Applications of Seasat to the Offshore Oil, Gas, and Mining Industries

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Seasat-1, a NASA satellite launched in June 1978, was designed to provide synoptic, repetitive data on the ocean areas of the world. Seasat-1 carries five sensors, four with all-weather capability. The principal data products will be surface wind speed and direction, wave height, and sea surface temperature. Other information provided will include wave length, wave direction, ice characteristics, and ice movement. One of NASA's objectives is to demonstrate Seasat capability and to permit evaluation of the practical value of the data to offshore industry users. Thus, this paper describes several industrial experiments planned by NASA during the operation of Seasat-1. These experiments are to be conducted with several industries, including oil, gas and mining organizations which will be investigating the usefulness of the data. Applications include 1) improvements in weather and wave forecasts, 2) improved knowledge of past wind and wave statistics for setting design requirements, and 3) monitoring ice formations, breakup, and movement in arctic regions. A number of geographical areas are being examined, including the Beaufort Sea, Labrador Sea, Gulf of Mexico, U.S. East Coast, West Africa, Equatorial East Pacific, Bering Sea, and the North Sea. These investigations are being done jointly by NASA and the participating industrial organizations. NASA will provide the appropriate Seasat-derived data, and the industrial organizations will compare these data with their own observations and estimate the usefulness to offshore operations. Results will be available to the entire offshore industry and to the general public once the evaluations are completed.

Introduction

IN June 1978, NASA launched Seasat-1, the first satellite dedicated primarily to measurement of the characteristics of the ocean surface. It is also the first satellite to make extensive use of microwave sensors. With the exception of the synthetic aperture radar (SAR), the sensors provide global coverage (excluding the extreme polar regions) on a 36-h repetitive cycle. With these instruments, Seasat can provide global coverage of such parameters as 1) significant wave height, 2) ocean currents, 3) surface wind speed and direction, and 4) sea surface temperature. In addition, the SAR can provide information (over restricted areas) on ice characteristics and movement and on wave length and direction. Because of orbit characteristics, SAR coverage will be most effective in high latitudes. It can, however, be used on other ocean regions and for observation of land areas as well. It also may be possible to detect internal waves and to develop a better understanding of ocean circulation. Thus, Seasat will cover many natural phenomena of importance in offshore oil, gas, and mining operations.

Preliminary estimates of Seasat benefits were made during 1974-1975.[1] In the case of offshore oil and gas, these showed that benefits during the years 1985 to 2000 would range from $214 to $344 million (1975 dollars). In addition, $96 to $288 million should accrue to arctic operations, most of which are associated with the oil and gas industries. No estimates were made in that study for the deep ocean mining industry, but the benefits should be substantial.

In economic terms, these industries are highly significant. The offshore oil and gas industry represents the largest single economic activity in the world's oceans.[2] The value to the U.S alone was estimated at $3.2 billion in 1973, with projections of $18.9 billion by the year 2000. Ocean mining activities are projected to reach $2.5 billion by the year 2000; the U.S. mining industry alone will have spent some $300 million before the first commercial operations begin.[3]

Throughout the Seasat program, NASA has devoted substantial effort to getting potential users involved. From the early conceptual phases to the present, there has been in existence a users' committee, consisting of representatives from government, the academic community, and industry. This committee has been a major influence in bringing the Seasat program to its present configuration.

Although Seasat-1 is a "proof-of-concept" satellite, NASA included as one of its goals the actual demonstration of the utility of Seasat data to operational users. To accomplish this, NASA is setting up experimental programs with selected potential user industries. Thus, NASA is exposing satellite performance to the outside user prior to full verification of capability. However, this early evaluation by users can contribute to the verification and to a better understanding of the requirements of an operational system. Through these demonstrations, NASA plans to transfer its technology directly to the user, who, in turn, is expected to provide evaluation of Seasat capability and its impact on its operations.

In addition to the offshore industry demonstrations, which are the subject of this paper, there are a number of other similar activities that will be undertaken in the same period. These include activities in the areas of marine resources, marine transportation, fisheries, and other biotic resources. If the experimental results justify it, an operational Seasat may be orbited in the early to mid-1980's.[4] This operational system probably will have multiple satellites, as well as improvements in sensors and data-handling capability. This paper covers the offshore oil, gas, and mining industries' experimental plan for verification of Seasat benefits to these industries and provides some description of Seasat capabilities as they apply to the industries' requirements.

Objectives of the Offshore Industry Verification Experiments

These experiments are designed to 1) assist in verification of the capabilities of the Seasat-A sensors, 2) permit potential

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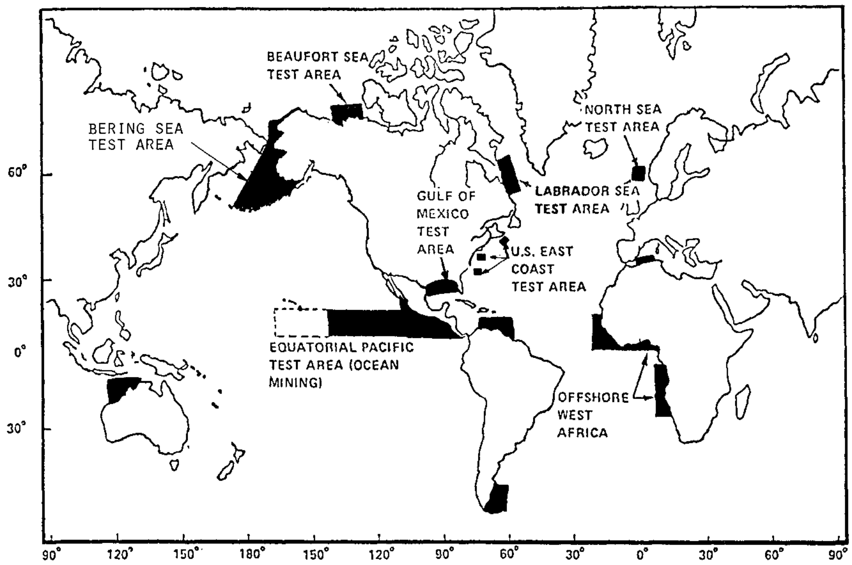

Fig. 1 Approximate locations of offshore oil, gas, and mining industries test areas for the Seasat-1 verification experiment.

users to evaluate the practical value of the data in their activities, 3) begin the process of transferring the technology to the user community, and 4) assist in developing the requirements for an operational system for monitoring the oceans from space.

Experiments and Participants

Table 1 summarizes the verification experiments, showing the industry organizations that are participating and their geographical areas of interest. Figure 1 shows the approximate location of the proposed test areas.

Description of Seasat-1

The total system to be used in the experiments consists of a number of components, from the instruments on the spacecraft to the mechanisms for delivering data at the user's facility. These system components are described briefly below. For more complete details, see Nagler and McCandless,[4] NASA's system description,[5,6] and Apel and Siry.[7]

Instruments

Radar Altimeter

The altimeter has two functions. First, it monitors the average wave height from 1 to 20 m along a narrow swath directly below the satellite path. Second, by measuring changes in the satellite-to-sea-surface distance, it can detect variations in mean sea level (geoid), tides, storm surges, and currents. This is an improved version of the altimeters flown on Skylab and GEOS-3.

Radar Scatterometer

The scatterometer acts as an anemometer for measurement of surface wind speeds and wind direction. The instrument covers two 500-km swaths, one on each side of the nadir. The Seasat-1 scatterometer is an improved version of the Skylab instrument. Global coverage (95%) is possible every 36 h.

Microwave Radiometer

The scanning multichannel microwave radiometer (SMMR) is a passive system that measures the emitted electromagnetic radiation in selected regions of the spectrum. It has five separate frequency bands and performs four functions: 1) measurement of the surface temperature, 2) measurement of foam brightness, which can be converted into a measurement of wind speeds, 3) detection of ice age, extent, concentration, and dynamics, and 4) atmospheric corrections for the radar altimeter and scatterometer. Similar instruments were flown on Skylab, Nimbus 5, and Nimbus 6. Global coverage (95%) will be obtained every 36 h.

Visible and Infrared Radiometer

The V/IR provides clear-weather surface temperature data, cloud coverage patterns, and corroborative images of ocean and coastal features. The instrument is a modified version of those flown on the National Oceanic and Atmospheric Administration (NOAA) operational satellites.

Synthetic Aperture Radar

The SAR is an instrument that has not flown previously in a satellite. It provides imagery of ocean features such as ice fields, icebergs and leads, slicks, wave and current patterns, and coastal conditions. The SAR is capable of penetrating clouds and nominal rain.

Data System

Data from all of the instruments except the SAR will be recorded onboard the satellite as the measurements are made. These data then will be transmitted to the ground when the satellite passes over one of the Seasat ground stations. The data then will be retransmitted to two locations: 1) NASA Goddard Space Flight Center (GSFC) and 2) the Navy's Fleet Numerical Weather Central (FNWC) at Monterey, Calif. At GSFC, the data will be combined with precise orbit information (obtained some days after the data are taken) and sent to the Jet Propulsion Laboratory (JPL) at Pasadena, Calif. There, the data will be archived to provide the major permanent repository of Seasat data. Some of the data from this file will be available to the public through the NOAA Environmental Data Service.

The use of the data at FNWC is rather different. The raw sensor outputs first will be converted to geophysical units (wind magnitudes, temperatures, etc.), and then the geophysical data will be used, along with conventional data sources, in preparation of FNWC's standard analysis and forecast products. Both the Seasat-1 data themselves and the analysis and forecast products based on the Seasat data will be sent over telephone lines to participants in the verification experiment program. In this near-real-time data system, data should become available to users within something like 6 h after the data are taken.

The SAR data will follow a different course. Because of the very high data rate produced by the SAR (10^6 bits/s), it is not practical to store the data on board, and so the data will be transmitted to the ground as they are being taken. This means that the SAR can be used only while the satellite is in view of a

Table 1 Summary of offshore industry Seasat verification experiments

Test area/no. of companies[a]	Objectives	Data requirements	Applicable Seasat-A instruments[b]	Industry surface truth parameters
Beaufort Sea 125°-140°W offshore to 72°N APOA: 3 companies AOGA/ARC: Several	Improve meteorological forecasts Improve wave forecasts Monitor ice dynamics Ice forecast	Ice regime, breakup, growth and dynamics Wind Waves	V/IR, SMMR, Alt., SAR, (IR) Scat., SMMR (Alt., SAR) Alt. (SAR)	Ice condition Meteorology Wind Wave spectra (height, period, direc.)
Labrador Sea 150 miles offshore W 45°-65°N EPOA: 2 companies	Improve wind wave forecast Improve freezeup & breakup forecast Locate icebergs Provide historical data for design	Sea ice Icebergs Sea state Current speed Current position	SAR, Alt., SMMR SAR Alt., SAR (Scat., SMMR, Vis.) Alt. (SAR, Scat.) IR, SMMR, Alt., SAR	Waves, (height, period and direction) Wind speed/direction Iceberg size, position Sea ice type, leads, roughness ridges Iceberg (in pack ice)
Gulf of Mexico Primary: 88°-96°W 27°-30°N Secondary: 80°-97.5°W 26°-30°N AGA/PRC: 25 companies Getty Oil, Texaco	Improve design criteria for pipelines Validate sensor data Correlate surface data with subsurface data Improve accuracy of prediction of severe storms	Wind Waves and swells Current Surface temperature Water vapor Tides Extra tropical/ tropical storms	Scat., SMMR (Alt., SAR) Alt., SAR (Scat., SMMR, Vis.) Alt., IR, SMMR, SAR (Scat.) IR, SMMR (Scat., Alt.) SMMR Alt. Alt., SAR, Scat., V/IR, SMMR	Wave Spectra Wind speed/direction Water temperature Air temperature Water vapor
U.S. East Coast 70°-75°W 38°-43°N CONOCO: operator for several companies	Improve wind-wave forecast (real time data) Provide historical ocean/meteor. data to determine applicability for operations and design criteria determination and model calibration	Waves Wind Surface currents Tide Temperature Storm track	Alt. (SAR) Scat., SMMR (Alt., SAR) Alt., IR, SMMR, SAR (Scat.) Alt. IR, SMMR, Alt. (Scat.) Alt., SAR, Scat., V/IR, SMMR	Wave height/spectra Wind speed/direction Sea/air temperature Tide Current profile
Offshore West Africa 0°-12°N and 18°-35°S up to 2000-m contour W Getty: operator for several companies, and Texaco	Provide historical data for design Provide near real time wind, wave and current data	Waves Wind Current speed/ direction Surface temperature	Alt. Scat., SMMR (Alt.) Alt., IR, SMMR V/IR, SMMR (Scat., Alt.)	Water temperature & salinity Waves (height, period, direction) Wind speed/direction Current speed/ direction, temperature
Equatorial East Pacific Ocean Primary: 110°-150°W 5°-20°N Secondary: 110°-180°W 5°-20°N Ocean Mining: 4 consortia	Reliable prediction of sea and atmospheric conditions at 12, 24, 48 and 72 h	Storm genesis, location and path Wave/swell Wind Cloud cover Precipitation Temperature Currents	All instruments except SAR[c] Alt., SAR (Scat., SMMR) Scat., SMMR Vis. SMMR (Alt.) IR, SMMR (Scat., Alt.) Alt., IR, SMMR (Scat.)	Wave height/spectra Wind speed/direction Sea/air temperature Current
North Sea 56°-62°N 5°W-5°E CONOCO and Union Oil	Improve on design of structures Determine utility of data in operations	Waves Wind Temperature Storm	Alt. Scat., SMMR SMMR All	Wave height/spectra Wind speed/direction Sea/air temperature Tides & current
Bering Sea 54°-70°N 157°W to US/USSR border AOGA/Bering Sea Ice Task Force	Assess SAR imagery for assisting offshore operations in ice	Ice conditions type, distribution and dynamics	SAR and SMMR	Visual observations of ice and aerial photography

[a] Acronyms used include the following: APOA: Arctic Petroleum Operators Association; AOGA/ARC: Alaska Oil and Gas Association/Arctic Research Committee; EPOA: Eastcoast Petroleum Operators Association; AGA/PRC: American Gas Association/Pipeline Research Committee; CONOCO: Continental Oil Company.
[b] Parentheses denote secondary applications. Abbreviations used are as follows: V/IR visible and infrared radiometer; SMMR = scanning multifrequency microwave radiometer; Alt. = radar altimeter; SAR = synthetic aperture radar; Scat. = radar scatterometer; and Vis. = visible.
[c] SAR will not operate except in areas near U.S. and Canadian shores.

ground station equipped to receive the SAR data. At the ground station, the raw SAR are stored on tapes, which are sent to JPL for processing. At JPL, a portion of the data will be processed into images. These should be available within two to three weeks after the data are recorded.

Data Products

There will be many users of Seasat-1 data, and the range of products which will be prepared is correspondingly wide. Some of the principal characteristics of the planned data products are suggested below.

Near-Real-Time Data

The products that will be prepared by and disseminated through FNWC are of two types: the Seasat-1 data themselves, and the derived analyses and forecasts. The Seasat-1 data will be sent out in tabular form, e.g., sea surface temperature, together with the geographical location and time at which they were taken. The analysis and forecast products will be sent as maps showing lines of constant pressure, lines of constant temperature, wind directions, etc. Wave spectra will, however, be sent in tabular form.

Non-Real-Time, Non-SAR Data

The archive of non-SAR data at JPL will consist primarily of time- and position-tagged raw instrument outputs. Only selected portions will be converted to geophysical units. The raw data could be made available to users, however, as could any portions of the data which have been converted to geophysical units. In both cases, the data would be in digital form, stored on tapes.

SAR Data

SAR data will be collected only on a limited basis. The SAR will make some 1500 passes/y, although only 260 of these passes are scheduled for reduction to images. Each pass will consist of 10 min of observation, representing a ground track coverage of 100 × 4000 km. The images can be made available in digital form on tape, as prints, as positive transparencies, or as negatives.

Applications of Seasat-1 Data

Seasat-1 will be providing types and amounts of data, most of which never before have been available. It is expected that offshore industry users will develop uses for the data which cannot be foreseen now, but a number of uses have been identified in preliminary planning and will be tested during the experiment period. Two major types of applications are planned: 1) use of historical data for designing offshore structures or for long-range operational planning, and 2) use of weather and wave forecasts to assist in making operational decisions. There is a third potential area that could develop later: use of Seasat data to assist in geophysical exploration.

In these types of applications, the new capabilities of Seasat are quite valuable. The global all-weather coverage permits collection of environmental information in those remote and/or inhospitable ocean areas that are of increasing interest as the search for oil, gas, and mineral resources widens. In some of these areas, human activity has been minimal, so that there is little information. In other cases, cloud cover is quite common, so that other satellite systems are not highly effective. Some of the specific data applications are suggested below.

Waves and Wave Forecasting

Historical wave data will be collected and stored for generating wave statistics. These will be useful for platform design, pipeline laying and design, and ocean mining operational planning.

Positioning of mobile rigs, installation of fixed structures, hole re-entry, salvage operations, and resupply are executed best when winds and waves are low. Prediction of hurricane-produced winds and surges is required to shut down operations when necessary. The primary parameters involved in wave forecasting include storm surge/setup, wave spectra, surface winds, and wind stress. Altimeter wave-height observations, along with the scatterometer and microwave radiometer data on winds, will be used to verify existing models or improve on the accuracy of wave forecasting. Several organizations, such as NOAA and FNWC, expect to have improved spectral wave forecasting models in operation by 1978. Their extension to a truly global scale will depend upon the establishment of satellite techniques for measuring surface winds.

Winds

Surface wind information generated from Seasat will provide a major new data source for meteorological forecasting. It is expected that this will be particularly significant in certain regions in which limited weather data are available. On a historical basis, wind statistics will be significant in the design of offshore facilities such as fixed platforms, mobile rigs, mining ships, salvage equipment, and ocean dumping barges.

Weather Forecasting

The global coverage of surface wind and temperature will provide a major new resource for weather forecasting. Since the Seasat data are different from conventional data sources in spatial extent and in timing of the measurements, some adaptation in analysis and prediction models will be required. Ultimately, new and much more accurate models may be developed, but this is beyond the scope of the Seasat experiment program. FNWC will be adapting their analysis procedures to accept the synoptic Seasat data and distributing the resulting products to participants in the program. The impact of wind data on global 36- and 72-h forecasts will be assessed by FNWC, NOAA, and Canada's Atmospheric Environmental Services. Comparisons between forecasts and observations could be made available to experimenters in specific areas. Offshore industry experimenters will be comparing the Seasat-based forecasts with their own observations and experience.

Hurricane Forecasting

Seasat instruments, especially the scatterometer, the SAR, and the altimeter, should make possible better understanding and prediction of hurricanes. However, this will depend also on improved modeling, which may not be available during the experiment period but is promising for the longer term. The SMMR should give a rather rough picture of the wind field.The SAR can penetrate the hurricane and provide much more detailed information on waves, but complete, repetitive SAR coverage will not be possible with Seasat-1.

Surface Temperature

Measurement of surface temperature also will be useful in meteorological forecasting. In northern latitudes, information on air and water temperatures is needed to predict icing on structures.

Sea Ice Mapping and Statistics

Monitoring of iceberg location and movement is extremely important for drill rigs and shipping. Mapping of ice leads, floes, and movement is critical for ship navigation and extension of the operating season. SAR and microwave imagery will be used to update and improve the analysis of sea ice in the Beaufort, Bering, and Labrador Seas.

Ice Dynamics

Studies by the Surveillance Satellite Project Office of Canada's Department of Energy, Mines and Resources, along with those of NOAA,[8] will involve 1) determining the quantitative accuracy and detail with which sea ice can be mapped employing SAR and SMMR data, 2) assessing the capabilities of SAR and SMMR to collect the required all-weather temperature data for sea ice dynamics measurements, and 3) applying Seasat-1 capabilities to classification of ice types and distribution of features. Monitoring of ice dynamics during freezeup, including growth and progression of landfast ice and the southerly migration of the polar pack, is important in assessing the ice loading on fixed platforms.

Experiment Program

As mentioned earlier, Seasat-1 was launched in June 1978. It is expected that the distribution of data to the offshore industry users will begin late in 1978, after a period allotted to validation of the instruments and the data system. The experiment period will last for approximately two years. As of this writing, all hardware and software required to support the experiments is either complete or in late stages of preparation. Planning for the experiments is nearly completed, and NASA and the users are working out details of agreements on the responsibilities of the various parties. At the end of the experiment period, the offshore industry participants will provide NASA with a report covering the experimental activities and evaluating the Seasat data as to validity, as well as to significance in assisting offshore industrial activities.

It should be emphasized that there will be many activities using Seasat-1 data in addition to the offshore industry uses reviewed here. There will be a number of instrument validations, scientific investigations, and commercial applications such as in marine transportation and fisheries. In all of these activities, NASA is placing an unusual degree of reliance on other organizations to assess the data, whether that assessment is in technical, scientific, or practical terms.

Conclusions

In recent years, several satellite systems have proved their usefulness in providing data on a global basis with speed and cost advantages over existing systems. Seasat-1 is the first satellite dedicated to ocean monitoring. If it is successful, it is expected that more advanced versions will follow, leading to an operational system in the mid-1980's.[5] Seasat-1 is the first step, then, to a major new capability for understanding, controlling, and using the ocean environment.

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