS) automatically communicates information about a vessel's identification, position, course, and speed to other vessels and shore stations. AIS also facilitates the communication of vessel traffic management and navigational safety data from shore stations to vessels.

During the last two decades, much has been done to define the technical and communications requirements for AIS, but little effort has addressed the shipboard display of information. The world fleet of merchant vessels has begun to adopt the international carriage requirements, which specify the charts, publications, and equipment that must be on board. The requirements mandate AIS for ocean-going vessels under the International Convention for the Safety of Life at Sea (SOLAS). The United States Coast Guard (USCG) regulates AIS for vessels in U.S. waters and aboard U.S.-flag vessels.

To assist in developing AIS carriage requirements, USCG asked the Transportation Research Board (TRB)–Marine Board, through the National Research Council (NRC) of the National Academies, to assess the state of the art in AIS display technologies, evaluate system designs and capabilities, and review the human factors aspects of operating these systems. Consideration was to be given to the effects on shipboard AIS displays from

- Technology, security, economics, operating considerations, and human factors design;
- The range of tasks to be supported;
- Differences in operating environments and in qualifications and skills requirements;
- Changes in technology, equipment and technical integration, requirements for harmonizing with international standards, and requirements set by manufacturers and standards-making bodies; and
- Lessons learned and best practices from relevant domestic and international AIS programs.

Under the auspices of the TRB Marine Board, NRC assembled a committee of experts in instrumentation and electronic systems engineering, human factors, ship design and marine engineering, marine navigation and ship operations, and inland waterways operations (see box, page 41).

PHOTO: DAVID NATALI, CLIPPER NAVIGATION, INC.

Wheelhouse of high-speed ferry.

Identifying Concerns

The committee was asked to evaluate the state of the art for AIS displays, analyze current problems, and make recommendations to aid USCG in developing AIS standards and requirements. The committee reviewed a large amount of background information and conducted information-gathering sessions, including a workshop in New Orleans, Louisiana, and site visits to the United Kingdom, Germany, and Sweden.

The committee identified many concerns affecting the shipboard display of information. Some of the concerns are the result of AIS being in the early stages of implementation, and others stem from the issues of mariner workload and data management. Members of the committee noted that AIS data must be

integrated carefully into the volume of information provided to mariners from a variety of sources, or much of the potential benefit from AIS could be lost.

These concerns are implicit in the committee's recommendations. The committee advises USCG to ensure that safety and human factors are priorities in the development of AIS regulations.

Systematic Implementation

Because of the complexity of implementing AIS aboard vessels, the committee finds that a systematic plan is needed. The plan would address assumptions about the types of onboard equipment to be integrated with AIS. For example, requirements are needed for integrating AIS information with information from other onboard electronic navigation systems. Additional work is needed to determine the best way to integrate current and new systems.

Recommendation 1: USCG should establish an implementation plan and schedule for AIS shipboard display standards in consultation with stakeholders. Key elements of the plan should include

- Research in technical and human factors,
- Determination and analysis of requirements, and
- Development of international and domestic standards.

AIS and Shipboard Displays

Although displays can be the means for converting AIS data into useful information for the operator, little has been done to define the information needs and priorities for display parameters. In the United States, AIS is in the early stages of implementation, and the technology is experimental or prototype.

Concerned that problems could result without the timely and prudent introduction of AIS displays, the committee advises that AIS displays should be introduced to meet the needs of mariners without adding a burden of inessential information.

AIS complements traditional aids to navigation but does not replace them. For example, AIS does not replace the need to establish vehicle position using all available means appropriate to the circumstances. The system should display three types of vessel-specific data: static information, dynamic information, and voyage-related information.

The International Maritime Organization (IMO) has defined three functions for AIS:

1. To assist in collision avoidance when operating in the ship-to-ship mode,
2. To provide information about a ship and its cargo to authorities on shore, and
3. To assist authorities in vessel traffic management.

To assist in collision avoidance, an AIS display should supply information directly to the mariner for maneuvering within close quarters or planning a meet-and-pass encounter. A shipboard display, however, probably would have little use in providing ship and cargo information to local authorities.

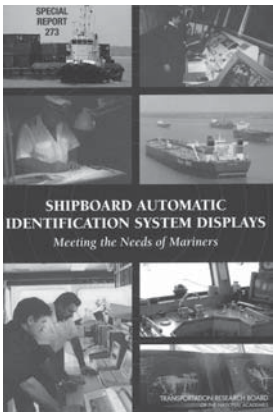
Operating Environment

Nonetheless, AIS can communicate a range of data to assist in vessel traffic management, and a shipboard display may have a significant role in this task, depending on the nature and design of the traffic management system. The relationships between AIS functions, information types, and data elements are summarized in Figure 1.

AIS information will be displayed in many different operating environments: rivers and inland waterways, high-density ports with mixed traffic, coastal waterways, urban harbors with scheduled ferry and passenger vessel operations, and major commercial ports accommodating large deep-sea vessels. In the United States, operators of tugs, towing vessels, passenger ferries, and other non-SOLAS vessels are most likely to be required to use AIS.

The operating environment will affect the configuration of the displays with which AIS must interface for proper operation. Many of these smaller domestic vessels, however, may not carry all of the equipment with which an AIS needs to interface for proper operation—they may carry none at all.

The majority of the large commercial vessels transiting U.S. waters are of foreign registry and are manned by a variety of nationalities. This complicates display issues because a common operating



TRB Special Report 273, *Shipboard Automatic Identification System Displays: Meeting the Needs of Mariners*, is available from the online TRB Bookstore, www.TRB.org/bookstore/. (View the book online, www.TRB.org/publications/sr/sr273.pdf.)

AIS Data Elements

Static	Dynamic	Voyage-related	Functions
Beam Length Antenna location	Navigational status Weather	Hazardous cargo Draft ETA* Route plan*	Vessel Traffic Management
Antenna location Length/beam	Course Heading Speed Position Rate of turn* Length/beam	Draft	Collision Avoidance
Vessel name Call sign/MMSI Type of ship/IMO# Cargo	Cargo on board	Cargo on board	Identification

Information Type

*Optional information

FIGURE 1 Representative AIS data elements, functions, and information.

environment must be established for mariners, independent of the area in which they are operating.

Carriage Requirements

Carriage equipment is designated as Class A, Class A derivative, or Class B. Class A units are for oceangoing vessels. Class A derivative units are portable carry-on units generally used by pilots in U.S. ports and waterways. Class B units have less stringent requirements and are intended for use by inland and coastal vessels.

Class A derivative units have received the most attention in the United States because they are similar to those that pilots have used as carry-aboard units. The definition, role, and display requirements for Class A derivative units, however, are incomplete. Class B units also are not well defined. More analysis of Class A derivatives and Class B is necessary before unit requirements can be specified.

The initial carriage requirements do not specify shipboard display for use by the mariner, except for the minimal, basic numerical identification data. The minimum keyboard and display (MKD)—a minimal numerical system—is used widely as a shipboard display but does not provide adequate information for the mariner and could be detrimental to safe vessel navigation. USCG therefore should establish new minimal display standards before MKD becomes the default standard for U.S. operations.

Taking the Lead

Recommendation 2: USCG should establish requirements for shipboard display of AIS information in navigable waters of the United States by

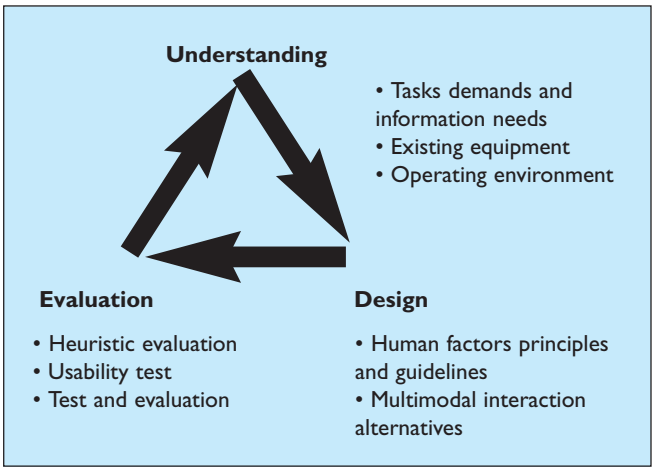


FIGURE 2 Iterative cycle of system development. (Adapted from Woods, D. D., E. S. Patterson, J. Corban, and J. C. Watts. Bridging the Gap Between User-Centered Intentions and Actual Design Practice. *Proc., 40th Annual Meeting*, Vol. 2, Human Factors and Ergonomics Society, Santa Monica, Calif., 1996, pp. 967–971.)

- Defining the information needs of mariners;
- Defining key functions for AIS displays aboard different types of vessels and in different operating environments;
- Developing appropriate requirements for each major vessel class, taking into consideration the differences in operating environments;
- Involving the key stakeholders in the entire process; and
- Developing a new requirement for minimum information display of AIS.

USCG should take the lead in establishing display requirements for AIS information and should work with appropriate international organizations to ensure compatibility with international requirements.

Recommendation 3: USCG should recognize the evolving nature of AIS display technology in its requirements process and allow for technological change, growth, and improvements.

Human Factors in Design

For AIS to promote safe vessel navigation, an effective onboard interface with the vessel's operator is essential. An interface should include both the display and the control mechanisms that allow the exchange of information between the operator and the rest of the system. Information may be displayed through such means as a cathode ray tube, graphics, auditory warnings, and data entry and through control elements such as keyboards or switches.

A typical iterative cycle of system development focusing on human factors is shown in Figure 2 :

1. Understanding the operational demands and the needs of the mariner. Advanced technology can increase errors and risk even when appearing beneficial.

2. Initial design incorporates the large body of knowledge about human factors interface. Human factors principles relevant to AIS interface design include ensuring that system behavior is completely visible to the operator, avoiding interface management tasks during high-tempo situations, and realizing that the representation of AIS data can greatly affect interpretations. Multimodal display alternatives should be considered in addition to graphics and text.

3. Evaluation of the design. The evaluation tests a design's performance and leads to adoption or redesign to correct a problem. A trial-and-error method, usability testing, and operational evaluation are complementary approaches to identifying problems.

Maritime technology and AIS applications are difficult to predict. USCG needs to allow designers the freedom to adapt to changes.

Recommendation 4: In its standards, USCG should specify that design, process, and performance standards be used in combination to promote adequate shipboard AIS displays.

System Limitations

The committee finds several limitations to AIS:

- The systems are not fail-safe. Equipment that is not operating onboard can drop out of use for surveillance. A decision to turn the equipment off or otherwise disable it also removes the vessel from the display.
- The integrity of the data that must be provided by the carrying vessel is not assured. Some data are manually entered by an operator and can be changed or could contain errors.
- Multiple shipboard sensors can produce multiple displays of single targets. The target ambiguity must be resolved through a sorting process not yet fully developed.

Further attention may need to be given to such issues as the system capacity for transmitting messages, transponder coverage and the spacing of shore-based repeater stations, the adequacy and accuracy of digital charting, the availability of vessel instrumentation, and the need for standardized interfaces between equipment.

Training will be needed. Stakeholders such as vessel operators, equipment manufacturers, and vessel traffic managers should be involved in developing training guidelines.

Recommendation 5: USCG should identify critical AIS limitations and infrastructure requirements and coordinate them with display requirements. USCG should establish a mechanism to inform all users about system limitations that cannot be corrected readily.

Recommendation 6: USCG should work with stakeholders to develop appropriate training and certification guidelines for AIS users that will lead to effective use and an understanding of system functions and limitations.

Ongoing Research

The development of AIS displays requires consideration of the human interface attributes that affect what information to display, how to present it to the operator, how to integrate other displays or other bridge information systems, and how to give the operator what is most needed to perform critical tasks. A key research area that has received little attention is whether AIS data will be presented to the operator separately or integrated with other equipment and information flows.

Another area for research is how the input of data into AIS during the normal conduct of vessel operations may interfere with mariners' other duties. Additional topics for research include symbology, cost–benefit trade-offs, data input strategies, and multiple tasking.

Recommendation 7: USCG should establish an ongoing research program to investigate information displays and controls appropriate for AIS. The research program should consider AIS use with other navigational and communications technologies. The research program should include

- Human factors aspects of interface design and the subsequent process of determining requirements, setting standards, and evaluating performance;
- Evaluation of multimodal interfaces—for example, tactile and auditory—that could support mariners' needs for attention management.
- Investigation of trade-offs between information requirements and the associated cost for shipboard display of AIS.

Operational Testing

Although USCG and other authorities have conducted operational tests of AIS technology in the United States and abroad, none of the tests has produced clear evaluations of performance measured against specific standards. Few of the tests on displays have involved AIS equipment built to IMO standards.

Recommendation 8: USCG should sponsor continuing operational tests, evaluation, and certification of new display and control technology in consultation with stakeholders and should prepare test and evaluation reports. To conduct tests and evaluations, USCG should develop standards for human performance with display and control technology. Heuristic evaluation should be used, so that several designers can assess how well a design conforms to human factors principles. Usability tests and operational evaluations should be incorporated as complementary approaches to assess how well AIS displays and controls support mariner performance.

The author is Research Associate, TRB Division of Studies and Information Services. Beverly M. Huey, Senior Program Officer, Transportation Research Board, served as Study Director for this project, assisted by Pete Johnson, Consultant.