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**FROM CAS TO ARPA
A PRACTICAL APPLICATION OF RESEARCH**

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ABSTRACT

Research may provide important data for operational and regulatory programs. A simulator research project and its application to such a program are described.

The opinions or assertions contained herein are the private views of the writer and are not to be construed as official or reflecting the views of the Commandant or the Coast Guard at large.

INTRODUCTION

In reviewing papers presented in previous CAORF Symposiums, I noted that the emphasis was decidedly on research. This is as it should be, since this is a research symposium conducted at a research facility and attended by research specialists. This paper does not report the results of a research project, but I think it is very relevant to this program and does have a message for all of you participating in this symposium. Some of the other papers will cover the actual research on this subject conducted at CAORF and elsewhere, but this paper describes how research may provide meaningful support to operational and regulatory programs. It is a case study of a project with practical and timely results.

BACKGROUND

Within the past two decades several companies, domestic and foreign, have developed and marketed shipboard collision avoidance systems (CAS). These have been developed using several different basic methods of navigators so that they can make more efficient use of their time. The systems use computer technology to solve vector relationships with inputs taken directly from the radar and other shipboard equipment. The computer's almost instantaneous solution of numerous situations provides the navigator with time to concentrate on other activities by eliminating the need for manual plotting of targets. Additionally, most navigators reach a saturation point beyond which they are unable to maintain accurate plots on multiple targets. This saturation point for most of us is well below the capability of the computer assisted device, which typically can handle 20 to 40 targets simultaneously.

A device designed to promote vessel safety will eventually come to the attention of regulators, and the CAS was no exception. In mid 1974, the United States Coast Guard published an advanced notice of proposed rulemaking that would require, along with various other navigational equipment, an anti-collision device on vessels over 10,000 gross tons. When the final rules for the navigation equipment were published, the requirement for the anti-collision device was deleted from the final rule. This was due to comments in response to the advance notice of proposed rulemaking which held that the anti-collision devices were still in the developmental stage.

Shortly after this decision, the U.S. experienced the "Winter of the Argo Merchant," during which a series of devastating tanker casualties focused public and political concern on tanker safety. The demand for improved tanker safety standards led to the President's March 1977 decision to direct the Secretary of Transportation to develop regulations for tankers over 20,000 DWT, including the requirement to carry collision avoidance systems. In response to that directive, in May 1977, the Coast Guard published a notice of proposed rulemaking to require carriage of a computer aided collision avoidance system on vessels 10,000 GRT and over. Since the President preferred international to unilateral action, the U.S. submitted a note to the September 1977 session of the Navigation Safety Subcommittee of the Intergovernmental Maritime Consultative Organization (IMCO) proposing development of an international standard and requirements for carriage of collision avoidance devices. The standards proposed in the note were those developed by the Radio Technical Commission for Marine Services Special Committee 65 (RTCM - SC 65).

The U.S. was also successful in obtaining international consideration of CAS requirements at the Tanker Safety and Pollution Conference (London 1978). Although the international community was not ready to endorse a requirement for devices meeting RTCM - SC 65 specifications, the London Conference did request IMCO to develop appropriate performance standards for Collision Avoidance Aids by 1 July 1979. Incidentally, this action prompted the Coast Guard to withdraw the 1977 proposed rule in July 1978 in order to avoid influencing the international action. As is sometimes the case, the Congress became impatient at the rate of progress and in October 1978 passed the Port and Tanker Safety Act of 1978 (PL 95-474). This act required tankers over 10,000 GRT, by 1 July 1982, to be equipped with an electronic relative motion analyzer which is at least functionally equivalent to such equipment complying with specifications established by the U.S. Maritime Administration (MarAd).

While the Congressional action resolved the domestic regulatory issue (it set the standards, carriage requirements, and carriage date), the issue was far from resolved internationally. By the 21st session of the Navigation Safety Subcommittee (July 1978) two sets of standards had evolved, one for a computerized device and one for a simpler stored history device. These were considered at the 22nd session of the Subcommittee in January 1979.

During the January 1979 session, the United Kingdom, supported by the USSR, was strongly opposed to a standard that would require a computerized device. It became clear that the issue was no longer whether the devices should be required, but whether the required devices should be complex, computerized and costly or the simpler, less sophisticated and cheaper stored history devices. During the debate, two points which the U.S. could not effectively counter, were emphasized by the United Kingdom (UK).

- 1) There was insufficient evidence that the computerized CAS was more effective than the stored history device.

- 2) While evidence might indicate some benefit when one vessel in an encounter situation was equipped with a CAS, there was the possibility that, when two or more meeting vessels were equipped with the same or differing systems, they might engage in a "Dance of Death." Some research on this issue had already been completed by CAORF as reported at the Second Annual Symposium. These results were not consistent with the Liverpool Phase II study which initially raised the question of the potential hazard of interactive systems. It was clear that there was a need for further tests of interactive systems.

In addition to answers to the above, I felt the need for a good comparative analysis between the Potential Area of Danger (PAD) device and the vector device. Although several research simulators could have accomplished a study to provide answers to these questions, only CAORF could complete the research and report in time for consideration at a May meeting of an IMCO Intersessional Working Group.

The Intersessional Working Group met in London and the results were generally very favorable to the U.S. position. Many factors were considered during the May meeting, so success or failure in supporting the U.S. position cannot be attributed to the CAORF study alone. However, this was the first meeting from which a single international standard emerged. This was a standard for an Automated Radar Plotting Aid (ARPA) which came very close to the MarAd specification cited by the Port and Tanker Safety Act. The ARPA Standard was agreed to at the 23rd session of the Navigation Safety Subcommittee in September and has been submitted to the October session of the Maritime Safety Committee for its approval and submittal to the November session of the IMCO Assembly for its adoption. (At the time of this writing the results of the October session, scheduled from 8-12 October 1979 in London, were not available.)

ARPA PERFORMANCE STANDARDS

The ARPA has undergone a series of name changes during the political consideration of standards, but is basically similar to the originally envisioned computer assisted anti-collision device. The basic purposes of the ARPA are (1) to reduce the workload of observers by enabling them to automatically obtain information so that they can perform as well with multiple targets as they can by manually plotting a single target and (2) to provide continuous, accurate, and rapid situation evaluation. Performance of the ARPA is generally compared to that of a trained radar observer using a radar display.

The ARPA standard does not require a separate target detection capability. However, it does require that if separate facilities are provided for detection of targets, other than by the radar observer, the facilities should have a performance not inferior to that which could be obtained by the use of the radar display alone. The standard permits either manual or automatic acquisition, but requires that automatic systems include a feature for manual acquisition and cancellation of targets. Additionally, for systems with automatic acquisition, there must be a facility to suppress acquisition in certain areas. The MarAd specification is silent on the detection feature and, for target acquisition, it permits manual, automatic, or both.

The ARPA should be able to automatically track, process, simultaneously display, and continuously update the information on at least 10 targets or, if automatic acquisition is provided, 20 targets. In the absence of target swap ("swop" in the international

standard), a target clearly distinguishable on the display for 5 out of 10 consecutive scans should continue to be tracked. The ARPA should also be able to display on request at least four equally time-spaced past positions over a period of at least eight minutes of any targets being tracked. Although this latter feature is not part of the MarAd specification, MarAd supported its incorporation into the standard. The USSR was concerned over the impact of this feature and favored retaining it as an option rather than a mandatory element; however, they were unable to gain any support for their position. There is no known operational justification for the difference in the number of targets required to be tracked by the manual and automatic systems in the IMCO standard. The manual systems are just not able to handle the numbers of targets that the automatic acquisition systems can handle. Since the MarAd specification is silent on the numbers of targets, the draft requirement was acceptable to the U.S.

The MarAd specification requires that the display be contained in a console capable of installation adjacent to the radar displays, where as the ARPA standard permits integration with the radar display. MarAd reviewed this provision and felt it was acceptable as functionally equivalent to the MarAd specification. Both standards also prohibit degradation of the radar performance and require a sufficiently bright display to permit viewing by more than one person at a time. Additionally, the IMCO standard requires an effective display diameter of at least 340 mm and at least 12 or 16 miles and 3 or 4 mile range scales. The ARPA specification also required a relative motion display with "North-up" and either "head-up" or "course-up" azimuth stabilization, which is consistent with MarAd requirements.

Both standards require a vector or graphic target display and, additionally, an alphanumeric readout which presents range, bearing, course, speed, closest point of approach (CPA), and time of CPA (TCPA) for any selected target. The ARPA standard also contains test scenarios to check the accuracy and speed of development of target's motion trend (within one minute of acquisition) and of targets predicted motion (within three minutes). These requirements are not contained in the MarAd specification but are considered desirable by MarAd for regulatory inclusion.

The ARPA standard requires the capability to warn the observer with a visual and/or audible signal of any distinguishable target which closes to a range or transits a zone chosen by the observer, or of a target which is predicted to close to within a minimum range and time chosen by the observer. This is the only portion of the IMCO developed standard which appears not to meet the test of being functionally equivalent to the MarAd specification.

Since the MarAd specification requires both audio and visual alarms, the U.S. had to reserve its position on this feature. The requirement for an operational alarm had been opposed by a substantial number of governments during the January session of the Navigation Safety Subcommittee, but during the September meeting only Australia registered opposition to the present language and reserved their position on the inclusion of any alarm feature.

The ARPA should be capable of simulating the effect on all tracked targets of an ownship maneuver without interrupting the updating of target information. This provision is a requirement of the MarAd specification. It was also a feature opposed by a substantial number of governments during earlier sessions of the Subcommittee, but was unanimously agreed to during the September session.

Finally, both standards require suitable warnings of malfunction of the system. Basically then, as you can see, the ARPA standard, as agreed at the 23rd session of the Navigation Safety Subcommittee, comes very close to meeting the statutory requirement of the Port and Tanker Safety Act.

FUTURE REQUIREMENTS

Where then do we go from here and what requirements are there for future research on the CAS?

The first part of that question is a little easier for me to answer, since I am more comfortable in the world of regulators and operators than in the world of researchers. In addition to the standard itself, the subcommittee drafted a proposed amendment to the Safety of Life at Sea (SOLAS) 1974 convention for ARPA carriage requirements. Unfortunately, we did not fare as well with carriage requirements as we did with the standard. Unless we can get it changed in the committee or assembly, the effective date for tankers of 10,000 GRT or more is 1 January 1985 which is unacceptable to the U.S. Since that date represented considerable compromise and the rest of the world was unanimously against the U.S. on the earlier date of 1 July 1982, it is highly unlikely that the proposed date will be changed. Therefore, the U.S. will have to proceed on a unilateral basis and require compliance by 1 July 1982 for all U.S. tank vessels over 10,000 GRT and for foreign tank vessels over 10,000 GRT entering U.S. ports. Unless MarAd's position is amended, the U.S. also will have to act unilaterally on the alarm feature. Although these unilateral actions will evoke protests by other countries, probably the majority of the affected vessels will be able to meet our requirements.

As indicated earlier, I am not as comfortable with the second part of the question regarding future research, but I do have some thoughts that you might consider. During the discussion of the ARPA features you will recall that the USSR reserved their position on the regeneration of previous target positions. Basically, they felt that the feature should not be included as a mandate but should be retained as an option. This was based on their concern that it introduces a new capability into existing systems, so further study of the potential benefits or disadvantages of this requirement should be conducted. Although the U.S. did not support the USSR, there is probably considerable merit in their position. It should be possible to structure a series of scenarios directed specifically at determination of the value of this feature.

The most important research, however, at least from the point of view of the U.S. action, is analysis of the benefits of the requirement for the visual and audio alarm. The U.S. was unable to produce enough data to show the necessity of the dual alarm requirement to gain a single supporter. Through suitable research it should be possible to quantify the benefits of systems with a visual alarm only, audio alarm only, and both. I realize this would not be an easy series to structure and conduct, but it would make the unilateral action more palatable. There is a very strong feeling internationally that the audio alarm will induce watch officers to place too much reliance on the alarm to the extent that they neglect their duties as lookout and radar observer. This is a difficult argument to counter and probably can not be resolved without some

manual override in order to permit selection of the desired plotting area with automatic acquisition and tracking. In addition, means for manual acquisition is provided.

Criteria and accuracy of calculation of target's course and speed for low values (3-5) knots of relative speed of target motion. In this case, the Alpha Beta tracking filter uses heavy smoothing in the filters. For high relative rate targets within 6-8 miles, light smoothing is used. Medium smoothing is used beyond 6-8 miles range for high relative rate vessels and heavy smoothing for all others. Heavy is also used for all 0-2 knot true speed targets. There is approximately a factor of two in filter times between light, medium and heavy.

On low relative speed, course is $\pm 1^\circ$ and speed 5% of speed or .5 knot.

In general, DIGIPILOT complies with IMCO performance requirements or will meet the following if not in conflict or unspecified by IMCO:

Course: $\pm 3^\circ$ or $30^\circ/v$, whichever is larger.
Speed: $\pm 5\%$ or ± 0.5 knot, whichever is larger.

Criteria and accuracy of calculation of targets course and speed in case of effects of sea returns, rain, snow, low clouds and non-synchronous emissions:

Sea Returns - If radar anti-clutter is adjusted properly there is no effect. If not, large tracking errors could result. Distant wave clutter is filtered out by 3 bang correlation and matching scan to scan.

Rain - If gain and FTC adjusted and rain is light; no effect. If heavy rain, system fails to operate in rain area. Lim Lines can be used.

Snow - Similar to rain but effect is less.

Low Clouds - No effect or negligible unless C Band.

Non-Synchronous emissions - no effect.

Criteria and accuracy of calculation of tracked targets course and speed in case of ship's own maneuvers or/and tracked target maneuver:

Own ship maneuvers:

For slow turns there is no effect. For extremely high turning rates (greater than $150^\circ/\text{minute}$ - depending primarily on gyro response) there is some influence on all tracked targets which lasts for a minute or so and then all tracked targets return to full accuracy.

Other ship maneuvers:

The other ship course lags - 15 to 30 seconds, depending on filtering applicable. It is less accurate during its turn, but it recovers full accuracy quickly.