ADVANCED MARINE INFORMATION DELIVERY

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ABSTRACT

SEASAT-1 is now an established fact. It is providing continuous sensing of the world's oceans and related meteorological phenomena from its satellite platform in space. What is the next step? This paper considers the information delivery challenges of the follow-on programs to SEASAT as they progress through the next decade. These include coping with the vast quantities of data to be transferred, fulfilling the temporal requirements on data delivery, and the trade-offs and developments needed to accomplish the various levels of processing required to convert sensor output into useful information. A need for critical development is clearly identifiable in the areas of low cost ground terminals capable of image extraction and image correlation; dynamic data assimilation to accomodate forecasters; low resolution onboard correlators; and low cost user advisory (display) terminals. The system planners for the Ocean Satellite advanced programs are utilizing an end-to-end data systems approach in meeting these challenges. The economic and scientific impact of delivering decision making information to the marine community in real time and in useful form is recognized and is potentially achievable.

INTRODUCTION

Marine environmental information is vital to the ocean community in making key decisions. Earth-orbiting satellites, carrying sensitive microwave and visible and infrared sensors, provide the best available method for observing and collecting the wide variety of parameters required by marine users, in a synoptic manner. They are capable of observing large areas in a relatively short time span. Several appropriately spaced satellites can provide for frequent, accurately located, and complete global ocean coverage more cost effectively than any existing alternative. However, delivery of the collected information in a timely manner and in a form most useful to users is another matter. Users have found it difficult to acquire data in the form, time and content they desire at a cost they can afford. This has been due in part to the lack of communication between those responsible for implementing the remote sensing platforms in space and those implementing the ground system. There is also a lack of understanding and appreciation for the needs of the users, particularly in terms of product level, repeatability, delay in delivery, and means of delivery and display. The end-to-end data system of the recently launched SEASAT-1 satellite is not capable of meeting the true needs of the users, nor was it meant to. SEASAT-1, as a proof of concept mission (not an operational system), is meant to determine if newly developed microwave sensors can accurately measure the state of the ocean surface and to then determine whether collected data will be of significant use to meteorologists, oceanographers, and commercial users of the marine information.

The first of a series of demonstration satellite missions, which will provide remotely sensed ocean observations in a limited operational mode, is planned for launch in early 1984. This satellite is a part of a National Oceanic Satellite System (NOSS) and will be undertaken as a joint NASA, NOAA, DOD activity. All three of these agencies will participate at all levels of activity. The characterizing personality of this demonstration program is to achieve improved data utility at the user interface. This will be accomplished in part by utilizing a total systems approach extending from the satellites and their sensors through all facets of end-to-end data flow, analysis and interpretation, with the output merging with other data and interpretation sources in various marine services and operations. The NOSS end-to-end data system design will recognize and meet common data needs. It will not, however, succeed in fully meeting these needs due to a requirement which precludes a satellite from transmitting information directly (from the satellite) to ships and rigs at sea. The Advanced Marine Information Delivery System discussion that follows ignores this constraint, and refers to post-NOSS planning.

USER INTERACTIONS

In developing Marine missions, it was recognized that broad user groups with common data needs could be identified. These needs appear to be driven primarily by the problem of data perishability. Secondly, it was noted that all users would accept data processed to a certain level. Beyond this level there is a divergence of opinion as to (a) which algorithm(s) should be used to derive certain information (e.g., wind fields), (b) the extent of areal interest (e.g., local, regional or global), (c) the format in which the information is to be displayed, and (d) the time frame for delivery (e.g., real time, a few hours, days, or archival). Based upon these and related commonality and difference factors, well chosen institution preprocessing functions (potentially onboard the satellite) can be followed by fulfilling four user processing information delivery system modes in a mission oriented information flow. These four modes, then, have been identified with differing characteristics in terms of information content, time scale and possible location of the various processing functions. The four system modes are referred to as the direct-to-user mode, the regional/local user mode, the global modelling user mode, and the research user mode. Such a system could provide for multiple user control, provide good synergism, provide real-time delivery, and grow in response to changing needs.

The institutional preprocessing function is that portion of processing with high user commonality of need and low user concern with the method of implementation. Institutional preprocessing is located for delivery efficiency either onboard the spacecraft or on the ground. Examples of these functions include location processing, sensor bias correction, image correlation, image formulation and image rectification. The forthcoming Global Positioning Satellite (GPS) will be utilized to provide a basis for onboard processing of the earth locations of sensor boresight views (i.e., footprint computations). With GPS providing an accurate up-to-date ephemeris, and with the satellite attitude information and related sensor data all coming together at one point in time aboard the satellite and with current and anticipated capabilities for utilizing microprocessors aboard a satellite, this appears to be the ideal place for the location processing function. Sensor calibration and bias correction represent two additional processing functions over which there is little controversy; they are, therefore, amenable to onboard spacecraft processing (i.e., before any split in data stream is made for dissemination). The Synthetic Aperture Radar, with a bit rate of 120 Mb/s, would consider quick-look (low resolution, real-time) correlation, or direct information extraction from the raw signal (if possible) as candidates for onboard processing in order to aid in the selection of regions for full on the ground, image correlation, as a means of greatly reducing the overall downlink data quantity, through sampling, and also to reduce the burden on the ground processing facility. In the conversion of data to geophysical meaning, a simplified conversion scheme might be implemented onboard for real-time delivery of information direct to local users (from the spacecraft). The four delivery/processing modes are then user peculiar.

PROCESSING FLOW

A brief overview of the information delivery system processing flow is described below and illustrated in Figure 1 prior to characterizing each of the user modes. Location and calibration is recommended for onboard processing since there is no controversy and it is easily accomplished. Conversion to geophysical meaning, merging (with other sensors aboard), and blending (introducing data from other sources) may be accomplished onboard the satellite or at the ship and rig for real-time (direct) users. These same processes could be accomplished in near real time by user agents. The long-term archiving and accessing function would normally be handled by a project or the potential user agency. Spreading, hindcasting, forecasting and other analysis would be undertaken in near real time by user agents like the weather services and commercial routers. Research users would carry out their analysis in non-real time using the archive as a complete data base for data/information at all levels. Decisions and displays can be made or provided at several processing levels. It is important to note that the hindcast-forecast processing provides a feedback loop to provide improvements to the entire system.

The “direct to local users” mode is generally for ships, rigs and coastal management organizations that are interested primarily in wind, wave and temperature data. They will receive and display just sufficient information on APT (Automatic Picture Transmission) type terminals to make decisions. They may store information around their local area (several hundred to a thousand kilometers) for several delivery periods (e.g., 3 hours apart) and display the progressing features in order to make simple forecasts/decisions as to probable weather conditions, waves and fish location/movement. Their bit rate receipt on any one transmission would be about 2.4 kb/s, received as the spacecraft travels by overhead (i.e., during their view period from horizon to horizon for several minutes of receipt). The number of direct local users may run into the thousands.

Regional centers and user service organizations, of which there may be a dozen or more, would receive their data directly in real time or indirectly via relay satellite for targets of opportunity. Although their range of interest is limited to their region, the information interest is much broader, including surface and topographical feature extraction and multispectral comparisons. These centers and user service organizations would process and respond quickly (in near real time) to provide advisories and maps to decision making end users such as ships and offshore rigs. They may also provide regionally extracted information to an archiving facility.

Global users have all the data collected by the spacecraft relayed to them in real time. They also receive data from other satellites and assimilate the data, providing current information (“nowcasts”) and forecasts for users in near real time; there may be several global users.

The research and archiving mode receives and processes all data at one or more centralized centers from all ocean satellites and prepares this data for archiving and accessing, for measurement validation experiments, and for economic verification experiments. This mode also utilizes a dynamic assimilator (see Figure 2) for generating geophysical information and climate data records for the archiving facility. The archiving facility may also contain images and sensor data records. The archived information and records will be used by governmental, university and private research organizations. The central processing center (technology transfer processing facility) may be operated by the appropriate operational Federal agency.

The characteristics of the four data delivery system modes are summarized in Table I. Note that all but the research or archival mode are real time and that each mode has its own personality. The preliminary characteristics of a needed dynamic-data-assimilator storage and hindcast system are shown in Figure 2.

The individual user oriented processing and delivery modes of Figure 3 can thus be coalesced into the overall system shown in Figure 4.

NEEDED DEVELOPMENTS

Critical development is needed in several areas in order to insure that the total marine information system works together. Twenty-one specific issues are listed below, requiring development in both software and hardware.

Table I. Data Delivery Processing System Modes

Direct to Local User Mode	Regional Center Mode
Real-Time Line of Sight Only	Real-Time Line of Sight or Relay
Direct to Ships, Rigs, etc.	Target of Opportunity
Advisories or Annotated Maps	Direct from Spacecraft
Immediate Decisions	Full or Partial Data Set
2.5 to 250 kb/s or Analog Equivalent	Coarse-to-Fine Resolution
Low Cost Terminals	10 kb/s to 10 Gb/s
Global Forecasting Data	Regional Forecasts
Real Time	Relay to Local Users
All Relayed to Central Site	Research Archival Mode
Dynamic Data Assimilation	Non-Real Time
Coarse/Medium Resolution	All Data as Available
10 kb/s to 10 Mb/s	Dynamic Archiving/Accessing
Global Forecasts	10 Mb/s to 10 Gb/s
Relay to Users	

1. Techniques for limiting access to telemetry links (mechanisms for limiting receivers to those who paid for privilege).
2. Simulation of onboard location/bias correction/coding for low rate data (buffering requirements, engineering information availability, implementation feasibility).
3. Valid bias correction and geophysical conversion algorithms (may be otherwise funded under discipline or sensor subprogram elements).
4. Dynamics data assimilation (strips data assimilation-dynamic merging/blending).
5. Dynamic nowcasts (spreading to fill temporal and areal gaps to produce best guess of total world, provide climate archival averages).
6. Real-time SAR (Synthetic Aperture Radar) image correlation (quick look to full swath/full resolution; ground to full onboard).

7. Real-time color/thermal image retification/calibration (quick look to full swath/full resolution; ground to full onboard).
8. Multispectral color/thermal image comparisons and information extraction (chlorophyll, turbidity, currents, sediment transport, etc.).
9. SAR point source information extraction (ships, icebergs, rigs).
10. SAR linear pattern information extraction (waves, pressure ridges, ice edge).
11. SAR areal pattern information extraction (currents, upwellings, shoals, pollutants, etc.).
12. Altimeter real-time information extractor (current bulge, tide, wave heights).
13. Standarized formats and displays.
14. Low cost user receiver/processor/display terminals for advisories (MARISAT link compatible and beyond).
15. Low cost user receiver/processor/display terminals for low data rate mapping with advisories (APT compatible and beyond).
16. Low cost user receiver/processor/display terminals for full color thermal analysis with overlays (HRPT compatible and beyond).
17. Low cost user receiver/processor/display terminals for SAR imagery.
18. Dedicated TDRS (Tracking and Data Relay Satellite System) relay link (TDRS follow-on with lower cost interfaces and multiple downlinks).
19. Low cost dissemination techniques.
20. Low cost archiving and accessing techniques.
21. Now forecasting-processing capabilities.

CONCLUSION

The need for an ocean monitoring system exists. Many of the capabilities are available, and programs like SEASAT-1 are establishing feasibility. What is required is a national purpose with multiagency interest (currently evident in the NOSS program), as well as the cooperation and continued interest of marine industrial users. Multiagency funding and industry involvement will be essential to achieving the level of development needed to meet the Advanced Marine Information Delivery System requirements. In addition to the information to be provided from multiple satellites, which will be monitoring both the ocean and atmosphere, the delivery system should include data of conditions observed from aircraft and surface systems as well as forecasts derived from the best available ocean and atmospheric modelling sources. The real benefits of providing globally dense marine information to end users can only be achieved by providing those users the means to receive the information rapidly and the means to rapidly assimilate it.

ACKNOWLEDGMENT

The research described in this paper was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under NASA Contract No. NAS7-100.

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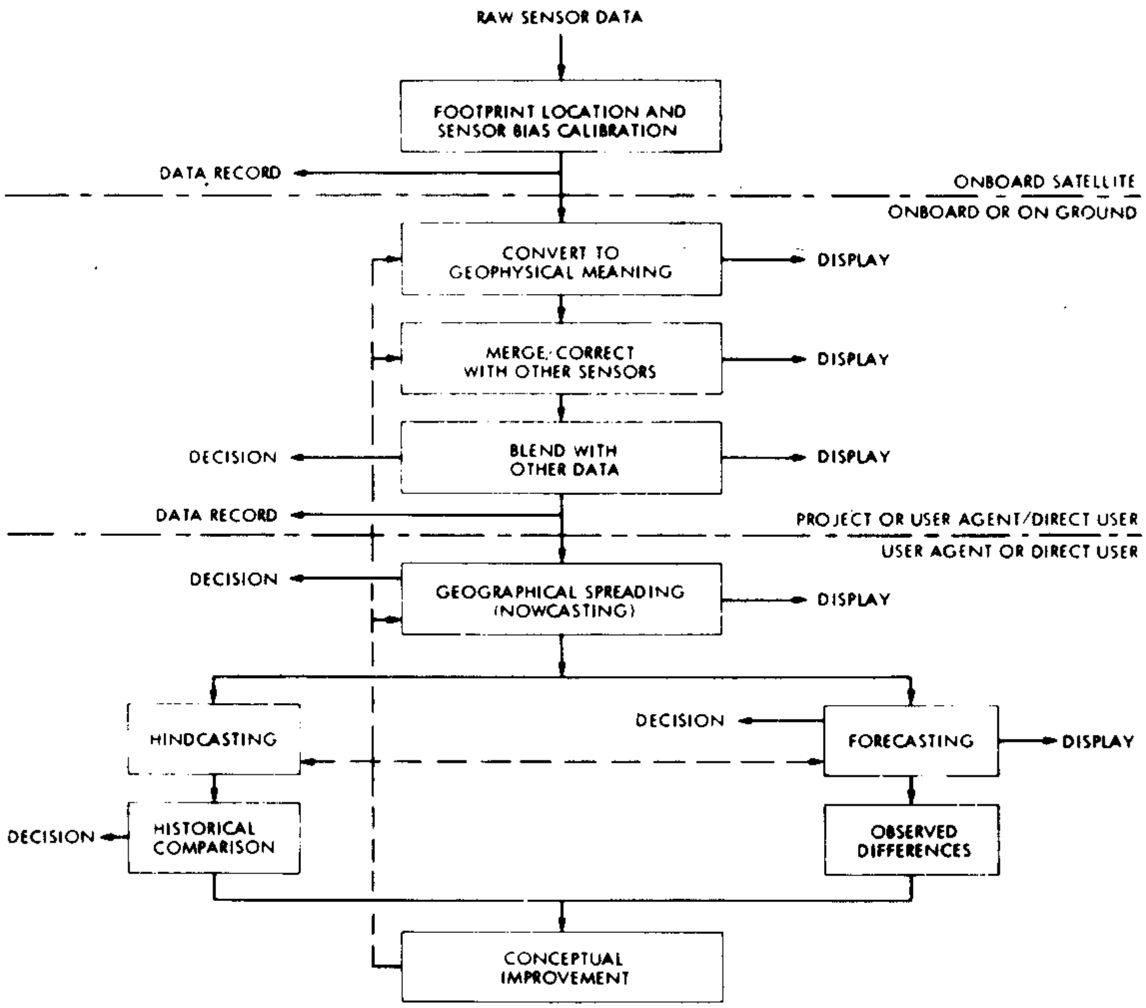

Figure 1 - Information Delivery System Processing Flow

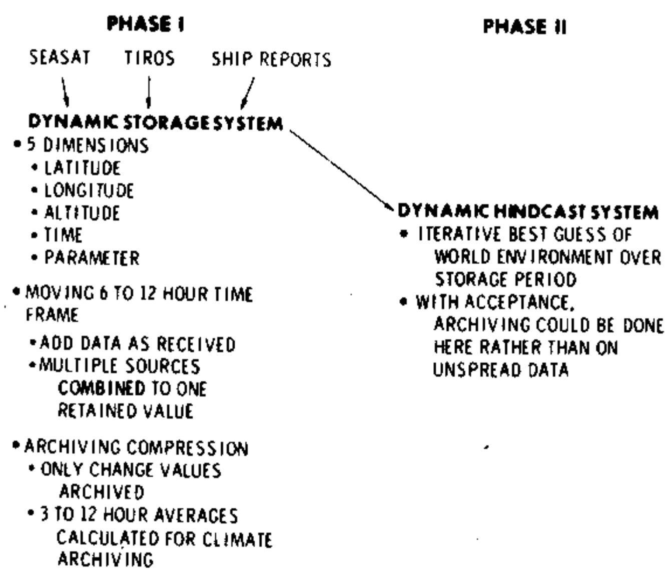

Figure 2 - Dynamic Data Assimilator

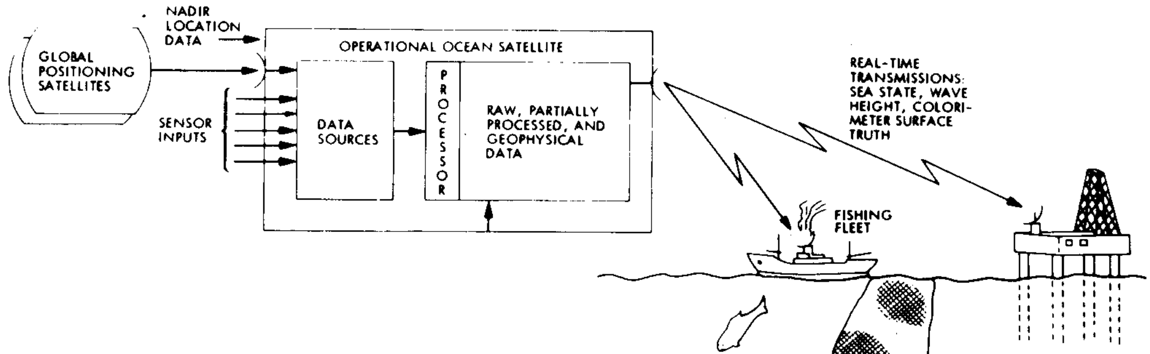

Figure 3a - Individual User Oriented Processing/Dissemination Modes; Direct to User Mode

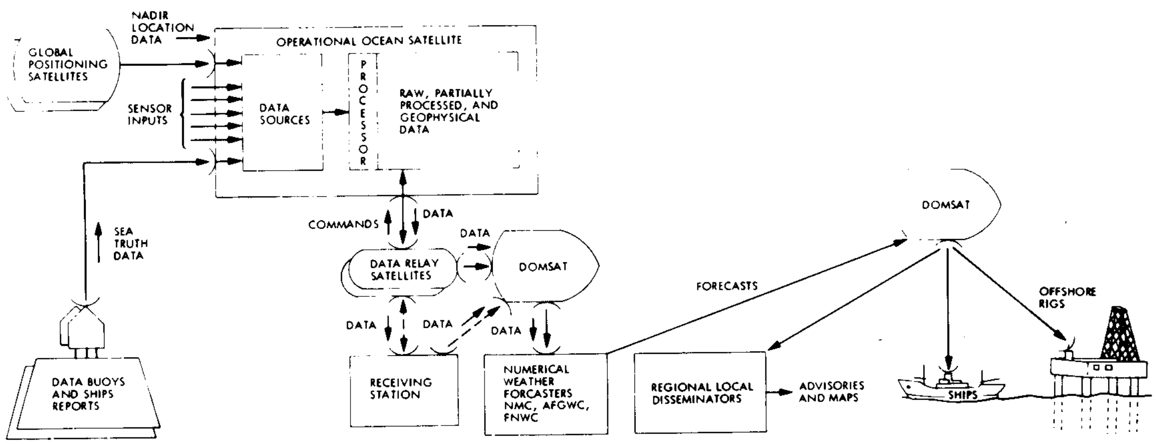

Figure 3b - Individual User Oriented Processing/Dissemination Modes; Regional/Local User Mode

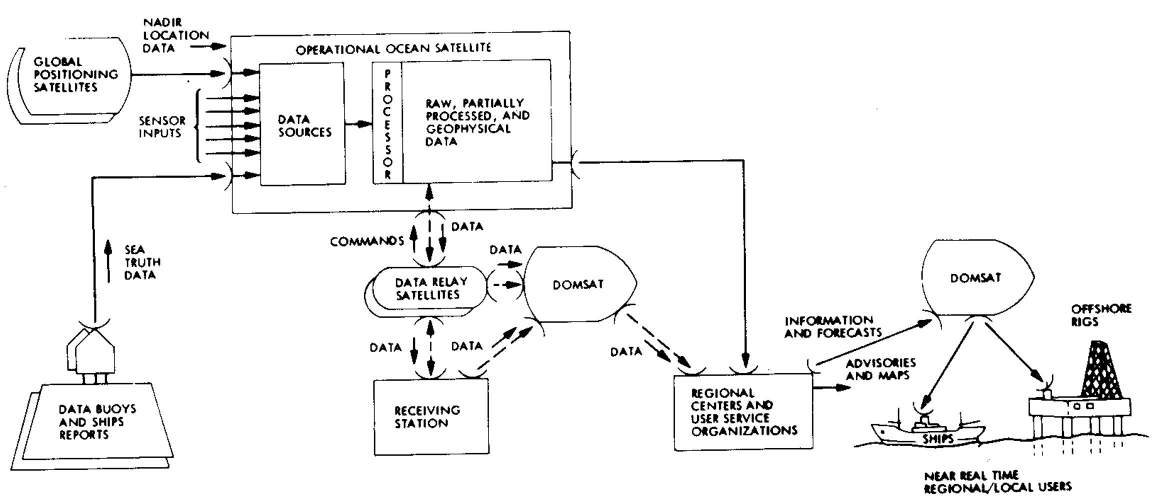

Figure 3c - Individual User Oriented Processing/Dissemination Modes; Global User Mode

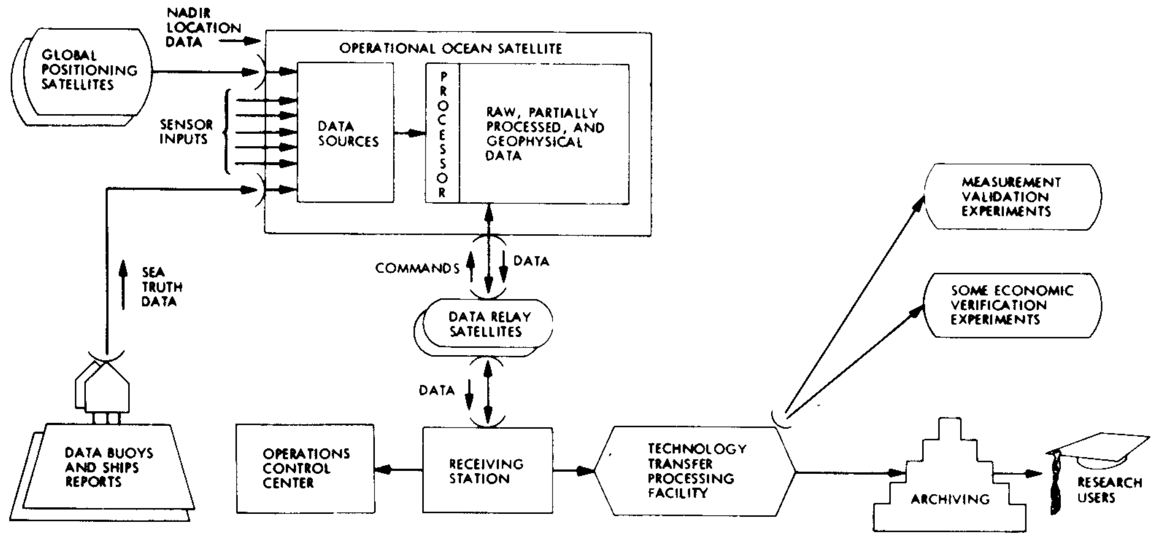

Figure 3d - Individual User Oriented Processing/Dissemination Modes; Research User Mode

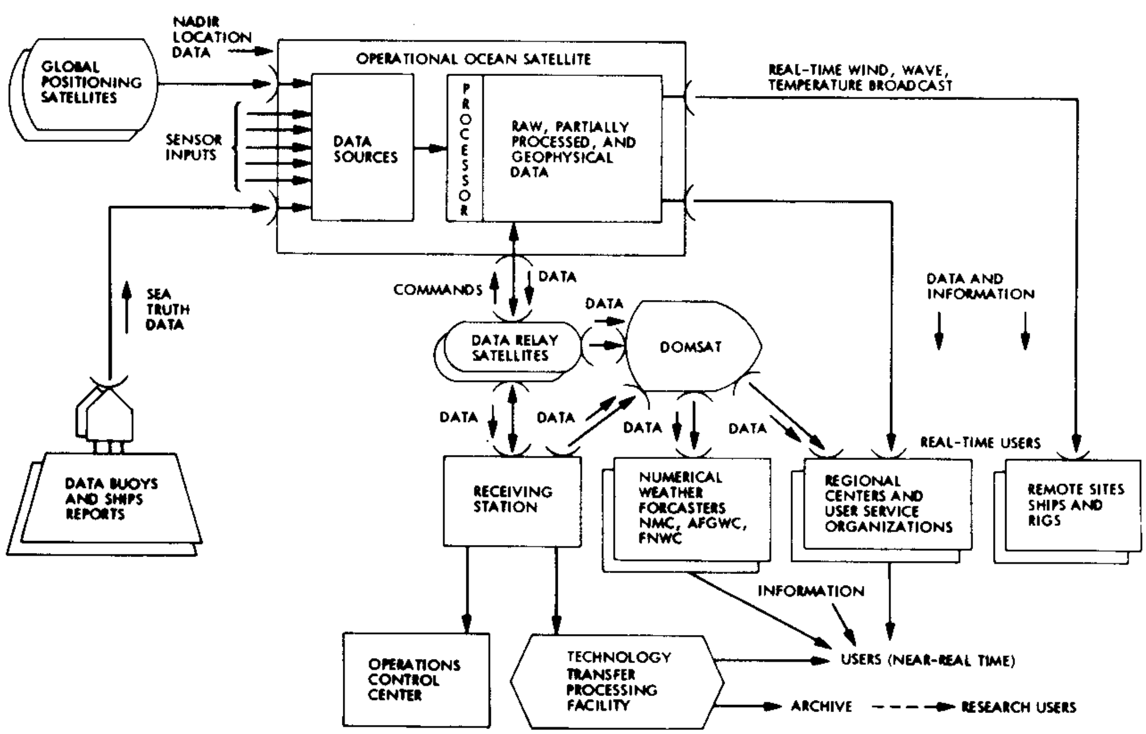

Figure 4 - Marine Information Delivery System