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Autor: Greneker, E.F. / Eaves, J.L. / McGee, M.C.
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Bridge Ship Collision Electronic Detection and Early Warning

Détection électronique et pré-alarme de collisions de ponts et de navires

Elektronisches Ortungs- und Frühwarnsystem für Schiffsbrückenkollisionen

E. F. GRENEKER
Senior Research Associate
Georgia Institute
of Technology
Atlanta, GA, USA

J. L. EAVES
Principal Research Engineer
Georgia Institute
of Technology
Atlanta, GA, USA

M. C. McGEE
Research Scientist II
Georgia Institute
of Technology
Atlanta, GA, USA

Mr. E. F. Greneker received his M.S. from the Georgia Institute of Technology and is an acknowledged authority on marine navigation systems, intelligence and data based systems, and homodyne techniques. His contributions have been included in the Proceedings of the Bridge Engineering Conference and the Proceedings of the Third International Conference on Security through Science and Engineering.

Mr. J. L. Eaves is Associate Director of the Radar and Instrumentation Laboratory at the Georgia Institute of Technology. His numerous contributions to the Proceedings of the Tri-Service Radar Symposiums and bridge engineering conferences attest to his stature as a national authority on radar technology and applications.

Mr. M. C. McGee has extensive experience in electronic warfare, radar, display, and digital signal processing. He has been responsible for handbooks for graphic display systems, intelligence terminal systems, and air traffic control display subsystems, as well as technical plans defining technologies and concepts for electronic, infrared, and radar systems.

SUMMARY
This paper discusses the ship bridge collision problem and the use of early warning detection devices. The authors feel that the use of such devices may be of benefit and may possibly prevent bridge ship collisions.

RÉSUMÉ
Cet article traite du problème des collisions de bateaux et de ponts et l'utilisation d'appareils de détection avancée. Les auteurs sont d'avis que l'utilisation de tels appareils présente des avantages et pourrait prévenir les collisions entre ponts et bateaux.

ZUSAMMENFASSUNG
Dieser Aufsatz bespricht das Problem von Schiffsbrückenzusammenstößen und den Einsatz von Frühwarnungssystemen. Die Autoren behaupten, daß der Gebrauch solcher Geräte vorteilhaft sei, und Zusammenstöße zwischen Brücken und Schiffen verhindern könnte.

1. EFFECTS OF SHIP/BRIDGE COLLISIONS

Ships colliding with bridges often affect property, income, and human lives. Many of these lives might have been saved by effective collision warning systems. The Georgia Institute of Technology Engineering Experiment Station (GIT/EES) began formulating concepts for ship/bridge collision warning systems in 1972, shortly after a major accident near Brunswick, Georgia.

The Sidney Lanier Bridge near Brunswick, Georgia, was rammed by the freighter African Neptune on 7 November 1972. Ten people were killed. This was not an isolated incident.

A similar accident occurred during January 1975 when the Tasman Bridge spanning the Derwent River at Hobart on the Australian island of Tasmania was struck by the freighter Illawarra. Six persons died.

The Lake Pontchartrain Causeway in Louisiana has been damaged by waterway traffic 13 times since 1955. Nine persons were killed in these accidents.

On 24 February 1977, the sulphur carrier Marine Floridian smashed into the Benjamin Harrison lift bridge, dumping vehicles into the James River near Hopewell, Virginia.

On 9 May 1980, the Liberian bulk carrier M/V Summit Venture rammed a support pier of the western span of the Sunshine Skyway Bridge in Tampa Bay, Florida. Thirty-five people were killed.

2. CAUSE OF SHIP/BRIDGE COLLISIONS

Equipment failure, acts of nature, and human negligence are the primary causes of ship/bridge collisions. Human error caused the collision of the African Neptune with the Sidney Lanier Bridge.

Eight of the accidents involving the Lake Pontchartrain Causeway Bridge were caused by human negligence; five were caused by equipment failure. All but one of the accidents caused by negligence occurred at night or under twilight conditions.

The collision of the Summit Venture with the Sunshine Skyway Bridge can be attributed to the weather - the collision occurred as a storm suddenly blew across the bay area, cutting visibility and blanking the ship's radar. The time available after the collision, however, was more than sufficient to allow drivers approaching the broken span to stop safely, but they were not aware of the bridge condition ahead.

This fact is brought home in the National Transportation Safety Board's marine accident report[1] on the Sunshine Parkway Bridge Accident near Tampa, Florida. A motorist who was able to stop before driving through the hole left by the missing span recalled, "After I stopped, I remember that three cars and then a bus passed traveling southbound." The bus continued with no warning, carrying 26 people to their deaths.

The authors first suggested a solution to the problem of motorists driving off of a bridge with a severed span in a report prepared for the State of Georgia in 1973[2] on the subject of bridge hazards and their solutions. The authors recommended to the Georgia Department of Transportation that gates should be installed on the state's lift/draw bridges to stop vehicular traffic should bridge span over the shipping channel be severed.

One of the National Transportation Safety Board's recommendations is that the Federal Highway Administration develop standards for the design, performance, and installation of bridge span failure detection and warning systems.

There is a second system that could be developed to lower the probability of collision occurring in situations where human error is to blame for the vessel's collision with the bridge. The automatic collision early warning system was first proposed by Georgia Tech in 1973.[2] This system concept would be a cost effective alternative to consider where fendering systems to protect the bridge supports are impractical or not cost effective. The system would provide the pilot with precision data concerning vessel location and ground speed. This information would alert the pilot to mistakes made by the helmsman in the interpretation of rudder commands. The system could also protect motorists on the bridge by supplying an advanced warning of an impending collision, thus allowing motorists to clear the affected span(s). It could also actuate a gating system to ensure motorists who are not on the affected span do not enter the impact area of the bridge.

3. THE ELEMENTS OF AN EARLY WARNING SYSTEM

There must be seven basic elements included in the early warning system as defined by the Georgia Institute of Technology concept. These elements are:

1. <u>The Vessel Tracking Sensor System</u> must be capable of determining the location of the vessel of interest in relation to the waterway and the bridge to be protected. The sensor system must be able to provide not only real time vessel location, but also amplify data that will provide a prediction of future vessel position as a function of time.

2. <u>The Environmental Sensor System</u> provides data on the variables such as tide and wind. This data is required to improve the accuracy of vessel "future position" estimates.

3. <u>The Sensor/Computer Interface</u> converts the analog signals from the vessel tracking and environmental sensor systems to a digital format that can be treated as input data by a mini-computer.

4. <u>The Radar Signal and Sensor System Processing Software Package</u> is a computer resident program that processes the raw radar data, performs detection enhancement algorithms, performs target coordinate conversion routines, stores the processed radar data in temporary holding buffers, and processes and stores temporarily the wind and current sensor data for use by the assessment and warning algorithm.

5. <u>The Pilot's Display System</u> is a software driven communications link to the pilot. The purpose of this link is to give the pilot the vessel's ground speed and its location in relation to channel centerline. This data is transmitted to the pilot's hand-held display unit. The pilot's display shows the vessel's speed and location as referenced to the channel centerline. If a collision situation is predicted, the pilot would be warned by a visual "Collision Alert" annunciator, and a pulsed aural alert annunciator included on the pilot's hand-held display.

6. <u>The Assessment and Warning Software</u> is a computer program that models vessel handling characteristics based on vessel location, length, heading, past track history, and the effects of wind and tide.

   The vessel's computed future position is evaluated by the warning algorithm, on the basis of the data supplied by the assessment software. If the probability of collision is high, the warning algorithm computes the time to impact with the bridge and the probable point of impact. When ship handling characteristics are known, even the effects on position of last minute emergency maneuvers can be assessed with a high level of confidence.

7. The Warning Dissemination System is adaptive in nature and resides in both software and hardware. The software part of the system selects the appropriate motorist warning mode or modes in response to the threat. The warning function may include the selection of one of several voice warning messages for broadcast or an action message for display on the billboard. The system would also handle the closure of gates at specific locations on the bridge to stop traffic well behind the point of predicted impact.

4. THE ILLUSTRATED GEORGIA TECH CONCEPT

While elements of a collision warning system have been defined in a conceptual design, no fully automated system has been built around the Georgia Tech concept first proposed in 1973 in a Georgia Department of Transportation report[2] and again in 1978 in a paper[3] presented at The Bridge Engineering Conference, held in St. Louis, Missouri, and sponsored by the Transportation Research Board and again at the Conference on Bridge and Pier Protective Systems in 1981.[4]

Figures 1 through 4 illustrate the principles of the Georgia Tech concept. Referring to Figure 1, a high resolution shore based radar scans the waterway and detects the approaching vessel. A current and wind monitoring system is located in the vicinity of where the vessel begins lining up on an approach to the bridge. The high resolution radar provides the range and azimuth to the target. The resolution of the radar is high enough to allow the bow and stern to be resolved as individual radar cells. The high resolution range and azimuth profile of the vessel is processed by the tracking computer's radar signal and sensor system processing algorithm. As a track history is established, vessel speed, "gross" heading, and vessel distance from channel centerline become available data.

Figure 2 shows the display used by the pilot on the vessel to monitor the vessel's distance from channel centerline and "ground" speed. The computer supplies this data via a shore based radio transmitter link. The data is received by the pilot's hand-held display unit, and the speed and channel centerline information is displayed to the pilot. A row of eleven light emitting diodes display channel centerline distance on the hand-held unit. The different colored center diode would represent the channel center marker. Each of the five light emitting diodes located on either side of the center channel marker represents a discrete distance from the channel centerline. If the vessel is three increments (increment distance is chosen on the basis of radar resolution and channel width) to the left of channel centerline, the third light emitting diode left of the center channel marker would flash. This same information could also be displayed in digital read-out format where distance and drift rates could be shown as numeric values. Vessel speed would be displayed as a numeric value in units of knots. Other display formats are possible.

The importance of this data being provided to the pilot cannot be underestimated. Many of the ship/bridge collision reports studied by the authors show that during the critical time preceding the collision, the pilot either was unaware of his position on the waterway, did not detect an incorrectly interpreted rudder command, or lost his shore-based visual reference for an extended period of time.

Figure 3 shows one of several systems that could be used to provide motorists with one of several possible safety messages in the event of an impending collision. The system would broadcast a message via short range AM or FM carrier. In times of an emergency, the broadcast message would be selected by computer on the basis of the time until collision and predicted point of impact.

Figure 4 shows the back-up approach of a "billboard" used as a general warning system. The sign displaying the message "SHIP IN TROUBLE" or a similar warning would be used as a first warning to motorists without a radio or those who do not monitor the warning channel.

5. THE GEORGIA TECH DESIGN CRITERIA

The first goal of the Georgia Tech design criteria was to eliminate the need for any location system that would require the navigation equipment normally found on board the veseel to be used as part of the vessel location scheme. Use of the vessel's own systems was avoided due to the fact that there is no way to certify calibration of the shipboard systems, and in some cases, the basic operability of the equipment.

A second criteria was that any system to be carried on board the vessel by the pilot would not be larger than a "handi-talkie." Rigging of special transmitters or receivers on the vessel on a temporary basis was rejected outright. This rejection is due to the unorthodox methods used to transfer pilots between the pilot vessel and the "host" vessel, and the general reluctance of some pilots to "fool with newfangled equipment."

A third criteria was that the location system should be primarily a shore based system with built-in calibration test.

A fourth and most important criteria is that the system can not require all vessels to maintain the same "ground track" regardless of their size or short term wind, tide and harbor river traffic conditions. There are many harbors where the "ground track" of a vessel will never be the same for any point in time during the vessel's approach to the bridge, due to the effects of the aforementioned variables. In fact, the "track lines" will change from hour to hour and vessel to vessel if any maneuvering is required.

A fifth criteria was that no system would be developed that takes any responsibility away from the pilot.

The sixth and last criteria was that the system would not require the vessel to be extremely "off track" before issuing a collision alarm. However, it was realized that the system false alarm rate must be extremely low if the system is to maintain credibility with the public.

6. THE WARNING SYSTEM SENSOR

Radar is attractive for application to the detection of ship navigation problems because range and angular resolutions can distinguish the bow, stern, and heading of even small vessels. Furthermore, moderate amounts of signal processing can provide real-time information on the vessel's present location, heading, and velocity along with predicted future positions. Thus, the radar can derive a precise vector that fully describes the dynamic situation (position, direction, and magnitude) of a vessel under track. The radar and signal processor can simultaneously accommodate as many targets (ships) as desired. The coverage area along with any fixed objects of significance can be stored in the signal processor such that a vessel's position and future position relative to those fixed objects and other vessels in the coverage area is readily available.

The radar and signal processor data can be recorded easily on magnetic tape; thus, a permanent record of all activities in the coverage area is available.

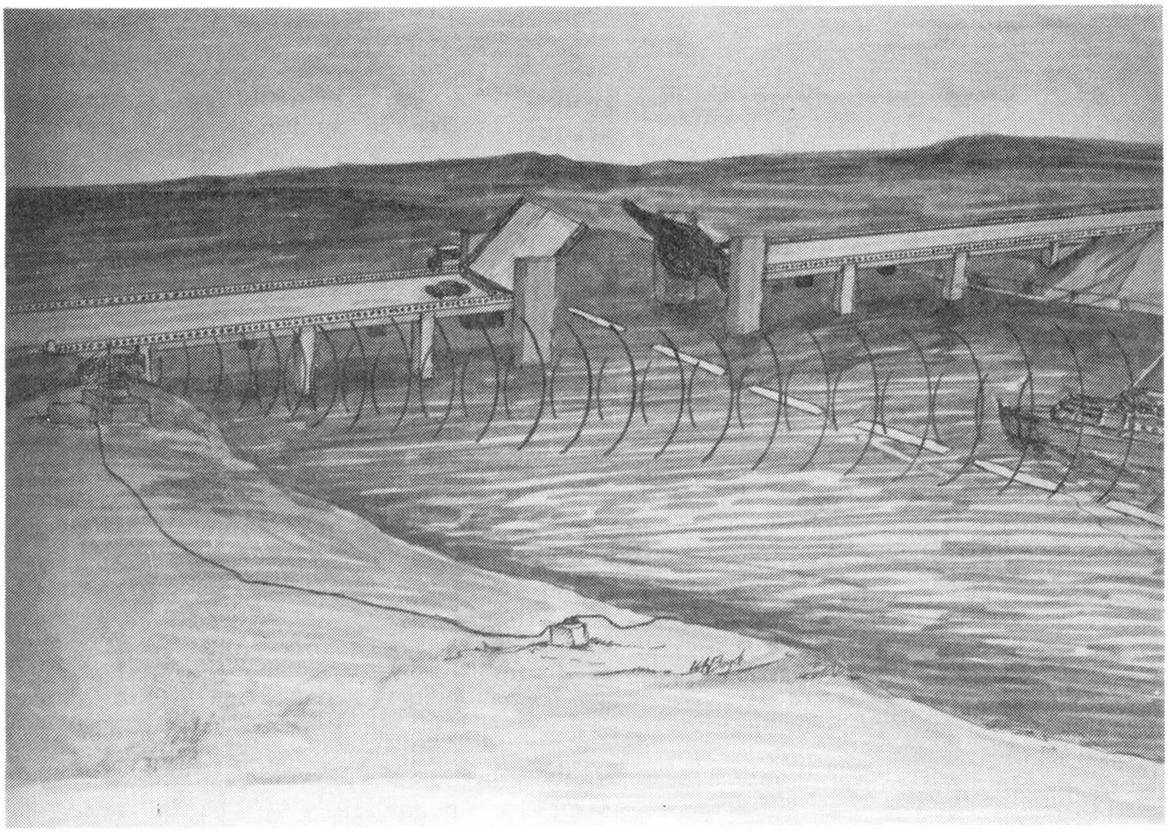

Fig. 1. Shore based radar monitors approach of vessels while wind/current sensors monitor environmental factors.

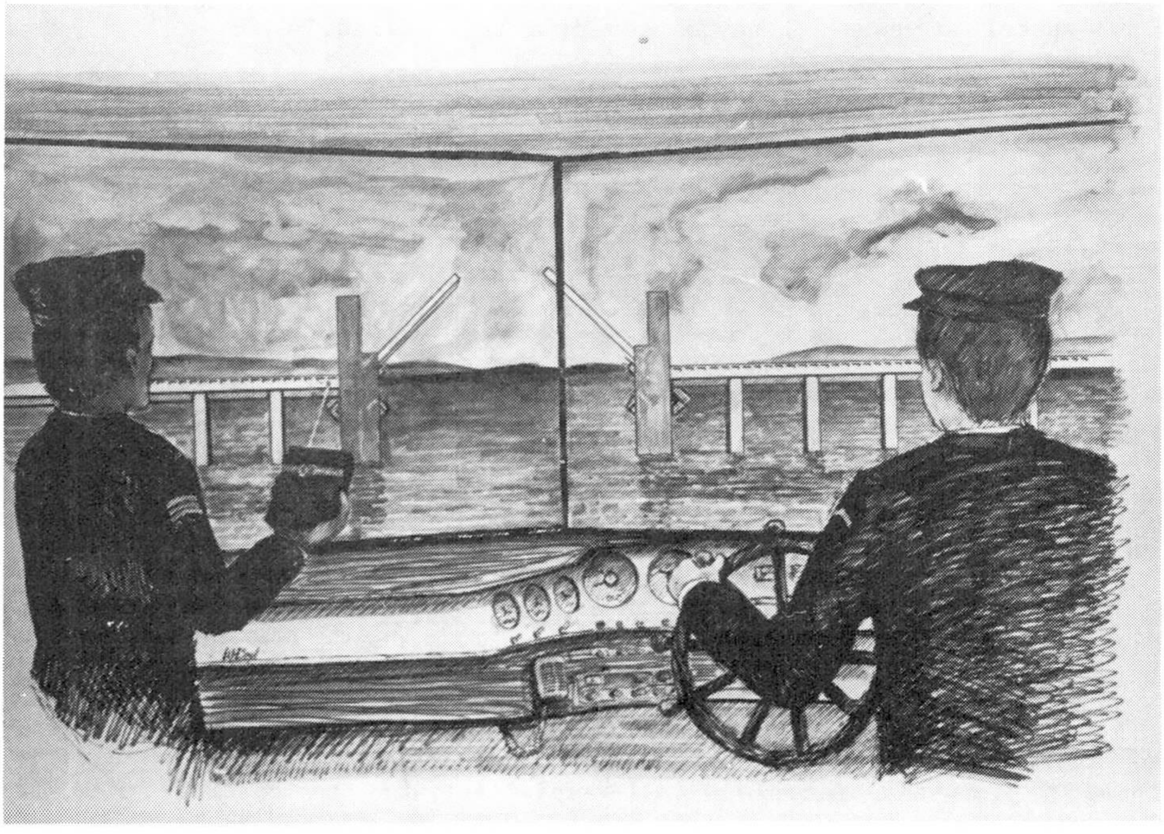

Fig. 2. The pilot using a hand-held telemetry data link showing vessel location in relation to the center channel line and vessel speed.

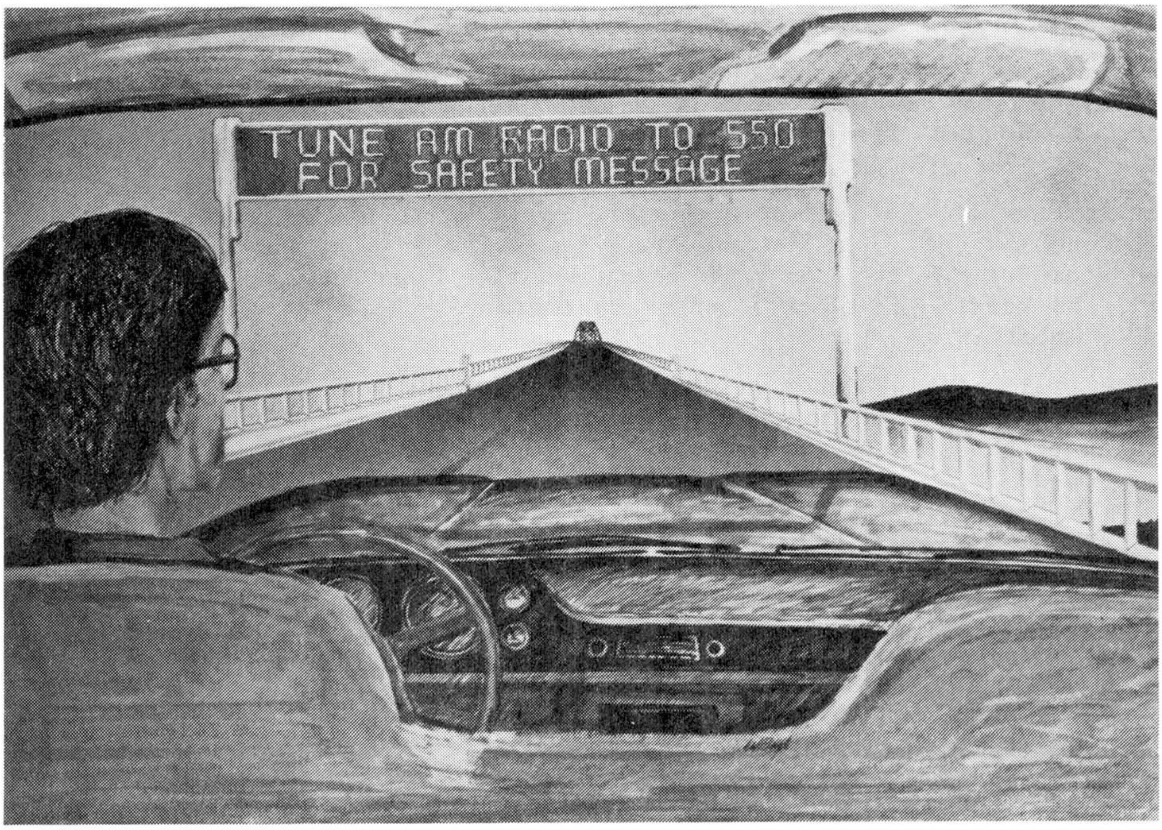

Fig. 3. Sign showing motorists the instructions on how to use the safety information radio system.

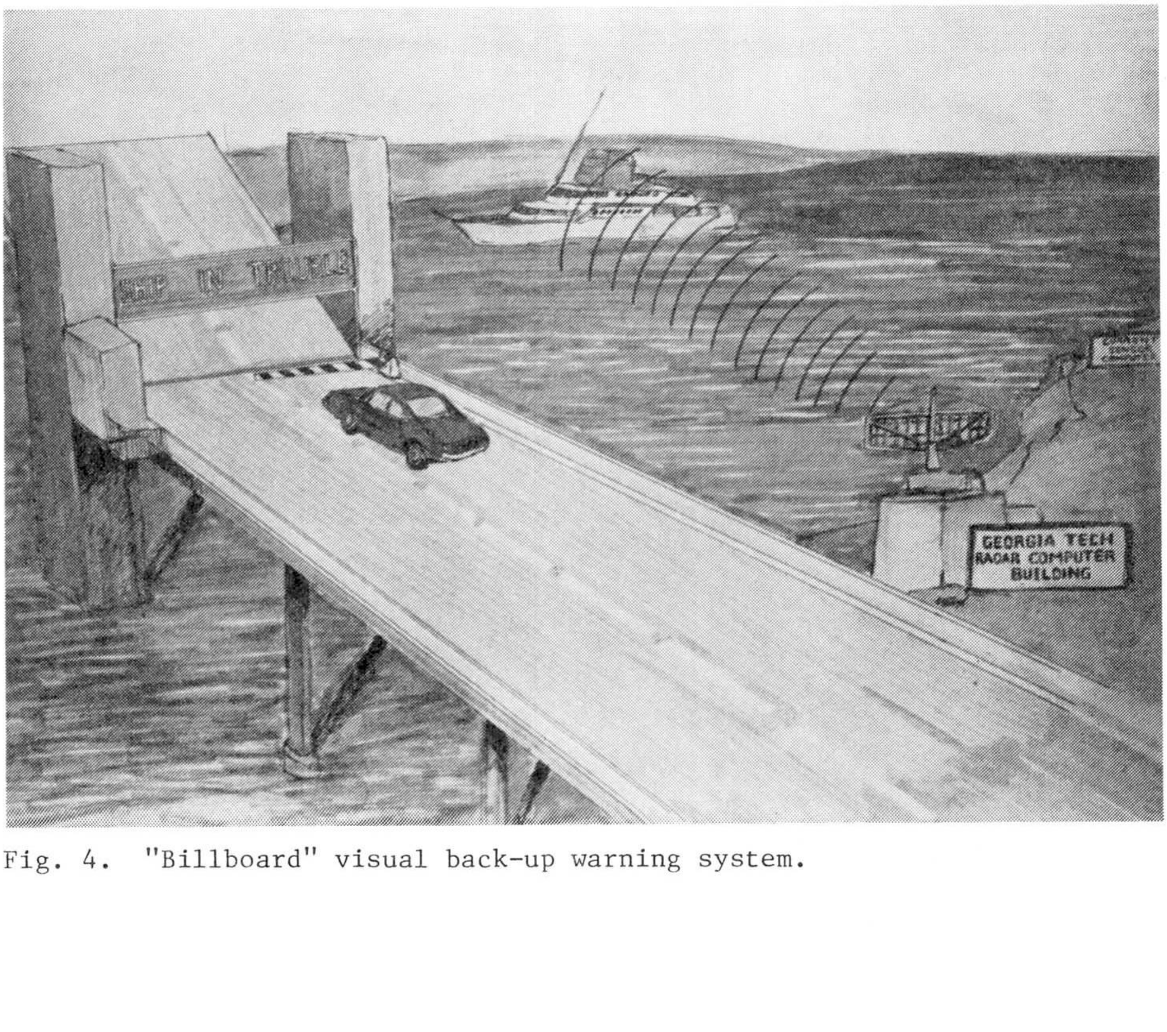

Fig. 4. "Billboard" visual back-up warning system.

6.1 Radar System Analysis

The optimum radar configuration for a given collision avoidance application must be derived from a system and trade analysis of various parameters associated with the geometry of the desired coverage area, the meteorological/hydrographical environments, and the radar itself.

The geometry of the area to be covered will dictate where the radar must be located and how high the antenna must be elevated above surrounding area. Once the geometry of the coverage area and the location of the radar are specified, the ranges (distances) to the perimeter of the desired coverage area are readily obtainable.

If the collision avoidance system must operate under severe meteorological and/or hydrographical conditions, the radar must be designed with the worst case effects of those adverse environments factored into the system performance requirements.

7. SUMMARY

The collision warning system outlined appears feasible. A first system must be funded, built and tested to generate the "numbers" to prove feasibility, acceptability, and cost benefit.

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REFERENCES

1. "Marine Accident Report...Ramming of the Sunshine Parkway Bridge by the Liberian Bulk Carrier Summit Venture, Tampa Bay Florida, May 9, 1980." A report by The National Transportation Safety Board, Washington, D.C.

2. E. F. Greneker, J. L. Eaves, T. M. Miller, "A Study to Determine the Feasibility of Using Remote Sensing Techniques to Prevent Ship Collisions With Selected Draw/Lift Bridges in Georgia," a study conducted for the Georgia Department of Transportation, Contract No. 6-73, December 1974, pp. 54-55.

3. E. F. Greneker, J. L. Eaves, M. C. McGee, "Considerations in the Development of An Early Warning Vessel/Bridge Collision System," Volume 2, Proceedings of a conference conducted by the Transportation Research Board, September 1978. pp. 258-260.

4. E. F. Greneker, J. L. Eaves, M. C. McGee, "Bridge Ship Electronic Detection and Early Warning: Possible Prevention through Advanced Knowledge," The Conference on Bridge and Pier Protective Systems and Devices, Stephens Institute of Technology, Hoboken, N.J., December 14-16, 1981.

SECONDARY REFERENCES

1. William R. Burke, Jerome Pepper, J. J. Krebs, "Safety Study: Lake Pontchartrain Causeway," a safety study conducted for the Greater New Orleans Expressway Commission, March 1975. pp. 20-43.

2. "Second Hobart Bridge - Risk of Ship Collision and Methods of Protection," a technical report prepared for the Department of Main Roads, Tasmania, Maunsell and Partners Pty. Ltd., Consulting Engineers, and Capt. P. J. E. Brady, AM, Marine Consultant, September 1978.

3. "Alternative Surveillance and Warning Systems for the Sunshine Skyway Bridge Across Tampa Bay," a technical report prepared by the State Traffic Operations Office, Florida Department of Transportation, December 1980.

4. E. F. Greneker and J. E. Matthews, "Conceptual Radar Piloting Techniques Using Radar Beacon (RACON) Technology and Other Advanced Marine Technology," a final technical report, prepared for the Commandant, U.S. Coast Guard, Washington, D.C., April 1981.