



GAMBLE

Global Altimeter Measurements By Leading Europeans

Description of Work

Based on proposal EVR1-2001-00029

30 October 2001

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1 – Project summary

Earth-observing satellites designed to detect the changing nature of ocean surface features have made important contributions to climate change programmes. The great advantage of polar-orbiting satellites over more conventional measurements is their extensive and uniform global coverage, completing some 14 to 15 orbits per day over the rotating Earth. But a single satellite is necessarily severely limited in its sampling of fast moving events. To take one example, the very precise Topex/Poseidon takes 10 days to complete its orbit pattern leaving gaps of up to 300km between adjacent profiles. This grid determines the size of features which may be monitored.

Over the last decade Europe has been particularly active in the use of satellites to measure ocean surface conditions. ESA's first EO satellites, ERS-1 and ERS-2, are equipped with sensors primarily designed for ocean monitoring, and Topex/Poseidon is a joint venture between France and the USA. The European space industry has developed precise, all-weather radars that measure surface currents, waveheights and wind speed. A more recent development in Europe has seen the emergence of very small satellites (nanosats and microsats) which in a number of missions have already demonstrated their ability to carry special-purpose sensors.

Europe is therefore well-placed to implement a system of fast sampling using a constellation of comparatively inexpensive, dedicated small sats to work in conjunction with the 'premium' research platforms Envisat and JASON (successor to Topex/Poseidon). Such an initiative would place Europe in pole position providing an innovative new technology - the first major EO breakthrough in over 2 decades. The benefits to the space industry would be matched by the socio-economic benefits to Europe providing a leading role in monitoring global climate change. From an operational standpoint the seas, which are presently used to transport over 90% of goods in and out of Europe, remain hazardous and claim many thousands of lives each year, as well as causing substantial damage and delay to ships. Last year, marine insurance losses in weather-related incidents totalled \$2.5 billion.

It becomes imperative to focus the expertise that resides in European institutes and attempt to identify the cost/benefits of different mixes of small satellites in improving the effectiveness of the larger, solitary missions.

The benefits to science stem from sampling the ocean's surface at a rate more nearly in tune with observed rates of change. The behaviour of the ocean and the way it transports energy across the globe is one of the most important factors in determining climate change. Yet, at present, it is seriously under-sampled.

The GAMBLE Workshops are designed to bring together the skills within the European space industry - in space engineering, in satellite tracking, signal processing, and data interpretation - while benefiting from advice from a broad 'user' community drawn from both academic research and daily marine operations.

The aim is to design future ocean space systems in Europe that respond directly to the needs of a wider community than at present. After over 2 decades such a 'user-led' approach represents a milestone in advancing European expertise.

2 – Scientific / technical objectives and innovation

There exists within Europe a complete range of expertise in all aspects of satellite altimetry, from the manufacturing of hardware and precision tracking systems to calibration and validation procedures through to processing and data distribution. The aim of this Thematic Network is to achieve a greater degree of European unity by providing a focus for this experience in a series of Workshops and Study Groups designed to discuss and evaluate ways in which future constellations of small satellites could work in tandem to extend the global coverage of high- precision altimeter missions (such as JASON and Envisat).

The converse problem - the means by which the products of these science-driven missions could be integrated and made more readily available to meet the requirements of daily marine operations for information on winds, waves and current - will also be addressed in the series of Workshops.

Although the Workshops will follow each other in a logical sequence, the consequences of every major option that emerges will be presented to, and discussed by, a Steering Group composed of representatives from both the climate research and marine operations community. This form of ongoing interaction with potential users of the satellite combinations under construction will ensure that practical solutions are proposed that satisfy the requirements and capture the imagination of a wider community. The usefulness of the GAMBLE Workshops will be measured by their influence on the design of the satellites subsequently deployed.

In summary, the main objective is to investigate how to maximise the synergy between European satellite missions **before** launch. This by itself makes GAMBLE unique in the annals of planning future satellite mission over the oceans and represents a notable first for Europe. The immediate users of GAMBLE results will all be members of the European Oceanographic community (scientific and commercial). Ultimately all European Citizens will benefit, through improved efficiency in offshore operations, more effective use of money spent on Earth Observing Satellite missions, and improved knowledge of ocean climate.

BACKGROUND

The remarkable precision and versatility of satellite-borne radar altimeters, as demonstrated in a succession of missions over the last 15 years, has led to a number of space agencies announcing plans to continue altimeter observations of the ocean surface into the foreseeable future. The altimeter's ability to detect changes in surface height at the sub-decimetre level makes it one of the most powerful tools available to the ocean climate research community. The impact of the contribution of the US/French Topex/Poseidon satellite over the last 8 years is reflected in the decision to follow up with a similar mission, JASON, in 2001, and plans are already advanced for JASON 2 to be launched in the 2005/2006 timeframe. ESA's Envisat, the successor to ERS-2, is due for launch in July 2001 and will also carry a precise radar altimeter in its payload.

Another feature of the radar altimeter is its ability to estimate along-track surface wave height and wind speed by the analysis of the shape of the return echo. This has led to production of the first global maps of average and extreme values of significant wave heights and wind speeds based on direct measurements. Inter-annual variations in wave climate extracted from an almost continuous 15 years record also act as important indicators of a changing global climate.

It is this duality of roles - detecting ocean currents and global tides, while at the same time estimating the roughness of the sea surface in terms of significant wave height and wind speed - that makes the altimeter so versatile and ensures it high priority in future missions to monitor the

oceans from space. The archives of altimeter observations have already proved their worth to the planning of operations within the shipping and offshore industries as well as to naval exercises.

It is recognised, however, that the community of users of altimeter-derived information would be dramatically increased if the ocean surface could be sampled over the globe at a rate commensurate with the rate at which storms develop at sea, so that adequate warnings could be issued to shipping in near 'real-time'. This would necessarily require deployment of a constellation of altimeters, and the only way that this could be made economically viable is to deploy microsats. Technical studies have shown that although the limitations on size, weight and power would permit a special-purpose altimeter to function, there would be constraints on the level of support instrumentation that could be carried as opposed to that installed on the larger scientific platforms.

WHAT IS PROPOSED

The main objective of GAMBLE is to bring together in a series of Workshops all of the major players in Europe engaged in radar altimetry to investigate *before* the launch of independently-conceived missions how they could best be combined to maximise the synergy between them. Each mission is targeted principally at different communities - research scientists on the one hand seeking to understand the role of the oceans in global climate; ships, platforms, and forecasting centres on the other, needing to be updated at frequent intervals on the location and severity of storms observed from a constellation of polar-orbiting platforms. But each mission has something to offer the other. It would clearly be less productive if separate altimeter missions were planned within Europe without first discussing with the wider community of scientists and marine operators the scale of benefits to be derived from joint operations.

That, then, is the real purpose of GAMBLE. It may be asked 'Who is this study for? Who is the end-user?' The answer is the wider community of potential 'clients' in global research and commercial operations that is increasingly consulted by individual space agencies on the nature of their requirements. Ultimately, the designers of satellites aim to maximise the number of customers for their data. A criticism that has been levelled at ocean missions in the past is that they were over-concerned with the technology and paid scant attention to the requirements of marine communities outside scientific research.

Like their progenitor Topex/Poseidon, the JASON missions should provide the highest precision in the measurement of surface heights. But with coverage limited to a single, polar-orbiting platform (where the gaps between successive tracks in one day can reach over 3,000km), a major feature located between consecutive tracks (such as a storm) could go undetected. As we have seen the problem of inadequate coverage for real-time operations can only be addressed by deploying many small platforms, but the attendant constraints placed on the payload must then be circumvented.

The objective of GAMBLE is to have experts discuss and debate the different trade-offs that may be made. In effect the basic questions to be addressed are:

- i) Can a constellation of microsats extend the daily coverage of single-satellite missions such as JASON and Envisat so that ocean currents, eddies and tides are detected over a higher network of observations?
- ii) What modifications could be introduced, and at what cost, to the design of a predominantly wave-measuring microsat to make it more compatible with the larger, science-driven, ocean topographic missions?
- iii) How far can the greater precision of JASON and Envisat be used to 'calibrate' the less precise measurements of topography taken by the microsat-borne altimeters?

- iv) With what precision could (say) weekly global charts of major surface currents and eddies be issued for the benefit of general shipping?

These questions will be addressed in GAMBLE and possible solutions presented to a wider spectrum of end-users comprising scientists, forecasters and marine operators.

There is little doubt that the basic elements of the system - a single, precise altimeter observing small changes over a long time-frame, plus a constellation providing real-time observations of surface waves and winds to forecasting centres - will serve its own community of users well. But, with proper advance planning, we aim to investigate how useful it is to climate change programmes to build up also a reliable record of wave heights observed over the globe. And, how useful is it to commercial marine operations to gain frequent access to the location and strength of surface current boundaries. GAMBLE will define how feasible it is to generate such products, what compromises may have to be made - and at what cost.

INNOVATION

GAMBLE is a Thematic Network programme aimed at bringing together all of the relevant expertise in satellite altimetry that presently resides in Europe. The intention is to shape the design of future satellite systems and integrate separately-conceived missions to the greatest possible degree. Judging from the history of Earth Observation, any attempt at maximising the synergy between individual missions before launch is not just innovative - it is unique!

Polar-orbiting satellites have been measuring the state of the ocean surface to useful accuracies for over 2 decades. In particular the two Earth Observing spacecraft launched and operated by the European Space Agency were designed primarily for ocean surveillance, as is their successor, Envisat, to be launched in 2001. NASA pioneered this technology with the ground-breaking Seasat spacecraft and since then, (apart from ESA), France, Canada, Russia, Japan, India and others have launched ocean observing missions. There has been little planned synergy between these separate space initiatives although the output of ESA's radar altimeter carried on ERS-1 and ERS-2 were combined with the output of the more precise Topex/Poseidon sensor dedicated to the measurement of ocean topography - but only after launch.

The innovative element of GAMBLE is to stimulate discussion on the degree of overlap between missions primarily directed at continuing the programme of precise topographic measurements (JASON and Envisat) *and* the missions which plan to deploy constellations of microsats for the 'real-time' monitoring of storms at sea (GANDER, AltiKa and SWIMSAT). It is now generally agreed that the economies being introduced into Earth Observation will require a wider use of very small platforms. But, inevitably, compromises will have to be made to accommodate the much reduced size, weight, power, attitude control etc. of the microsats. The role played by the more familiar larger, science-driven satellites in working in concert with the constellation may prove to be critical. The innovation in this proposal is to hold Workshops to discuss *beforehand* the best options - not only with the experts in satellite altimetry but also with representatives of the main client groups - climate researchers, forecasters *and* marine operators.

The state-of-the-art in the measurement of sea surface topography by Jason will follow closely the performance of Topex/Poseidon. In ideal conditions changes of $\pm 1\text{cm}$ can be detected at a basin scale, but on any one day the gap between consecutive orbits at the equator is over 3000km. Jason is planned to track low-frequency signals and build up archives of 10-day sampling period rather than

for daily operations. Combining T/P with ERS data increases the space-time sampling and hence the resolution, especially useful for tracking short scale ocean signals. Merging Jason-1 and ENVISAT data will provide the same sampling characteristics. AltiKa, a post-ENVISAT altimetric mission, is presented as a complement to Jason-2 to detect short scales.

By contrast, GANDER is planned to provide the coverage required for daily, 'real-time' operation, but the GANDER platforms will not have the capacity to support the precise orbit determination and maintenance payload provided on JASON or ENVISAT. In principle, however, the GANDER microsats could host a simple GPS system. Alternatively, or in addition, adjusting GANDER on to Jason tracks may be an efficient and low cost way to reduce its orbit uncertainty. Other possibilities to be considered include the fitting of a laser retro-reflector on each microsat.

These are just some of the major issues to be debated before deciding on the final configurations. In this respect GAMBLE is breaking new ground in discussing and planning future missions capable of delivering the greatest benefits to the widest community of users. This is perhaps the most innovative enterprise in satellite altimetry since the launch of TOPEX/Poseidon 9 years ago.

INFORMATION ON SATELLITE MISSIONS

Timetable of missions to be considered by the GAMBLE network

Confirmed	JASON-1	Launch 2001	Operational 2001-2006
Confirmed	ENVISAT	Launch 2001	Operational 2001-2006
Proposed	JASON-2	Launch 2005	Operational 2005-2010
Proposed	GANDER series 1	Launch 2003	Operational 2004-2011
Proposed	AltiKa	Launch 2005/6	Operational 2005-2008
Proposed	SWIMSAT	Launch 2006	Operational 2007-2010

- THE JASON MISSION

Early, in the 70's, satellite altimetry demonstrated its unique potential to measure at a global scale dynamic sea surface topography. When the much greater variability of the sea level caused by changes in the Earth's gravity field and the altitude of the satellite have been removed from the altimetric range measurement, the signal that remains can be interpreted in terms of ocean surface currents. But, it has been recognised since the earliest precise altimeter measurements made by Seasat in 1978 that the isolation and extraction of the signal produced by currents and eddies requires a programme of support measurements aimed at monitoring other contributions to the altimeter's measurement of its own height. The most important of these is a precise tracking of the satellite's orbit. Corrections must then be made for the effect of atmospheric and ionospheric variability on the measured travel time of the altimeter's stream of pulses, and for forces acting on the sea surface such as barometric pressure and waves. Even when the gradient of the sea level caused by a current is isolated and identified this represents only the component of the current perpendicular to the track. In short, the precise measurement of surface currents by a radar altimeter is a relatively complex procedure requiring a dedicated mission, such as TOPEX/POSEIDON (T/P) or its follow-on JASON.

JASON-1, a joint US/France mission designed as a follow-on to the phenomenally successful TOPEX/POSEIDON (T/P) mission, will be launched in 2001. During most of this decade T/P has delivered very precise measurements of the variations in the level of the ocean surface to the ocean and marine research community. This data set has permitted tremendous progress in research on ocean circulation, specially for the low frequency part, and in studying its impact on climate. The contribution of T/P data has been essential in many other domains (tides, mean sea level, seasonal and intra-seasonal signal, planetary wave propagation etc.). The early recommendation from the scientific community arguing the necessity for continuing such dedicated altimetric missions proved strong enough to convince of the need for a follow-on to T/P.

The Jason-1 satellite payload is as for T/P except for the mass, volume and power consumption which have been reduced by a factor of 3 to 4, due to miniaturisation of the instruments. Mounted on-board will be the Poseidon 2 dual frequency altimeter (Ku and C bands for ensuring accurate ionospheric corrected range measurements), the Doris system, a GPS receiver and a laser retro-reflector (for precise orbit determination) and a radiometer (to accurately measure the troposphere water vapour content). Despite a reduced total mass of about 500 kg, the Jason-1 satellite will deliver sea surface height measurements with the same accuracy as T/P along the same ground tracks (identical 10 days repeat orbit).

Jason-1 will continue the T/P research mission but will also support the development of emerging operational oceanography by providing usual Interim Geophysical Data Records (within 3 days) and near-real time products (within 3 hours). These new real time products will include not only on-board computed range measurement and Doris orbit, but also wind speed and wave-height, as derived from altimeter signal, to be used in particular in forecast sea-state models. It is already planned that Jason-1 will be succeeded by Jason-2 in 2005, at a time when global ocean forecasting systems are planned to start running in an operational way.

- THE PROPOSED GANDER MISSION

A remarkable feature of the radar altimeter first exploited in 1978, and in the four other altimeter missions since then (Geosat, ERS-1, TOPEX/Poseidon and ERS-2), is that a good estimate of surface wave height and wind speed (as opposed to sea level) can be made by analysing the shape and amplitude of the return pulse. Unlike the measurement of ocean topography, no precise tracking or atmospheric monitoring is required. The record of global measurements is long enough to allow good statistical estimates of average and extreme sea state conditions to be made and these are now used routinely in ship routing and offshore platform design. Information on sea state delivered to ships at sea in near real-time could significantly improve safety and reduce damage and delays suffered by ships if only the sampling could match the spatial and temporal rates of change. Unfortunately, one or even two altimeters in polar orbit falls far short of sampling requirements. What is recognised as essential is a constellation of satellites passing several times each day.

That is the philosophy that inspired GANDER which relies on a constellation of microsats each carrying a special-purpose altimeter in polar orbit around the Earth. GANDER, which stands for **G**lobal **A**ltimeter **N**etwork **D**esigned to **E**valuate **R**isk, is a programme, proposed by UK groups, that has gained national government support as well as private investment. The baseline GANDER specification, supported by a detailed technical feasibility study, comprises a 100kg microsat platform providing 50 W power, operating a single frequency (Ku band) altimeter. The provisional orbit is 650km, with 80° inclination. This design allows for up to 8 GANDER microsats to be launched at a time. Because of the number of platforms involved in GANDER it is imperative to keep the payload simple, dedicated only to measuring sea state (*but with a potential for measuring sea level, an option to be investigated in this study*). Apart from a GPS receiver the GANDER microsats carry none of the sensors and precise tracking devices required for current measurements, but it can take advantage of crossing satellites well known orbit to reduce its own orbit uncertainty. An initial launch of the first 5 GANDER satellites is feasible within a time scale of 24 months..

- THE PROPOSED ALTIKA MISSION

AltiKa is a conventional pulse limited altimetry mission using a single frequency altimeter at Ka-band (35.75 GHz), one advantage of which being to minimize the ionosphere effects that are roughly 9 to 10 times lower than for Ku band altimetry. The whole payload, as proposed by French and European groups, also includes a dual frequency radiometer (23.8 GHz and 36.8 GHz), a second generation DORIS package and a laser retroreflector array. The science goals of the AltiKa mission include ocean objectives, as well as continental ice contributions. The technical objective is to demonstrate that a low mass, low power consumption and low cost altimetry mission using a microsatellite platform is feasible and fully answers performance requirements of ocean mesoscale studies as well as of other objectives. When demonstrated, such a concept could then be a candidate for participation in a Global Ocean Observing System. The orbit is chosen to be highly inclined (near polar) to sample the polar caps: Indeed, the use of the Ka-band is also of great advantage over surfaces

for which penetration of electromagnetic waves is significant. The repeat period will be selected to optimize the sampling of the ocean mesoscale signals when analysing the AltiKa data together with the data from at least one Jason class reference mission plus other existing missions (typically, an order of 35-day repeat period may be envisaged). A drifting orbit may also be considered. In terms of system performances, numerous studies are underway. For instance, it was found that the altimeter noise level is far lower than 1.5 cm for high wave-heights and even below 1 cm for waveheights lower than 3.5 m. Wave-height and wind speed are the two other parameters which will be measured by the AltiKa system. Besides the micro-satellite Ka-band altimetry concept, it should be noticed that the Ka-band altimeter instrument as it is presently defined is able to fly as a passenger on any ocean observation opportunity space mission. AltiKa program is presently in a Phase A study to finish in 2001. The 2005-2006 time window is the target date for a first AltiKa mission.

- THE PROPOSED SWIMSAT MISSION

Presently, assimilation of satellite altimeter data in wave prediction models is based upon observations of the total energy (or significant wave-height) of the wave spectrum, ignoring spectral properties. Assimilation of spectral properties of the waves is important since the assimilation of only significant wave height requires assumptions on the characteristics of the wave field, in particular on the separation between wind-sea and swell, which causes errors or weak impact of the assimilation. Attempts to include spectral information in the assimilation process have been mainly limited to regional areas, e.g. the Atlantic Ocean, but they have shown encouraging results, and have demonstrated the value of spectral wave data for sea-state prediction models. The same added value will also contribute to wave climate and coastal applications. Also, the estimate of sea-state bias affecting range altimeter measurements should be considerably improved when the spectral properties of the wave field are taken into account. This has lead French groups to propose the SWIMSAT concept, which will use real-aperture rather than the synthetic aperture radar techniques. The measurement principle is to use a dual-beam radar at Ku-band (13.6 GHz). One of the beams is pointed towards nadir, the other is pointed at a 10 degree incidence angle and scans around the vertical axis over 360 degrees in azimuth. Such a technique has already been developed and validated using airborne radar systems in France and USA. Feasibility studies of the spaceborne concept have proved very positive, so that instrument and mission characteristics are now well defined. In terms of orbit, an inclination between 65 and 115 degrees is acceptable to cover the whole ocean, whereas sun-synchronism will allow minimising constraints on the electric power supply by the satellite, even if not mandatory. The altitude of the orbit is partly constrained by geometrical considerations. The requirement is that the swath of the radar beam (swept during one rotation of the 10 degree incidence beam) be comparable to grid mesh sizes of wave prediction models and be compatible with reasonable assumptions concerning the homogeneity of the surface within the swath. An altitude ranging between 450 and 600 km is acceptable. However, optimising orbit parameters for one or several SWIMSAT satellites within a GAMBLE constellation (including GANDER satellites, Jason-2, AltiKa and SWIMSAT) is of course different from optimising them for a sole SWIMSAT mission. SWIMSAT will be proposed in 2001 to ESA in the context of "Opportunity Missions" of the Earth Explorer Program, for an expected launch in 2006.

- THE ENVISAT MISSION

The European Space Agency's earth observing satellite ENVISAT is due for launch in 2001. Among other instruments, this satellite will carry an advanced dual frequency radar altimeter, the RA-2, which will build upon the success of the altimeters on the ERS-1 and ERS-2 satellites, and the Doris positioning system. As for ERS missions, ENVISAT will generate highly accurate ocean topography measurements, and also will provide near real time sea state data to the GTS. ENVISAT measurements, jointly with Jason-1 data (and ERS and T/P data), will be invaluable in describing, understanding and forecasting the ocean dynamics at short to long scale. Because of their early launch in 2001, these two data sets will be extensively used in preparing and assessing the potential synergy between future altimetric missions, as advocated in this GAMBLE thematic network proposal.

3 – Project work plan

INTRODUCTION

GAMBLE is a thematic network. Thus the activities detailed below are in form of workshops and discussion forums whereby new results and existing expertise are brought to bear to help maximise the benefits of independently initiated satellite projects. The network will review and assess the results of recent research, and where appropriate co-ordinate new RTD activities. The aim is to establish a wide and inclusive network which engages as wide a community as possible. Thus most of the deliverables will be publicly accessible through a project web site, and open e-mail discussion forum. Only interim reports and GAMBLE management reports will be for restricted distribution. The time scale for GAMBLE is 21 months, with a view to providing timely recommendations for the GANDER, SWIMSAT and AltiKa missions, and for scientific research programmes. However, it is planned that the network will be maintained beyond the 21 month time frame, through the stimulation of users groups within GAMBLE, and there is a specific work package (exploitation) which is designed to work towards this aim.

Responsibility for co-ordinating the sequence of events described in the Work Packages will be assumed by partner CO1 (Satellite Observing Systems - SOS). Together with the other principal contractors: CR2 (Centre National des Etudes Spatiales - CNES), CR3 (Delft University of Technology - DUT), and CR4 (Istituto per lo Studio della Dinamica delle Grandi Masse - ISDGM), and the members MB5 (Southampton Oceanography Centre - SOC) and MB6 (Collecte Localisation Satellites - CLS), each of whom lead GAMBLE Work Packages, they will form a joint management committee. An independent Steering Group will be appointed, and authoritative representatives of industry and the scientific community have agreed to take part. The independent role of the steering committee will be central to GAMBLE. It will be asked to review and oversee progress on behalf of the user community and the EC. Thus it will ensure the work and subsequent recommended programmes are well focused.

The GAMBLE management committee will be responsible for most of the co-ordination activities, workshop organisation, and the initiation of actions following workshop recommendations. The responsibilities of the remaining GAMBLE participants will be to co-ordinate with all interested parties in their scientific sphere of interest, to prepare and present the state of the art, and to participate in discussions at workshops or in scientific "expert groups". The work programme, as we shall see later, is arranged along scientific themes, running parallel to the necessary management and co-ordination activity. Thus each of the scientific/technical work packages will address a specific issue, and provide recommendations as to the best ways to combine, or modify, proposed missions to maximise the scientific and operational benefit. These various recommendations will then be reviewed together at a final workshop with the aim of reaching a consensus on the actions required to ensure best value is achieved from the combination of satellite missions.

We should emphasise that the aim of GAMBLE is to solicit and include input from all interested European parties, whether or not they were involved in the initial GAMBLE proposal. We intend the forum to be as open and inclusive as possible, and will not exclude any organisation who could make a valid contribution. To satisfy this aim a contingency fund has been included in the budget so that extra participation can be supported once GAMBLE is under way.

MILESTONES

GAMBLE will work towards the achievement of two milestones:

M1 (month T0 + 16): The definition of a research programme to make best use of data from missions studied under GAMBLE. The main aim of this programme will be to create a methodology for combining these data sets into higher level data products for research and applications.

M2 (month T0 +18): Recommendations for the optimisation of the GANDER, SWIMSAT and AltiKa missions (orbits, tracking, orbit maintenance, payload specifications, scheduling).

REPORTING AND COMMUNICATION

Communications will mostly be through email. A GAMBLE Web Site will be created. Summary reports of the progress made will be made at intervals of at most 3 months. The conclusions of the 3 planned Workshops will be reported in written form. Where possible workshops will be convened to co-ordinate with other meetings, to reduce cost and increase attendance.

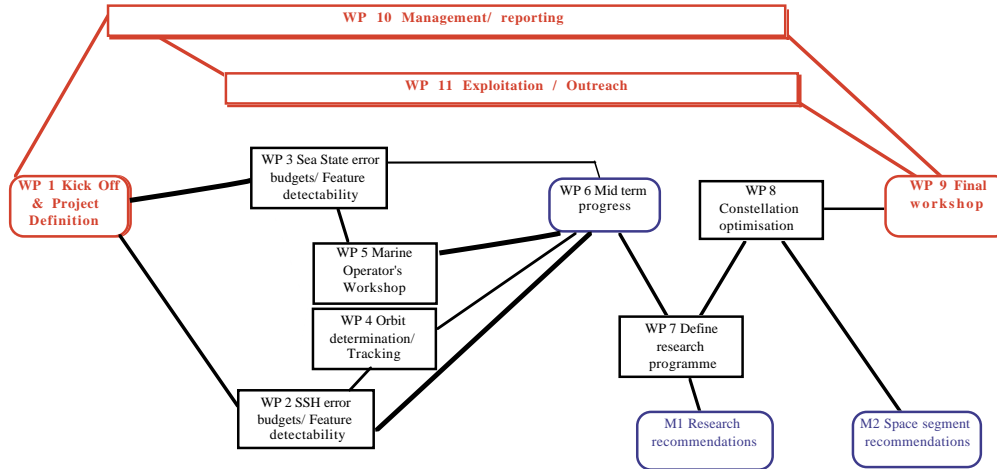
A draft Final Report containing recommendations for future missions and research activity will be prepared and distributed prior to the final Workshop which brings all 3 communities together - operators, oceanographers, and satellite trackers. The main recommendations will be discussed at this Final Workshop, and a series of pilot trials will be decided. These will be forwarded to the programme managers of JASON, GANDER, AltiKa and SWIMSAT.

Note:

The evolution of the programme, and the schedule of workshops and interactions with the expert groups, are marked out in the following two diagrams. For ease of clarity these are depicted in the same format as an equivalent RTD programme. But, since GAMBLE is a "Thematic Network" a certain flexibility must be built in to allow new ideas to be pursued.

GAMBLE OVERVIEW

GAMBLE programme



GAMBLE GANTT CHART

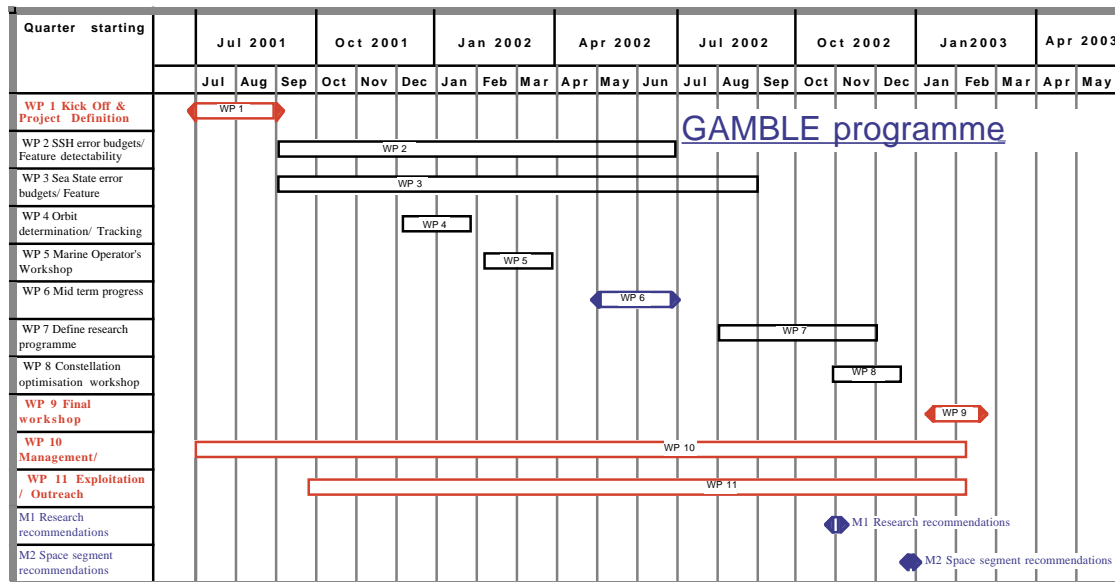


TABLE WPL: WORK PACKAGE LIST

Work Package No.	Work Package Title	Lead Partner	Person months	% of cost	Start Month	End Month	Deliverable No.
1	Kick Off / Proj. Definition	CR2 (CNES)	3.25	7	0	2	D1
2	Sci/ Tech Theme 1 SSH Error Budgets / Feature Detectability	MB6 (CLS)	4.5	10	2	12	D2, D3
3	Sci/ Tech Theme 2 Sea-state Error Budget / Feature Detectability	CR4 (ISDGM)	3.5	8	2	14	D4, D5
4	Sci/ Tech Theme 3 Orbit Determination / Tracking	CR3 (DUT)	3.0	7	5	7	D6
5	Sci/ Tech Theme 4 Marine Operator's Workshop	CO1 (SOS)	3.5	12	7	9	D7
6	Mid Term Progress	CR3 (DUT)	3.5	9	10	12	D8 (D13)
7	Sci/ Tech Theme 5 Define Research Programme	MB5 (SOC)	5.25	8	12	16	D9 / <i>MI</i>
8	Sci/ Tech Theme 6 Constellation Optimisation Workshop	CR2 (CNES)	5.65	13	16	18	D10, D11 / <i>M2</i>
9	Final Workshop	MB5 (SOC)	6.2	16	18	20	D12
10	Management / Reporting	CO1 (SOS)	4.75	7	0	21	D13, D14, D15, D16, D17, D18
11	Exploitation / Outreach	CO1 (SOS)	1.5	3	3	21	D19

DL DELIVERABLES LIST

Deliverable No.	Deliverable Title	Delivery Date	Nature	Dissemination Level.	% cost (approx)
1	Project Definition	1	Re, Me	RE	8.2
2	First Report on SSH Error Budgets / Feature Detectability, for Tracking Workshop	6	Re	PU	4.3
3	Final Reports on Error Budgets / Feature Detectability	12	Re	PU	4.3
4	Interim Report on sea-state error budget/Impact of GAMBLE in sea-state analysis and forecasting	6	Re	PU	4.1
5	Final Report on sea-state error budget/Impact of GAMBLE in sea-state analysis and forecasting	14	Re	PU	4.1
6	Recommendations for Orbit Determination and Tracking	9	Re, Me	PU	6.8
7	Report on Marine Operator's Requirements	9	Re	PU	10.9
8	Report on Error Budgets and Potential Solutions	12	Re, Me	PU	8.0
9 / <i>M1</i>	Framework for Recommended Research Programme	16	Re, Me	PU	8.0
10 / <i>M2</i>	Orbit Recommendations	18	Re	PU	6.2
11 / <i>M2</i>	Satellite and payload specification recommendations	18	Re	PU	6.2
12	Workshop report	20	Re	PU	7.0
13	Interim Management Report	6	Re	PU	<1
14	Interim Management Report	12	Re	PU	<1
15	Mid term Report	12	Re	PU	6.1
16	Interim Management Report	18	Re	PU	<1
17	Draft Final Report	19	Re	RE	5.8
18	Final Report	21	Re	PU	7.0
19	Website and exploitation report	21	Re	PU	3.0

Note - Nature: Re - Report
 Me - Methodology

Dissemination : RE - Restricted

PU - Public

WORK PACKAGE DESCRIPTIONS

There are eleven work packages in all.

Six of the work packages address specific scientific or technical issues. These Work Packages (WP) will be managed by GAMBLE partners who are recognised as leading international experts in the field addressed by the WP. Other GAMBLE members with appropriate expertise will form the core of expert user groups whose task will be to compare results and identify best practice, and to evaluate emerging and existing technology. The WP lead partner(s) will be responsible for management of the work package, co-ordination, and organisation of any workshops, and have been allocated staff time accordingly. The other partners participating in the work package have been allocated effort for co-ordinating with the lead partner, and with other organisations outside GAMBLE who can provide useful contributions. The exact time allocated depends on the effort that the organisations have indicated that they are able to provide and on the contribution that is expected from them.

All parties with relevant expertise will be invited to contribute to expert group discussions, including those who are not partners in the original GAMBLE network proposal. Thus, a contingency fund has been included in the budget to allow GAMBLE to support contributions from organisations not presently within the network.

Three of the work packages will support general GAMBLE project workshops (in addition to the theme specific workshops) which will address organisational issues, and review results. These workshops will be held at the beginning, middle and end of the 21 month GAMBLE programme.

The final two work packages cover management and exploitation.

Under each work package description that follows, the codes of the leading partner and participating partners are indicated. The number of person months allocated for each partners is indicated in brackets.

WP 1 INITIAL PROJECT DEFINITION AND KICK OFF MEETING

Start Date T0 Finish Date T0+2 Total person months 3 WP Leader, CR2 – CNES Participants, CO1 (0.75), CR2 (0.5), CR3 (0.5), CR4 (0.25), MB5 (0.5), MB6 (0.5), and Steering Group Cost 8% of Total
Objectives: To generate detailed work plan and establish expert groups. Establish GAMBLE Steering Group.
Inputs: GAMBLE work plan
Methodology: Convene workshop at which the GAMBLE team will: <ul style="list-style-type: none"> • Define the best approach to apprehend the whole problem • Define the best approach to simulate the combined missions of the future • Identify resources • Assign responsibilities • Establish a series of topic specific expert review groups Funds for 15 attendees have been allocated (7 GAMBLE partners plus the Steering Group).
<i>Deliverables D1 Project Definition Re, Me RE T0 +2 months Cost 8%</i>

Description

The main purpose of this work package is to generate the Project Definition, which will provide the work plan for the rest of the duration of GAMBLE. It will be important to co-ordinate the GAMBLE timetable with that of the satellite missions under consideration, to ensure that recommendations from GAMBLE are made in a timely fashion.

Secondary aims will be to set dates and venues for the GAMBLE workshops, ideally to match existing plans for TOPEX/JASON/ ENVISAT workshops, to establish the working groups which will address the various scientific and technical themes, and to define the remit of the Steering Group.

At this stage the management committee will also consider which other organisations could contribute to GAMBLE, and how the GAMBLE contingency fund can be best used to support this contribution.

WP 2 SCIENTIFIC / TECHNICAL THEME 1 : SEA SURFACE HEIGHT ERROR BUDGETS, FEATURE DETECTIBILITY
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Start Date T0+2

Finish Date T0+12

Total Person months 5.5

WP Leader, MB6 - CLS

Participants: CR2 (0.5), CR3 (0.75), MB5 (0.75), MB6 (0.5), MB8 (0.5), MB9 (0.5), MB11 (0.25), MB13 (0.25), MB14 (0.25), MB17 (0.5), MB19 (1.0), MB21 (0.25)

Cost 10%

Objectives:

To generate requirements for accuracy , space-time sampling of altimeter measurement and orbit maintenance/ measurement to provide detectability of target oceanic features.

Inputs:

D1: Project Definition

Conclusions/recommendations from most recent workshops, reports and literature.

Jason, GANDER, AltiKa, SWIMSAT mission specifications documents.

Methodology:

Engage expert advice, review and assess state of the art knowledge from most recent workshops and literature. Analyse past and present records, and results from simulations. Funds have been allocated to support a workshop (12 attendees), the workshop date will be set towards the end of the work package in co-ordination with JASON SWT meetings /ENVISAT symposia.

- Discuss and investigate possible error budget and sampling of GANDER-only measurements of topography
- Discuss and investigate possible error budget and sampling of GANDER/Jason/ AltiKa/SWIMSAT measurements of ocean topography
- Report on offshore features that may be detected including major current boundaries, mesoscale variability, thanks to a GANDER-only constellation and a combined GANDER/Jason/ AltiKa/SWIMSAT constellation
- Report on coastal features and tide components that may be detected with improved altimeter techniques and sampling capabilities.

Deliverable D2 - Report for Tracking Workshop Re PU T0 + 6 Cost 5%

D3 - Final Features/Errors Report Re PU T0 + 12 Cost 5%

Technical Description

The main activities of this work package will be the presentation and discussion of recent research involving the use of combined data from different altimeter missions with relation to applications (scientific and operational) of ocean sea surface height measurements. The aim will NOT be to duplicate the work of such groupings as the TOPEX/JASON science Working team, or ENVISAT symposia - but to build on the work presented at these meetings. The aim is to establish (a) the best way to combine data from different missions, and (b) the optimum combination of orbits and sampling patterns that will allow key ocean features to be studied.

Initial efforts will establish the key features to be investigated, and the accuracy of height data and sampling rates that will be required. These findings will then feed into the discussions about suitable sampling regimes, and hence the best arrangements of orbits from multi-mission scenarios

WP 3 SCIENTIFIC / TECHNICAL THEME 2 : SEA-STATE ERROR BUDGETS, FEATURE DETECTIBILITY

<p>Start Date T0+2 Finish Date T0+14 Total Person months 3.0 WP Leaders, CR4 - ISDGM Participants: CO1 (0.75), CR2 (0.25), CR4 (0.75), MB5 (0.5), MB9 (0.25) MB10 (0.5) Cost 7%</p>
<p>Objectives: To generate requirements for accuracy , space-time sampling of altimeter measurement and orbit maintenance/ measurement to provide detectability of target sea-states.</p>
<p>Inputs: D1: Project Definition. Conclusions/recommendations from most recent workshops, reports and literature. Jason, GANDER, AltiKa, SWIMSAT mission specifications documents.</p>
<p>Methodology: Engage expert advice, review and assess state of the art knowledge from most recent workshops and literature. Analyse of past and present records, and results from simulations. Funds have been allocated to support a workshop (9 attendees), the workshop date will be set towards the end of the work package in co-ordination with JASON SWT meetings /ENVISAT symposia.</p> <ul style="list-style-type: none"> • Discuss and investigate possible error budget and time-space coverage to GANDER only measurement of sea-state. • Discuss and investigate possible error budget and time-space coverage to GANDER/Jason/AltiKa/SWIMSAT measurements of sea-state. • Report on the contribution of wave spectral information as provided by SWIMSAT together with a GANDER type constellation (providing high density wave-height and wind speed) towards a better understanding of the physics of ocean waves. • Report on the contribution/ assimilation of a GAMBLE constellation, including SWIMSAT spectral observation, into models for sea-state analysis and forecast.
<p><i>Deliverable</i> <i>D4 - Interim Report for Tracking Workshop Re PU T0 + 6</i> <i>Cost 3.5%</i> <i>D5-Final Features/ Errors Report</i> <i>Re PU</i> <i>T0 + 14Cost 3.5%</i></p>

Technical Description

The main activities of WP3 will be similar to those of WP2, applied to a different scientific theme. Thus recent developments and research will be discussed to establish the best way to combine data from different missions and the optimum combination of orbits. The results from new assimilation schemes in wave models will be investigated, see below, and the best way to approach the problems of different temporal and spatial scales in different ocean regions (e.g. North Atlantic, Mediterranean Sea) will be considered.

The results of a new assimilation scheme at partner MB7 will be considered. Once implementation is complete it is planned to perform wave data assimilation experiments (outside GAMBLE, but the results will form a key part of the GAMBLE discussions) using simulated data from various type of instruments (SAR, RAR, Altimeters). Although assimilation of satellite derived wave height and wind speed have been identified as important reasons for improved forecasting skills, other studies have demonstrated that the assimilation of buoy derived wave spectral data also improves

operational forecasts. So, the impact of the combination of several altimeters with instruments providing directional wave spectra information in wave predictions will be investigated.

WP 4 SCIENTIFIC / TECHNICAL THEME 3 : ORBIT DETERMINATION AND SATELLITE TRACKING WORKSHOP

Start Date T0+5
 Finish Date T0+7
 Total Person months 3.0
 WP Leader, CR3 - DUT
 Participants, CO1 (0.75), CR2 (0.25), CR3 (1.0), MB6 (0.25), MB8 (0.5), MB15 (0.25)
 Cost 7%

Objectives:
 To provide recommendations for optimum orbits, orbit maintenance and satellite tracking and expected orbit error budget for GANDER

Inputs:
 D1, Project Definition; D2 and D4 - Initial Reports on Error budgets

Methodology:
 Convene meeting with orbit determination community, which will:

- Ascertain how much tracking of GANDER microsats is needed to sufficiently characterise features as determined in D2, in a GANDER-only constellation
- Ascertain how much tracking of GANDER microsats is needed, in a combined GANDER/Jason/AltiKa/SWIMSAT constellation
- Estimate overall accuracy of height determination, in a GANDER-only and a combined constellation with and without GANDER laser tracking
- Recommend if all or some GANDER microsats require modification to design .

Funds have been allocated to support a workshop (7 attendees).

Deliverable D6 Orbit and Tracking recommendations Me, Re PU T0 +9 Cost 7%

Technical Description

This workshop will be a key activity. It will take in the accuracy and sampling requirements from WP2 and WP3, and make recommendations regarding orbits and satellite tracking. A number of complex issues need to be addressed and understood, as described below.

To be able to make benefit of all three principle measurements of satellite radar altimeters (wave height, wind speed and range), one needs to know the position of the satellite accurately at any time. The way in which the position is determined depends on the required accuracy, which in turn is application driven.

To meet the mission goals concerning the measurement of wave height and wind speed, it is, in principle, sufficient to know the position of the altimeter footprint with an accuracy of about 100 m. These 100 metres are still dwarfed by the size of the footprint itself.

The range measurement of the radar altimeter, the distance between the satellite and the ocean surface, is only useful when it is compared with an independently determined altitude of the satellite above a given reference surface. The difference between the orbital altitude and the altimeter range then defines the height of the sea level. When the orbit of the satellite is accurately

known, it very easy to derive from this the footprint location and the orbital altitude. But to determine the orbit accurately we first need to model all forces acting on the satellite, and secondly, because this is an impossible task, we need to track the satellite and use this tracking information to adjust the computed orbit and our knowledge of the forces and other relevant parameters. The complicated process of modelling the orbit dynamics, adjusting the parameters and the orbit is called precise orbit determination (POD). Many levels of accuracy of the POD process are conceivable. Nowadays, satellite orbits can be determined, at any time around the orbit, with an accuracy of around 5 cm. However, this number is heavily determined by the quality and the quantity of satellite tracking data.

It is not difficult to realise that the accuracy at which the sea level can be determined is fully driven by the accuracy of the determination of the satellite altitude. Conversely, the POD accuracy is driven by the applications that are foreseen with the use of the altimeter range measurement. It is therefore important first to make an analysis of the intended mission goals, forthwith translate this to the required sea level and orbital altitude requirements, and finally which tracking system would meet these requirements. On top of that there may also be operational considerations that drive the type of tracking system or even the POD method.

It is important to realise that the altimeter range measurement itself can assist the orbit determination. Converted to sea level height using a low-precision orbit, the difference of this sea level with respect to a mean sea surface model or, even better, a sea level determined by another satellite is indicative of the precision of the orbit. Although there is no implicit relation between the sea level differences and the orbit error because of other errors involved in the construction of the sea level measurement out of the altimeter range, an abundance of these sea level differences can be used for a more precise determination of the satellite orbit. This strategy has been used effectively for the improvement of orbits of the low-flying ERS satellites using sea level measurements of the TOPEX/Poseidon satellite. Where the two ground tracks of the satellites cross the sea level measurements made by the two satellites are compared. The resulting crossover height difference is assumed to be due to errors in the least accurate orbit, that of ERS. These height differences can then be used in a POD process.

Likewise, orbits of a constellation of altimeter satellites can be improved by using the crossover height differences of several satellites. In principle it is not even necessary to assume that one has the higher precision: all orbits can be adjusted simultaneously.

WP 5 SCIENTIFIC / TECHNICAL THEME 4 : MARINE OPERATOR'S WORKSHOP

Start Date T0+7
 Finish Date T0+9
 Total person months 3.5
 WP Leader, CO1 - SOS
 Participants, CO1 (1.0), CR4 (0.75), MB5 (0.5), MB6 (0.5), MB10 (0.25), MB11 (0.25), MB21 (0.25) +
 representatives of offshore operators.
 Cost 12%

Objectives:

To gain input from operational end-users and determine required provision of near real time
 seastate and ocean current information.

Inputs:

D1, Project Definition, D2 and D4
 Return from on-going experiments in operational oceanography and marine meteorology (e.g.
 SOPRANE, MERCATOR programmes and sea-state forecast services)

Methodology:

Convene a Workshop of marine/ocean applications operators (possible venue:- Rotterdam). Funds
 have been allocated for 30 attendees.

- Determine more precisely their requirements for near real-time information on sea state and
 current regime.
- In particular establish with what accuracy currents and severe sea-state information may be
 detected and delivered to ships at sea within a specified time-frame.

Deliverable *D7 Report on Operational Requirements Re PU* **T0+ 9** *Cost 12%*

Technical Description

Offshore operators are working to specifications that become more challenging year by year. These specifications can relate to operational activities, e.g. the need to operate within precise sea state limits, or for advance knowledge of "weather windows", or they can form part of the design procedure (operational planning or vessel design). It is a priority of Gamble to consider input from offshore operators, so that the requirements for future missions are driven as much by the needs (on account of commercial, safety or environmental considerations) of offshore operators as they are by those of the scientific community. Thus the workshop will allow operators to communicate their priorities, and to engage the GAMBLE partners in a dialogue as to the best way that these requirements can be satisfied.

WP 6 MID TERM PROGRESS REVIEW

Start Date T0+10 Finish Date T0+12 Total person months 3.75 WP Leader, CR3 - DUT Participants, CO1 (0.75), CR2(0.25), CR3 (0.75), CR4 (0.75), MB5 (0.5), MB6 (0.5), MB8 (0.5) + steering group Cost 9%

Objectives:

To assess progress at GAMBLE mid-point, and consolidate programme for 2nd year.

Inputs:

All Deliverables to date D1-D7

Methodology:

Report on progress to date. Gain feedback from Steering Group and assess 2nd year work programme. In particular

- Review GANDER height error budget and consider how it might be reduced
- Define what can be measured within this error budget
- Define the role of JASON, AltiKa and SWIMSAT in enhancing GANDER's ability to observe and quantify marine features and ocean circulation at the level of accuracy required by users
- Define the role of JASON in 'calibrating' GANDER orbital heights
- Review the joint role of all missions in providing sea state information to forecast models and direct to operators

Funds for 16 attendees have been allocated. (8 GAMBLE partners plus the steering group)

Deliverable	<i>D8 Report on Error Budgets and potential solutions Re, Me PU</i>	<i>T0 + 12 Cost 9%</i>
	<i>(also D14 - see WP10)</i>	

Description

The main purposes of this work package are twofold: To review progress over the first year of GAMBLE, and, in the light of this review (and of other developments external to GAMBLE), to reassess, and if necessary, redefine the programme for the second year. The Steering Group will play a central role in this activity. The second purpose is to produce the report on Error Budgets which will feed into Work Packages 7 and 8.

The management committee will consider if other organisations outside GAMBLE could contribute to GAMBLE in its second year, and whether it is able to offer financial support to any of these organisations.

WP 7 SCIENTIFIC / TECHNICAL THEME 5 : DEFINE RESEARCH PROGRAMME
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Start Date T0+12
 Finish Date T0+16
 Total Person months 5
 WP Leader, MB5 - SOC
 Participants, CO1 (0.25), CR2 (0.25), CR3 (0.75), CR4 (0.75), MB5 (1.0), MB6 (0.25), MB10 (0.5), MB11 (0.25), MB13 (0.5), MB14 (0.25), MB17 (0.25),
 Cost 7%

Objectives:

Define a recommended programme of research to be pursued by research centres (outside the terms of the GAMBLE thematic network) during the life of the GANDER, JASON and ENVISAT missions.

Inputs:

D1, D3, D5, D7, D8

Methodology:

- Establish work to be done to ensure that wave, wind and current data products can be generated and expeditiously delivered for
 - a) Climate studies
 - b) Routine marine operations
- Investigate potential impact on ground segment system designs, including data processing, distribution etc.

No Workshop is supported for this activity.

Deliverable D9 / Milestone M1

Framework for Recommended Research Re, Me PU T0 + 16 Cost 7 %

Cost up to M1: 65%

Technical Description

The main purpose of this work package is to generate recommendations for the production of high-level multi-mission data products, for scientific research and operational applications.

Through missions such as TOPEX/POSEIDON and ERS-1 and 2, radar altimeters have made a major contribution to oceanographic science. One of the major limitations of such data arises from the narrow footprint of the instrument. Whereas other remote sensing instruments have broad swaths of hundreds of kilometres across, the radar altimeter only takes measurements in a very narrow (c 10 km) swath directly below the satellite. There are two ways around this problem, one is to design wide swath altimeters, the other is the GAMBLE approach, to make use of data from different altimeter missions. The main advantage would be the ability to look in more detail at the mesoscale. Because of the wide spacing of the tracks mesoscale eddies are lost by the present day altimeter systems. For example, depending on the number of satellites involved a constellation should be able to track eddies as they propagate across the ocean. Similarly there are many small scale, topographically forced, features we have probably not even seen with the data we have at the moment. The other area where we expect scientific advances is in the area of mapping ocean characteristics. By having more passes in a given area we will gain a better understanding of the

processes being mapped. This will not only lead to a better understanding of mean fields but also to what extent we can use satellite data to make inferences about extreme events.

WP 8 SCIENTIFIC / TECHNICAL THEME 6 : CONSTELLATION OPTIMIZATION WORKSHOP
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Start Date T0+16
 Finish Date T0+18
 Total Person months 5.5
 WP Leader, CR2 - CNES
 Participants, CO1 (0.75), CR2 (0.5), CR3 (0.75), MB5 (0.5), MB6 (0.5), MB9 (0.5), MB10 (0.5), MB11 (0.25), MB13 (0.25), MB15 (0.5), MB17 (0.25), MB21 (0.25)
 Cost 12%

Objectives:

Provide recommendations for orbits, orbit maintenance and tracking, orbit phasing, and satellite / payload specifications.
 Provide preliminary GAMBLE multi-satellite configurations/scenarios.

Inputs:

D3, D5, D6, D7, D8

Methodology:

Convene Workshop. Funds have been allocated for 14 attendees.
 Bring GANDER, Jason, AltiKa, SWIMSAT project people together with experts in multi-satellite simulations to:

- Evaluate existing and emerging technologies
- Analyse simulation outputs
- Issue recommendations for possible improvements to the GANDER constellation with respect to user requirements (from marine/ocean applications and science users) and to the performance/cost ratio.
 - (a) Orbit specifications
 - (b) Modifications to satellite and instrument specifications

Deliverables

D10 Recommendations for GANDER, SWIMSAT, AltiKa Orbits Re, PU, T0 +18 Cost 6%

D11 Recommendations for GANDER, SWIMSAT, AltiKa satellite and payload specifications Re, PU, T0 +18 Cost 6%

D10 and D11 together constitute *Milestone M2: Cost up to M2 77 %*

Technical Description

The specifications (orbits, payload) of some missions (e.g. JASON, ENVISAT) have for a long time been established in line with the science programmes towards which the missions are addressed. The aim of this work package is to take a wider view than any single mission and to investigate and recommend possible modifications to missions that are still at the planning process. For instance the scientific output of a GANDER microsat constellation might be improved significantly by the relatively inexpensive addition of an on board GPS orbit determination and maintenance capability. In addition the orbits could be phased to maximise the benefit, in terms of cross-overs with other

satellites, or temporal spatial coverage, for scientific investigations without adversely affecting the performance with regard to operational provision of Near Real Time data.

WP 9 FINAL WORKSHOP

<p>Start Date T0+18 Finish Date T0+20 Total person months 6 WP Leader, CR2 - CNES Participants, CO1 (0.75), CR2 (0.25), CR3 (0.75), CR4 (0.75), MB5 (0.75), MB6 (0.5), MB8 (0.5), MB9 (0.5), MB10 (0.25), MB11 (0.25), MB13 (0.25), MB14 (0.25), MB15 (0.25), MB17 (0.25) + steering group Cost 15%</p>
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Objectives:

Provide final recommendations for co-ordinated European activity on Altimeter Ocean measurements

Inputs:

All deliverables to date (D1-D11)

Methodology:

Bring modellers and marine operators together with satellite programme managers Convene Final Workshop which will provide forum for interested parties to discuss GAMBLE project and contribute to final recommendations. Funds have been allocated for 25 attendees.

<i>Deliverable D12 Workshop report Re PU T0+20 Cost 15%</i>

Description

The workshop will agree the final recommendations to be made to all relevant parties (satellite mission managers, national and international science programme managers, bodies that represent the interests of offshore operators). The GAMBLE team will also agree a dissemination strategy for the GAMBLE results, and work to ensure that the user groups established within GAMBLE will continue to work together in the future.

WP 10 MANAGEMENT AND REPORTING

Start Date T0+0
 Finish Date T0+21
 Total person months 5.25
 WP Leader, CO1 - SOS
 Participants, CO1 (2.5), CR2 (0.25), CR3 (0.5), CR4 (0.75), MB5(0.5), MB6(0.5), and Steering Group
 Cost 9%

Objectives:

Management of GAMBLE thematic network and reporting to European Commission .

Methodology:

Appoint Project Manager, and establish GAMBLE website and exchange forum.
 Provide three Interim Management reports at T0+6, 12 and 18 months.
 Provide Mid-term and Final reports of Work Packages to the Commission.
 All five reports will be written in English and delivered to the Commission in three copies.
 Provide reports to Steering Group, and convene Steering Group meetings which will provide guidance to GAMBLE project managers.
 Provide cost statements at T0+6, T0+12, T0+18 and T0+21 months.

Deliverables

D13	First Management Report	Re, PU	T0+6	Cost <1%
D14	Second Management Report	Re, RE	T0+12	Cost <1%
D15	Mid term Report	Re, PU	T0+12	Cost 4%
D16	Third Management Report	Re PU	T0+18	Cost <1%
D17	Draft Final Report	Re, RE	T0+19	Cost 4%
D18	Final report	Re PU	T0+21	Cost <1%

WP 11 EXPLOITATION AND OUTREACH
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Start Date T0+3 Finish Date T0+21 Total Person months (2) WP Leader, CO1 - SOS Participants, CO1 (1.0), MB5 - SOC (0.5), CR3 - DUT (0.5) Cost 3%

Objectives:

To ensure that the widest possible group of interested parties are aware of the GAMBLE network, to enable this community to contribute to discussions and gain access to the recommendations and reports.

Methodology:

It is important to ensure that the GAMBLE network will bring in and involve all members of the European altimeter and ocean using community who can make a valid contribution. It is also important that the co-ordination activity initiated by GAMBLE will continue beyond the initial 21 month phase for which Framework V support is requested.

- Ensure that all relevant organisations (research institutes, space agencies, offshore operators, funding bodies) are informed of GAMBLE recommendations.
- Establish a GAMBLE web site which will contain all reports and documentation, and which will be open to view for the wider community. The web site will feature an open feedback option, so that all interested parties can keep up to date with progress and contribute to the ongoing GAMBLE network discussions.
- Establish an information network through which future satellite plans can be disseminated and discussed.

<i>Deliverable</i>	<i>D16 Web site and Exploitation Report</i>	<i>T0 +21</i>	<i>Cost 3% of Total</i>
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4 – Contribution to objectives of programme

GAMBLE is a Thematic Network programme since its main purpose is to co-ordinate a number of separate activities in the area of satellite radar altimetry to produce a greater degree of European collaboration in future ocean satellite initiatives.

The recently published note¹ from the EU identifying the types of activities that might qualify for support for a Thematic Network lists a number of priorities. GAMBLE appears to satisfy a majority of these. Specifically,

¹ *Experiences with Thematic Networks and Concerted Actions within the Environment and Sustainable Development sub-programme*

- It aims to create a 'critical mass' within Europe to ensure that a more integrated programme of altimeter measurements of the ocean's surface will attract the greatest number of users from both the research and applications sectors.
- It will co-ordinate existing RTD activities.
- It will help to stimulate existing user groups as well as creating groups of new users.
- It will identify possible areas of new research.
- It will enhance the state-of-the-art by extending the uses of satellite altimetry
- Within the marine applications sector it will increase awareness of the relevance of satellite products to their operations.
- In that sense, it should increase the potential for commercial exploitation.

If it is the stated aim of the European Union and its member states to express their requirements for environmental information, it is the aim of projects such as GAMBLE to investigate how these requirements could translate into the most economical way of providing that information from Earth Observation systems.

It is now agreed nationally and within the European communities that more emphasis must be placed in future on the design of operational systems, particularly those directed to the monitoring of natural hazards - floods and fires on land, storms and pollution at sea. These areas are all given priority within the Framework V programme. The specific key actions targeted by GAMBLE are identified as follows:

Support for Research Infrastructure Priorities (EESD 1999-9)

The 'Support for Research Infrastructure' programme (EESD 1999-9) identifies as its key priorities the need for a greater degree of European co-operation in the areas of *global change, climate, marine research* and *natural hazards* research.

EESD Key Action 2 - Global Change, Climate and Biodiversity

Two aspects of this key action are targeted: First, *2.4 European Component of the global observing system*, in particular the requirement to *adapt existing observing systems*, and the *development of a new long term observing capacity*. The second aspect is Action 2. 1, - *to understand, detect, assess and predict global change processes*.

EESD Action 7.2 - Development of Generic Earth Observation Technologies

This generic action is particularly well matched by the GAMBLE proposal. All of the scientific objectives of the Key Actions identified above within the EESD programme will gain appreciably from greater co-ordination of existing EO technologies. That is the principal aim of GAMBLE. In particular GAMBLE will seek to explore and *improve the exploitation of Earth Observation and create favourable conditions to develop the market*.

5 – Community added value and contribution to EU policies

It would be difficult for an individual nation on its own to implement a programme with the aims of GAMBLE. Open forum discussions between the partners, involving also an exchange of views with a wide selection of European 'end-users', will exploit the resources and experience that reside within individual research and aerospace centres throughout the EU. The products that emerge as a result of these workshops will be more directly relevant to the implementation of EU policy goals than those of any single, national programme.

In that respect this Thematic Network will contribute directly to a fundamental tenet of EU policy, namely, the need to optimise the synergy between national programmes so that the total information content is significantly greater than the sum of the parts. GAMBLE aims to make $1 + 1 = 3$ in the sense that the outputs of separately conceived space missions can be enhanced through integration to generate 3 key products, provided certain adjustments can be agreed *before* launch. These are defined in the table below:

Product	Client	Contribution to EU policy
Frequent daily bulletins reporting sea state observations of surface wave height and wind speed	<ul style="list-style-type: none"> • Met forecasting centres • Ships at sea 	<ul style="list-style-type: none"> ▪ Increased marine safety ▪ Increased efficiency through reduced delays ▪ Innovative use of Earth Observation technology
Weekly charts of major surface currents and eddies	<ul style="list-style-type: none"> • Ships at sea • Met centres • National navies • Off shore platforms 	<ul style="list-style-type: none"> ▪ Increased ship efficiency ▪ Creation of new markets for EO data
Monthly/seasonal/inter-annual charts of ocean circulation and eddies	<ul style="list-style-type: none"> • Climate and ocean research centres 	<ul style="list-style-type: none"> ▪ How heat is transported across the globe is key to a better understanding of climate change.

SEA STATE

Over 90% of the transport of goods in and out of Europe is by sea. Despite the increased resolution of computerised models for forecasting sea state, and despite the progress made in communication systems, storms at sea still take their toll in lives, damage and delays. Some 150 ships of over 500 tonnes are lost every year; the marine insurance industry pays out \$2.5 billion, and 24,000 lives are lost. Weather forecasts may be reliable for most of the time but the development of the storms which do the damage is difficult to follow with pinpoint accuracy by conventional means.

A combination of a constellation of small satellites carrying wave/wind measuring altimeters together with the observations of JASON-1, and Envisat, and those of the proposed SWIMSAT wave measuring radar, will provide a density of observations which has been lacking in the past. GAMBLE will examine the best mix of i) 'real-time' delivery to the major meteorological forecasting centres to initiate, validate and re-tune their models, and ii) direct broadcasts to ships that wish to 'see' the sea state surrounding them.

This part of the study will take account of other sources of relevant information that will also be available including scatterometer wind fields and SAR vignettes of wave behaviour. The EU policy addressed in this part is an **increase in marine safety** which has been a recurring theme for many years, especially in DG VII.

OPERATIONAL CHARTS OF SURFACE CURRENTS

Whereas the observations of waves and wind speed can be extracted from each of the altimeters in the constellation independently, the detection of the changing sea level, which reveals current boundaries and eddies, requires an integrated programme devoted to adjusting the small sat

observations of height by minimising the discrepancies at the track intersections with the more precise, well-tracked 'mother' platform JASON. That JASON can detect and identify very small changes in sea level has been well-demonstrated by its predecessor Topex/Poseidon. A single satellite, however, cannot provide the coverage required to keep up with the changing pattern of surface currents over all global oceans.

GAMBLE will study the extent to which this coverage could be extended by combining the JASON measurements with those from other missions. For the first time ever, it is possible to contemplate a service that provides ships at sea with weekly charts of currents, allowing them to take better advantage of the prevailing conditions. Europe will be seen to be occupying a challenging position. So many of the initiatives over the last 2 decades in the area of ocean satellite surveillance have emanated from just a handful of countries with the USA playing a leading role. GAMBLE aims to establish Europe as a leading player.

OCEAN CIRCULATION

The strength of GAMBLE is that it aims to combine a daily service for routine marine operations with regular delivery of a product that is key to global climate studies - a description of ocean circulation around the globe. GAMBLE will examine the extent to which this latter product will be improved by the addition of a number of 'outriders' to extend the spatial coverage of JASON. The grid laid down by JASON over its 10-day cycle is of the order of 300km spacing. Eddies smaller than this can therefore slip through the mesh, and since mesoscale currents are responsible for more than 95% of the ocean's kinetic energy, it is important that inputs to climate programmes are not under-sampled.

Monitoring key features of the environment in order to provide an 'early warning' of global climate change has always been a top priority for the EU. Many would rate this one of the most important services that European marine research workers can contribute to the world. Within 50 - 100 years changing sea levels and surface temperatures could have a profound effect on Europe's coastal defences, fisheries, aquaculture, tourism and weather patterns. The latest report of the IPCC highlights the serious implications of present climate trends.

The issues addressed by GAMBLE - understanding processes governing global currents, improving short term predictions of sea state and currents, enhancing global observing systems - form the backbone of the first scientific challenge identified in a recent report by the European Science Foundation's Marine Board². In addition this report calls for the development of infrastructure to support operational oceanography from satellites, and an improvement in co-ordination of space based activities to provide an enhancement of complementarity and competitiveness.

GAMBLE offers the opportunity to make better use of satellites by combining programmes in a way that has never before been attempted. *By supporting this proposal the EU will be helping to integrate 3 fundamental parts of its existing marine policy - increased safety at sea, increased efficiency, and increased awareness of global environmental changes.*

² "Towards a European Marine Research Area", European Science Foundation, Marine Board, December 2000, <http://www.esf.org/marineboard>

6 – Contribution to community social objectives

The estimates of the rates of increase in global surface temperature and rising sea levels made by the international IPCC panel on climate change in their most recent paper (January 2001) are higher than any previous estimate. The decade of the 1990's was the warmest of the last Millennium. In the face of the evidence the need for precise and continuous monitoring of the global oceans is greater than ever before. Satellites have already proved their value in past missions and there is little doubt that the international community will seek to augment existing monitoring programmes.

An altimeter can now measure changes in sea level to within 2 - 3 centimetres. With this level of precision, variations in the slope of the sea surface can reveal small changes in the distribution of the geostrophic currents and eddies that determine the global transport of heat as a key factor in climate studies.

Similarly, since the launch of Seasat in 1978, a substantial record of surface waves and winds has been created from the observations of polar-orbiting radars, and these, too, have been analysed to reveal large-scale trends related to global climate change. European scientists supported by advanced European technology are playing an increasingly important role in the search for evidence of a changing environment. Clearly, the protection of European coastlines is one of the most fundamental social objectives of the Community, but of equal importance in the shorter-term is the need to increase safety at sea while also making the European marine industry more competitive by reducing damage and delays inflicted on ships by bad weather.

The scale of loss is not always fully appreciated. A recent report by the Food and Agricultural Organisation (FAO) identifies fishing at sea as the most dangerous occupation in the world. Their study, based on estimates from the International Labour Organisation, says that at least 24,000 lives are lost every year. The true figure is probably higher since not all countries keep reliable statistics. The risks are increasing as fishermen venture further and further from shore. The causes are two-fold - inadequate boats and ignorance of the conditions that await them. The environmental cost of cleaning-up oil spills following avoidable weather related incidents at sea can also be high. Last year Total Fina Elf spent over 500 million Euros in the clean up operation after the Erika disaster, and it is expected that the French government will have incurred a similar cost.

Many European countries have highly developed meteorological forecasting centres and through the use of detailed models and high speed computers, warnings of gales and their progression across the oceans are forecast in advance. Unfortunately, no matter how good the models or fast the computers their accuracy depends on the quality of the input data and this may be sparse, especially in bad weather where it has been shown that quality is diminished.

Constellations of wave/wind measuring microsats will provide an adequate coverage of wind speed and wave height observations every day. The immediate effect is to allow every ship to 'see' the state of the sea around them and to assess what lies ahead but, perhaps as important, the forecasts of what developments will take place will become much more reliable.

In summary, there will be substantial social benefits from developing the most cost/effective mix of the rapid coverage provided by small satellites with the precise measurement of sea level change detected by JASON and Envisat. It is not only ships of all sizes that will ultimately benefit, but as

offshore oil exploration moves into increasingly deeper waters a timely warning of the approach of eddies and gyres, not to say dangerous squalls, is considered a high priority by the industry.

The programme proposed here reflects the new awareness in Europe that space policy must be shaped by the requirements of a wider user community. Science - especially an increased understanding of the changes taking place in our own environment - will retain a high priority. But satellite observations of the oceans have been almost exclusively directed in the past to climate/marine research. By investigating how science missions may now be combined with daily bulletins on the sea conditions that pose a threat to routine operations, Europe will be making significant progress. Satellite remote sensing of the ocean's surface may then appear more attractive to the private investors that have been disinclined to invest in the science missions of the past 2 decades.

The need to make industry and academia work together is placed first on a list of socio-economic issues identified in the ESF Marine Board Report referred to in Section C3. This need is recognised, and addressed, within GAMBLE by the presence of industry representatives in the Steering Group, and the inclusion of a Workshop to identify the operational needs of industry. By supporting co-operation between academia and industry, between nations, and harnessing individual skills to provide a wider range of products, Europe has the potential to lead the way into a new era of Earth Observation that must surely create more employment.

The proposed GMES programme is now gathering support throughout Europe where the 'S' stands for 'Security'. Greater security will require sampling the oceans from satellites at a much greater frequency than is possible at present. The recent ESA/EC report concluded:

'We want Space to count in European policies, and Europe to count in the use of Space'.

GAMBLE represents one small, but significant, step.

7 – Economic development and S & T prospects

i) A new era

Traditionally, that is since the inauguration of oceanography from space in 1978, satellite observations have been made freely available to the scientific research community. This has been true of the ocean satellites launched by ESA, NASA, US Navy, France and Japan. In the case of ESA a charge was made to commercial companies planning to add value and sell on the information, but the market for the archive material produced from single, polar-orbiting satellites is limited.

The economics of Earth Observation are being re-visited by the countries that, in the past, have invested comparatively large amounts of funding. Envisat, for example, will cost the European taxpayer €3,000M. Nations are aware of the imbalance that exists between the number of space platforms designed for long-term environmental research and those directed to shorter-term applications.

Paradoxically, as many, if not more, satellites have been designed for ocean monitoring (including ESA's triplets) as for terrestrial surveys; yet from the start, it was the terrestrial satellites such as the SPOT and Landsat series that were more closely directed to applications – crop yields, urban planning, management of forests, land subsidence, flood warnings etc. The ocean satellites were designed to demonstrate that radars could detect changes in sea level and sea surface roughness

which could then be interpreted respectively in terms of currents, wind and wave conditions. Colour sensors have re-appeared after an absence of almost 15 years but they, and temperature sounders, remain inhibited by cloud cover.

The major economic problem now facing the agencies who have designed ocean satellite missions is, to put it at its simplest, a reluctance on the part of the funding nations to continue to support demonstration, 'proof-of-concept' missions. As long as large 2-tonne platforms are used as a test-bed of new, improved sensors, the costs will continue to escalate and serious questions will be raised about the value of the benefits. Features at the ocean surface change rapidly, and the 'real-time' information required by many ships/platforms at sea cannot be adequately sampled by a solitary, polar-orbiting spacecraft with a re-visit time of 10 or 35 days.

How can ocean satellites be made more relevant to the daily routine of marine operations? If they can be designed for a wider user community, is that community prepared to pay for information? If so, is there enough of a commercial market to encourage private investment into what was previously an exclusive public domain? Or should information on sea state and other features of operational value remain the province of national meteorological centres and be paid for from the public purse?

Near real-time operation can only be achieved by a constellation of several observing platforms and the only way to afford the number required to (say) track the progress of storms at sea is to use small, special-purpose platforms. Recent studies carried out in European centres have confirmed that dedicated altimeters can achieve a good performance within the constraints of power, weight, size and pointing angle imposed by an 80kg microsat. The means are at hand then to monitor sea state at the frequency required by marine operations. In themselves, these routine applications represent a considerable market which encompasses container ships, tankers, fishing boats, naval vessels, offshore platforms and leisure yachts as well as the routing and meteorological forecasting centres which serve them.

What GAMBLE now sets out to do for Europe goes beyond that. A cluster of small satellites will certainly provide the coverage required for what is now referred to as 'operational oceanography'. However, the small size of these microsats precludes the precision required by the research community to detect very small changes. Where GAMBLE may be making an economic breakthrough of interest to all European countries that subscribe to satellite programmes, is the proposed study of the optimum mix of research and operational platforms so that the individual missions complement one another – the larger, well-equipped platforms such as JASON and Envisat sharing their precision with the fleet of smaller craft, while the microsats extends the coverage lacking in the single platform missions.

The economic importance of this investigation cannot be over-emphasised. A total of 15 European organisations – research, commercial, military, space engineering, climate modellers and shipping companies – have signed up to GAMBLE. After 2 decades of environmental research programmes being supported almost exclusively from the public purse, here is an opportunity to combine science with day-to-day marine operations to the benefit of each.

To become economically viable the missions proposed within Europe with similar purpose (such as detailed surveys of the oceans' surface) must seek common ground. It is to the credit of all the European organisations involved in satellite altimetry, and in the infrastructure to support it, that they have now agreed to pool their resources and examine mechanisms for mutual assistance. This

is a programme which could only emanate from a European Union intent on investigating ways to benefit the lives and livelihood of all who go to sea – and all who are anxious about the future impact on our economy if the oceans continue to rise around our coastlines.

ii) Exploitation and Dissemination

The high degree of interest from both the commercial and research communities in seeing a wider and more economical exploitation of satellite technology demands that GAMBLE will report progress step by step on a dedicated Website. As the advantages, disadvantages, and potential costs of different scenarios are discussed before, during and after the Workshops, the main options and conclusions will be posted and comment invited from a wider community.

Too often in the past the ‘marketing’ of ocean satellite products – even to the research community – has taken place after the launch of the satellite. By then it is often too late. TOPEX/POSEIDON and Jason-1 are exceptions as these two programs were and are currently supported by a very active Science Working Team which has participated in the mission design. When such support is absent, if the mission has not been designed for a particular category of user, it can be difficult, if not impossible, to try to ‘sell’ the results later. The products will rarely suit the needs.

GAMBLE will try to avoid that mistake by involving the wider operational community in the planning scenarios. At the conclusion of the consultative process a market plan will be drawn up which will consider i) the destination of the 3 basic products, ii) the potential commercial value of the daily storm tracking information and the weekly current charts, and iii) the arguments for public and private funding of the satellite programmes which emerge.

One thing may be stated categorically at this stage: in the area of ‘operational oceanography’ the greatest use will be made of the synergy between planned satellite support missions.

European nations are no longer willing to pay for expensive satellites that promote only their national aerospace industry. The eventual users of the products that are recommended from the GAMBLE study will be representative of that wider community of all who earn their living from the sea, use the sea for their leisure, or study its behaviour as a harbinger of global change. The economic benefits of more useful and reliable information to that community are truly enormous.

8 – The consortium

The identities of the principal contractors and members of the GAMBLE consortium are given below:

GAMBLE Main Contractors

UK	CO1	For GANDER	Satellite Observing Systems (SOS)
F	CR2	For JASON	Centre National des Etudes Spatiales (CNES)
NL	CR3	Orbit analysis	Delft University of Technology (DUT)
IT	CR4	Sea-state, Mediterranean Studies	Istituto per lo Studio della Dinamica delle Grandi Masse (ISDGM)

GAMBLE Members

		<u>Organisation</u>	<u>Interest</u>
UK	MB5	Southampton Oceanography Centre (SOC)	Large scale oceanographic circulation and climate studies
F	MB6	Collecte Localisation Satellites (CLS)	AltiKa, oceanographic circulation studies
UK	MB8	Univ. Newcastle (UNEW)	Satellite Tracking, JASON PI
F	MB9	ALCATEL	Altimeter Instrumentation
F	MB10	Centre d'Etudes des Environnements Terrestre et Planetaires (CETP)	Leader of SWIMSAT proposal
F	MB11	Service Hydrographique et Oceanographique de la Marine (SHOM)	AltiKa. Responsible for French Navy and global Mercator ocean forecasting systems, JASON PI
F	MB12	Universite Joseph Fourier (UJF)	Principal Investigator of AltiKa. Multi-satellite studies, JASON PI
F	MB13	Laboratoires d'Etudes en Geophysique et Oceanographie Spatiale (LEGOS)	Tidal modelling, JASON PI
UK	MB14	Proudman Oceanographic Laboratory (POL)	Tidal Modelling, Coastal Studies, JASON PI
UK	MB15	Surrey Satellite Technology Ltd. (SSTL)	Microsat technology.
F	MB16	Universite Versailles St Quentin (UVSQ)	Linked to MB10 as joint research unit
F	MB17	Laboratoires des Ecoulements Geophysiques et Industriels (LEGI)	Linked to MB12 as joint research unit
F	MB18	Institut National Polytechnique de Grenoble (INPG)	Linked to MB12 as joint research unit
DE	MB19	Max Planck Institut (MPI)	Meteorology, modelling

UK	MB20	Environmental Systems Science Centre (ESSC)	Assimilation, modelling
NO	MB21	Nansen Environment and Remote Sensing Centre (NERSC)	Climate and environment studies, operational forecasting, modelling

It would be no exaggeration to claim that these 15 organisations in France, Netherlands, Italy and the UK who have agreed to collaborate on GAMBLE are among the main players in Europe in the field of satellite altimetry over the ocean. They have worked together for over 20 years in some cases.

To assist and guide the work to be carried out and to make recommendations when necessary we will establish a Steering Committee representative of future clients. The steering committee will have a balanced membership with equal representation from the “operational” and “scientific” communities. The following have all agreed to participate in such a role (Letters of acceptance from have been received by SOS):-

Steering Committee

OceanRoutes
 Shell International Exploration
 and Production
 BP AMOCO Exploration
 DockWise
 EuroGOOS
 CLS
 Meteo France
 ENEA

Partner Roles

The individual roles of partners are detailed below. Often expertise of individual organisations spreads across a number of fields, and GAMBLE partners may contribute to several of the Scientific Themes. The reader is also referred to the Table in Section 9 which shows the amount of staff effort each partner is providing to each work package.

CO1 Satellite Observing Systems (SOS)

Total Staff Effort 9.25 Months

SOS are the Co-ordinating Principal Contractor in GAMBLE. They lead the Project management Work Package (WP10), and will be responsible for project administration, and co-ordination with the EU including the provision of all project deliverables and reports, according to the project timetable. SOS will co-chair the project management committee (6 members). In addition they lead WP11, Exploitation, with the support of SOC. Together WP10 and WP11 will account for just under one half of SOS's staff effort.

SOS will also make a significant scientific contribution to GAMBLE. They will lead WP5 (Marine Operator's Workshop) and organise the workshop that is the central activity of the work package. As Work Package leaders they will be responsible for reporting on the findings of the workshop, and generating the project deliverables. SOS will attend, and report to the Kick-Off workshop - WP1, the Mid term Review Workshop (WP6), and the Final Workshop (WP9). They will assist CNES in the organisation of the workshops for WP1 and WP9, and assist DUT in the organisation of the workshop for WP6. SOS will present results of technical studies carried out for GANDER to WP4 (Orbit Determination), and WP8 (Optimisation). In WP3, SOS will also present their experiences of providing services based on altimeter data to offshore operators.

CR2 Centre Nationale D'Etudes Spatiales (CNES)

Total Staff Effort 3 Months

CNES are, with SOS, joint co-ordinators of GAMBLE. They are well suited to this role through their leadership of the TOPEX/Poseidon, JASON and Altika programmes. Thus CNES will assist SOS in project administration, and co-ordination with the French partners in GAMBLE. CNES will co-chair the project management committee, and share responsibility for the generation of project reports. Thus CNES will contribute directly to WP10 - Project Management.

CNES have the responsibility for the organisation of the Kick Off workshop (WP1) and the final workshop (WP9), and will contribute to the Mid Term Review (WP6). CNES also have wide scientific experience and so will provide valuable contributions to WP2 (Sea surface height error budgets), WP3 (Sea state error budgets), WP4 (Orbit studies), and WP7 (Research Programme). They will lead WP8 (Optimisation), and so will be responsible organising the workshop, for reporting on the findings, and generating the WP deliverables.

CR3 Delft University of Technology

Total Staff Effort 6.5 Months

Delft University of Technology are internationally recognised for their expertise in Precise Orbit Determination, with special interest in studies based on satellite altimeter data. Thus DUT will lead the GAMBLE activities relating to orbit determination. DUT will be a member of the project management committee, and will contribute significantly to project reports. Thus DUT will contribute to WP10 - Project Management. They will also contribute to exploitation and outreach (WP11).

DUT will lead WP4 (Orbit Determination) and so will be responsible for organising the workshop, reporting on the findings, and generating the deliverables due from WP4. DUT will present the most recent "State of the Art" with regard to orbit determination at the Kick Off workshop (WP1), and to WP2 (Sea surface height error budgets). DUT will organise the Workshop for the Mid Term Review (WP6), and present WP4 results to WP7 (Research Programme) and WP8 (Optimisation). In addition they will contribute to the final workshop WP9.

CR4 Istituto per lo Studio della Dinamica delle Grandi Masse (ISDGM)

Total Staff Effort 4.75 Months

ISDGM will be responsible for assessing the use of multi-satellite altimeter data sets in the Mediterranean Sea, with special regard to sea state. ISDGM will be a member of the project management committee, and will contribute significantly to project reports. Thus ISDGM will contribute to WP10 – Project Management.

ISDGM will lead WP3 (Sea State Error Budgets). They will organise and chair the workshop, in report on the findings, and generate the project deliverables. ISDGM will attend and present the special case of using altimeter data in semi-enclosed seas at the Kick Off workshop (WP1), WP3, and WP5 (Marine Operators workshop). They will contribute to the Mid Term Review (WP6), and present recommendations to WP7 (Research Programme). In addition they will contribute, scientifically and as members of the Project Management Committee, to the final workshop WP9.

MB5 Southampton Oceanography Centre

Total Staff Effort 6 Months

Southampton Oceanography Centre boasts a wide range of expertise in remote sensing and ocean modelling. Because of this experience they are amply qualified to lead WP7 (Definition of Research Programme). As WP leaders, SOC will also sit on the Project Management Committee and play an important role in WP10 – Project Management. They will also assist SOS in WP11 (Exploitation) by supporting the GAMBLE web site.

SOC will present results of recent studies, with an emphasis on multi-satellite sampling and error budgets, at the Kick Off workshop (WP1). They will make important contributions to WP2 (Sea surface height error budgets) and WP3 (Sea state error budgets), having relevant experience in both areas. They will be responsible for present UK plans for operational oceanography to the Marine Operators workshop (WP5). As leaders of WP7 (Research Programme) they will co-ordinate with all GAMBLE partners who are contributing to this WP, and solicit contributions from organisations external to GAMBLE. SOC will be responsible for generating the deliverables due from WP7. Note that no workshop has been scheduled for WP7, as the workshop activities did not justify one. SOC will present the results of WP7 at the optimisation workshop (WP8). Finally, SOC will contribute, scientifically and as members of the Project Management Committee, to the Mid Term Review (WP6) and the final workshop WP9.

MB6 Collecte Localisation Satellites CLS

Total Staff Effort 4 Months

CLS also has much experience in remote sensing and ocean modelling. They will lead WP2 (Sea Surface Height Error Budgets). As WP leaders, CLS will be members of the Project Management Committee and contribute to WP10 – Project Management.

CLS will present results of recent studies of multi-satellite sampling and error budgets, at the Kick Off workshop (WP1) and at the WP2 workshop. They will be responsible for the organisation of the WP2 Workshop, and for generating the deliverables from WP2. WP2 activities will take place over a period of 10 months, and over that time CLS will be responsible for co-ordinating with all other contributors to WP2. CLS also have expertise in Orbit determination (and so will contribute to WP4), and in operational ocean modelling (and so will contribute to WP5 – the Marine Operator's

workshop). CLS will contribute their own expertise, and report on the recommendations from WP2, to WP7 (definition of research programme), and to WP8 (Optimisation). They will also contribute, scientifically and as members of the Project Management Committee, to the Mid Term Review (WP6) and the final workshop WP9.

MB7 Météo France (MF)

Total Staff Effort 0 Months

Unfortunately MF, member 7 in the proposal, are unable to commit to the GAMBLE contract due to a heavy workload. They are still interested in the project and will contribute as part of the steering committee.

MB8 University of Newcastle (UNEW)

Total Staff Effort 2 Months

UNEW are recognised experts in the field in Orbit Determination, and so will make a valuable contribution to the work packages associated with this issue They will contribute to WP2 (Sea surface height error budgets), and WP4 (Orbits). In addition they will contribute to the Mid Term Review Workshop (WP6) and the Final Workshop (WP9).

MB9 ALCATEL

Total Staff Effort 1.75 Months

ALCATEL provided the innovative solid state Poseidon altimeter for TOPEX/Poseidon, and subsequently supplied the altimeter for JASON. ALCATEL will therefore be able to provide essential input to GAMBLE regarding the capabilities of altimeters, and advise on possible modifications to design. ALCATEL will contribute to WP2 (Sea surface height error budgets), and WP3 (Sea state error budgets). They will provide a key contribution to the Optimisation Workshop (WP8), and will attend the Final Workshop (WP9) to help form the final recommendations.

MB10 Centre d'études des Environnements Terrestre et Planétaires

Total Staff Effort 2 Months

CETP are leaders of the SWIMSAT proposal, described in the Annex to Section B3 of this proposal. CETP have expertise in radar measurement of waves, and in air-sea interaction studies. They will contribute expert opinion and a review of the state of the art of wave measuring radar to WP3 (Sea state error budgets), and help to form recommendations from the Marine Operator's Workshop (WP5), which may impact on plans for SWIMSAT. Similarly SWIMSAT plans will be important in the development of the definition of the research programme (WP7). It is also clearly important that SWIMSAT plans are co-ordinated with those of other missions (GANDER, Altika) at the Optimisation Workshop (WP8). CETP will also contribute to the Final Workshop (WP9) where the final recommendations will be developed.

MB11 Service Hydrographique et Oceanographique de la Marine

Total Staff Effort 1.25 Months

SHOM have played a leading role in the development of the Mercator operational ocean forecasting system, which involves the assimilation of altimeter height data, and are also involved in the Altika altimeter project. Based on this experience of the use of altimeter height data in operational models, SHOM will provide valuable contributions to WP2 (Sea surface height error budgets), WP5 (Marine Operator's Workshop), and WP7 (Research programme). The experience with operational models will also help to inform the discussion of optimum sampling strategies within the Optimisation Workshop (WP8). SHOM will also contribute to the Final Workshop (WP9).

MB12 Universite Joseph Fourier (UJF)

Linked to MB17 (LEGI) as a joint research unit but not committing staff time.

MB13 Laboratoire d'Etudes en Géophysique et Océanographique Spatiale (LEGOS)

Total Staff Effort 1.25 Months

LEGOS has an international reputation for its contribution to Tidal Modelling, and considerable experience in the application of satellite data in this field. Accurate tidal information is essential to allow the extraction of sea surface height from altimeter data, and so LEGOS will have an important contribution to make to WP2 (Sea surface height error budgets). Whilst GAMBLE has focussed mostly on sea state and (dynamic) sea surface height, tidal models could themselves benefit from multi-satellite studies, and so LEGOS will participate in the development of a combined research programme (WP7). The presentation of results of multi-satellite studies will also form an important contribution to the Optimisation Workshop (WP8). LEGOS will also contribute to the Final Workshop (WP9).

MB14 Proudman Oceanographic Laboratory (POL)

Total Staff Effort 0.75 Months

POL has considerable experience in the application of altimeter data for ocean circulation studies, tidal studies, and wave modelling. They also have an interest in coastal applications. POL will present their recommendations for multi-satellite applications of altimeter data to WP2 (Sea surface height error budgets) and WP7 (Research Programme). POL will also contribute to the Final Workshop (WP9).

MB15 Surrey Satellite Technology Limited (SSTL)

Total Staff Effort 1 Month

SSTL are the leading UK manufacturer of small satellites, and are partners with SOS in GANDER multi-satellite project (see Annex to Section B3). They have considerable experience in the design, construction, launch and operation of micro-satellites, and, with SOS, have demonstrated that a

wave measuring altimeter could be hosted on one of their microsatellite platforms. This experience will be valuable in the discussions of the Orbits workshop (WP4), and the Optimisation Workshop (WP8). SSTL will present their experiences and technical studies to the workshop, and contribute to the development of the subsequent recommendations. SSTL will also contribute to recommendations from the Final Workshop (WP9).

MB16 Universite Versailles St Quentin (UVSQ)

Linked to MB10 (CETP) as a joint research unit but not committing staff time.

MB17 Laboratoire des Ecoulements Géophysiques et Industriels (LEGI)

Total Staff Effort 1.25 Months

LEGI has carried out multi-satellite studies, and is PI for JASON and Altika. LEGI will present its experiences to WP2 (Sea surface height error budgets) and contribute to WP7 (Research programme). The presentation of results of multi-satellite studies will also form an important contribution to the Optimisation Workshop (WP8). LEGI will also contribute to the Final Workshop (WP9).

MB18 Institut National Polytechnique de Grenoble (INPG)

Linked to MB12 (UJF) as a joint research centre but not committing staff time.

MB19 Max Planck Institut (MPI)

Meteorology and Climate research institute in Hamburg with interests in altimeter assimilation and modelling. Involved in WP2 – Sea surface height error budgets (staff time 1 month).

MB20 Environmental Systems Science Centre (ESSC)

Part of the University of Reading, ESSC now includes a specialist group in data assimilation and modelling. Will attend workshops for WPs 2, 5 and 9.

MB21 Nansen Environment and Remote Sensing Centre (NERSC)

Research institution linked to university of Bergen with interests in climate research and operational oceanography. Involved with WPs 2, 5 and 8, and will also attend the kick-off meeting (WP1) and final workshop (WP9) (staff time 0.75 months).

Other interested parties

It is intended that the GAMBLE network should be an inclusive network, welcoming contributions from all with the relevant expertise. To allow for this, a contingency fund has been included in the GAMBLE budget under “other costs” for CO1. This fund is sufficient to support travel and

subsistence for an extra four participants in each of WP2, WP3, WP4, WP5, WP7, WP8, WP9. The allocation of this fund will be decided by the GAMBLE Project Management Committee, subject to approval by the EU programme officer.

European Space Agency (ESA)

Representatives of the ENVISAT Radar Altimeter programme at ESA were contacted regarding GAMBLE, and expressed enthusiasm for the project. Whilst it is administratively difficult for ESA to become a partner in GAMBLE, a number of the GAMBLE partners are ENVISAT PIs. Thus the contribution of the ENVISAT altimeter will be included in all the discussions for multi-mission applications.

9 – Project management

Responsibility for co-ordinating the sequence of events described in the Work Packages will be assumed by CO1 - SOS (Satellite Observing Systems). SOS will be responsible to the EC for all administrative and finance purposes, and will ensure that the reports and recommendations generated by the network will be issued in a timely manner.

CNES (Centre National d'Etudes Spatiales)/JASON team are with SOS, joint co-ordinators of GAMBLE, and will work with SOS in all aspects of management and co-ordination. CNES and SOS will together chair a six member Project Management Committee, comprised of the Work Package leaders. These are the principal contractors, SOS, CNES, DUT (Delft University of Technology) and ISDGM (Istituto per lo Studio della Dinamica delle Grandi Masse), and two of the GAMBLE network members, SOC (Southampton Oceanography Centre) and CLS (Collecte Localisation Satellites). The GAMBLE management committee will be responsible for co-ordination activities, workshop organisation, and the initiation of actions following workshop recommendations. The approval of this committee will also be required prior to any expenditure of that part of the GAMBLE budget put aside to support the contribution of new members.

The responsibilities of the remaining GAMBLE participants will be to co-ordinate with all interested parties in their scientific sphere of interest, to prepare and present the state of the art, and to participate in discussions at workshops or in scientific "expert groups". The work programme, as detailed in Section B, is arranged along scientific themes, running parallel to the necessary management and co-ordination activity. Thus each of the scientific/technical work packages will address a specific issue, and provide recommendations as to the best ways to combine, or modify, proposed missions in order to maximise the scientific and operational benefit. The reporting lines are indicated in the management diagram, overleaf. Where Work Packages include workshops, the WP leader takes responsibility for the organisation of the workshop. SOS will assist in workshop preparation.

An independent steering committee will be appointed, and authoritative representatives of industry and the scientific community have agreed to take part in this capacity. The independent role of the steering committee will be central to GAMBLE. They will be asked to review and oversee progress on behalf of the user community and the EU. Thus they will ensure the work and subsequent recommended programmes are well focused.

At the first level communications will be through e-mail, with all information being mirrored between partners 1 and 2 (SOS and CNES). CNES will take responsibility to ensure that all members based in France are kept informed, SOS will maintain contacts with those based in the UK, ISDGM will provide the connection to researchers working on problems in the Mediterranean.

With support from SOC, SOS will establish a GAMBLE web site which will contain all reports and documentation, and will be open to the wider European altimeter community.

SOS has a wide experience in co-ordinating satellite programmes aimed primarily at the marine environment. The founder of the company was Chairman of the Satellite Users Research Group of Europe (SURGE) which, in 1978 led to European participation in the NASA satellite which sparked the interest of the oceanographic community. Subsequently he organised an international workshop on Satellite Altimetry for the NATO Scientific Affairs Division which helped establish the need for the Joint US/French Topex/Poseidon mission.

Others within the company have managed multi-national programmes under Framework IV (see Section C7), for CEO, and for national authorities. SOS will apply the same high standard of co-ordination practised in previous, larger RTD programmes. In this case their task will be made easier by the familiarity of the collaborators with each other's work. Also with their own enthusiasm to identify ways to make each mission relevant to a wider community of users.

MANPOWER TABLE (STAFF MONTHS / WORK PACKAGE)

	WP1 Kick- Off	WP2 SSH	WP3 Sea State	WP4 Orbits	WP5 Marine Ops	WP6 Mid Term Rev	WP7 Res. Prog.	WP8 Optim	WP9 Final W'shop	WP10 Manag	WP11 Exploit	Total
CO1- SOS	0.75	0	0.75	0.75	1.0	0.75	0.25	0.75	0.75	2.5	1	9.25
CR2- CNES	0.5	0.5	0.25	0.25	0	0.25	0.25	0.5	0.25	0.25	0	3.0
CR3- DUT	0.5	0.75	0	1	0	0.75	0.75	0.75	0.75	0.75	0.5	6.5
CR4- ISDGM	0.25	0	0.75	0	0.75	0.75	0.75	0	0.75	0.75	0	4.75
MB5- SOC	0.5	0.75	0.5	0	0.5	0.5	1	0.5	0.75	0.5	0.5	6.0
MB6- CLS	0.5	0.5	0	0.25	0.5	0.5	0.25	0.5	0.5	0.5	0	4.0
MB8- UNEW	0	0.5	0	0.5	0	0.5	0	0	0.5	0	0	2.0
MB9- ALCA	0	0.5	0.25	0	0	0	0	0.5	0.5	0	0	1.75
MB10- CETP	0	0	0.5	0	0.25	0	0.5	0.5	0.25	0	0	2.0
MB11- SHOM	0	0.25	0	0	0.25	0	0.25	0.25	0.25	0	0	1.25
MB12- UJF	0	0	0	0	0	0	0	0	0	0	0	0
MB13- LEGOS	0	0.25	0	0	0	0	0.5	0.25	0.25	0	0	1.25
MB14- POL	0	0.25	0	0	0	0	0.25	0	0.25	0	0	0.75
MB15- SSTL	0	0	0	0.25	0	0	0	0.5	0.25	0	0	1.0
MB16- UVSQ	0	0	0	0	0	0	0	0	0	0	0	0
MB17- LEGI	0	0.5	0	0	0	0	0.25	0.25	0.25	0	0	1.25
MB18- INPG	0	0	0	0	0	0	0	0	0	0	0	0
MB19- MPI	0	1.0	0	0	0	0	0	0	0	0	0	1.0
MB20- ESSC	0	0	0	0	0	0	0	0	0	0	0	0
MB21- NERSC	0	0.25	0	0	0.25	0	0	0.25	0	0	0	0.75
TOTAL	3.0	5.5	3.0	3.0	3.5	3.75	5.0	5.5	6.0	5.25	2.0	45.5

GAMBLE MANAGEMENT DIAGRAM

