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## Passage planning and weather routing

Yi-Shun Chen

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WORLD MARITIME UNIVERSITY MALMÖ - SWEDEN

PASSAGE PLANNING AND WEATHER ROUTING

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China

A paper submitted to the Faculty of the WORLD MARITIME UNIVERSITY in partial satisfaction of the requirements of the MARITIME EDUCATION (NAUTICAL) COURSE.

The contents of this paper reflect my own personal views and are not necessarily endorsed by the UNIVERSITY.

Signature:  
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PASSAGE PLANNING & WEATHER ROUTING

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1. BACKGROUND

Although ship operation in marine navigation is one of the oldest arts of civilization, since 1960s, a large number of maritime casualties have taken place, particularly strandings. Some of these have resulted in loss of many lives, vast pollution of the marine environment and enormous loss of property.

For example, in 1963 the Chinese first ocean-going general cargo ship "YAU JIN" grounded, then immediately sank during the voyage from QINGDAO to MUJI. In 1967, the VLCC "TORREY CANYON" (LIBERIA) stranding caused very severe vast pollution in English Channel, which shocked the whole world.

However, afterwards such maritime casualties took place continuously, such as:

- in 1971 "CERNO" (NORWAY) stranding
- in 1974 "METULA" (HOLLAND) stranding
- in 1975 "JAKUB" (DENMARK) stranding
- in 1978 "AMUCU CADIZ" (LIBERIA) stranding

"It is remarkable to focus on the fact that the Liverpool Underwriters Association over the year 1963 reported on casualties over 500 gross tons :

	Collisions	Strandings
Percentage of number of ships "1/	63%	37%

and over the year 1977 the reports were :

	Collisions	Strandings
Percentage of number of ships	24%	76%

It indicates that the percentage of the strandings has increased and have become a more severe problems over the years. A great attention was paid by the International Maritime Organization (I.M.O.) to the strandings.

In November 1973 I.M.O. adopted Resolution on Passage Planning and from this Resolution the I.M.O. published

in 1978 its well known "GUIDE TO THE PLANNING AND CONDUCT OF PASSAGES". "This organization thereby aimed at setting out a code of practice for two essentially inter-related aspects:

1. the organization required for the planning of passages, and

2. the subsequent requirement to ensure that such passages are accomplished in compliance with the plan."2/

The indications given in the I.M.O. GUIDE present a complete set of measures and procedures to promote a practice of navigation which would enhance the safety of the ship and the protection of marine environment, would minimize the risk in ship operation and by this simultaneously improve the economic profit of the ship.

"Some of the recommendations and statements made in the "I.M.O. GUIDE" are:

1. The principles outlined in this GUIDE are not new; they have long been practised in many ships

2. There are four distinct stages in the planning and achievement of a safe passage: Appraisal, Planning, Execution and Monitoring

3. The information necessary to make an appraisal of the intended passage will include details of:-----  
ship's manoeuvring data

4. In planning the passage decide upon the key elements of the navigational plan. These should include but not be limited to:

points where accuracy of position fixing is critical

and the primary and secondary methods by which such positions must be obtained for maximum reliability

5. Every fix should if possible be based on at least three LOP's

6. On every occasion when the ship's position is fixed and marked on the chart in use, the EP at a convenient interval of time in advance should be projected and plotted

7. The navigating officer has the task of preparing the detailed passage plan to the masters requirements prior to departure

8. that all officers of the watch should be fully acquainted in advance with the details of the passage plan "3/

Also mentioned in "RECOMMENDATION ON BASIC PRINCIPLES AND OPERATIONAL GUIDANCE RELATING TO NAVIGATIONAL WATCHKEEPING":

The master of every ship is bound to ensure that the watchkeeping arrangements are adequate for maintaining a safe navigational watch. Under his general direction the officers of the watch are responsible for navigating the ship safely during their periods of duty when they will be particularly concerned to avoid collision and stranding.

The stipulations concerning passage planning made by the I.M.O. are detailed enough and good enough, but since 1973 there have been many examples that clearly show the shortcomings in the execution of the fundamental principles of passage planning.

The maritime community was faced with the fact that it should revise its traditional attitude towards the ship-

ping industry, because the reasons leading to the stranding which were identified after the casualty indicated that there were fundamental misconceptions about modern shipping in the thinking, attitude and behaviour of navigators, shipowners, national departments of maritime affairs and boards of inquiry.

Sailing a ship was to be enriched by better planning of navigation and closer monitoring of the passage.

It is necessary for the navigator at times to resort to the traditional methods of navigation, though many electronic navigation aids has been introduced. So it is absolutely necessary to master the principles of Passage Planning and to select the optimum route.



## 2. WHAT IS PASSAGE PLANNING

Sea navigation is defined as the process of conducting vessels between selected points in accordance with certain limitations and criteria. This process will be concerned with voyage and passage planning.

Sensible people have practised passage planning since the earliest periods of navigations. The passage planning should lead to a safe and economic voyage.

Passage planning was born from the recognition of the fact that many disasters with ships were caused by the conjunction of a certain number of ill-fated circumstances, wrong decisions, unexpected happenings, bad procedures, professional inabilities and technical failures. Composition of a good passage plan requires a good knowledge of the complete spectrum of navigation and shiphandling. The detailed plan should embrace the whole passage from berth to berth and include all waters where a pilot will be on board.

The passage planning embraces a broad scope of theoretical and practical problems. Preparation of a good passage plan requires long sea experience and deep knowledge on different nautical and seamanship subjects on the part of navigators, so the passage planning is a significant subject.

The passage planning is a process with a great variety of problems, while the problems themselves differ greatly with the type of ship, the route, the season, the type of cargo, etc.

On deep-sea ships, it is customary for the master to

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delegate the initial responsibility for preparing the plan for a passage to the navigating officer, usually the second mate. So he has to undertake the task to prepare the detailed passage plan to the master's requirements prior to departure.

All in all, Passage Planning is to make a detailed navigational plan before departure to ensure a <sup>①</sup> safe and economic voyage from departure port to destination port.  
Passage Planning requires a good knowledge and experience in navigation and seamanship.

### 3. WHY SHOULD PASSAGE PLANNING BE MADE

The objective of passage planning in marine navigation is the safe passing of a craft from point of departure to point of arrival according to prescribed criteria and given limitations. The main safety criteria for all crafts are grounding and collision avoidance.

The aim of passage planning is the prevention of disasters and the modernization of ships operation including the minimizing of the risk to navigation. The scale-enlargement of vessels and the greatly varying properties of modern ships create new problems. Hence the problems encountered in passage planning partly stem from the development of ships.

For passage planning purposes, the position fixing systems parameters in all voyage phases should be discussed:

1. Accuracy ✓
2. Availability (interval)
3. Time needed to obtain a fix
4. Coverage
5. Reliability
6. Ambiguity
7. Environmental disturbances and operational constraints
8. Presentation of information
9. Suitability for given phase of voyage

The plan will have to have details of tides, tidal streams, VHF frequencies, reporting points, traffic monitoring station, navigational warnings, weather reports, times of sunrise/

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sunset, etc. These should be part of the routine but many times they are not done, however a passage plan will serve as a reminder.

The phenomenon of a rise in the number of strandings was mentioned in the introduction to the IMU GUIDE:

"There is a disturbing number of casualties, particularly strandings, continuing to occur in restricted waters and port approaches."

"With regard to strandings the causes are follows:

1. No or inadequate planning of the navigation
2. not checking the ship's position
3. not bringing back the ship on the intended track
4. only one navigation system in use without backing up by a secondary system
5. too much confidence in visual navigational aids
6. no independent checking of important decisions on navigation to prevent the one man's error
7. ineffective use of navigational instruments available
8. errors in identification of conspicuous points
9. delayed processing of WtMs and navigational warnings
10. duty officers who have not prepared themselves in advance for the navigation during their watch
11. lack of a clear bridge organization
12. lack of or incomplete exchange of information between pilot and bridge team "4/

All in all, in any case of stranding, the reason is the lack or incompleteness of a passage plan, so a efficient passage plan is a must in navigation.

#### 4. HOW IS PASSAGE PLANNING MADE

Passage Planning formerly was the typical ship master's job, now however it tends to be a team work. i.e. the passage planning can be done by an officer in co-operation with the rest of the officers and supervised by the ship master.

A team effort is very important and effective, because transfer of experience is a matter of concern in passage planning. The advantages of a team work are as follows:

- " - transfer of experience
- preventing one man's errors
- reducing the probability of hiatus in planning "5/

Passage planning gives detailed attention to the port departure/arrival requirements of the voyage as well as specific constraints enroute, such as around head lands, through straits and the like. The passage plan must take everything into account for promotion of safety in navigation and improvement of the economic profit of the ship.

In some ships problems are related to Under Keel Clearance, manoeuvring characteristics, pathwidth, margins of safety and navigational accuracy, and in other ships, problems relate to fuel consumption, ship's behaviour in respect to the cargo and sticking to the timetable.

In all cases safety and economics govern passage planning. Sometimes, contradictions may happen between safety and economics. If so, safety should be taken into account first, then economics. i.e. "SAFETY IS FIRST" and "ECONOMICS IS SECOND". Safety is maximum economics and safety improves

the economical result in the long-run. Safety is for economiccs.

" There are four distinct stages in the planning and achieving of a safe passage: Appraisal, Planning, Execution and Monitoring. The first and second stage may be defined as the static stage. Third and fourth defining the dynamical stage of a voyage. These stages /must of necessity/ follow each other in the order set out above.

An appraisal of information available must be made before a detailed plan can be drawn up."6/ Appraisal is the process of gathering together all data and information relevant to the contemplated passage. The collection, selection and weighing of data is the most time-consuming activity in passage plan production. Bearing in mind the condition of the systems, crew, ship, cargo and environment and any other circumstances, a judgement of the margins of safety which must be allowed in the various parts of intended passage can be made.

All information may be divided into variables and fixed data which define the state of the systems: crew, ship, cargo and environment.

✓ CREW: number, experience, qualifications and the psychological condition. Particularly every ocean-going ship should be properly manned with a fully qualified and experienced crew. Particularly in constrained waters and in areas difficult for navigation the manpower requirements should be well planned.

✓ SHIP: dimensions, machinery, manoeuvring parameters, stability, seakeeping, speedkeeping and navigation aids and equipment, communication equipment, etc." The approach to passage planning of a VLCC will mainly concentrate on navi-

gational accuracy and manoeuvring characteristics, because the bottle neck is caused by the small margins of safety in restricted waters and port entrances. The heavy lift carrier or a RoRo-vessel, the main concern might be the stability and the sea-keeping qualities of the ship. "7/

CARGO: kind, nature, distribution and place of loading and destinations, etc. Particularly, dangerous cargo should be paid extra attention.

ENVIRONMENT:

1. seasons, weather, sea, currents, fog, ice, storms, etc.
2. navigational and position fixing systems.

Position fixing plays the main role in safety of navigation. Establish the points where accuracy of position fixing is critical and the primary and secondary position fixing methods by which such fixed may be obtained for increasing reliability.

3. navigational information should be accurate and on-time.

The season and weather in connection with the navigational information are playing the fundamental role in passage planning and executing the voyage. Taking into account these elements the navigator will select the proper route and time of passage when planning the voyage.

The first three elements produce a ship system. The ship system is a technological (man-machine) system incorporating operations, guidance, safety and support systems integrated to achieve cost-effective economical results.

The environmental system incorporates all other sophisticated factors surrounding the ship.

The scheme shown in Figure 1 concerns all system like ship, cargo, environment and ships personnel.

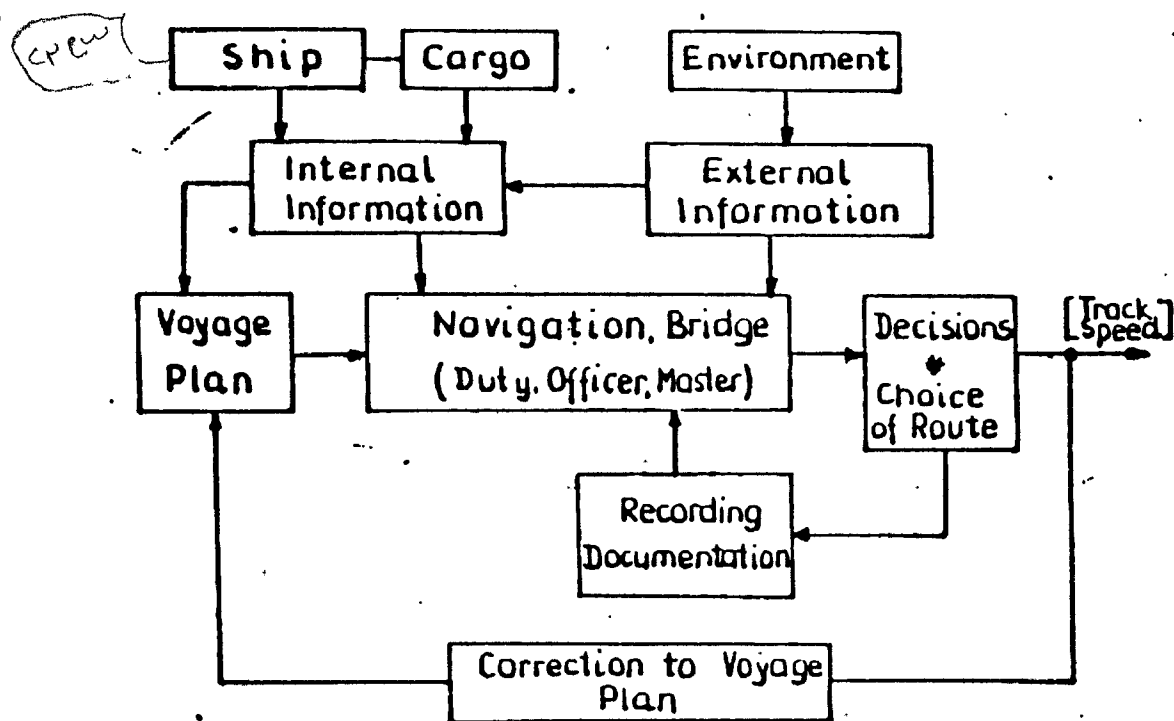


Figure 1 Scheme block illustrating the execution of the Passage Planning 8/

The external and internal informations are processed and in the result decision is made concerning the steering vector as speed and course.

Passage planning is an application of all relevant knowledge. In order to make up a good passage plan, collection, selection and procession of different informations and data concerning such systems as the environment, the ship-cargo and the crew should do well. The weighing of data is the most time-consuming activity in passage plan production.



کتاب

" The shipmaster should carefully check all necessary sources of information needed for passage planning and ordered to keep it on board up to date in respect of all Notices to Mariners. The information necessary to make the intended passage plan may be obtained from such publications as:

1. Ship Atlas
2. Catalogues of nautical publications
3. Guide to Port Entry
4. Guide to Tanker Ports
5. A set of charts for the operating area (Loran, Decca, Omega Lattice)
6. world Wide Distance Table
7. Sailing Directions (Pilots)
8. Lists of Lights and Fog Signals
9. Admiralty List of Radio Signals
10. Mariner's Handbook
11. Ship's Routing I.M.O. Handbook
12. Tide Table
13. Tidal Stream Atlases
14. Ocean Passages for the World
15. Meteorological atlases and charts (ocean currents, ice, etc.)
16. Pilots Charts
17. Nautical Tables
18. Nautical Almanac
19. Manual for carrying out the meteorological observation at sea
20. Decca Data Sheets

21. Omega Correction Tables .
22. Guides for passage planning for certain areas
23. Reed's Ocean Navigator
24. Manuals and Handbooks
25. IMO-Recommendations(Basic principles to be observed  
in keeping a navigational watch SAR, etc.)
26. IALA Voyage Systems
27. International Code of Signals
28. Chart of Load Line Zones
29. Harmonic Tidal Prediction Form  
Brit. Adm. Forms 159
30. Star finder or Star charts
31. Astronomical Reduction Tables

When every information is gathered, the passage plan can be drawn up. Points of attention are follows:

1. where to draw the course line in the chart taking into account safe distances bases on the 95% confidence area of positions
2. marking wheel over points in more than one way
3. marking tidal stream vectors in the chart at various points and times
4. expected ranges of lights and radar targets
5. intended speed taking into account required time of arrival, tidal stream, current and sea state
6. positioning systems to be used
7. backing up system
8. preparation of parallel index plots
9. embarking/disembarking pilots →
10. using manoeuvring characteristics

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11. minimum UKC (Under Keel Clearance)

12. navigating team

When the passage plan is plotted on the chart, the following items should be taken into account:

1. The intended tracks should be drawn on appropriate, larger scale charts.
2. All areas of danger should be marked clearly taking into account the margin of allowable position error.
3. The planned track should be plotted to clear hazards at a safe distance as circumstances allow.
4. A longer distance and route should always be accepted in preference to a shorter more hazardous.
5. The true directions and bearings of the planned track should be marked on the charts indicating in 360 degree notation.
6. The radar conspicuous objects, racons which may be used in position fixing should be marked.
7. Any transit marks, clearing bearings, clearing ranges which may be used in position fixing should be plotted.
8. Shallows, wrecks and other bottom dangers should be marked.
9. If no clearing marks are available, a line or lines of bearing from single objects may be drawn at a desired safe distance from danger.
10. The abbreviations referring directions, tracks, courses, bearings, velocity and correction angles should be standardized and used on the charts with great consequences.
11. Decision upon the key elements of the navigation plan,

including such point as:

- marking the safe speed regarding the draught, heel and effect when turning
- speed alternations, where there may be limitations on night passage, tidal restrictions, etc.
- positions where a change in machinery status is required
- marking the course alternation points, taking into account the ship's turning circle or current effect on the ship's movement during turn
- calculating the required minimum under the keel clearance in critical areas and mark it on the charted track
- indicating the points where the accuracy of position fixing is critical pointing out the primary and secondary methods by which such fixing must be obtained for maximum reliability making calculation showing the results of accuracy
- marking contingency plans changes for alternative action to direct the ship in deep water or proceed to an anchorage in the event of any emergency

These main details of the passage plan should in any case be recorded as sketches in a bridge note book used specially for this purpose.

A general check list of items for passage planning is given as a guidance to prepare a passage plan:

1. select the largest scale appropriate charts for the passage

2. check that all charts to be used have been corrected up to date from the latest information available
3. check that all radio navigational warnings affecting the area have been received
4. check that sailing directions and relevant lists of lights have been corrected up to date
5. estimate the draught of the ship during the various stages of the passage
6. study sailing directions and Ocean Passages for the World for advice and recommendations on route to be taken
7. consult current atlas to obtain direction and rate of set
8. consult tide tables and tidal atlas to obtain times, heights and direction and rate of set
9. study climatological information for weather characteristics of the area
10. study charted navigational aids and coastline characteristics for landfall position monitoring purposes
11. check the requirements of traffic separation and routing schemes
12. consider volume and flow of traffic likely to be encountered.
13. assess the coverage of radio, aids to navigation in the area and the degree of accuracy of each
14. study the manoeuvring characteristics of the ship to decide upon safe speed and, where appropriate, allowance for turning circle, at course alteration points.

15. If a pilot is to be embarked, make a careful study of the area at the pilot boarding point for pre-planning intended manoeuvres.
16. Where it is appropriate, study all available port information data.
17. Check any additional items which may be required by the type of ship, the particular locality, or the passage to be undertaken.

The stages in the Passage Planning — Appraisal, Planning, Execution and Monitoring are shown in Figure 2.

Having finalized the passage plan, the ETA can be made to critical points in the route and the tactics to be used in the execution of the plan should be decided.

When executing the navigation plan, the factor to be taken into account will include the following:

1. ETA at critical points for tide heights and flow.
2. The reliability and condition of the ship's systems including navigation equipment, communication procedure, etc.
3. Environmental system hydrometeorological conditions, particularly in hazardous areas known to be affected by high seas, gales, strong currents, frequent periods of low visibility and ice.
4. Position fixing accuracy when passing danger points taking into account the day-time versus.
5. Traffic conditions especially in narrow waters and at navigational focal points. *slowly, carefully = 20 knots*
6. The ship master should consider whether any particular circumstances introduces an unacceptable hazard to the

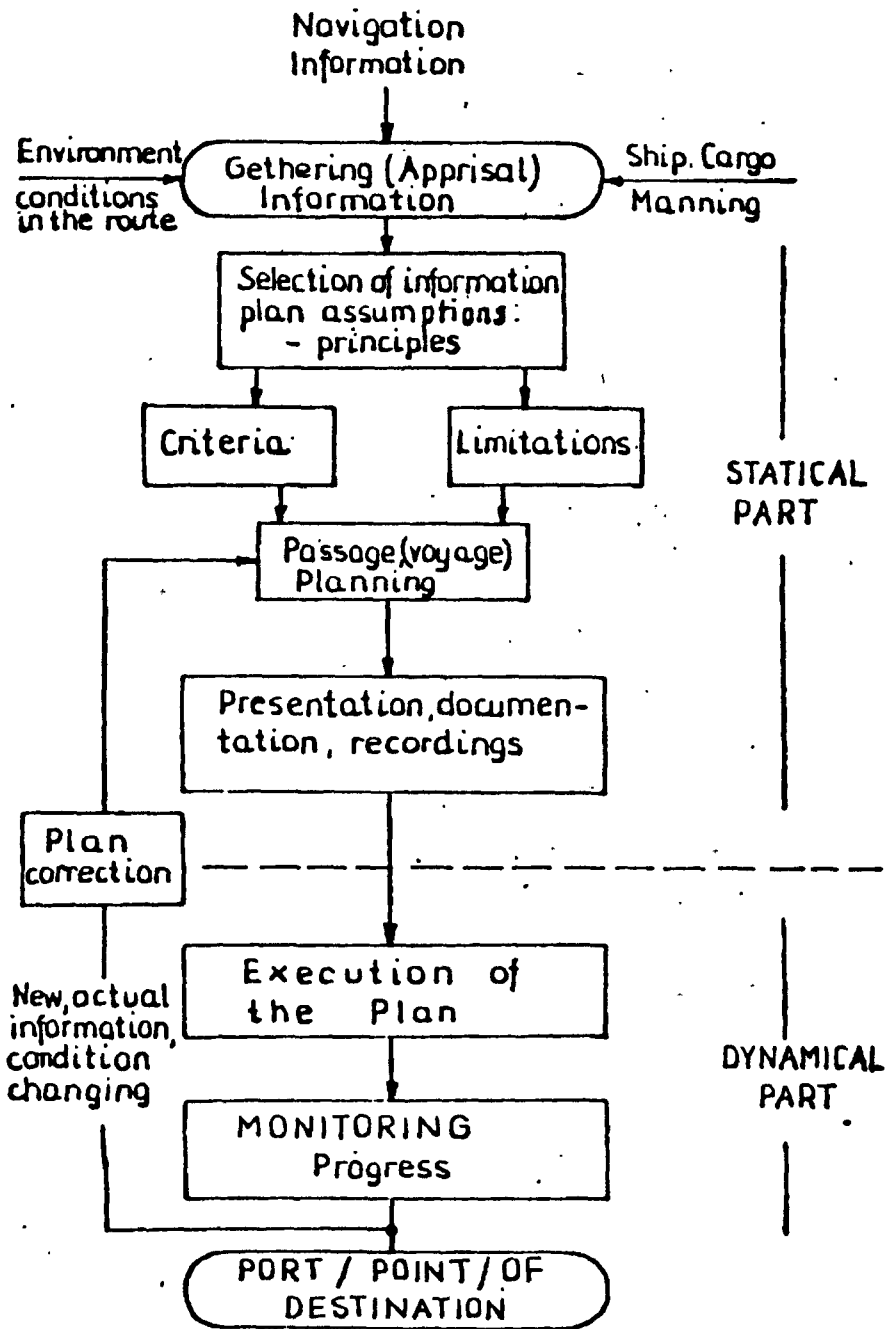


Figure 2 Block-scheme illustrating the passage planning algorithm 9/

safe conduct of the passage and also consider at which specific points in the route it is need to utilize additional engine-room or deck personnel.

7. Establish bridge or engine-room procedure for above mentioned situations taking into account preparation for sea or arrival to pilot station and harbour.
8. It is recommended to ship masters and watch keeping personnel to observe the IMU "RECOMMENDATION ON BASIC PRINCIPLES AND OPERATIONAL GUIDANCE RELATING TO NAVIGATIONAL WATCHKEEPING"

The passage planning and continuous monitoring of position during the voyage are highly important in the interest of safe navigation. Monitoring must be carried out to ensure that a passage plan is followed. The continuous monitoring of a ship's progress along the preplanned track is very essential for the safe conduct of the passage. *video*

When monitoring the passage as regards to position fixing should bear in mind the following points:

1. Visual bearings are usually the most accurate means of position fixing.
2. Every fix should, if possible be based on at least three position lines.
3. Transit marks, clearing bearings and clearing ranges (radar) can be of great assistance.
4. When checking, use systems which are based on different data.
5. Positions obtained by navigational aids should be checked where practicable by visual means.
6. The value of the echo sounder as a navigational aid.



7. Buoys should not be used for fixing, but may be used for guidance when shore marks are difficult to distinguish visually; in these circumstances their positions should first be checked by other means.
8. The functioning and correct reading of the instruments used should be checked
9. An informed decision in advance as to the frequency with which the position is to be fixed should be made for each section of the passage. "10/

Human error is in many cases avoidable provided that navigators have a responsible attitude and conscientious style of work at all times. "Failure to sight a particular light at the stipulated time will prompt action to check the ship's position. Frequent cross-checking of one navigational system against another will verify the ship's position as well as conform the systems themselves."11/

During the carrying out of the passage plan, in the event of any unexpected emergency conditions, it is necessary to alter the planning. In that time, the attitude of alertness, firmness, scrupulousness and accuracy should particularly be taken. Otherwise serious consequences would be happened.

Passage Planning is done in all cases, but not always in very detail to familiar routes.

## 5. THE SHIP WEATHER ROUTING

### 5.1. What is ship weather routing

The oldest reports on weather routing came from India and Africa about the practice by Arab Dhows trading between India and the east coast of the African continent in that they utilized the NE monsoon on west-bound passages and the SW monsoon on east-bound passages.

In 1787, B. Franklyn published a chart of the north Atlantic showing the currents and the ships used this chart improved their performance significantly.

In the 1950s, the routing of ship by shore establishments began in the USA. Then the practice was adopted by various European government meteorological services.

In the 1980s, China Shangdong Navigation Institute and Qingdao Ocean Shipping Company have been studying the weather routing in the north Pacific. So far an initial success has been obtained in this experimental works. In the near future, the Chinese own ship weather routing service will be built in Qingdao, China.

Ship weather routing is a procedure whereby an optimum route is developed based on the forecasts of weather and seas and the ship's characteristics for a particular transit. Within specified limits of weather and sea conditions, the term optimum is used to mean maximum safety and crew comfort, minimum fuel consumption, minimum time underway, or any desired combination of these factors.

Weather routing is not a new part of navigation or seaman-ship knowledge. It has been conducted by ship master from on board information and weather report. By applying

the available surface and upper air forecasts to transoceanic shipping, it was possible to effectively avoid much of the heavy weather.

For East-West crossing outside the tropical regions in particular and for other voyages where short term variations of the weather are to be expected, weather routing is widely used. Figure 3 shows Alternate Routes on N. Pacific Ocean.

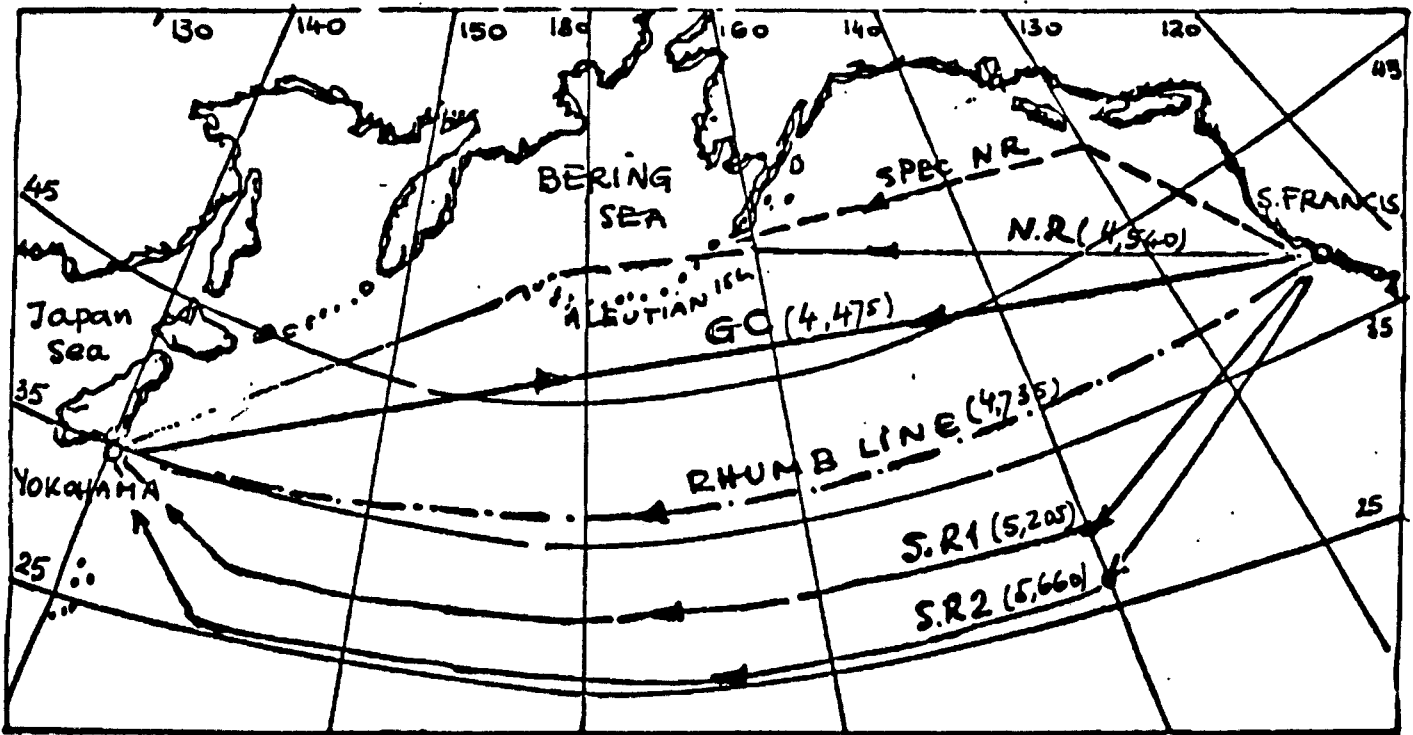


Figure 3 Alternate Routes on N. Pacific Ocean

Although weather is one of the main factor in ship weather routing, the principles of navigation, seamanship, naval architecture and oceanography, etc. must also be considered before a route can be selected.

The ship weather routing service is manned by experienced meteorologists, ocean hydrographers and nautical experts. To be a successful weather routing analysis requires the

integration of three disciplines: meteorology, oceanography, and nautical science.

The criteria of optimizing the route during a voyage can be as follows:

1. Least time

The main objective is to reduce time on passage regardless of other considerations.

This refers to ships which do not suffer cargo damage as tankers and bulk carriers. These ships are less susceptible to hull damage than other ships.

2. Least time with least damage to hull and cargo

Some ships have very low center of gravity and are prone to heavy rolling. The small ships carrying valuable cargoes in all seasons of the year in the N. Atlantic or N. Pacific routes should be routed on this criteria.

3. Least damage to cargo

This is requested in cases when ships are carrying a particularly sensitive cargo such as uncrated cars, livestock or deck cargo, etc.

4. Constant speed

In cases when the charters stipulate to maintain constant speed over a certain period of time. Also some passenger ship or container ship which should keep the schedule and bound for the destination port in time.

5. Fuel saving

Increased oil costs carry weight in the ships operation

expenses. The most significant advantage of ship routing has been in fuel saving.

All in all, the advantages of ship weather routing are:

1. Enhancing safety
2. Time saving
3. Fuel saving
4. Minimising storm damage to the ship and cargo
5. Comfortable to crew and passenger
6. Attaining of punctuality, maintaining of schedule
7. Meeting special requirements of the individual voyages

However, many of these objectives tend to conflict with each other. Minimized sailing time must be weighed against increased fuel costs and risk of heavy weather damage.

There is no guarantee that a "least time" route will be a "least cost" route when all factors are considered.

The passage planning in the ocean areas based on the weather routing is to avoid the areas of highest waves as far as possible. A poorer speedkeeping environment may be acceptable if it allows for a more direct route or more favorable ocean currents. Thus the essence of the ship routing problem is to assess the relative effects of a wide variety of conditions in establishing suitable tradeoffs among appropriate cost criteria.

They should lead to the choice of a reasonably good route.

The final route selection may represent a voyage which has been optimized with respect to passage time, ship safety, fuel consumption, passenger comfort, etc. or some combination of these goals.

The greatest potential advantage for this ship weather routing exists when:

1. The passage is relatively long, generally about 1500 miles or more;
2. The waters are navigationally unrestricted so that there is a choice of routes (alternatively, navigational restrictions are limiting but at the same time offer possible protection from adverse weather);
3. Weather is a factor in determining the route to be followed.

" Recommendations in ship weather routing usually are:

1. Diversion

A diversion is an underway adjustment in track and is intended to avoid or limit the effect of adverse weather conditions. In most cases, the distance to the destination is increased, but this is partially overcome by being able to maintain near normal speed of advance.

2. Adjustment of speed of advance

It is a recommendation for slowing or increasing the ship's speed as much as practicable in an attempt to avoid an adverse weather situation by adjusting the time of the encounter. This is also an effective means of maintaining maximum ship operating efficiency and not diverting from the present ship's track. By adjusting the speed of advance, a major weather system can sometimes be avoided with no increase in distance.

3. Adjustment of departure time

It is a recommendation for delay in departure, or early departure if feasible, and is intended to avoid or

significantly reduce the adverse weather and seas forecast on the first portion of the route if sailing on the original estimated departure time. The initial route is not revised, only the timing of the ship's transit through an area with currently unfavorable weather conditions. Adjusting the departure time is an effective method of avoiding a potentially hazardous situation where there is no optimum route for sailing at the originally scheduled time." 12/

According to weather routing, diversions or reduction of the ship's speed are made to avoid adverse weather conditions and shorten the track or the transit time. Significant savings can be the result.

Ship weather routing is useless without an efficient communication link between the ship master at sea and the transmitting stations to obtain all the informations needed. Delays in the transmission and the limited information of advisories put further uncertainty into the situation, so the ship weather routing is successful or not, the key question is the accuracy of the forecast and the on-time of communications.

## 5.2 The factors in ship weather routing

It must combine environmental factors with a number of economic considerations to determine the effectiveness of a particular weather routing decision. The weighing factors used in optimisation differ from ship to ship also depending on the type of cargo. For example, a tanker with heated cargo might wish to avoid cold water (depending on the cost for the heating). A dry cargo ship may need weather to be able to overhaul the cargo gear.

The knowledge of expected weather conditions and the ship's seakeeping and the speedkeeping response characteristics have an important role in the total operational planning and decision making procedure.

The requirement at sea is for an accurate extended period forecast, that is for a five or six day forecast of a comparable accuracy to the present twenty-four hour forecast. This will enable the ship weather routing to be used to greater advantage. Since storm avoidance has been one of the principal criteria in ship weather routing, marine weather forecasting efforts have concentrated on storm identification. In ocean navigation, the selection of the track to be followed in seasonal weather is based mainly on optimization of the tracks found in "Ocean Passages of the World" by taking into consideration ship's characteristics and comparing this with the "least track" based on climatological data valid for the duration of the passage.

" Various external weather factors influence the choice of route. Attention must be paid mainly on the long term



weather forecasts having in mind hydro-meteorological factors like storm, ocean currents, fog, ice, etc."13/ "The chosen track is adjusted according to ship's behaviour and the prospects of the voyage based on fascimile charts and weather reports."14/

The key to weather forecasting for ship routeing is the ability to recognize key upper air patterns in order to forecast storm track movement. The basic forecasting procedure consists of a three day forecast with extensions to five days based upon persistence and extra polation. The forecast is made to utilize all the data sources previously listed.

As new information becomes available, the forecast is updated and disseminated to the respective ships enroute section. Once the surface features are forecasted , the route analyst then checks the existing sea conditions and then makes a similar forecast movement with the associated surface feature.

Based on input data for environmental conditions and ship's behavior, route selection and surveillance techniques seek to achieve the optimum balance between time and distance and acceptable environmental and seakeeping conditions.

Figure 4 shows the scheme block of a algorithm for determination of the optimum route

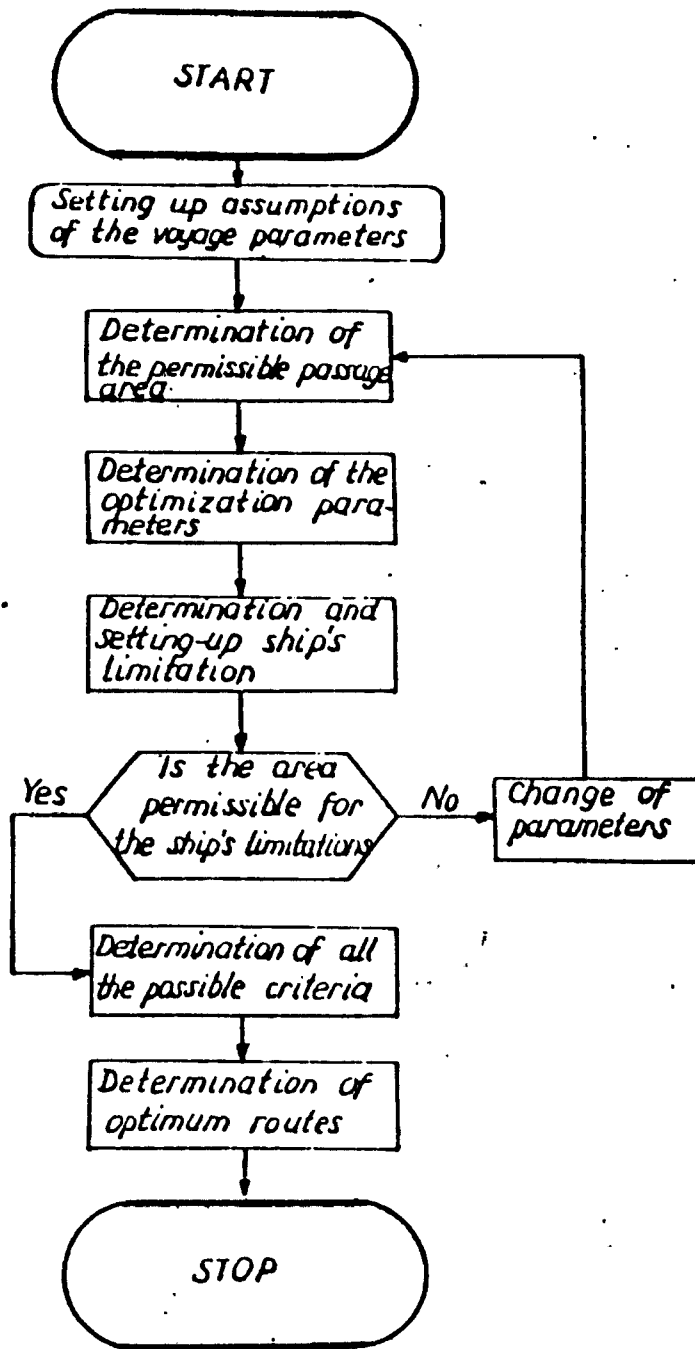


Figure 4 Block scheme of a algorithm for determination of the optimum route 15/

"At the present time, considerations for surface current in route selection are based upon data by the Scripps Institute and as depicted by the Pilot Charts. Two major currents which are in close proximity to major shipping lanes, the Kuroshio Current off Japan and the Gulf Stream off the U.S. east coast, are closely monitored by the latest satellite technology. Concise, updated information is utilized to provide maximum considerations in the route selections in these areas. In the case of deepening systems, where the wind field expands and wind velocities increase, generating seas are expanded outwards correspondingly. Beyond the 3-5 day extended forecast, the route analyst utilizes Oceanroutes' climatological methods to extend the forecast to cover the remainder of the voyage."16/

If the effects of wind and seas conditions can be optimized and sufficient data about speed-loss, rolling, slamming, acceleration, etc. are available, optimum routing should be obtained. Passage Planning and Ship Weather Routing provide more detailed decisions on the time sequence of distances, courses and speeds which are perceived to best meet scheduling and/or economic requirements of those specific voyage.

### 5.3. The importance of weather routing on ship own

In all cases of the passage planning based on the weather routing and execution of the passage, the ship master is responsible. The ship master of any routed ship is free to accept or reject the advise given by any weather routing service. The routing service supplied to the ship master is a recommendation only and the decision whether or not to follow the route is entirely up to the ship master's decision. This recommendation given by weather routing service should be considered as an "aid to navigation" only. Even when performing voyages under a time charter party, the ship master has freedom regarding the choice of the route.

The general pattern recognized by shore from limited weather informations and data may be correct, but errors in essential detail may occur, because the oceans are such vast expanses and sometimes the change of weather conditions is too fast to measure. However, the ship master is on the very spot in command of the ship, he can get exact, in-time weather data by his own measurement. So apparent discrepancies between shore side prediction and onboard observations can be checked.

I believe that the ship master can do some very effective weather routing by himself, if he is provided with great accuracy weather data.

For example, in 1981 I was on a ship bound for Qingdao, China from Vancouver, Canada. The nautical officers of the ship had applied weather routing service. During the voyage there were two typhoons. The first had just gone, the second was coming.

The position of our ship was just between the two typhoons. The routing service gave our ship a recommendation of diversion to  $50^{\circ}\text{N}, 160^{\circ}\text{W}$ . But according to the practical conditions, our ship determined to increase the ship speed as much as possible for rushing out of the gap between the two typhoons. At last we were successful. So, if the duration of the adverse weather conditions is limited, it may be better to ride out the weathers and seas conditions, which would make the diversion not necessary.

The ship weather routing from shore and on the own ship should be combined with each other. The ship master should never blindly obey the recommendations from the weather routing service on shore.

The practice is only a standard for testing truth.

#### 5.4. New developments of ship weather routing

Meteorology is a relatively young science as compared to mathematics, chemistry and physics, etc. Many of the weather phenomena today, still can not be fully explained or verified due to the fact that to re-create a certain phenomena is merely a hit or miss method due to the many parameters required to interreact within a specified amount of time.

Unfortunately, the actual techniques of route selection have not entirely kept pace with advances in other areas of weather routing. Route selection is at present largely based on weather charts giving both present conditions and medium to long range forecasts; however, it remains an essentially manual process and is still based primarily on storm avoidance. Its goal is usually minimization of transit-time.

There is ample room for improvement in the theory and practice of ship weather routing, and there is a significant potential market for such improved services. Much work has already been devoted to developing a highly rationalized approach to ship routing and its computer implementations. There is still much room for improvement in the efficiency of weather routing, mainly in connection with forecasting accuracy, particularly of storm tracks and the wave heights.

The success of the exercise in the ship weather routing demands an effort on the part of ship mariners, too, whether routed from ashore or on board. In the last two decades, there have been significant advances in the availability of detailed weather information and in

prediction of seakeeping and speedkeeping responses. However, significant efforts should be carried out toward the understanding of the marine environment and its effect on ship operation, because of the importance of safety of ocean transportation and the many difficulties associated with its economics and profitable conduct.

"To implement the ship weather routing procedure, large computer and data processing facilities, complete with a tele-communication system, seem imperative."17/ "The recent emergence of highly accurate methods for sea state forecasting and prediction of ship seakeeping characteristics, coupled with the ability to save time, fuel and associated costs through their use, has heightened the potential value of new computer based approaches to the ship routing problem."18/

"The present study has continued the development of the dynamic programming approach to ship routing with the purpose of moving it closer to practical application."19/ A concerted effort has been applied to bring new capabilities in weather forecasting, vessel simulation, communications and data processing to bear on the problem of ship weather routing. Further experiences in running the enlarged model in simulated sea conditions will help to determine the exact form and level of detail of the inputs that are required by the routing algorithm.

Sensitivity studies should be carried out for different types of cost functions together with the ship motion constraints in order to model different types of commercial operations realistically."20/ Today, ship weather routing

uses modern weather forecasting techniques and computer procedures to provide optimum routes. When technological advances introduced high-speed computers into the collection and transmission of meteorological data and into the prediction of the development and movement of weather systems, the ship weather routing became more successful.

"To obtain the comprehensive, quantitative wave data that are required for a more sophisticated treatment of weather routing, it is necessary to employ large scale numerical modelling techniques. These must be able to simulate wave growth and decay due to changing wind patterns, as well as propagation of energy from one location to another, over a large area in real time and for several days into the future. "21/

"Several routing simulation exercises were carried out. These exercises allowed assessment of the costs and benefits of using various levels of environmental data in route selection, and they provided comparisons between the costs of optimal routes, routes recommended by commercial routing services, and routes actually chosen by ship masters. " 22/

"In some areas, research efforts can be combined to utilize these valuable resources more effectively. For example, the Heavy Weather Damage Avoidance System can be used for the local optimization problem which the ship master could solve using his seagoing experiences and the sensor readings, while the weather routing program searches for a global optimum. "23/

"The development of satellites has greatly assisted the



forecaster in locating weather phenomena especially in areas of sparse weather reports. Each year more forecasting aids are being provided, such as improved satellite coverage and methods of analysis, automated electronic data buoys, high speed computers to handle the voluminous amounts of data, and faster, more economical modes of data transmission."24/ "Most ocean passages are of longer duration than 72 hours. The data through the Satellite Data Distribution System (SDDS) required for implementation of the optimal ship routing algorithm are presently available, at least for northern hemisphere, for up to 72 hour forecasts.

The data sources presently exist to provide sufficiently detailed wind and wave information to implement the optimal ship weather routing algorithm, using forecasts out to 3 days, climatology beyond 7 to 10 days, and a mixture of the two during the interim transition period."25/

"Initially, in order to save cost, it is recommended to utilize the existing time-sharing computer network and radio transmissions. Later when the maritime communication satellite, MARISAT, becomes fully operational, much of the delay and inconvenience due to severe weather or ionospheric disturbances can be avoided through the direct ship/shore communication capability provided by the satellite."26/

Figure 5 shows the basic elements of the proposed system.

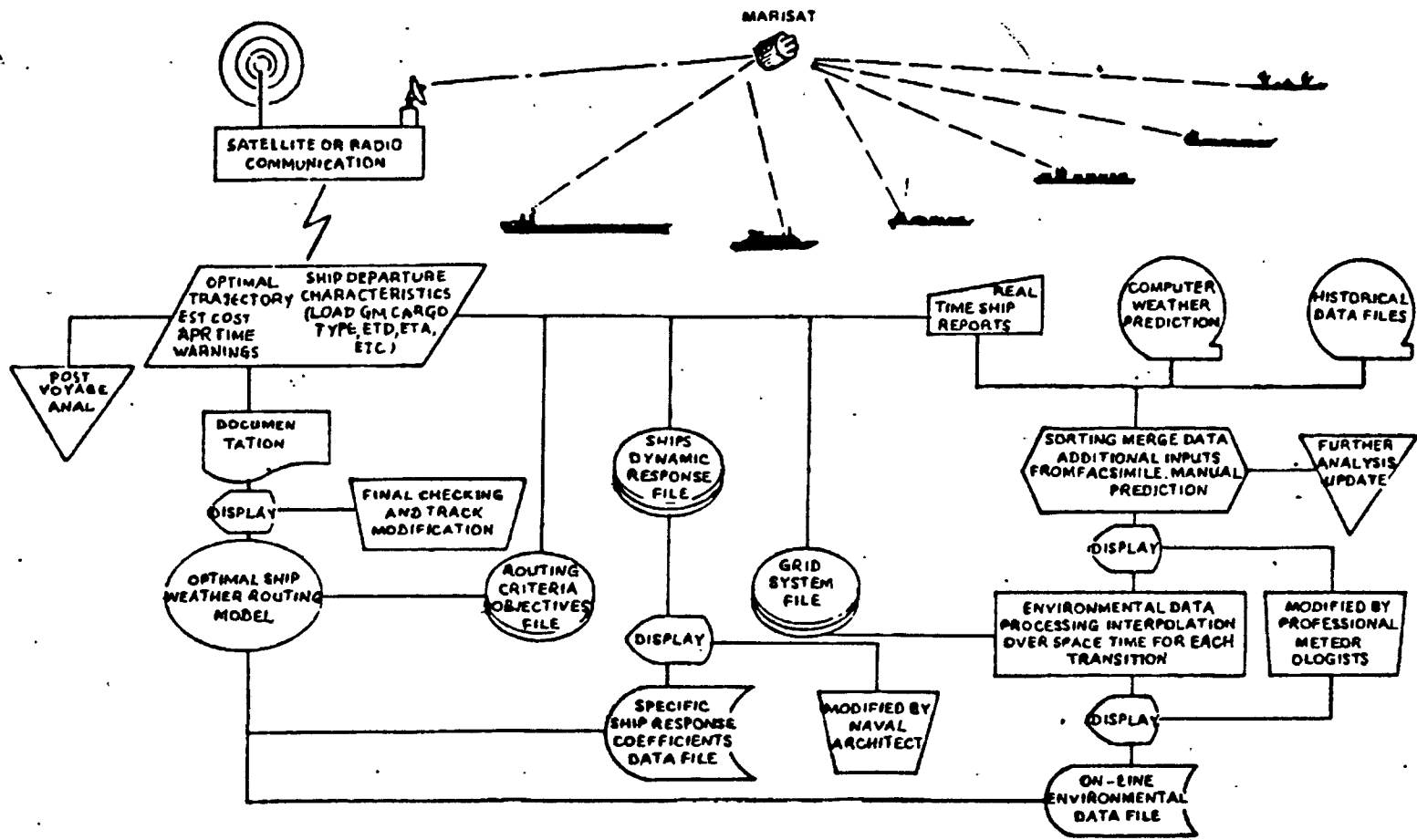


Figure 5 Schematic Set-up of the Entire Optimal Weather Routing System 27/

" The ship weather routing "algorithm" has been implemented as a system of four routines which carry out different tasks in finding the dynamic programming optimization of a particular voyage. This division of labour is outlined as following:

PROGRAM	FUNCTION
GRIDS	Establishes Latitudes and Longitudes within the system of grid points and provides for editing of geographic locations.
ENVIR	Defines the time variable for all grid points and performs spatial and temporal interpolations of environmental data to derive weather conditions at all grid points.
UVF	Computes optimal value function for the grid point system by performing speed-keeping and seakeeping analyses and calculating associated costs.
ROUTING	Traces out an optimal route starting at any grid point.

Two of the programs — GRIDS and ENVIR — prepare the grid system and environmental data which are input to the UVF program which calculates the optimal value function."28/ both programs require the documentation of the ship's dynamic response in waves and wave spectra input; the Marine Safety Data Center may provide the weather damage statistics which will become a valuable data source in formulating the cost functions.

" This function is then interpreted by the ROUTING program to give the final routing recommendation. The advantage

of this division of labour is that data files produced by the GRIDS and ENVIR programs may be used in solving several, if not many, routing problems. Once the geographical coordinates of the dynamic programming grid system have been defined for a particular route, they will serve as the basis of grid systems for all future voyages between the same points. If any ships with similar speed ranges are on the same route and in similar positions, then the environmental information generated by the ENVIR program may be applied to all of them."29/

Other improvements on modeling the uncertainty of weather changes are also possible. A conditional probability distribution may be attached to each state so that updating the weather forecast may be performed by using a formal analysis. The technique should use the power-speed relationship derived on the basis of analytical methods.

"On many sophisticated and new ships, it is increasingly popular to install multi-purpose minicomputers. The computer can carry out many different tasks, such as satellite navigation, collision avoidance, cargo loading, engine monitoring and regulation, etc. The size of programs varies from problem to problem and storage cores can be added by simply inserting an additional panel. Therefore, an existing computing facility can be easily adapted to carry out a weather routing procedure. After all of the feasible states of the voyage have been evaluated by the main computation facility, the state information is transmitted directly to onboard data storage units via communication satellite, if capacity permits."30/

"By using a simple subroutine, the trade-off and optimal track selection could be performed onboard under the ship master's supervision. The on-line trade-off on the onboard minicomputer would reduce the work load on the main computing facility. At the same time, it also provides a tool for the ship master to carry out various possible routes before making the final decision.

For environmental data processing and forecasting, the existing services are not sufficient for the proposed automated ship weather routing system."31/ "Looking toward future development, an automated data gathering/processing system using sophisticated satellite technology is currently under study."32/

"Technological advancements in the areas of satellite and automated communications, and onboard ship response systems will increase the amount and type of information to and from the ship with fewer delays."33/

Figure 6 shows the proposed NASA's SEASAT concept which may be utilized for a computer-aided forecasting system.

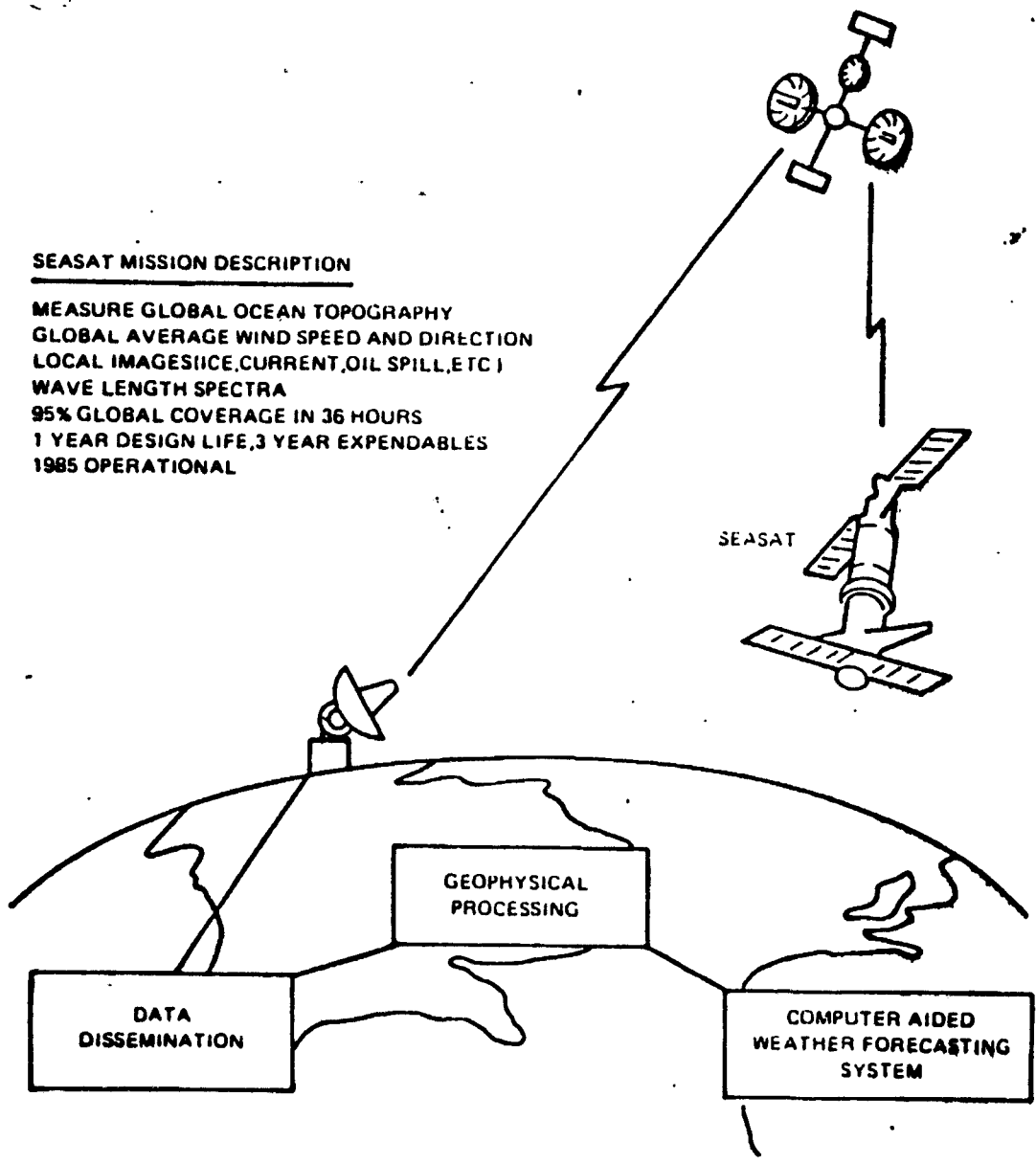


Figure 6 Environmental Data Gathering and Processing System through Proposed NASA's SEASAT Concept 34/

The sensors onboard SEASAT will continuously scan the Earth's ocean surface to record data on wave heights, winds, ocean surface temperature and ice formation. The gathered data will then be relayed to another satellite in higher orbit which transmits to ground stations. The disseminated data can be used for many scientific studies. After geophysical processing, the result can be directly fed into a computer-aided weather forecasting system for ship weather routing.

Generally speaking, there are four major areas that require further research and development efforts.

"Area 1 Environmental data processing and analysis

An automated data processing network should be established to receive environmental data directly. Subroutines for sorting, updating and checking have to be developed in order to handle the vast amount of data to be received.

Area 2 Analysis of ship dynamic response characteristics

The major obstacle in estimating a realistic speed function for a specific power output, however, is the uncertainty of a ship's propulsive coefficients due to the interaction between hull, steering and propulsion systems while in waves.

Area 3 Operating criteria and cost function analysis

This area itself requires a substantial research effort both in shipping management and related engineering fields.

Area 4 Modeling of uncertainties in weather prediction and ship's dynamic response"35/

Although an attempt was made in the present formulation to account for the stochastic disturbances of environment on the ship's dynamic response, further refinements should be incorporated in order to model the uncertainty in weather and the effect of such on a ship's performance.

Based on satellite data, numerical models and other sources, forecasts of atmospheric pressures and marine wind fields are developed and estimates are made of wave activity. As more observational data becomes available, the numerical prediction models can be improved, thus enabling the forecaster to improve his forecasting ability.

"It is to be hoped that methods of numerical analysis, an increase in effective observations and remote sensing techniques by weather satellites together with a wider use of computers for processing and storing data will alleviate the exposure to danger which the seaman and his ship continue to experience.

Automated solutions to the weather routing problem are under active development at this time. Some organizations are using computers as book keeping tools in the route following portion of the total operation. Computer programmes have been written and tested which will compute a least time track given the necessary sea wave fields far enough ahead.

The use of modern technology has the natural limitation imposed by human understanding. The future of weather routing lies in a greater knowledge of the processes involved, of the dynamics of meteorology. "36/



Advancements in mathematical meteorology coupled with the continued application of computers will extend the time range and skill of the dynamic and statistical forecasts. A new approach to ship weather routing has recently culminated in the development of an algorithm which combines presently available technologies in the areas of weather and wave forecasting as well as vessel seakeeping and speedkeeping, in conjunction with a comprehensive ship operating cost model. The resulting model will identify the optimum ship routing consistent with prevailing weather and operational constraints, as well as related economic factors, when solved by a dynamic programming technique.

"The initial success of the project in developing an efficient and working algorithm for ship weather routing renders a promising future for actual testing and evaluation under real operational conditions at sea.

At the present stage of development, the basic algorithm and attached models are still not refined in many respects. Much research and development will be required before it becomes operational. The proposed model actually provides a general framework into which more sophisticated techniques and refinements can be incorporated as they become available in the future. "37/

Now, it is possible to forecast with a fair degree of reliability expected weather and sea state conditions several days into the future, in the heavily traveled areas of the world, and further enhancements in forecast models are already in progress.

"a small computer or calculator could be used in the locus determination on board. The machine could have programmed packages of ship data; a commencement co-ordinate fed in together with wave information and a proposed set of locus co-ordinates would be available as output. The operator would transfer the locus to a chart, facilitating a choice of route."38/ With these technical advances, the reliability of ship weather routing will be promoted greatly. "Research products from the heavy weather damage avoidance system, wave height measurement instrumentation, marine safety data center, etc. will be invaluable to the future development of the ship routing project. "39/

Finally, it should be realized that more benefits may result if the entire research effort were closely coordinated with the other ongoing research projects.

Hopefully, the combined efforts will yield more fruitful results.

## 6. TRAINING FOR PASSAGE PLANNING IN MARITIME COLLEGES

"Investigations into shipping casualties have shown that a considerable percentage of their causes have to be attributed to human failure and in particular to failure resulting from lack of qualification."40/ These cases should be of great concern to responsibility of maritime education. Because transferring the necessary knowledge for completing a voyage to tomorrow's mariners is the task of a marine college.

Many disasters originate from poor passage planning. How to deal with the education and training of passage planning is a problem which is worth to study conscientiously. Recognition of the valuable standards of the principles of passage planning is one thing after which the question remains how and to what extent education and training of this code of practice is carried out.

First of all, in maritime college, nautical teachers should aim at changing the behaviour of students in such a way that they have the correct attitude towards their profession and to turn them into serious navigators.

Passage planning embraces all facets of navigation. As soon as specialisation develops, the disciplines tend to diverge and interrelationship of the various specialisations grows less distinct. Subdivision of a subject is useful from the teaching point of view. However, the navigator has quickly and efficiently to integrate this detailed knowledge into a whole again. So to the students, the study of passage planning is an application of all relevant

knowledge available and all skills during previous training. The application of knowledge presupposes the existence of it and so passage planning can only be properly taught to students in the last stage of their training.

Before starting to teach, the teacher should make the students realize that passage planning is a necessity. When teaching and training, the teacher should confront the student with as many contributing factors as possible and so they are having more problems than usual and because they lack experience.

" If a person has done something in detail, he is able to do the same correctly and fast after gaining experience, because he is aware of the problems that may arise and has learned to avoid them." 41/ So, many human failures could be avoided by detailed passage planning.

The experiences and teaching methods from our Senior F ARBEIDER and J MULDER'S are worth to learn. They introduced that "We open with the analysis of a couple of maritime disasters which show a variety of factors causing or contributing to the accident." These analyses woke much interest and reaction from the side of the students. Then, each student chooses a ship, a route and month for which he is going to make a passage plan. At the same time, lectures concentrate on the collection of relevant concerning the ship and the environment from ship's data bank and environment data bank for the particular voyage.

A lot of information, which has to be gathered in the school situation will be very available on board in the future practical situation, and passage planning can be

done more efficient and will cost less time, because a lot of contributing factors are known far ahead and in practice incorporated in the planning. Indeed the passage planning is a time consuming operation. In some cases, planning took longer than the actual trip would last.

In general, the students do not have a casual attitude towards passage planning. The opposite is true as they are very intently engaged with the subject and their own passage plan.

There is a virtual, desirable way of checking and assessing a passage plan. That is to utilize a navigation simulator. All necessary tasks can be carried out on a simulating bridge. For example, Decca ship simulator offers a unique possibility to demonstrate the necessity of passage planning to all concerned.

For the training of the principle of the passage planning, the simulator is badly needed. Students need to see the results of putting into effect what they have planned, and this may only be achieved by monitoring passages in real time on the simulator.

The close and continuous monitoring of a ship's progress along the pre-planned track can be done on the simulator. "The experience of adding simulator execution and monitoring to chartroom appraisal and planning, has demonstrated clearly the greater realism and improved understanding that students experience in this total approach to passage planning. " 42/

Simulators have the advantage of representing different

ports and different environmental and ship conditions, plus the fact that more training can be accomplished in a much shorter time than at sea. Also malfunctioning of navigational equipments and navigational systems, propulsion and steering system and the effect of adverse weather conditions should be part of the simulator functions. Another important factor is the capability to simulate general emergency conditions without incurring the risk or cost that would be involved in similar at-sea training.

To enable students to function as realistically as possible in the simulator ample "hands on" time must be given to build up familiarity with the equipment, before running passage planning exercises. It is essential for the lecturer in the simulator to create untoward situations which demand deviations from the original plan.

The simulator is proving to be an invaluable tool for certain tasks, although it is felt that the at-sea experience is and will always be a necessary major part of the training program. A simulator would tremendously improve our training methods in passage planning.

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