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MARITIME DYNAMIC TRAFFIC GENERATOR. VOLUME I: SUMMARY DOCUMENTATION

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Cambridge, Massachusetts

June 1975

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MARITIME DYNAMIC TRAFFIC GENERATOR
Volume I: Summary Documentation

Franklin D. MacKenzie

JUNE 1975
FINAL REPORT

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16. Abstract

To determine the number of maritime vessels which are potential users of a satellite communications service and the required satellite coverage to provide this service, the weekly movements of 18,000 merchant vessels were recorded for the year 1972. The method of recording and the applications of the dynamic traffic generator is described in Volume I: Summary Documentation. The processor program is designed to move these vessels along standard routes to their destination and keep statistical records of the ports visited, the five degree squares passed through and the occurence of casualties. Volume II: Electronic Data Processing Program describes this processor. One of the most useful forms of the data output is a weekly plot, on a world map, of the average, daily vessel density per five degree square. This output is applicable to many related programs in the maritime area and is the subject of Volume III: Density Data on World Maps.

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PREFACE

The analytical tool described in this report was created in support of an overall program at the Transportation Systems Center to define and analyze requirements for navigation and communication services through a satellite for commercial vessels. This program is sponsored by the Department of Transportation, through the United States Coast Guard, Office of Research and Development. The program supports Government activities designed to promote maritime safety through improved communication service.

Vessel movements during the year 1972 were recorded and processed by the maritime dynamic traffic generator. The routes and the numbers of vessels in each give degree square were plotted on a world map. The objective of this work was to determine the number of potential users of a satellite communication service and the required satellite coverage to provide this service.

The processor program was designed by Paul J. Connolly,* Kentron Hawaii Ltd., assisted by J. Van Etten and T. Talbot, Kentron Hawaii Itd.

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1. SUMMARY

1.1 PURPOSE

This report summarizes the Maritime Dynamic Traffic Generator and its potential contribution to the system engineering process. The generator will be used to assist the designer in the logical sequence of activities and decisions leading to the definition of the configuration, usage and support of a maritime satellite system for communication service. The generator will be used in the initial definition of the system requirements and throughout the satellite program for updating and reassessment when changes of requirements are considered or directed. The design solutions can be simulated with the generator for functional analysis to determine that the requirements are met, or to assess the potential impact of the various solutions on the original set of requirements.

1.2 RECOMMENDATION

The generator and its data output can be used in many maritime areas other than the satellite communication service; however, the assumptions used in the program should be examined.

The value of the generator to a user may be increased with modification of the program to include ship routes which vary month to month in consonance with the Pilot Charts.

The generator should be validated if there are major changes in the shipping routes; otherwise the data output should be valid for a ten year period.

2. INTRODUCTION

The Transportation Systems Center of the U.S. Department of Transportation is conducting programs and studies to analyze and define requirements for navigation and communication services throug'. a satellite with commercial vessels. One of these programs had as a goal the development of an analytical tool which would be used to determine the number of potential satellite users and the required satellite coverage. This goal was achieved with the completion of the Maritime Dynamic Traffic Generator. The generator is an electronic data processor program which uses the Lloyd's Shipping Index as a data input. The Index is a weekly record of the movements and latest reports of 18,000 merchant vessels. The processor program is designed to move the vessels along standard routes to their destinations and keep statistical records of the ports visited, the five degree squares passed through and the occurence of casualties. One of the most useful forms of the data output is a weekly plot, on a world map, of the average, daily vessel density per five degree square. This output is applicable to many related programs in the maritime area and is the subject of a separate report, Maritime Dynamic Traffic Generator - Density Data on World Maps.

3. MARITIME DYNAMIC TRAFFIC GENERATOR

3.1 SYSTEM ENGINEERING

The two operational needs to be transformed into a system configuration and system performance parameters are position determination and communication. The Maritime Dynamic Traffic Generator has the potential of making a major contribution to this transformation. The engineering effort to assure compatibility of the physical, functional and program interfaces in the satellite system can be verified by using the generator. The same engineering effort to integrate the parameters of number of users, accessing technique, tolerable delay, expected queues, channel capacity and others can be assisted with the data available in the generator.

3.1.1 Operational Needs

In 1969, the National Academy of Sciences published a report on the useful applications of earth-oriented satellites. This report concluded:

a. It is feasible to establish satellite systems for navigation and traffic control of vessels.

b. The most useful applications are confluence area traffic control and search and rescue.

c. The principal benefits are faster search and rescue, reductions in ship collisions, reduction in operating costs and increased efficiency in commercial fishing.

d. The benefits received by the overall marine community with a satellite based traffic control and enroute navigation for ships would exceed the costs of such a system.

In the same year, the report to the Maritime Safety Committee from the Inter-Governmental Maritime Consultative Organization Sub-Committee on Radio Communications recommended the following operation functions for a space relay system:

a. Distress, search and rescue, and ship location

b. Urgency and Safety message broadcasting

c. Position, environmental, meteorological and oceanographic information distribution

d. Automatic position report collection

e. Report, forecasts and warning distribution

f. Collection of meteorological, hydrographic and oceanographic data

g. Traffic control

h. Weather routing

i. Public correspondence

j. Company correspondence

k. Data transmission

l. Television

Priority is given to the functions which contribute to the safety and economy of shipping.

In the following year, Automatic Marine International prepared a report for the U.S. Coast Guard which emphasized the advantages of fulfilling the radio communication operational needs with a satellite system.

In summary, the operational needs are a combination of radio position determination and radio communications. The major maritime satellite studies have concentrated on the radio communication needs.

3.1.2 Mission Requirements

The primary mission of a maritime satellite system is to provide better safeguards for the safety of merchant shipping by frequent position reporting and better communication to improve rescue operations. The secondary mission of the system is to provide a communication link for telegraph and voice messages between the customer on land and the customer at sea. The tertiary mission of the system is to provide a position fixing capability as applied to the safety of life and property at sea and to search and rescue. Confluence area casualties and surveillance have not been studied in sufficient detail to ascertain the requirements, need or feasibility of such a service. An analysis is needed to establish the total satellite mission requirement.

3.1.3 Functional Requirements

The Inter-governmental Maritime Consultative Organization's (IMCO), Maritime Safety Committee has recommended that the following functions be provided to the maritime community by a satellite service:

Distress, Search and Rescue
Urgency and Safety
Meteorological Information and Guidance
Broadcast, Forecasts and Warnings
Meteorological, Hydrographic and Oceanographic Observation
Weather Routine
Traffic Control and Position Reporting
Terminal Weather and Notices-to-Mariners
Public Correspondence
Data Transmission
Position Determination
Television

IMCO has also given the highest priorities to those functions related to safety. These broad categories will be subdivided and requirements for each subfunction will be developed. At this stage of formulation, only gross requirements need to be established; however, the division should include sufficient detail to depict additional functions or subfunctions to be performed by the satellite system. The detailed analysis of the functions will be aided by the data from the generator.

3.1.4 Requirements Allocation

Each function provided to the maritime community by a satellite service is allocated by requirements based on the priority assigned by IMCO. Distress alerting and search and rescue have the highest priority. Distress messages and the ensuing search and rescue coordination activity require immediate access to the communication channels. On the average day, there will be 17 casualties; however, only four a day will be away from land masses and would use a satellite communication service for distress alerting. Between 20 percent and 40 percent happen in one of the five confluence areas. The output of the generator will be used to determine the number of vessels available for the search and rescue coordination. The requirements allocated for this function are: immediate access, capacity for 4 messages a day, 30 percent probability of a distress message coming from a busy (communication traffic) confluence area, and capability to coordinate up to a dozen aircraft and 6 - 8 vessels per distress situation (Ref. 1).

Messages in the safety and urgency category are considered perishable data, but they are not as critical as distress and search and rescue messages. These have a requirement for access to the satellite broadcast channels with a delay of less than one hour. The "other" category of messages can tolerate delays of up to four hours. The capacity of a satellite system is determined by the total communication load, and the tolerable delay in getting a message through. The communication load is a function of the number of users, message content, frequency of calls, type of communications and the accessing scheme. The generator will supply the number of users; the other parameters can be estimated. The requirements allocated to each function will represent minimum acceptable levels of performance for the accomplishment of the function. These performance requirements shall be derived with use of the generator.

3.1.5 Trade Studies

Trade studies are required to select among alternative configurations and designs. The major system problem for a communication service is the sharing of a small number of channels by a lai e number of users. A first order analysis eliminates random access as a viable design alternative.

A second order analysis conducted for the U.S. Coast Guard by Automated Marine International (Ref. 1) entailed a trade study of the time waiting in queue vs. the number of users. The study showed that access delay could be contained to an average of five minutes or less while the wait in queue is expected to be 1.4 minutes for data and 12 minutes for voice. The same report concluded that the per day, per ship cost would range from $5 to $13 for a three ocean coverage satellite system. If all the potential users were included, the cost per ship per day decreases to $1.30.

The National Academy of Sciences, National Research Council, Report from the Summer Study on Space Applications concluded that the navigation cost/benefits advantage to the maritime community would exceed the cost of the system to provide the function. Additional trade studies are required to select among alternative antenna configurations, ground station locations and other options. The trade studies will benefit from the data supplied by the generator.

3.1.6 Design Optimization/Effectiveness

Design alternatives will be examined for their impact on system cost. This process can be improved with the data from the generator. Land line costs and time can be reduced if the resources to support communications such as ground stations and terminals are located near the dense shipping areas. It would also be beneficial to locate search and rescue coordination centers near areas with a high probability of having casualties. The effectiveness of these decisions can be evaluated with data from the generator.

3.1.7 Effectiveness Analysis Modeling

The parameters which impact on the cost effectiveness model are number of users, frequency of message and message priority. Data exists (Ref. 2) on the latter two parameters and the generator will supply the first. As the system engineering phase progresses and gross decisions are made which relate to the cost effectiveness of the system, the model assumes a most important role. The system cost appropriation per ship decreases with an increase in users. Therefore, the number of users is pivotal for the analysis. The decision to include a high speed data link (1200 bits/sec) in the satellite channel capacity affects only a portion of the users, nominally those "newer" vessels. The decision to include a low speed, teletype, data link affects a great many users. The cost effectiveness model can assist the designer in his decisions if it includes this user data from the generator.

3.1.8 Synthesis

To ensure that the system requirements have been allocated to various subsystems, the system engineering process will include a synthesis. The requirements will be displayed in a schematic or flow diagram, where each block is related to a subsystem. The synthesis will also relate system operations to system requirements. For instance, the addition of a switchable antenna coverage capability has to be related to the density of traffic. The decision to have several sizes of antenna patterns also is related to the density coverage requirement. A traffic control advisory capability must be related to the radio position determination function.

3.1.9 Technical Interface Compatibility

The maritime satellite communication service must be compatible with the existing ground network of communications. The technical interface between the land lines and the satellite ground stations must be compatible. Any interface which requires an input for the number of users can get this input from the generator.

4. MARITIME DYNAMIC TRAFFIC GENERATOR APPLICATIONS

The three areas where the Maritime Dynamic Traffic Generator can assist a satellite system engineer are system configurations, system performance and simulation.

4.1 SYSTEM CONFIGURATION

If the communication service user population and distribution can be estimated, the system engineer can configure the satellite system and optimize the usage. Using the generator, the engineer can make a very accurate estimate. Knowing the number of potential users, their flags and the ports of origin, an engineer can design a network of land lines to service the maritime community, and estimate the required capacity for electronic data processing. The weekly distributions of the at-sea users give the designer the information required to determine satellite antenna coverage patterns and the number of communication channels.

4.1.1 Network

Although the maritime satellite communication service is international, it must consist of a single world-wide configuration. The ground stations must be coordinated in a communication network. One end of this network will connect to the various land communication systems, the other to the over 4000 potential users (ref.2) at sea. Even without the benefit of the filtering options on the data input to the generator, it is safe to assume that the 3467 tankers in the Index will be among the first users of a communication service. Many of these will regularly refill in the Middle East. There are from 40 - 55 vessels each day passing through the 5^{o} square centered near the Republic of Somali, 5^{o}N, 50^{o}E. Since the sail plans of all the users are to be stored for safety reasons in the system, the network could use a ground terminal in this area. The terminal would process the sail plans, and transmit them to the central ground station. The required terminal capacity can be estimated from the weekly density plots.

4.1.2 Computer

The electronic data processing to service the user community can be accurately estimated from the requirements of the Maritime Dynamic Traffic Generator. The generator processed the data for 18,000 vessels and the assumed number of users in this example is 3500 tankers. The generator arrays and variables occupy 22,000 words of core storage; the IBM 7094 system routine occupies 5000 words and the remaining 5000 words of capacity are used for the input/output buffer. This 32K core storage capacity is almost independent of the number of vessels; i.e., even though the input words could be reduced by a factor of 4 from 2500 to 600 words, the number is negligible compared to the total core storage. The generator processes 18,000 input data cards each week; an actual system will require updating every 6 - 8 hours for the 3500 users. Assuming for this calculation that updating is required every six hours, there will be four updates each day. The vessels' I.D., message address, sign-off and reply would require an average message length of 1000 bits or 4000 bits per day. Position, weather and company administration messages would require 232, 1696 and 150 bits per day respectively (Ref. 1). The processor would be required to handle 6K bits per day from each of the 3500 vessels. Using a 1200 bit per second data link, the messages could be processed in five hours (the channel would have a 21 percent utilization). The remaining electronic data processing requirements could be calculated in the same manner using the generator.

4.1.3 Channels

The channel capacity can also be calculated using the generator. The size or capacity of a satellite system is determined by the total communication load, and the acceptable delay in getting a message through. The load is a function of the number of users, message content, frequency of calls, type of communications and the accessing scheme. An approximate calculation estimated a data link would have a one-way utilization of 21 percent. The present four priority system is: distress, urgency, safety and all other messages. The number of users is derived from the generator and all the other parameters can be estimated.

4.1.4 Distribution

The distribution of messages among the ground stations and the satellite is a function of the number of users and their location at sea. The transfer of messages must be continuous throughout the voyage. Larger tankers have a mean trip length of approximately 10,000 nautical miles. The mean trip length of all the tankers is approximately 5700 nautical miles. The large tankers will spend 30 days at sea and pass through several coverage areas and will be sending and receiving messages as they travel. Their route from week to week can be traced with the generator. An examination of this weekly variation will give the system designer the information required to configure the hand-off sequence between ground stations and satellites to assure continuous coverage.

4.1.5 Coverage

The distribution of users along the shipping routes determines the coverage required for a satellite communication service. Assuming that the tanker vessels are the first users of the service, and that they require continuous service along their routes, the density plots show that the tanker routes from the Middle East extend to Japan, Europe and North America. The satellite system must cover both hemispheres. For other users on shorter voyages, the requirements for service are regional. The generator will be used to determine how the regional oceanic communications load will vary weekly or seasonally. It is possible to derive the expected communications traffic volume for restricted ocean areas that could be covered with narrow beam (2^{o}, 3^{o} even 5^{o}) satellite antennas. The coverage configuration can be optimized for efficient service for all the users.

4.2 SYSTEM PERFORMANCE

The satellite communication service will provide the maritime community with several operational capabilities, such as search and rescue, weather advisories, and surveillance, as well as communication channels for teletype, voice or digital data. The system designer using the generator can optimize the number of operational capabilities to match the variation in vessel distribution from week to week. A key factor is the method used by the vessels to gain access to the satellite's communication channel. The number of users prohibits a random access procedure for non-emergency calls. The number of simultaneously active channels required is directly related to the cost of the systems space segment. Another factor unique to the maritime industry is that the shore-based customer may be several oceans away from the ocean-based customer. All of the system operations demand continuity in the coverage from the satellite and a hand-over capability must be designed into the system.

4.2.1 Search and Rescue

In a search and rescue operation, there is a sequence of messages: distress, ship-to-shore, search, shore-to-ship; coordination, on-scene ship-to-aircraft; and on-scene ship-to-ship; and rescue, ship-to-shore. To design this operation into a satellite system, the system engineer must know where the distress messages are most likely to come from, where the potential rescuers are and how to guarantee immediate access to the communication system. The Casualty Tabulation for 1972, (Ref. 3) demonstrates that a third of the casualties which would use a satellite service happen in high density traffic areas. The same source shows that on the average, there will be four distresses per day, two of which come from the large ocean crossing vessels. These will be processed through a satellite system. There will also be an average of 13 casualties, of 500 gross tons or over, each day, which will use shore-based communication service for their distress signaling. This data will aid the designer in assigning emergency channels and choosing an accessing technique. The Maritime Traffic Generator will be used to determine the location of potential rescuers from week to week. If a distress was received from a vessel going through the Strait of Gibraltar during the last week of January 1972, there would be more than 130 vessels within a 10 hour traveling radius available for search and rescue.

4.2.2 Weather Advisories

Meteorological information is of great importance to the shipping operation. It not only enables the master to operate more safely with weather advisories, but it has the potential to increase the speed of travel in all types of weather with timely wind and current information.

The weather data would flow in both directions. Vessels would observe and report the meteorological data to the ground station, which would assimilate all input data and update the weather picture. The station would also forecast the weather. The weather picture and forecast would be transmitted to all vessels using the service. The system designer requires the location of the users as they travel from port to port and would tailor his weather broadcast accordingly. The generator has the capacity to assist the designer in this area.

4.2.3 Surveillance

If the safety of the merchant fleet requires the keeping of a location log for the vessels, the designer must be able to determine the vessels' position as they travel. On the high seas, the maritime community navigates celestially or uses transmitted electrical signals from Loran, Omega and other navigation aids. This location data can be collected and stored at a ground station. A communication service with this data could reduce the searching time of a search and rescue operation. Vessels would be requested to transmit their position messages on schedule and the absence of a position report would be a distress indicator.

To size the channel capacity required for this operation, the designer would refer to the generator output for the initial positions of the vessels and then calculate the bits per message required to update this information.

4.2.4 Accessing

One major system operation problem is the sharing of a small number of active communication channels by a large number of vessels. The location and number of these vessels is determined with the generator. A random access scheme for non-emergency messages is not practical for a satellite system; however the designer can choose between various controlled demand access schemes. He is required to trade-off between the satellite power used, the time between individual ship interrogations and the number of ships in the coverage area. This last factor can be optimized with the generator. The emergency messages must have priority and be given immediate access. The system designer must balance channel utilization with satellite power and immediate access. The search and coordination operation would be conducted over the same channel as the distress signal until the rescue was complete.

4.2.5 Station Handover

Another major system operation is to accommodate vessels as they travel from ocean to ocean on a single voyage. One satellite cannot provide the continuous communication service. Therefore, the satellite system engineer must design an operational procedure to handover vessels as they move from one satellite coverage zone to another.

The procedure can be implemented either by the vessel's radio officer or by the control center. This decision of who should do the implementing can be made with data from the generator. The input data would be filtered to select the potential users and their routes would be printed on a world map. Superimposed on the map would be the equal elevation angle lines of 10° for each satellite. The handover zone would be at the crossing of these lines. From the world map, the number of users in the zone can be counted. If a satellite is located approximately 180° west and another 30° west along the equator, one such zone would be off the coast of Acalpulco, Mexico. The generator shows on the average that there are 18 vessels each day requiring a handover operation; however, by filtering the input, the number of users may be less. This is one parameter needed by the system designer and available with the generator.

4.3 SIMULATION

After the system engineer has completed the trade studies to optimize the efficiency of the accessing and handover schemes, he could verify his results with a simulation using the Maritime Dynamic Traffic Generator as the input data. The data in the generator is the same data required by the satellite system. Periodically, the central ground station would update the ship lists maintained at the other stations. This updating would be transmitted through the satellite using a data link. The generator could be used to evaluate the quality of the data link.

4.3.1 Accessing

The ground stations for the satellite communication service will maintain a ship list which is very similar to the data tapes used in the generator. The main difference would be the addition of a look-up table in the memory core which assigns a call sign to each vessel. The central station would code each vessel and then group the call signs in coverage areas. This tape would be the polling sequence for interrogating each vessel for messages, position or weather reports. This tape would be transmitted to the ground station responsible to provide the area coverage. This process could be simulated with the generator and evaluated prior to the operational experiment.

4.3.2 Station Handover

The computer simulation designed for accessing evaluation would also be used to evaluate the handover scheme. The data tapes would include the positions as well as the call signs of the vessels. The decision to switch the satellite coverage zone could be made by either the vessel's communication officer or the ground station. The decision as to who should do the switching can be evaluated and the benefits demonstrated before the system becomes operational. The primary advantage of the generator tapes is that they are made from actual traffic and include all the information that is likely to be available during the period when satellites are being introduced for communication service.

5. MARITIME DYNAMIC TRAFFIC GENERATOR DESCRIPTION

The Maritime Dynamic Traffic Generator is a unique analytical tool for a satellite system engineer to use to determine the number and distribution of potential users of a maritime-satellite, navigation and communication service. As an example of one use, each weekly chart shows a heavy concentration of traffic from the Persian Gulf to ports in Asia, Europe, and North America. To provide a communication service to these vessels, there is a requirement that the user will have continuous access to a satellite system; therefore, the charts demonstrate that world-wide coverage using several satellites is required.

Prior to using this analytical tool, the system engineer should examine the input data source, the assumptions in the processing program, the rationale for the format for the data output and the method of control and feedback used in the generators.

5.1 INPUT

The source of the data for the Maritime Dynamic Traffic Generator is the Lloyd's Shipping Index. This is a weekly record of the movements and latest reports of all the merchant vessels except coasters, yachts, fishing vessels and those merchant vessels which trade exclusively along the European Coast or across the channel to the United Kingdom. There were 17,856 merchant vessels listed in the Index for the first week of January 1972. The number changes as new ships are added and old vessels scrapped. The data extracted for each vessel from the Index each week is the flag, age, weight, tanker or non-tanker, port for and from, latest report and the vessel's name. Although the vessel's name is an input, it is not used in the processor program. The vessel is identified in the generator by its flag, year built and gross tonnage. Two out of three data inputs must match before the generator will recognize the vessel and process the weekly input. The input data can be filtered for each of the entry categories or for a combination of the categories. It is possible to isolate American flag vessels, greater than 10,000 gross tons and built since 1969 from all the rest of the vessels, process them through the generator and display them as densities on the world map. This capability was designed as a subroutine into the program to make possible the isolation of several categories of users of a satellite communication service. For example, the first group of potential users are more likely to be the larger, newer vessels in the tanker category. The antenna coverage should service this group.

5.1.1 Flag

A statistical summary of the first weekly data input, January 5, 1972, listed vessels with 106 different flags representing 106 different countries. The summary of the vessels from each country for the ten most numerous flags in the fleet is:

Liberia	- 2072	Norway	- 1260
United Kingdom	- 1683	Japan	- 1169
Federal Republic of Germany	- 1556	Netherlands	- 840
USSR	- 1384	United States of America	- 695
Greece	- 1325	Denmark	- 670

Ten flag total = 12,654 vessels

The summary of the tankers listed in the index from each country for the ten most numerous flags in the fleet is:

Liberia	- 757	Greece	- 216
United Kingdom	- 407	Japan	- 199
Norway	- 362	Panama	- 159
USSR	- 249	France	- 109
United States of America	- 237	Italy	- 106

Ten flag total = 2801 tankers

5.1.2 Age

The same statistical summary reveals that not only are more ships being added to the fleet each year, but the rate of adding ships is increasing. There are 4915 ships five or less years old.

Age (Years)	Number of Vessels
1	1110
2	1019
3	942
4	917
5	927
Total -	4915

There are 851 tankers five or less years old.

Age (Years)	Number of Vessels
1	198
2	186
3	182
4	156
5	129
Total number of tankers =	851

5.1.3 Port For and Port From

There are more than 3000 ports listed in the Index each week. To reduce the storage requirements, a limit of 3000 ports was set. Ports in the same general area were grouped together. For example, one harbor may include several ports; in these cases all the ports were grouped into the major port. In addition to port names, prominent land features such as capes and islands were included. The data is used to validate ship routes and destinations and is entered each week.

5.1.4 Latest Report

Some of the vessels have latest reports in addition to their destination data. This information is also entered each week and used to update the vessel's position. The categories of latest reports are: arrived, sailed, passed and inport, as well as the dates of the report. If the vessel is a casualty, this is also included as a latest report and entered as a data input. The casualties are categorized as: sank, collision, emergency, aground and weather damaged. These are processed by the generator and tabulated separately. The statistical summary of the data entered for January 5, 1972 revealed 8819 arrivals, 19,255 departures, 10,415 vessels at sea and 3873 completed voyages. The number of vessels at sea will be used to size the communication satellite channel requirements. The same summary showed six vessels sank, 13 had collisions, 78 had other emergencies, 14 ran aground and five reported weather damage. In this summary, no distinction is made as to the location of the casualty. From another report, Casualty Tabulation, which lists only those casualties which would be serviced by a satellite communication system, the same time period shows one sinking, seven vessels in collision, nine with other emergencies, none aground and four reporting weather damage. This data entry is used to size the emergency channel requirements.

5.2 PROCESS PROGRAM

To reduce the processing time and storage requirements, several assumptions were made for the ship characteristics. Ports were grouped and standard shipping lanes were assigned. Two edit routines were used to control the quality of the data input, and the latest reports were used to update the predicted vessel positions.

5.2.1 Assumptions

All vessels were assigned a 15 nautical mile speed as they sail along the routes. This assumption is not critical for the generator, since the ship's position was entered each week and the processor would update the computed position and adjust the daily density averages. A two-day stay in port was assumed for every vessel when the actual time in port was not given. This also was revised each week if the duration was given in the following week's data entry. Standard shipping routes were assumed. The routes were based on Pilot Charts published by the Defense Mapping Agency Hydrographic Center. This assumption is not critical for the generator, since the data output format is in 5 degree squares. Five degrees is equivalent to 300 nautical miles, which would include most shipping lane variations.

5.2.2 Ports

A port table was created from the ports given in Lloyd's Shipping Index. This table includes the latitude and longitude of almost 3000 ports. To reduce the storage requirements in the processor, all ports using the same harbor were given one set of coordinates. Also in this table were names of prominent land masses, such as islands and capes and their respective coordinates. The source of the position data was Lloyd's Maritime Atlas.

5.2.3 Port Groupings

To reduce the processing time as well as the storage requirement, the ports were grouped into 15 areas, such as the eastern coast of North America, the Gulf of Mexico, and the west coast of North America. Using this classification, ships would be routed from port group to port group. To make the routing match the actual routes, some port groupings were subdivided. Originally, Australia was one port grouping; however, it has major ports on each coast and a vessel from a port on the southern coast should take longer to go to Japan, for example, than one from a port on the north coast. Therefore, this port grouping had to be sectioned to make the computed voyage duration agree with the actual duration.

5.2.4 Routes

The vessels were moved by the processor from port group to port group along standard tracks or routes. The generator required 16 tracks to match the vessel routes given in the merchant shipping charts. For short voyages, a subroutine named "free sail" was created. This subroutine would allow vessels to travel along the shortest straight line path, provided it did not cross land. The tracks and the free sail routine took care of all combinations of port groups. Whenever two tracks crossed, a decision point was created. There are 22 decision points in the processor. This expands the versatility of the shipping routes. A vessel would travel out of the Mediterranean Sea along a standard track to a decision point west of Gibraltar. From there it could follow a track north, south, to the east coast of North America or to the Gulf of Mexico.

5.2.5 Land Masses

A world map was created in the processor. Each 5^{o} square of this map was coded either as land, water, decision point or a ship track. Squares which included land in half or more of their area were coded as land and vessels were not permitted to enter. Special allowances were made for canals and other bodies of water where vessels usually travel.

5.2.6 Control

Before the input data was processed by the Maritime Dynamic Traffic Generator, it was passed through two edit routines which screened the data for keypunch errors and ports not listed in the port table. These edits controlled the quality of the input data. In addition, the filter routines were designed to be applied to the input data prior to processing to reduce the computer processing time requirements.

5.2.7 Feedback

There were several iterative processes designed into the generator. Each week the new data would be processed and compared to the computed data from the previous week. Differences were resolved in favor of the latest data. The iterative process would correct or improve one week of data output. The data entry for January 19, 1972 would be used to update the position of vessels from January 12 to January 19. The iteration did not go back further than a week.

5.3 OUTPUT

The output formats and the displayed data were chosen to assist the system engineer with graphical displays and vessel densities as well as data tabulations.

5.3.1 Maps and Projections

There are nineteen unique geographical displays available in the Maritime Dynamic Traffic Generator. These include a selection of cylinderical, conical, azimuthal, elliptical, or recentered projections. In addition, any longitude can be chosen as a central meridian and any longitude and latitude could be chosen as boundaries. The choice of the projection is directly related to the satellite antenna coverage requirements. A satellite antenna can be directed to provide communication service to the confluence area near the English Channel. To determine the number of messages to process or channel capacity required for this service, the output of the generator can be restricted to just the area of coverage and the number of users in this area can be counted. If the country of origin, age, or size is important to the engineer, then the input data would be filtered, processed by the generator and displayed as density numbers in the antenna coverage area.

5.3.2 Vessel Density

The vessel densities can be displayed as numbers or dots. The numbers are preferred when further analytical processing is to be done, while the density dots are used for a graphic impact. The numbers should be used only on the square projection. The density dots can be used on any projection.

5.3.3 Density Data

Each week, the density data are printed in the format used by the U.S. Coast Guard in its AMVER Program. The Coast Guard tracks the routes of vessels which are using the Automated Mutual Assistance VEssel Rescue system with a digital processor. Once a month, the Coast Guard prints the average daily density of vessels per five degree square in a computer format. The output from the generator is printed in this format each week. The difference between the Coast Guard and DOT/TSC data is the number of vessels plotted and the accuracy of the position reports. The update rate on the AMVER vessels is every 6 to 8 hours. The update on the generator is once a week. The number of vessels participating at one time in the AMVER program is approximately 2000; the number of vessels in the generator is approximately 18,000. By correlating the density numbers on the printouts, the position accuracy of the Coast Guard can be used to improve the selection of ship tracks for the generator.

5.3.4 Tabulations

In addition to the graphic displays, there are four tabulations in the weekly output of the generator. The first tabulation is the total number of arrivals, departures, at-sea and completed voyages for the week. The tabulation for the output for the week January 26, 1972, is 11,789 arrivals, 10,896 departures, 10,843 vessels at sea and 4362 completed voyages. The second tabulation is the weekly total number of vessels sunk, in collisions, having other emergencies or suffered weather damage. For the same period, there were two vessels sunken, 30 in collisions, 86 with other emergencies, 22 aground and 1 with weather damage. The third weekly tabulation is the number of arrivals and departures per port. For the report of January 26, 1972, there were 127 departures and 121 arrivals at Bremen. The fourth tabulation is the listing of the arrivals and departures from each port grouping. The largest number of vessels departing and arriving during the week reported in the Index of January 26, 1972 were from and for port group 2, the ports of the United Kingdom. There were 2271 vessels departing and 2906 vessels arriving in the ports of the United Kingdom during this period.

TABLE 1. WEEKLY STATISTICS (JAN 5 - JUNE 28, 1972)

REPORT DATE	ARRIVALS	DEPARTURES	AT-SEA	COMPLETED VOYAGES
JAN 5	8866	19323	10436	3909
JAN 12	12313	11918	10813	4327
JAN 19	11747	11234	108[illegible]9	4390
JAN 26	11707	11021	10921	4384
FEB 2	11422	10696	10959	4558
FEB 9	11806	11247	10957	4383
FEB 16	10809	10420	11063	4347
FEB 23	12279	11568	11136	4512
MAR 1	11688	11024	11216	4486
MAR 8	9847	9268	11219	4462
MAR 15	10534	10234	11595	4368
MAR 22	13929	12939	11232	4371
MAR 29	12096	11335	11297	4443
APR 5	12557	11643	11003	4591
APR 12	10532	9935	11046	4541
APR 19	11765	11030	11025	4511
APR 26	10890	10356	10433	4031
MAY 3	13338	12412	11082	4455
MAY 10	10506	9828	11124	4590
MAY 17	11991	11258	11209	4584
MAY 24	11768	10778	10892	4733
MAY 31	11179	10485	10954	4778
JUNE 7	12143	11352	10770	4700
JUNE 14	11913	11259	11010	4888
JUNE 21	11291	10682	11110	4722
JUNE 28	11496	10751	11026	4771
AVE PER WK	11554	11308	11016	4494

TABLE 2. WEEKLY STATISTICS (JULY 5 - DEC 27, 1972)

REPORT DATE	ARRIVALS	DEPARTURES	AT-SEA	COMPLETED VOYAGES
JULY 5	11535	10859	11001	4912
JULY 12	11534	10868	10869	4940
JULY 17	11645	11127	11186	4736
JULY 26	11809	11269	11339	4644
AUG 2	9733	9134	11177	4756
AUG 9	12485	11694	11038	4684
AUG 16	11047	10353	10916	4897
AUG 23	11136	10500	10630	4782
AUG 30	11730	11264	10965	4727
SEPT 6	11603	10989	11125	4557
SEPT 13	12230	11630	11249	4573
SEPT 20	11736	11030	11013	4545
SEPT 27	11804	11147	11104	4478
OCT 4	11988	11372	11113	4398
OCT 11	11893	11293	11394	4489
OCT 18	12046	11272	11182	4368
OCT 25	12286	11676	11232	4407
NOV 1	12359	11631	11079	4398
NOV 8	12203	11518	11023	4512
NOV 15	11728	11212	11131	4411
NOV 22	12188	11306	10966	4639
NOV 29	11945	11495	11209	4462
DEC 6	12227	11476	11029	4511
DEC 13	11581	11111	11324	4545
DEC 20	11880	11404	11399	4404
DEC 27	9509	9055	11436	4449
AVE PER WK	11621	11186	11068	4540

TABLE 3. REPORTED CASUALTIES (JAN 5 - JUNE 28, 1972)

REPORT DATE	SUNK	COLLISIONS	OTHER EMERGENCY	AGROUND	WEATHER
JAN 5	6	13	78	14	5
JAN 12	4	22	33	13	3
JAN 19	2	23	48	10	0
JAN 26	2	30	86	22	1
FEB 2	3	20	77	18	2
FEB 9	5	12	117	18	1
FEB 16	8	37	99	27	0
FEB 23	6	16	75	23	0
MAR 1	2	36	93	23	0
MAR 8	7	33	128	31	2
MAR 15	5	40	57	22	1
MAR 22	0	33	64	18	0
MAR 29	4	41	103	26	0
APR 5	10	25	63	30	0
APR 12	13	27	63	15	4
APR 19	7	25	43	12	2
APR 26	3	15	48	12	2
MAY 3	2	22	42	8	0
MAY 10	0	18	37	10	1
MAY 17	0	12	93	0	0
MAY 24	0	12	32	15	0
MAY 31	12	31	82	40	0
JUNE 7	4	28	193	25	1
JUNE 14	0	7	98	0	0
JUNE 21	6	12	78	8	1
JUNE 28	4	15	87	9	2

TABLE 4. REPORTED CASUALTIES (JULY 5 - DEC 27, 1972)

REPORT DATE	SUNK	COLLISIONS	OTHER EMERGENCY	AGROUND	WEATHER
JULY 5	2	18	62	13	5
JULY 12	1	20	54	10	4
JULY 17	1	30	2	0	0
JULY 26	6	29	29	11	3
AUG 2	4	32	52	20	0
AUG 9	1	18	57	2	1
AUG 16	4	62	76	18	0
AUG 23	4	26	16	14	0
AUG 30	0	5	9	0	0
SEPT 6	2	16	28	6	0
SEPT 13	2	22	44	15	0
SEPT 20	2	16	68	11	1
SEPT 27	1	15	27	15	0
OCT 4	0	15	55	2	0
OCT 11	4	25	32	13	2
OCT 18	0	20	0	10	0
OCT 25	0	11	19	1	0
NOV 1	0	24	6	13	0
NOV 8	3	12	14	4	1
NOV 15	0	36	35	17	4
NOV 22	0	24	29	9	0
NOV 29	0	32	14	18	0
DEC 6	2	7	9	5	0
DEC 13	0	18	21	16	0
DEC 20	1	29	12	11	5
DEC 27	0	16	45	1	4
WEEKLY AV	3.0	22.8	54.5	13.5	1.1

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