A Tool for Operational Oceanography in the Tropical and South Atlantic

NOR-50

Navire Océanographique Rapide

Position Document

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Jacques Servain
Philippe Marchand
Raymond Zaharia

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«Annexe du Document NOR-50»

Jacques SERVAIN PIRATA Program Manager
Centre IRD de Bretagne
B.P. 70 F29280 Plouzané, France
Tél: +(33) (0)2 98 22 45 06
Fax: +(33) (0)2 98 22 45 14
E-mail: Jacques.Servain@ird.fr

Philippe MARCHAND Coriolis Program Manager
Ifremer B.P. 70 F29280 Plouzané, France
Tél: +(33) (0)2 98 22 41 26
Fax: +(33) (0)2 98 22 41 35
E-mail: Philippe.Marchand@ifremer.fr

Raymond ZAHARIA EX CNES Program Manager (Retired)
29 Av. de la République
F92140 Clamart, France
Tél: +(33) (0)1 4630 8023
E-mail: Arzi77@aol.com

Note: The views expressed here are purely those of the authors and may not, for the time being, be regarded as stating an official position of IRD or Ifremer

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Summary

Operational oceanography (OP/OC) is a new discipline, still in its childhood. It will become in the years to come an activity in its own right, differing from, though complementing research activities. Among the missions of OP/OC, those interesting oceanic basins as a whole should mainly address the needs of the international community for the study and forecast of the climate at the seasonal scale. Operational character calls for adapted, economical, safe, and long-lasting means, while the speed of intervention allows to reduce ship time booking.

Considering important costs - in investment and exploitation - of classic research oceanographic vessels (R/V), the authors address in the present document the use of a fast oceanographic vessel (at least twice the speed of usual ships) capable of insuring missions of light oceanography (mainly physico-chemical measures at the sea-air interface) and also, the deployment of semi-heavy instrumentations (e.g. surface moorings anchored on the sea floor).

This idea was derived from a double finding:

i) Reduction and prevention of natural disasters are for the agenda henceforth. Also, international cooperation for real time knowledge of the climatic variability is strengthening, as well as research for methods of appraisal well suited to the implementation of the UN FCCC (United Nations Framework Convention on Climate Change). The Tropical Atlantic Ocean is already recognised as one of the major work areas within the world ocean (PIRATA Program and Argo project). The climate of the neighbouring continental regions (e.g. Sahel on the African side, Nordeste on the American side) is indeed widely dependent on climatic variations affecting different regions of the tropical Atlantic Ocean. It is also on the Tropical Atlantic that cyclones feed before raging on the Antilles and the South of the United States. One knows that there is a strong climatic connection between the oceanic region of the tropical Atlantic Ocean and the more northerly regions (e.g. the NAO - Western Europe) and those of the Indo - Pacific (e.g. ENSO). Besides, and especially because of the dramatic lack of in-situ observations, the climatic impact of the south Atlantic Ocean (nevertheless opened on the rest of the oceanic world), is badly known, be it at the regional scale or at the global scale.

ii) In spite of noticeable efforts from the three countries that participate so far, (Brazil, France, United States), methods used today to develop and to maintain the PIRATA network are widely inappropriate, often oversized (e.g. use of the Atalante, a 80 m length R/V, for a PIRATA mission in the Gulf of Guinea), and suffer from their lack of flexibility. Furthermore, they are expensive, not long-lasting and by too dependent on outside factors (strategic, economical, even political). Finally, there is little hope that present day methods will be manageable on the long run; this will become even more obvious with the likely development of this type of network within other oceanic regions.

The authors propose here a ship directly adapted to the case of the tropical Atlantic Ocean (but it could indeed be convenient for other regions in other circumstances).

This dedicated ship would be allocated basically to two well complementing activities: The PIRATA Program and the in situ surveillance (with Argo floats) of the south Atlantic Ocean, region with very few surface observations as opposed to the north Atlantic Ocean, frequently crossed by numerous ships whether for trade or for Research.

The present document provides the stand of the authors and a brief description (physical as well as financial) on a 50 m Fast Oceanographic Vessel (named "NOR-50" for the time being). It is based mainly on preliminary studies elaborated some years ago within Ifremer (when a concept of fast vessel intended for passengers transport was put forward). These studies are resumed here to tackle the change of scale that OP/OC implies: insuring quickly and economically numerous missions, scattered on trans-oceanic distances. The principle considered is that of the "slender mono hull", stabilised by two active foils. Sea water ballast's, when full, allow the vessel to offer a strong stability during a stop (since the mono-hull becomes then a trimaran) and, when the vessel relieves (after ballast's have been emptied), a high speed (22 knots in continued cruise). The rear bridge (equipped with a crane and an A-frame) allows stocking and manoeuvring, (e.g. installing or recovering), four moorings of ATLAS type, such as they are presently used in the PIRATA program. Classic and specific equipment allow dynamic and physico-chemical measurements in continuous or by sampling.

Besides its great speed, and associated fast intervention capability, NOR-50 is characterised also by its low costs of investment and operation with respect to present "classical means". Taking as a reference the R/V "Antéa" (an IRD's catamaran of 34 m) and the R/V "Le Suroît" (an Ifremer's classical mono hull of 56 m), the NOR-50 "costs" 0,875 Antéa or 0,175 Suroît in term of investment. In term of operations, the ratio is also favourable: Taking as example a typical PIRATA campaign, the cost-in-use of the NOR-50 is 0,59 times the cost of this same cruise when it is insured by Antéa, and 0,36 times when it is made by "Le Suroît". For another operational mission (of Argo type), the difference is even more blatant (ratios of respectively of 0,38 and 0,29).

The reader will find below a scientific and quantified rationale allowing to assess the annual work load for the NOR-50, and its operating cost, with the assumption that it is based in Natal, East of Brazil, i.e. close to the "center of gravity " of the tropical Atlantic basin. To have a realistic annual work load, the authors consider the maintenance of a completed PIRATA network (in years 2003-2004, it should comprise approximately 22 ATLAS buoys), as well as the deployment of several tens of Argo floats between 20°N and 40°S, according to the international recommendations in support of a grid 3° in longitude X 3° in latitude. In complement of these specific PIRATA and Argo activities (respectively 4,5 and 2 months per year), it is expected that within the remainder of "active time", the NOR-50 will be used approximately 3 months per year for "surface" oceanographic work with complementary physico-chemical measures.

This ship being devoted to work valuable to the whole international community, the authors recommend that the NOR-50 be financed and managed within an international framework, covering the initial investment cost (35 MFF, or 5.4 MEuros, or 5 M$US), as well as subsequent operations. Based on an independent *cost estimate (from OCEA Shipyard, Les Sables d'Olonne, France), some realistic assumptions with respect to annual operating costs, (fixed and variable parts), are discussed.*

It has been possible, for several years, to establish successful cooperation agreements in various fields of space meteorology, climatology and oceanography: Climate numerical models (within ECMWF), or space born sensors (Topex-Poseidon, Jason-1&2). Time is ripe for proposing that operational oceanography be equipped in turn with means managed in common and aiming at the same successes. The NOR-50 can be an emblematic example for this new type of international collaboration, which at the end of the day will be beneficial, for the bordering populations.

A project schedule is also proposed, considering the goal to enter in day to day exploitation of the NOR-50 in the 2004-2005 time frame, i.e. at the time when OP/OC should truly take-off on a global scale.

1- Introduction : Towards operational oceanography

In the edge of 21-th century, we enter another “new frontier”: *operational oceanography (OP/OC)* intends to provide predefined information to its users. Topics at hand are very different: 3D currents, tides, survey of the quality of the environment, assessment of stocks of fishes, survey and forecast of ice masses, marine meteorology, forecast of sea states, seasonal climatic forecast.

Some of these subjects are already being handled and useful information has been periodically supplied for many years. It is quite another picture with respect to global currents and seasonal climatic forecast. These two "deep-sea" subjects depend upon the world ocean and are still at the stage of research. Taking as an example meteorology, a field which has been operational for several decades, deep-sea operational oceanography requires deployment and maintenance in the maritime environment of a network of met-oceanic autonomous instruments transmitting their measurements in real time, (operational mode), by way of space born systems (e.g. Argos system).

Thanks to a worldwide monitoring network devoted to the global ocean-atmosphere, continents and cryosphere system, and to the assimilation of these observations in Global Coupled ocean atmosphere Circulation Models (GCCM), we will be able to make decisive steps in climatic forecast on the seasonal scale (some months in advance).

We are considering here the deep-sea dimension of operational oceanography, and more particularly the oceanic domain of the Atlantic Ocean in its tropical and subtropical zones. In other words, our proposal deals with observation of the climatic variability on this region, and is related to the oceanographic missions which are and will be developed on the scale of this basin during (at least) the next decade.

To answer this global need for *in-situ* observations, as well as remote (space born) observations, an international organization is being set up gradually, aiming also their optimal management on scientific and economical grounds. This international effort is mainly related to the GOOS and Argo programs, and to their regional and national constituents, such Euro-GOOS (the European branch of GOOS) and Coriolis. Coriolis is the French constituent of Argo for the Atlantic Ocean. Coriolis gathers the whole data set of *in situ* real time observations for the Mercator project of ocean modeling, which is the French constituent of the international program Godae. For further information on these programs, please refer to their respective Web sites (www.eurogoos.org, www.argo.ucsd.edu, www.ifremer.fr/coriolis, www.mercator.com.fr).

In the following section (Section 2), we describe the missions and requirements of operational oceanography in the case of the tropical Atlantic Ocean, then we propose (Section 3) the great lines of a solution based on an oceanographic vessel dedicated to the zone of the tropical and south Atlantic Ocean. The concept and the technical characteristics of this vessel (NOR-50) are then described in a quantitative and graphical way (Sections 4 & 5). The document continues (Section 6) with a quantitative comparison with two other types of vessel and this is done for two types of missions (PIRATA and Argo). An assessment of the workload in the tropical and south Atlantic Ocean is provided (Section 7). It then suggests some tracks for the financing (Section 8) and ends (Section 9) by some recommendations for starting such a project, its phase of realization, its routine operations, along with a forward-looking calendar.

2- The case of the tropical Atlantic Ocean and its observations needs

The work to carry out within the framework of the OP/OC at global ocean scale is gigantic. Division and coordination of tasks at international level are therefore badly needed. In this context, at national level, France has chosen to focus its competence in observations and in simulations on the domain of the North Atlantic Ocean: a nationwide effort includes the Gyroscope experiment (with European support for provision of 80 autonomous floats), the first deployments of Coriolis floats in the framework of the Argo program, and the first Mercator model outputs (http://www.mercator.com.fr/).

However, thanks to the historic action of IRD (formerly ORSTOM), French interventions were and are still numerous, and often decisive, in the intertropical zone of the Atlantic Ocean. This action should continue during the next years. That is why we focus here on the tropical Atlantic Ocean, but the south Atlantic Ocean is also considered. This last region, contrary to the north Atlantic Ocean, is dramatically deprived of *in-situ* met-oceanic means and systems of observations. A particular effort must therefore take place. In this respect, the Coriolis program plans to spread autonomous floats in this area as soon as 2001.

2.1 PIRATA

With respect to the tropical Atlantic Ocean *stricto sensu*, The PIRATA program (Servain *et al.,* 1998) (http://www.brest.IRD.fr/pirata/piratafr.html) is an experimental network of *in-situ* met-oceanic observations. Its present status is now midway between the “research mode” and the “operational mode”.

PIRATA was established end of 1997 at international level (Brazil, France, the United States) under joint sponsoring of CLIVAR and GOOS. French participation in PIRATA is done mainly through the IRD, which is carrying its mission of aid to developing countries of the Atlantic tropical belt. The National Centre For Scientific Research (CNRS), Météo-France and Ifremer have contributed, and for the two last quoted still participate in various degrees, in the placing, development and preservation of the PIRATA network in the eastern part is of the basin (essentially the Gulf of Guinea).

The initial PIRATA observing network consists of a dozen ATLAS buoys presently anchored in the tropical Atlantic Ocean (Fig. 1). These buoys are genuine met-oceanic weather stations measuring in key points of the tropical Atlantic Ocean various parameters of the energy transfer between the atmosphere and the mixed layer (until 500 m of depth). The initial PIRATA network will be gradually completed until it comprises about twenty buoys, around 2002-2003, by a series of three extensions towards the African and American coasts (Fig. 2), by relying upon the participation of bordering countries (e.g. Morocco, Senegal and South Africa as regards the eastward extension of the network). The PIRATA Program as a whole is intended to become purely operational in the 2005 time frame, at the end of a consolidation phase starting in the beginning of 2001.

Between recovering and refurbishment, the nominal life time of an ATLAS mooring at sea is about one year. It follows that roughly once per year, each ATLAS mooring must be raised in its totality (except the mooring block of 2 tons which is lost and remain on the sea floor). Another ATLAS mooring is then installed right away in the same place. The different mechanical elements of the mooring (float, tripods, steel cables, nylon cables, …) that have just been recovered are cleaned, tested, repaired if needed, and repainted. This refurbishment can be done in any PIRATA ground base. For the sensors and other electronic constituents which have been recovered, they are sent at once in an agreed laboratory, (at present the PMEL in Seattle, USA), where they are tested very accurately, re-calibrated, repaired if needed or exchanged. The total of these elements (mechanics and electronics), as well as a stock of new batteries can then embark for a new "field" campaign and mooring. Excellent coordination is prerequisite for insuring efficient rotation of equipment between different sites (Seattle, Abidjan, Brest, Natal, Fortaleza, Dakar, Port Gentil, Pointe Noire, …). Several teams are involved and facing from time to time unpredictable delays related to shipping by containers and also small "concerns" with customs officers and regulations…

The main technological constraints for the nominal duration of one year, (at any rate less than 15 months), of an ATLAS system in sea are the following:

- Capacity of the chemical batteries (the most "energy-consuming" element being the daily transmission of data by way of the Argos space born system),
- Biologic and chemical spots on certain sensors (conductivity, sun radiance, rain, …)
- Electronic drift of some sensors (conductivity in particular).

The PIRATA network needs the passage at least once a year on each of the sites. When the PIRATA network will be complete (about 22 sites) the annual load of ship time for its maintenance, will be equivalent to about 6 months of a classic oceanographic vessel with a cruising speed of 11 knots (e.g. R/V "Antéa" or "Le Suroît", …). <u>This for a baseline of one visit per year</u> (which corresponds, as described above to the nominal duration of instruments and sensors embarked on ATLAS buoys).

However, as this is already proven with the similar TAO/TRITON network in the Pacific, an optimized maintenance of the network requires <u>more than once a year visit</u>, especially in areas subject to vandalism connected to tuna fishing (for example along the equator in the Gulf of Guinea). Despite this matter of fact, harmful but real, a second annual visit may also be an opportunity for some maintenance ops, (preventive/corrective), such as sensor exchange, (surface sensor), and/or defective batteries replacement. This increased ship time brings up the annual load to an estimated 8 months of classic oceanographic vessel, but on the other hand, this ship time may also be used for additional operations (e.g. spreading or recovering of autonomous floats, and/or various biogeochemical samplings, etc.).

2.2 Argo - Coriolis

The Argo program plans to spread by 2004 in the world ocean 3000 autonomous floats (Figs. 3 and 4). This new network will provide real time information on the thermo-haline structure in the top 2000 meters of the water column.

It is going to revolutionize our today very partial observation of the ocean water masses. This network is intended to become permanent, as it was the case for the TAO-TRITON network of anchored buoys in the Pacific at the end of the 1990's.

In this context, about 600 autonomous floats will need to be spread by 2004 in the Atlantic Ocean. France participates actively in this effort through the Coriolis project, by developing instruments (PROVOR floats), by realizing the Coriolis Centre of operational data, and by having a schedule for procurement and spreading of 300 autonomous floats by 2004.

Autonomous floats have an expected lifetime of 3 years at least. It follows that it will be necessary, to maintain a constant density of observations, to spread about a thousand of floats per year in the world ocean. Ships of opportunity indeed constitute a privileged means for floats deployment (in particular in the north Atlantic Ocean). It is at least the basic hypothesis that has been retained at international level by the Argo project. However, one could challenge this assumption for the two following reasons:

i) it should be acknowledged that the traditional good will towards scientists of the officers and crews of merchant vessels is … vanishing. Nowadays, with very different roots, they often are “hirelings under flags of convenience”; most of the time, they are very difficult to motivate, even financially. Sometimes, the individual with whom an agreement of collaboration has been made may be landing some weeks later in the next harbor; he will not pass on necessarily his commitments to his replacement, or this one will not feel obliged to implement them. Furthermore, the current trend of drastic reduction of the number of officers and sailors aboard, for economical reasons or as a consequence of automation, does not help for an increased availability of the crews in a new and supplementary collaboration with the scientists.

ii) It is doubtful that natural oceanic dispersal will allow to obtain everywhere the regular grid (about 3° in longitude x 3° in latitude), as that has been recommended in the international committees. It will indeed be necessary to “go at sea and block the holes”. This is very likely in low traffic oceanic zones and/or in difficult international maintenance areas (e.g. the Gulf of Guinea), as well as in wide “deserted” zones of the south Atlantic Ocean. Several months of ship time will therefore be necessary for the Atlantic Ocean every year (see section 7) and even more if one intends, under environmentalist lobbies pressure, to recover the floats after their nominal 3-year time-life.

3- A solution for the tropical and south Atlantic Ocean: A dedicated vessel

We have seen in the previous section that the optimized maintenance of the full PIRATA array will require around 8 months of classic oceanographic vessel (at about

11 Knots). Using similar classical R/V for covering the entire South Atlantic region according the Argo networks requirements, one would need about 3 months of additionally ship-time.

Under the current status of our fleet of research boats, it is difficult to see how this work load may be insured, unless at the cost of a heavy organization, requiring the complementarily of several vessels of various nationalities (France, Brazil, US, German, Morocco, South Africa, Senegal, etc.), with all kinds of subsequent difficulties related to the availability of the vessels, to competition between scientific activities, even political or economical difficulties (e.g. the recent political events of Côte d'Ivoire). It seems already that this system would be hardly manageable, and this at different levels, such as scientific, economical, human or political aspects. If this "ill fitted" operational solution would be retained, it is likely that complete pieces of the network would become ineffective during more or less long lapses of time.

We think that it is possible to remedy this kind of problem.

Under the individual responsibilities of each of the authors, a proposal is made here to the physical ocean science community. The purpose is to facilitate and to optimize field activities of operational oceanography in the tropical Atlantic Ocean and the south Atlantic Ocean (from the latitude of the West Indies islands to that of South Argentina, or, on the other side, from Moroccan to South African coasts).

We address the oceanic international community at large, with a view to bring in, within the PIRATA program, besides France, some more countries from the European Community (Germany, Spain, Portugal, Great Britain, …), and also other countries potentially interested in the program (i.e. besides Brazil and USA, other countries in South America and West Africa).

Characteristics of typical operational missions PIRATA and Argo:

OP/OC missions distinguish themselves from classic oceanographic missions:

- They are repetitive, long-lasting and have to adapt themselves quickly to a multitude of chances (of material, economical order, even political) related to the maintenance of the network of observations.
- They involve light autonomous equipment (e.g. PROVOR floats of the Argo network), and semi-heavy (e.g. ATLAS buoys of the PIRATA network) and a limited scientific staff (3 to 4 persons).
- They cover oceanic lengths on the basin scale (e.g. the tropical Atlantic Ocean).
- The time of transit is dominating the time spent on station.

Possible types of vessel

It is natural to look for the type of vessel which should be best adapted to the realization of these operational missions:

a/ <u>Oceanographic Vessels</u>

Designed to achieve scientific missions, often rather sophisticated, they are not suited to carry out repetitive operational missions: Being too general-purpose, too slow, too expensive, with an oversized capacity of scientists' accommodation.

b/ Vessels of servitude

Used mainly for the operations of maintenance of off-shore oil platforms, the "supplies" are less sophisticated, slow and not necessarily less expensive in operating cost than R/V such as the R/V "Le Nadir" or "Le Suroît". Furthermore, these vessels are only available in oil extraction zones and can be dramatically deprived of equipment indispensable to a specific mission (e.g. deep sea bottom sounder indispensable when installing a PIRATA mooring, crane for handling equipment above the water). In case of an urgent oil intervention, their guaranteed availability for OP/OC purposes is questionable.

c/ Fishing Vessels

Tuna boats or deep-sea trawlers may be used on occasion for missions of simple dropping of light instrumentation. But their routine use is not straightforward with respect to economical and social concerns (on going doubts, within most of the crews, on the output of the scientific community, and even among ship owners). It is a solution less expensive than an oceanographic vessel, but which remains illegitimate, a fishing vessel being designed at first … to go fishing !

d/ Vessel specially conceived for this type of mission

The use of a dedicated vessel for this type of operations [on the tropical and south Atlantic Ocean] would allow to centralize the scientific approach of the network of observations. Such dedicated vessel would be a considerable trump card to anticipate loads (including chances), to avoid juggling with international chartering and to decrease costs (transport of material, areas of stocking, customs charges, etc. …) and to make efficient use of various human skills (specialized crew, engineers, scientists). Operational missions on the tropical and south Atlantic Ocean may occupy at least one dedicated vessel, specially designed for this specific purpose (see Section 7). This solution is outlined below.

4- Proposition for a Fast Oceanographic Vessel: the "NOR-50"

The main criterion for optimization of an operational vessel is its operating cost for recurring missions. It is also necessary to assume that the volume of operational missions implies full time use of such a vessel and of its supporting equipment and staff, an assumption that does not seem to raise doubts, for the Atlantic Ocean in the coming years.

Operational missions requiring a lot of transits, we should focus on a fast vessel, a feature that makes sense only if it is a light vessel. Now, the simplicity of missions to carry out, (involving light or semi-heavy equipment), allows precisely to consider a vessel with a limited payload capability, and an accordingly small displacement, resulting in fuel costs noticeably smaller than that of a classic oceanographic vessel.

We shall adopt the following functional specifications for a such fast oceanographic vessel (named “NOR-50” for “*Navire Océanographique Rapide de 50 m*”):

- *Type of operational mission:*

  Mooring of at least 4 PIRATA/ATLAS buoys
  Routine deployment of light autonomous instruments (drifting buoys, Argo floats,)
  Light oceanographic cruises with physico-chemical measurements

- *Specifications:*

  Capability to moor at least 4 PIRATA/ATLAS buoys
  Autonomy: 5000 Miles (trans-oceanic capability)
  Speed: 22 Knots in cruise (twice that of a classic R/V)
  Payload: 15 Tons (e.g. 4 complete buoys PIRATA/ATLAS)
  Crew: 10 persons, and 4 scientists

4.1 The MES Concept (Monocoque Elancé Stabilisé): Stabilized Slender Monohull

Within the framework of a French inter-ministerial program MENTOR (P. Marchand, 1994), and in association with several naval architects and shipyards, Ifremer performed between 1990 and 1993 comparative studies of big express ferries (hundred of meters length, 40 Knots, more than 500 passengers and 150 cars for applications such as the France - Corsica liaison). A particularly interesting concept in term of performances and “sea behaviour” was put forward on this occasion: MES (Stabilized Slender Monohull, also called "Monofast"); MES was patented in 1991, while engineering studies and detailed analysis of model tests in towing tank were performed. A smaller version (35 m, 200 passengers, 25 Knots, intended for the sideboard of islands in difficult seas, such as Ouessant, off Brittany coast), was then studied with the cooperation of the naval cabinet of architecture “Paul Lucas” (Brest, France).

We therefore benefit today from a solid architectural base and related computations for a fast vessel which seems to us able to answer the above specification.

The MES concept

Studied within the framework of the MENTOR program quoted above, the MES is a "monohull - trimaran" consisting of a very slender hull flanked with two small side floats which give her its stability at rest, when the main hull is ballasted with water, and therefore “low at sea”: it is then a trimaran. En route, the vessel is emptied of its ballast water, the side floats take out the vessel, now “high at sea”, becomes a slender monohull stabilized by two active (piloted) foils situated under the side floats.

By transforming, during the cruise, the trimaran into a stabilized monohull, one remedies the main defect of the trimarans which suffer a high resistance to movement due to the drag of floats, at high Froude indices. MES is therefore a “smart solution”, when compared to a trimaran, as far as speed and comfort in strong sea conditions are concerned.

Example of fast trimarans

Several vessels (see in Annex) have already been built, namely:
"Ilan Voyager", a 21 m ship,
"Ocean Alchemist", a 30 m ship, and
"Cable and Wireless", a 35 m ship.

This last one, even though weakly motorized has achieved in 1998 "*un tour du monde*" with an average speed of 16,5 knots (cf Figure in Annex).

Furthermore, the English Navy is closely interested in the concept of big trimarans, since their performances at sea are superior to that of the equivalent monohull. A 100 m prototype, the "Triton" was launched in 2000 for real size tests. The US Navy has also an interest for trimarans.

With the MES design, we think that it is possible to build even better ships than the trimarans. Although successful for speed performance, the catamaran will not deliver the same comfort on swell. In turn, the classic monohull (archimedian hull with not too much slenderness for remaining stable), needs to be over motorized, unless its hull design is of the "gliding type", in which case it will be particularly uncomfortable on a well formed sea. Finally, gliding catamarans and fast monohulls, such as those which carry passengers along coasts, have limitations in term of sea state conditions.

4.2 Characteristics of the MES (NOR-50)

To benefit at the same time of a high speed, a great "radius of action" and a reasonable driving power, the NOR-50 resumes the concept of stabilized slender monohull, "MES", described above. A fast extrapolation derived from previous studies leads us to the following characteristics:

Main characteristics of the NOR-50

Length	51.8	m
Overall breadth	14.4	m
Draft	2.10	m
Light displacement	90	T
Mean Displacement	138	T
Installed power	1500	KW
Average speed	22.0	Knots
Fuel tank capacity	57	T
Cruising range	5000	Miles

Other characteristics of the NOR-50

Length between perpendicular	49.2	m
Main hull breadth (deck)	6.50	m

Main hull breadth (waterline)	3.25	m
Ratio L/B ratio	15	
Freeboard bow/middle	2.95	m
Wetted surface main hull	186	m^2
Main hull volume	125	m^3
Displacement half load	138	T
Reserve of fuel	4	T
Fuel for propulsion engine	50	T
Fuel for generator set	3	T

Performances

Calculations were made with the following assumptions:

- Configuration MES (NOR-50) with small floats and side foils
- Speed: 22 Knots; Delta: 138 t; Overall propulsive efficiency: 0.60

R/Delta	43.4	Kg/t
Towing power	668	KW
Power required, calm sea	1116	KW
Power required, moderate sea (+ 15%)	1283	KW
Installed power (22 Knots at 85 % MCR)	1500	KW
Range at 20 Knots	5200	Miles
Range at 22 Knots	4600	Miles

Comfort at sea

Comfort at sea is a vital feature for a long haul express. NOR-50 does present favorable characteristics with respect to comfort:

- Not gliding monohull with fine hull (no "slamming", or knocking on waves)
- Centre of gravity very low
- Roll stabilization under the timaran option and very effective with the MES option.

1. In configuration of “classic trimaran”, the passive stabilization is insured by the side floats. They are sized with a view to give a roll behavior similar to that of a monohull.

2. With the MES option the active stabilization is insured by the side foils. The immersed volume of floats is smaller. As a result: less trail, less roll excitation than for the trimaran option.

3. The passive stabilization in harbor or during an oceanographic station is achieved by ballasting of the central hull. 2 ballasts located before and at the back of the oil tanks fill and empty automatically according to the speed (empty - fast in open fixed position). In what follows, we provide a quantitative assessment, (along with figures), of the MES design.

Additional description and features:

Working bridge / Stocking space

- Dimensions: 16 x 6 m, surface: 95 m^2
- Stocking space for 4 PIRATA / ATLAS buoys (diameter 2.30 m) and about thirty reels of cables (1/4 steel and ¾ nylon),
- Or, place for 1 container of 20 feet.

Means of lifting / Mooring

- Lateral crane, force 3 T to 4 m
- Oscillating back A-frame. Backward leaning allows to raise the buoy
- Winch

(A detailed study of the handling of PIRATA loads, including the 2.2 T PIRATA anchors, will be performed at a later stage)

Technical premises

- Back checkpoint (sight on the working bridge, rudder and engine controls)
- A “wet” laboratory 10 m^2, a “dry” laboratory 11 m^2
- Cockpit with zone NAV (chart house, devices, housings)
- Reserve 11 m^2 with cold compartment, mechanical workshop 10 m^2

Staff Premises

- Upper bridge: squared and dining room 4.5 x 6 m (27 m^2)
- Lower bridge: kitchen 6 m^2, sanitary facilities, toilet
- 10 independent cabins offering 14 sleeping arrangements

Machine, drive, direction

- Back main engine, on 1500 KW, reducer
- Line of tree with little tilt (2°), axial helix, suspended rudder
- Engine of supplement in front, 150 KW, transmission in Z
- Bow propeller or helix on a directional “pod” for “house keeping” on station

Electric generation

- Generator 50 KVA behind
- Alternator 50 KVA driven by the engine
- Back up generator above the bow propeller compartment

Cost Estimate

This draft was handed to the OCEA shipyard (Les Sables d’Olonne, France) for a first assessment of the cost. The budget for the ship itself would be 4.25 M$ US. It is safe to add a specific sum (0.75 M$ US) to cover engineering studies devoted to the many special features of this prototype. The resulting price (5 M$ US) should be compared with the 5.6 M$ US of the R/V "Antéa" and to the 28 M$ US estimated for an R/V such as “Le Suroît”.

5- **Figures** (see following pages) **and Plans and Pictures** (see Annex)

- Artist color-view under various angles (see pages 18 to 20)
    - Figure 5 : General view of 3/4 starboard aft
    - Figure 6 : View of 3/4 port bow from above
    - Figure 7: View of 3/4 starboard bow from under
    - Figure 8: View of 3/4 starboard aft from under
    - Figure 9 : Zoom on stern, view of 3/4 starboard aft

- General plans (1/100ème)
    - Plan 1: longitudinal section/decks
    - Plan 2: 3 views plan

- Pictures of existing Trimarans
    - "Cable and Wireless", a 35 m commercial ship
    - “Ilan Voyager”, a 21 m tourist ship
    - “Triton”, a 100 m military ship

Figure 1 : Deployment of an ATLAS buoy aboard R/V “La Thalassa”

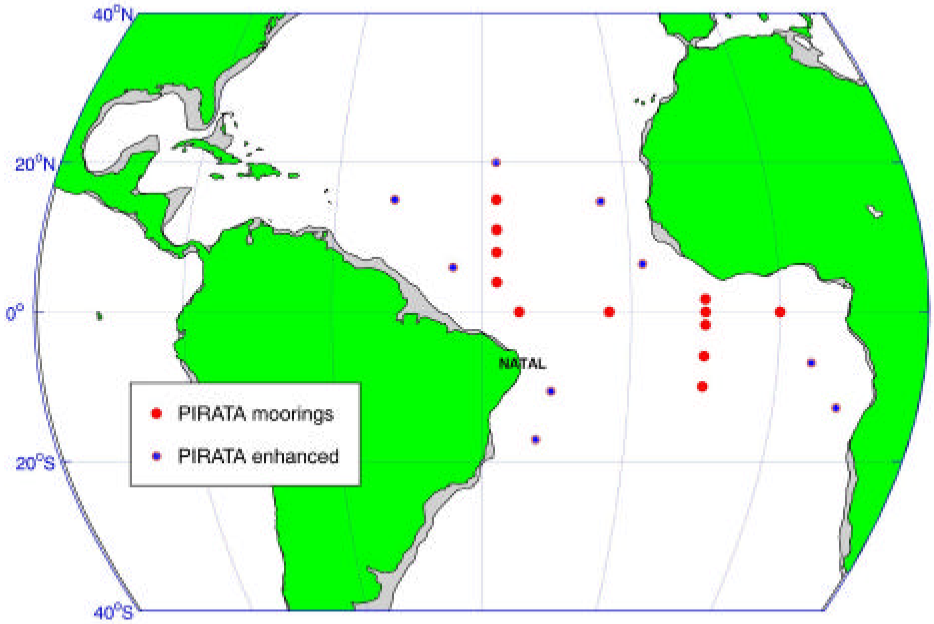

Figure 2 : Original network PIRATA (red points) and representation of anticipate (under discussion) spreading PIRATA array (blue points)

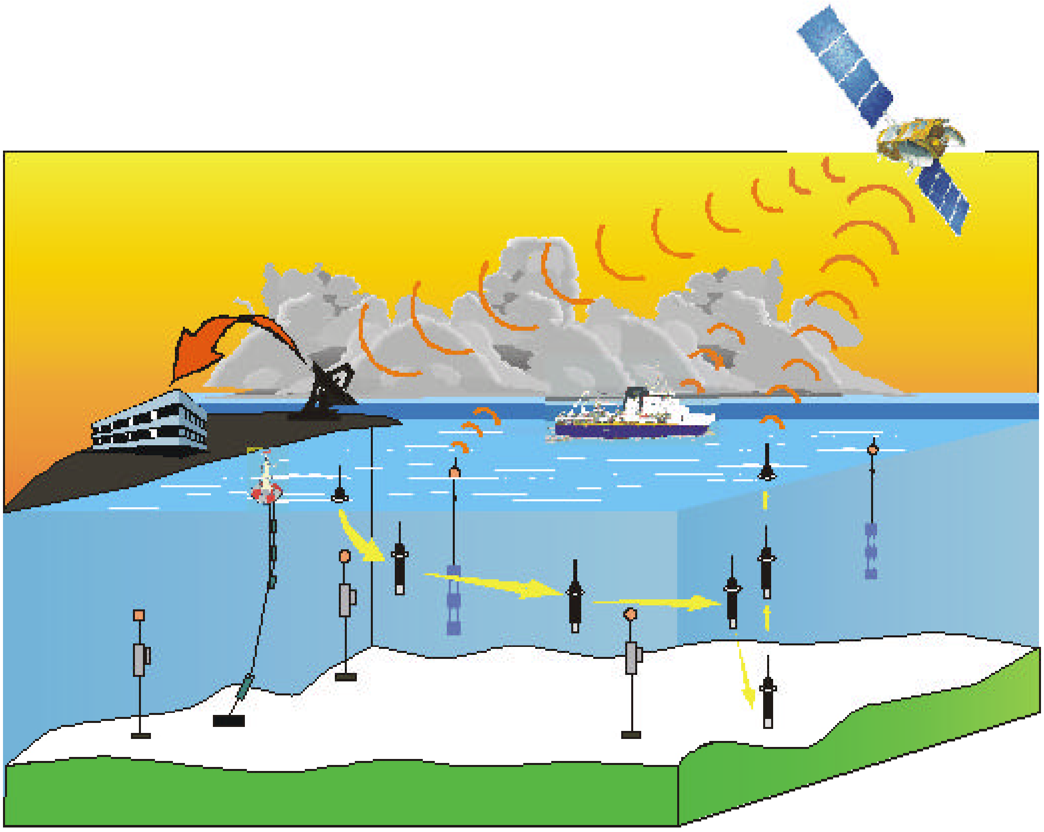

Figure 3 : Schematic of Argo and PIRATA means

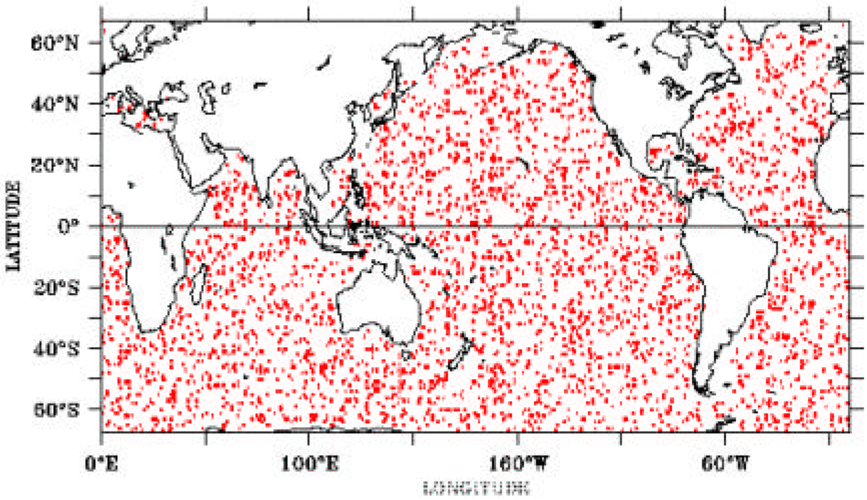

Figure 4 : Ideal distribution of 3000 Argo floats data return

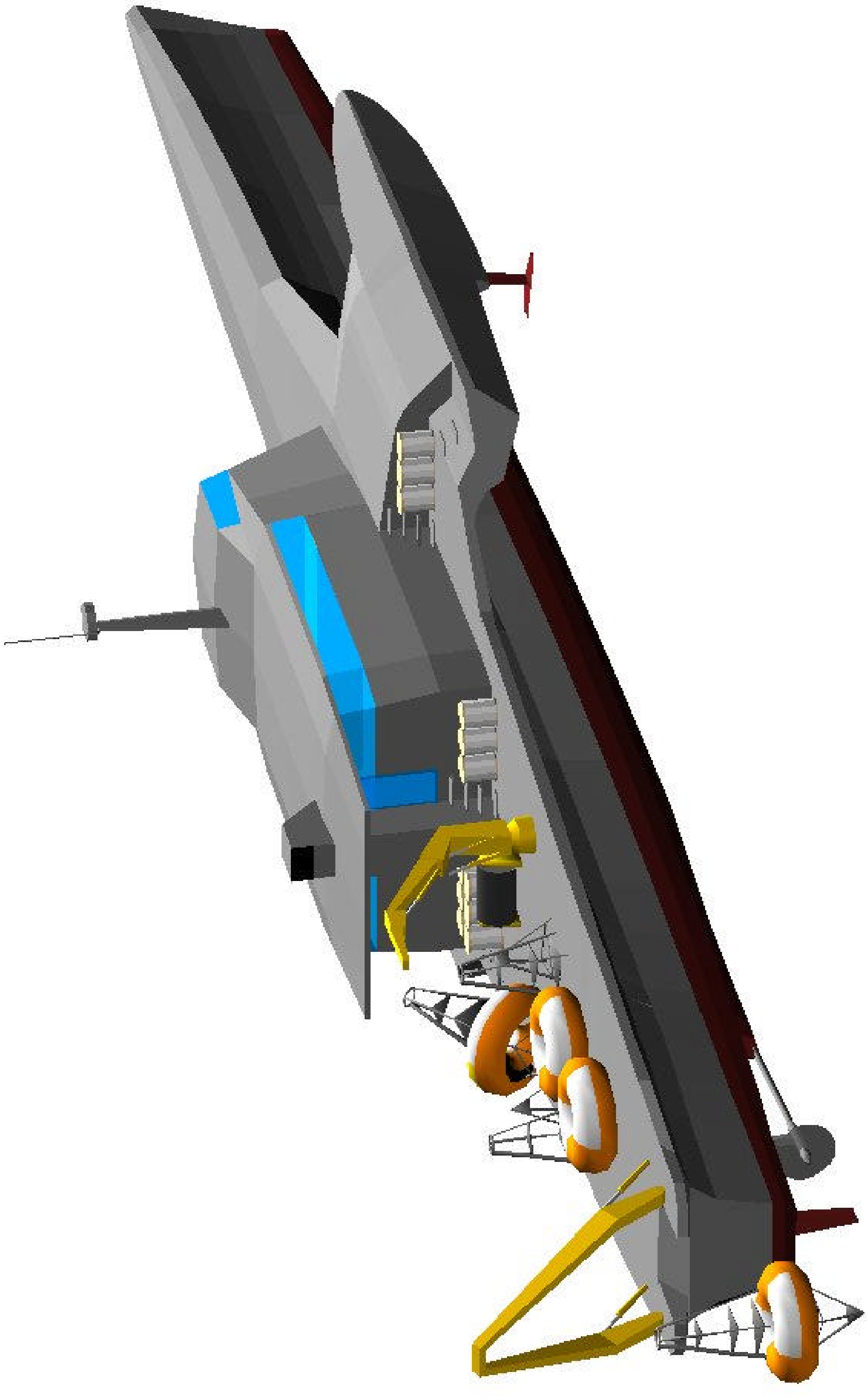

Figure 5: General view of 3/4 starboard aft

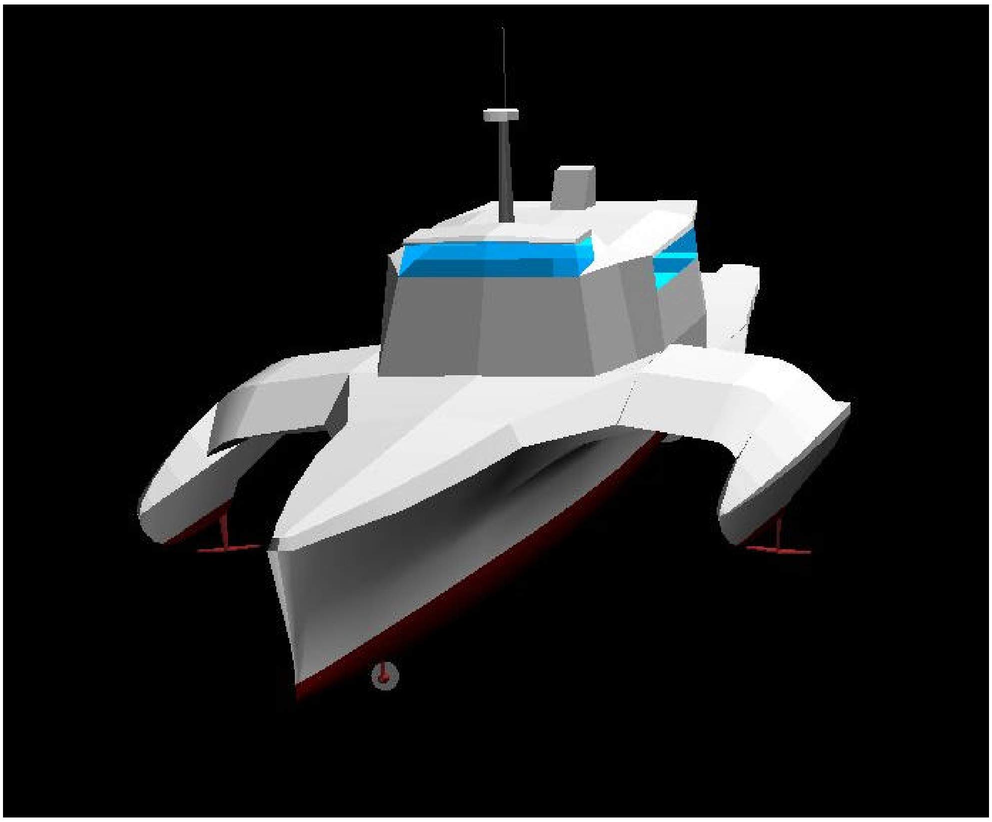

Figure 6: View of 3/4 port bow from above

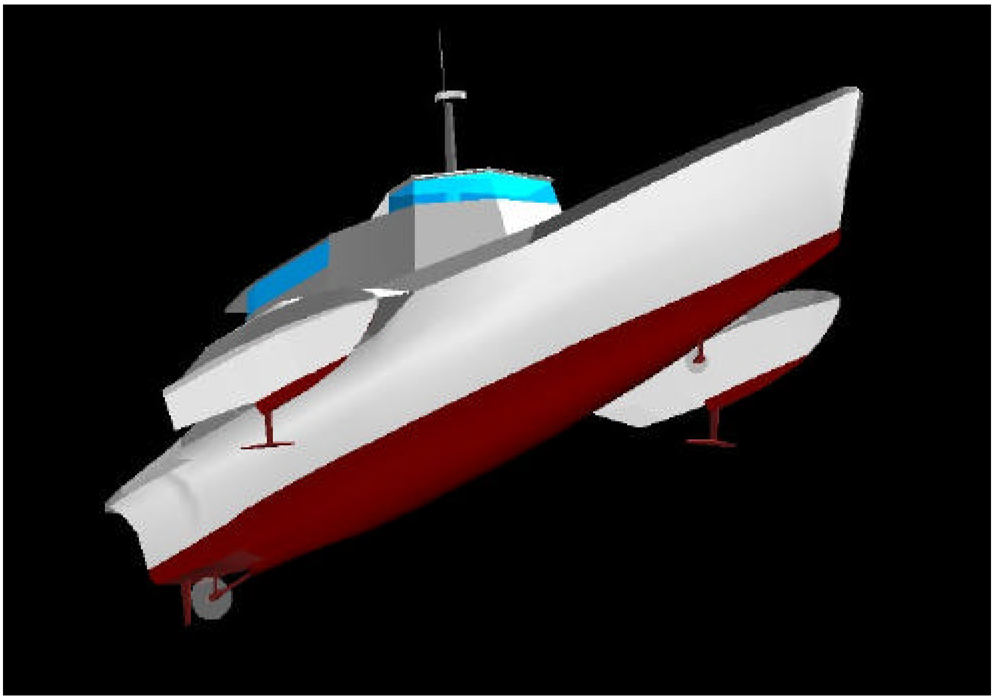

Figure 7: View of 3/4 starboard bow from under

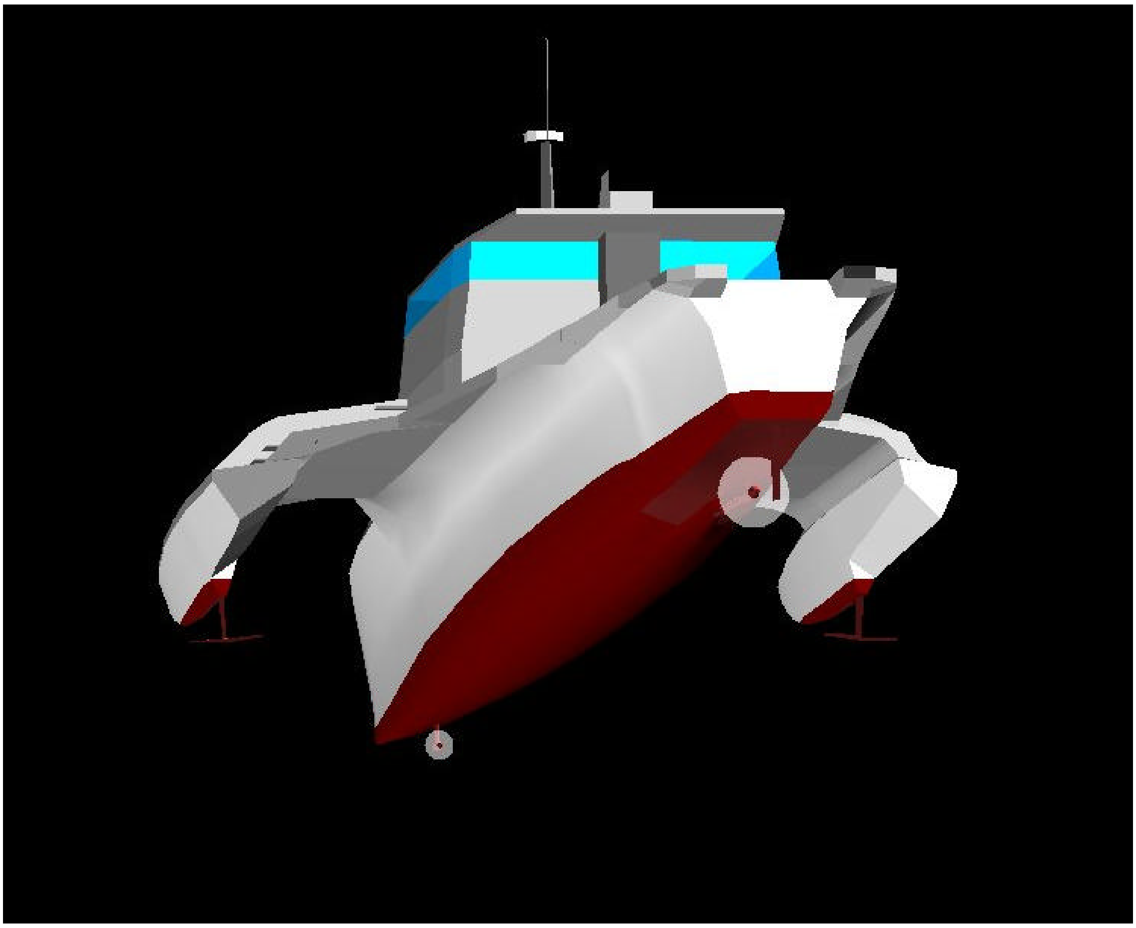

Figure 8: View of ¾port underneath

Figure 9: Zoom on stern, view of 3/4 starboard aft

6- Comparison of main characteristics and costs for three types of R/V

1) R/V L'Antéa
2) R/V Le Suroît
3) R/V NOR-50

Change (April 2001): 1$ US = 7.2 FF (= 1.1 Euro)

	Unit	Antéa	Suroît	NOR-50
CARACTERISTICS				
Length	m	35,0	56,0	52,0
Breadth	m	11,7	11,0	14,0
Full-load displacement	T	405,0	1130,0	165,0
Tank capacity (fuel density=0,9)	T	61,0	117,0	57,0
Vmax	Knot	13,0	13,0	25,0
Vcruise	Knot	11.0	11,0	22,0
Installed power	KW	940,0	1200,0	1500,0
Consumption Vcruise	Kg/hour	160,0	204,0	236,0
	Kg/day	3840,0	4896,0	5664,0
Range at Vcruise	Miles	3800,0	6000,0	4700,0
COSTS				
Investment	M$ US	5.55	27.8	5.0
Life-time	Year	20,0	25,0	20,0
Depreciation	M$/year	0.28	1.11	0.25
	K$/day	0.76	3.04	0.55
Men (crew//scientists)		13//4	15//4	10//4
Crew cost	K$/day	2.77	3.19	2.12
Other costs	K$/day	0.42	0.69	0.42

Comparisons of operating costs for two types of mission:

1) R/ V L'Antéa
2) R/ V Le Suroît
3) R/ V NOR-50

A) PIRATA mission (3 ATLAS buoys to remove/deploy)
B) Argo mission (30 PROVOR floats to launch)

	Unit	Antéa	Suroît	NOR-50
A- PIRATA cruise with 3 ATLAS buoys				
Transit duration at Vcruise	Day	11,5	11,5	6,3
Stations duration	Day	1,5	1,5	1,5
Total cruise duration	Day	13,0	13,0	8,8
Crew cost	K$ US	36.1	41.5	18.7
Depreciation	K$ US	9.9	39.6	5.9
Fuel (0.28 $ US/Kg)	K$ US	12.3	15.6	9.9
Other costs	K$ US	5.4	9	3.7
COST OF PIRATA CRUISE	**K$ US**	**63.7**	**105.8**	**38.1**
(cost/day)	K$ US	4.9	8.1	4.3
Relative cost / NOR-50		**1.7**	**2.8**	**1.0**
B- Argo MISSION, 30 floats, 4700 Miles				
Transit duration at Vcruise	Day	21,8	17,8	8,9
Stations duration	Day	2,0	1,0	1,0
Total cruise duration (1)	Day	23,8	18,8	9,9
Crew cost	K$ US	66.1	60	21
Depreciation	K$ US	18.1	57.2	6.6
Fuel (0.28 $ US/Kg)	K$ US	23.2	24.2	14
Other costs	K$ US	9.9	13	4.12
COST OF Argo MISSION	**K$ US**	**118.6**	**154.5**	**45.8**
(cost/day)	K$ US	4.9	8.2	4.6
Relative cost / NOR-50		**2.6**	**3.4**	**1.0**

(1) The Antéa autonomy requires a harbor stop to refuel and then an additional transit (total =5 days).

With respect to the TAO/Triton array already mentioned (cf. Section 2), the NOAA R/V Ka'imimoana (Ocean Seeker) is specifically designed for and dedicated to maintaining this array located in the tropical Pacific Ocean. 58 ATLAS (TAO+EPIC) moorings sites are visited twice per year, whether or not a recovery, repair, or deployment is done.

Given that i) the Pacific is a much larger basin, ii) ports of call are located further from the field of operations than in the Atlantic, (the R/V Ka'imimoana uses San Diego, Honolulu, which are distant ports from the moored array - See Figure 10 below), it is felt that a comparison of its costs with those of a typical PIRATA mission, (as described above), would not bring more to the rationale for the NOR-50 proposal.

Basically, most of the time devoted to servicing a buoy array spread out across an ocean basin is spent steaming. Therefore, it is evident that a fast ship will spend fewer days (and therefore less money) to maintain such an array.

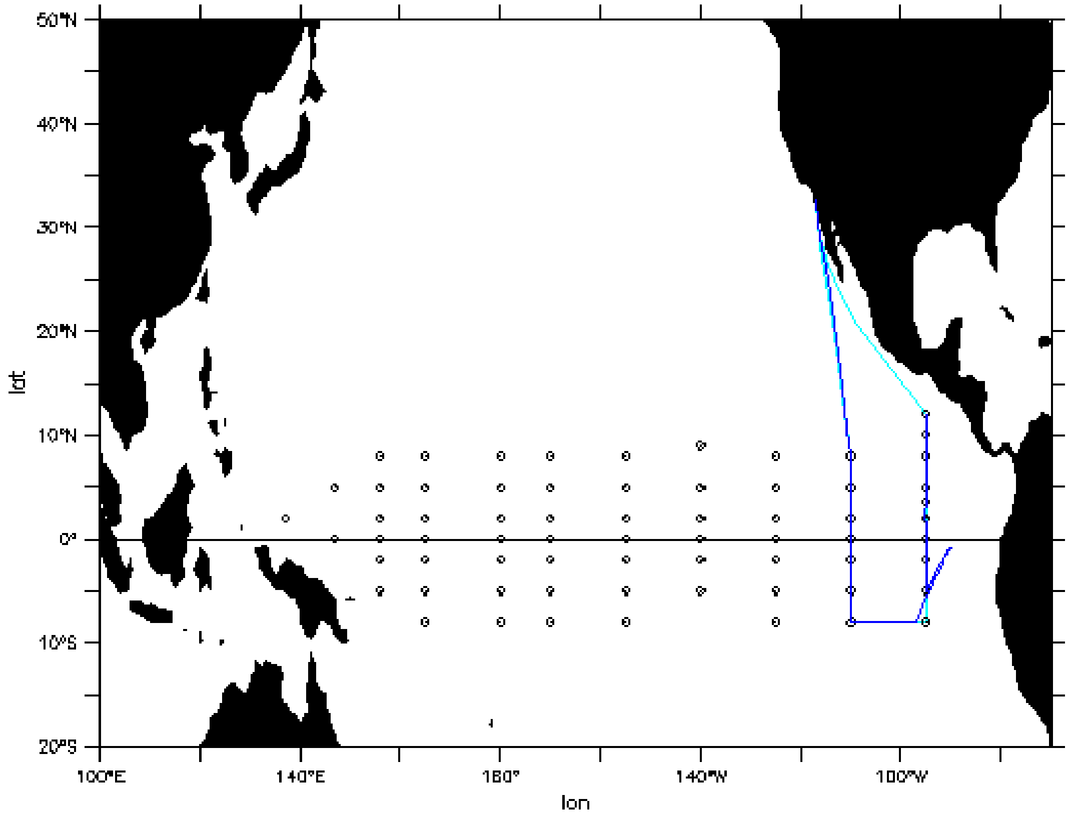

Figure 10: The TAO/EPIC-Triton network with a typical cruise done by the R/V Ka'imimoana

7- Assessment of the average annual workload (with NOR-50 assumed based at Natal, Brazil)

Assuming she is based in Natal (Rio Grande do Norte, Brazil), the NOR-50 annual average use is computed as follows:

One assumes that all the elements of the operational program for the Atlantic Ocean have already been set up (i.e. “routine mode” of operations).

As a result the following elements are accounted for:

- Maintenance of a “complete” PIRATA network, consisting of 22 sites (see Figs. 2 and 11).
- Maintenance of a “complete” Argo network, (with a theoretical point of deployment/measurement on an “ideal grid” 3° lat. X 3° longit.) between 20°N and 40°S in the Atlantic Ocean.

Other working hypothesis:

The NOR-50 “useful year” is about 10 months (i.e. except 2 months overall for yearly maintenance and dock),

The NOR-50 is used during the remaining parts of the “useful year” for operations of light oceanography (e.g. CTD 0-2000 m, various physico-chemical measures in the oceanic mixed layer) by chartering either regional, or national or international (see also Section 9).

7.1 Maintenance of the PIRATA network (4.5 months)

Requirements and working hypotheses are as follows:

- 22 PIRATA sites (see Figs. 2 and 11), from 20°N to 15°S,
- Recovering and/or mooring of 4 ATLAS buoys (maximum) by leg,
- Once per year recovering /mooring for each of 22 sites,
- At least one supplementary annual visit by site,
- Departure from and return to Natal (Brazil), with an optional stopover (2 or 3 days) if transit length is greater than 4500 miles,
- Cruising speed = 22 Knots

Taking into account for each of the sites only the operations of recovering/mooring, the whole network is yearly covered with six legs. Based on previous experience and considering an overall goal of availability/reliability, it is deemed necessary to pay a visit on each of the sites at least twice a year, which makes up for an estimate of three more legs. The overall annual total of nine legs, (see Fig. 11 and associated Table), represents a total yearly duration of about 4.5 months and an accumulated distance of about 45,000 miles. It must be clear that these nine legs should not be made in a single sequence and that the maintenance of the PIRATA network should be distributed on the 12 months of the year, in alternation with the other works (maintenance of the Argo network and additional oceanographic operations).

7.2 Maintenance of the Argo network (2 months) - Atlantic Ocean (20°N to 40°S)

7.2.1) In the zone not covered by the PIRATA network (15°S to 40°S)

It is indeed written in Argo (and Coriolis) documents that the maintenance of the Argo network should be insured mainly by the dropping of floats from merchant ships. This is true for vast portions of the world oceans, but not warranted of course in all the world oceanic zones. This is particularly the case for the south Atlantic Ocean where the routes of merchant ships are very scattered and leave an enormous hole between South America and South Africa (see Fig. 12). To be sure to get an adequate “Argo sampling” (that is a profile 0-2000 m according to an initial meshing 3 ° latitude x 3 ° longitude, see Fig. 4), it will be necessary to drop floats from specially dedicated platforms. We think that the NOR-50 can be used as an answer to this question of floats dropping on “difficult Argo grid locations” in the Southern Ocean.

Requirements and working hypotheses are as follows:

- Northern limit of the Argo zone to be covered = Southern limit of the PIRATA zone; for the sole purpose of this NOR-50 assessment, this limit has been set at 15°S,
- South limit the Argo zone to be covered = around 40°S (for reasons of safe navigation of the NOR-50),
- A standard Argo grid of 3° longitude x 3° latitude
- An average life time of floats of 3 years, which implies (theoretical) re-sowing in the same place once every three years
- A single annual Argo mission (with a single departure and a single return in Natal), but consisting of multiple transits with eventual intermediate stopovers
- Length of every transit limited to 4500 miles with a stopover of 2 to 3 days between every transit
- Average speed of cruise of 20 Knots (average between 22 Knots in low latitudes and 15-18 Knots in higher latitudes)
- Negligible loss of time (not accounted for) for dropping of floats.

Maintenance of the Argo network in the totality of the zone described above is insured with three missions during three years (1 mission/year). See Figure 12 and associated Table for more details. Every mission breaks into four East-West trans-oceanic crossings spaced out by about 9° of latitude. Distance crossed for every annual mission is about 16,000 miles, and about 50 days in duration (Natal-Natal), with four intermediate stopovers. The number of Argo floats dispatched every year will be around sixty, for a total number covering this region of 190.

7.2.2) In the zone covered by the PIRATA network (20°N to 15°S)

The nine legs described above for the annual maintenance of the PIRATA network should also be used to sow the network of Argo floats in this zone. During each one of these nine legs needed annually, it is felt that 10 floats (maximum) will be dropped. This supplementary work will have only marginal consequences in term of additional duration. Consequently, no specific Argo mission is foreseen in this region.

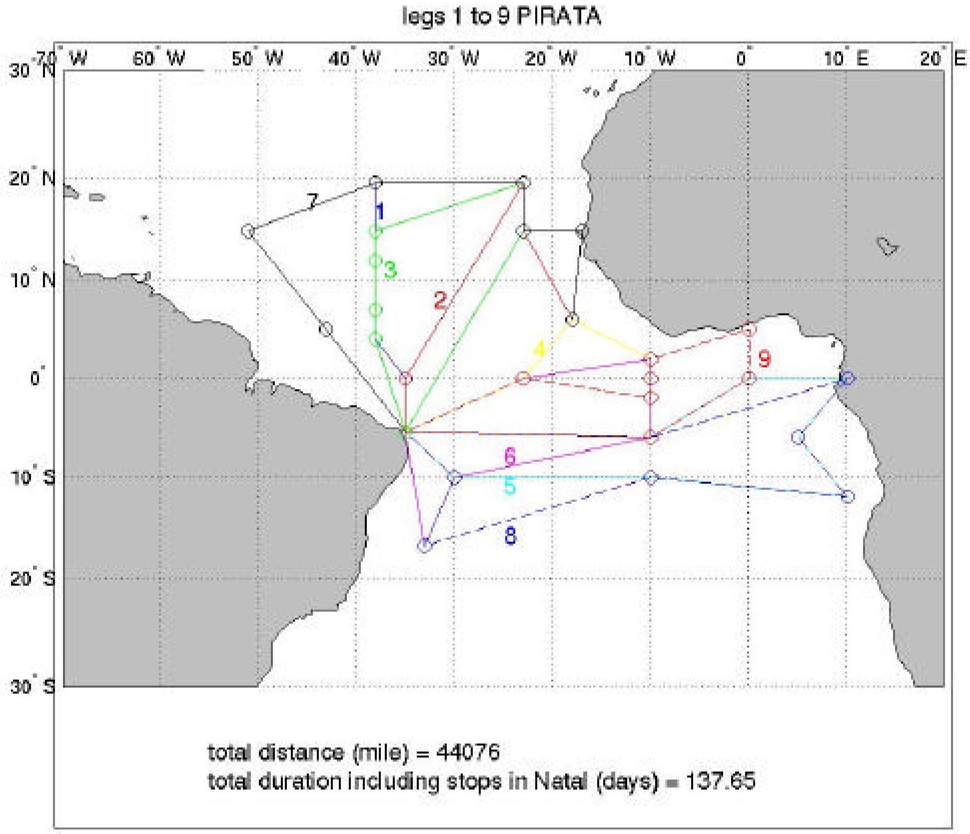

Figure 11 : PIRATA yearly maintenance

N° Leg	Total Cruise Distance (miles)	Total Cruise Duration (days)	Number Depl./Rem. (days)	Number Checkings (days)	Stop Place (days)
1	3925	9.60	4 (1.67)	4 (0.50)	- (0)
2	3878	9.13	4 (1.67)	1 (0.13)	- (0)
3	3867	9.85	3 (1.25)	3 (0.38)	- (0)
4	3765	9.05	4 (1.67)	2 (0.25)	- (0)
5	6503	17.23	4 (1.67)	2 (0.25)	Pte Noire (3)
6	4427	10.13	3 (1.25)	4 (0.50)	- (0)
7	5641	13.56	0 (0)	7 (0.88)	Dakar (2)
8	7132	17.25	0 (0)	6 (0.75)	Pte Noire (3)
9	4937	11.85	0 (0)	6 (0.75)	Abidjan (2)
Number Stops in Natal (days)	-	10 (30)	-	-	-
Yearly TOTAL	**44076 miles**	**137.65 days (4.5 months)**	22 Depl./Rem. (9.18 days)	35 Checkings (4.39 days)	3 3 Stops (9 days)

Duration of 1 Deployment/Removing = 10 Hours
Duration of 1 Checking = 3 Hours
Velocity during the transits = 22 Knots

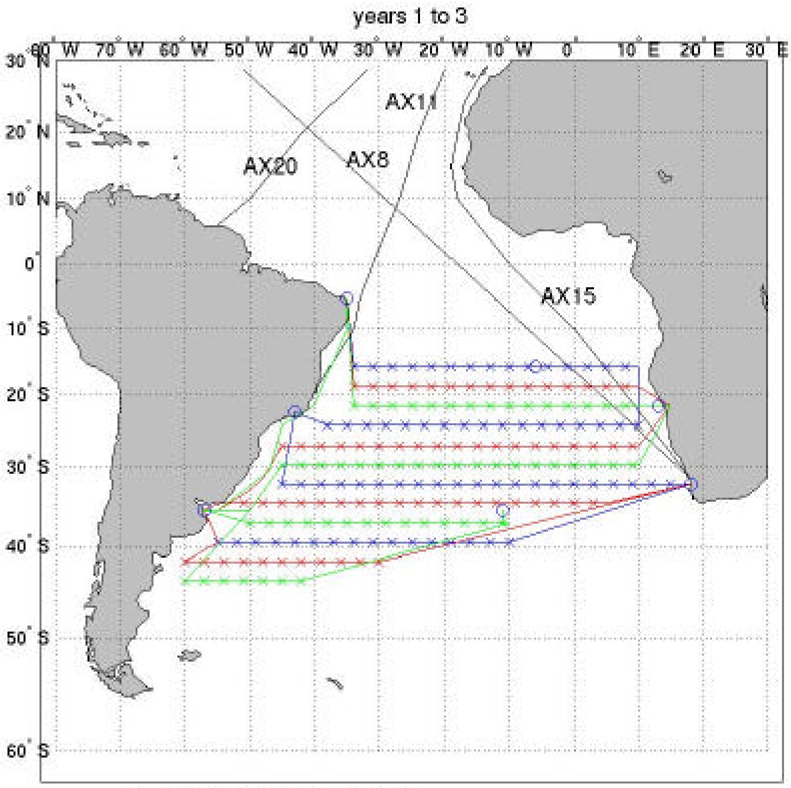

Figure 12 : Argo maintenance (3-year coverage) and XBT tracks (AXxx)

Year	Total Cruise Distance Natal-Natal (miles)	Total Cruise Duration Natal-Natal (days)	Number Argo Floats	Stop Places (days)
1	16400	50.3	65	Natal/Sta Helena(2)/Rio de Janeiro(3)/Cape Town(3)/Mar del Plata(3)/Natal(3) (Total = 14 days)
2	17868	54.4	63	Natal/Swakopmund(3)/Mar de Plata(3)/Cape Town(3)/Mar del Plata(3)/Natal(3) (Total = 15 days)
3	15951	49.4	59	Natal/Swakopmund(3)/Mar del Plata(3)/Tristan da Cunha(2)/Mar del Plata(3)/Natal(3) (Total = 14 days)
3-Year TOTAL	**50219 miles**	**154.1 days**	**187**	43 days

Duration of 1 deployment = no time accounted for
Mean velocity during the transits = 20 Knots

7.2.3) Additional sowing of Argo floats

Putting on a side the PIRATA and Argo missions properly said, some floats could be dropped by NOR-50, (as by other platforms), during oceanographic campaigns occurring in an Argo zone of interest (see below).

7.2.4) Other Argo missions

It is not considered necessary today to get back the Argo floats at the end of their life. In the future, environmental pressure on such a requirement may become stronger. It is clear that a fast vessel would be better to face it, at least partially.

7.3 Additional light oceanographic campaigns (3 months)

According to the assessments given above, the annual NOR-50 time needed for maintenance of the PIRATA and Argo networks is close to 6.5 months. Two other reasonable assumptions may be made as follows:

- A technical stop of about two months every year is foreseen for a vessel of such an advanced conception
- An annual reserve of two to three weeks is provided for in order to cope with fast and not programmed interventions (e.g. acts of vandalism on a PIRATA site)

As a result, the NOR-50 would be available during about 3 months/year for additional operations of oceanography.

This additional mode of exploitation of NOR-50 should naturally be managed in accordance with a global workload foreseen several months in advance and in association with institutes and research teams involved in the NOR-50 project (see also the next Section).

One should keep in mind however that the cruises to be carried out should be of the "light oceanography" type. They will need to comply with specific vessel constraints (e.g. limited stocking), its operating mode (e.g. limited crew and scientific staff), and the type of instrumentation which will be installed aboard, either permanently, or on times. Some of these observations would be carried out in transit in an automatic way, either at high speed, or at reduced speed. Some other measures will require a stop (not necessarily at a particular location).

The great speed of the vessel will allow to limit the transit time between the places of departure and/or arrival and one or several zones of study. In the same way the coverage of a particular zone including works on zone will be achieved in a minimum of time. This last point should be noted in view of the limited number of researchers-engineers able to embark on the NOR-50 (at most four) and in view of the workload which will be asked them and which could be, occasionally, concentrated on a limited time.

During these additional campaigns the NOR-50 could be chartered by national institutes, (e.g. IRD, INPE, Ifremer, NOAA), in different places of the Atlantic basin and could be used within the framework of regional or even international programs (e.g.

works in the ZEE of Brazil, or along Angola-Namibia-South Africa's coasts…). The goal of these measures could be, for some study zones, a "classical" seasonal follow-up of the dynamics and thermo-haline contents of the first superficial layers of the ocean. These measures could, occasionally, be coupled with an accurate determination of ocean-atmosphere interaction parameters, thus providing a direct or indirect correlation with other observations, such as those of the PIRATA network.

The NOR-50 could also be used to implement a novel approach that could be named "surface oceanography" with re-iteration of deep-sea routes and with continuous measuring, (or fast sampling), of various elements related to the carbon cycle. From several perspectives, the ocean surface is indeed interesting by itself, independently of the deeper water properties. As it is well known, the surface is in contact with the atmosphere: the interaction already mentioned consists primarily in exchanges of heat and steam, but also gases. On the other hand, the surface receives sunlight, and witnesses evidence of photosynthetic carbon fixation and biological activity in the euphotic layer of the ocean (the first 50–150 m). Finally, space born remote sensing is primarily related to surface parameters (even though space born altimetry gives an *integral information* about the water column) These properties therefore confer to the surface of the ocean a critical role in the carbon cycle, making it a strategic target for the study of this cycle.

Numerous examples of useful studies could be quoted in this context of additional missions of the NOR-50. The interested (and French-speaking!) reader will find a list, by no way exhaustive, in the Appendices.

8- Possible financing scheme for the NOR-50 project

As described above, the NOR-50 will be used for tasks undertaken in a multilateral framework and benefiting the international community: its costs of construction and operations should be shared among some of the bordering countries, pending wider international cooperation. Let us consider now in more depth some economic aspects of this project.

8.1) Assessing the need: Is there a "Market"?

As usual when technological advances are considered, the cost/benefit analysis provided in Section 6 depends upon one critical assumption:

On the long run, despite the wider use of automated/autonomous devices, the emergence of OP/OC will trigger more needs for continued ocean and climate monitoring: trends to follow up, hypothesis to test, controversial issues such as heat and carbon dioxide stored by the ocean. Overall, the R/V fleet/time available will not match these needs. (See also Section 2.2.i above). Indeed, if there was R/V over-capacity available in the next 20 years, the NOR-50 project would bring only marginal benefit.

More specifically, it is assumed that the 14 to 16 months of R/V's time which would be otherwise devoted, (if there was no NOR-50), to the tasks described in Section 7 will be effectively used for other "domestic" research campaigns, and/or for chartered cruises by international companies and agencies (facing a "make or buy" choice…).

Under such an assumption, it is clear that savings, (or extra income from R/V chartering), will be achieved overall.

However, the NOR-50 project is not considered in isolation: the agencies that could be involved are already owning and/or operating R/V's; they do have plans for fleet renewal and how to meet future needs. When compared with the corresponding capital investment required, "purchasing a fraction of the NOR-50 project" is more or less a "minor decision"… Nevertheless, its mere existence would allow for closer consultations with respect to overall fleet renewal, as well as "fine tuned" optimization.

8.2) Costs assessment confidence:

It is not possible, at the present stage, to define in details what could be the development and exploitation plans. However, as far as the investment cost is concerned, since it is based upon an independent cost estimate**,** (see end of Section 4), it can be granted a good level of confidence.

With respect to annual operating costs, the assessment of Section 6 is based on several explicit or implicit assumptions, such as:

- Even though the NOR-50 is a novel ship with specific requirements, it is assumed that only 2 or 3 crew members, (other than the shipmaster), will need to be highly specialized in NOR-50 operations; in other words, more than one half of the crew may be recruited in a wider "pool of sailors" (see next item).

- As usual the NOR-50 owners may consider to subcontract ship operations to some specialized firm [(i.e. Genavir in France?)], in order to minimize fixed costs.

- With these assumptions, the monthly cost for a PIRATA campaign, (~ 130 K$ US, cf. Section 6), may be split in fixed and variable costs: ~ 52 K$ US and ~ 78 K$ US respectively. One third of the fixed cost is related to ship depreciation (and subsequent renewal). As a result, the fixed cost to be covered each year with new funding may be estimated between 0.40 and 0.45 M$ US[1], or a little less than the figure given by the "rule of thumb" based on "10% per annum of the capital investment"…

Such a rough estimate will obviously need to be refined when the funding and operations schemes are defined more precisely. It has however the merit, for the time being, to show with a somewhat good confidence, that the funding to be covered by each of the partners is in the 100 K$ US per year range (assuming 4 or 5 owners).

All in all, the remaining, (variable), cost for actual navigation appears to be an average of 2.6 K$ US/day (one half being fuel cost).

[1] Specialised crew (800 $ US/day) + others (repair, harbour, …) (400 $ US/day) = 1200 $ US/day thus for 365 days : 1200x365 = 0.438 M$ US.

A tentative list, in no way exhaustive, of the agencies, public institutes, and nations susceptible to take part in this project may be drafted as follows:

- France (Ifremer, IRD, Météo-France, CNRS/INSU, …)
- Rest of European Community: Germany, UK, Spain, Portugal, …)
- Non European: regional, national, and international Institutes: e.g. INPE and MCT (Brazil), NOAA (USA), Morocco, South Africa, Argentina…

Costs of the project and possible sources of financing:

- Initial investment: 5 M$ US (= 35 MFF or 5.4 MEuros) to be found among international partners involved in operational oceanography activities like PIRATA and Argo, and also among institutes willing to charter occasionally such a vessel, while being a “privileged partner”.

- Operations related to PIRATA and Argo operational activities (~ 7 months/year and 100,000 Miles): 0.85 M$ US/year, (fixed cost share included), to be found among a consortium of the international partners involved in these activities.

- Operations not related to an operational activity and light oceanographic campaigns (3 months/year and xxx Miles): financing insured by chartering institutes ("privileged " or not).

- Annual cost of the technical stop (2 months) and miscellaneous expenses: these costs are included in the 0.4 M$ US of fixed costs already considered.

9- Final recommendations for developing and managing the NOR-50 project

Project implementation – Vessel Construction – Management

Operational oceanography is an activity which must be envisioned at international level.

Several previous endeavors, with much wider financial envelopes, may be quoted:

- European Met-Ocean organizations: ECMWF and Eumetsat, operating complex facilities: massive parallel computers and numerical models, Met-sat’s housekeeping, inter alia.

- The French-US Topex-Poseidon and Jason series, devoted to high accuracy altimetry.

- European or international astronomical observatories: European Southern Observatory in Chile (interferometry with large instruments), the CFH (Canada, France, Hawaii) telescope.

- Last but not least, the Space Station and its rather daunting operating costs…

In the case of the NOR-50, despite its limited financial size, it is indeed valuable for this project to be financed, then managed in an international framework. One thinks of a coordinated contribution of the European Community (France, Germany, UK, Spain, Portugal, …), plus other stakeholders from Northern countries (namely the USA) and naturally the countries directly involved (primarily Brazil, and some countries of Africa of the West and the South). The contributions of each of the participating countries being inevitably heterogeneous, such coordination should be flexible enough in its design, while based on clearly pre-established basic principles and objectives.

International oceanographic base

In order to insure an economical management of the project and to optimize the scientific works of the NOR-50, it is clear that this vessel should be based in a place near the center of gravity of its area of activity. This place may already be named: it is Natal (State of Rio Grande do Norte), in the eastern point of Brazil (Fig. 2). An agreement of cooperation to this end is already in advanced discussion between IRD on the one hand and the Brazilian Institute INPE (Instituto de Pesquisas Espaciais) on the other hand. This last agency owns an important Center in Natal which already serves as a base for PIRATA- Brazil.

Tentative schedule for the NOR-50 project

- **February-April, 2001:** Broadcasting of this document (French and English versions); Presentation of the project and first discussions with French, European, and non-European partners; Search for financing (preferably "outside research budgets") for a detailed study of the project (~ 55 K$ US).

- **May-July, 2001:** Preliminary study of launching/retrieving operations of PIRATA buoys aboard NOR-50 and its impact on the vessel architecture.

- **July-December, 2001:** Identification of an “owner” for the project; Setting up of a study group at international level; completing requirements list and RFP document conditions of contract; Further detailed study of the project; On going action on financing issues and search for subsidies.

- **January-June, 2002:** International RFP for the construction of the NOR-50. Elaboration of vessel Principles Of Use & Regulations (“POUR” charter) in line with international law; Progressive implementation of the agreed financing scheme. Setting up of the first elements of an international base for observation of the tropical Atlantic Ocean climate in Natal (Brazil).

- **July, 2002–Fall of 2003:** Vessel construction; First tests; Development of the Natal base; Signature of the charter (POUR) by the different participating countries.

  First half of 2004: inaugural Campaign of the NOR-50; complete installation of the Natal base.

- **2005:** Beginning of routine operations (PIRATA and Argo networks, other campaigns …) from Natal.

Acknowledgments

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Annex

1/ General plans of NOR-50 (1/100)

- Plan 1: Longitudinal section/decks
- Plan 2: 3-D views plan

2/ Pictures of existing fast Trimarans

- "Cable and Wireless", a 35 m commercial ship
- “Ilan Voyager”, a 21 m tourist ship
- “Triton”, a 100 m military ship

Appendices

Examples of bio-geochemical "surface" measurements

(in French, adapted from a Personal Communication of Yves Dandonneau)

De nombreux exemples d'étude peuvent être détaillés dans le contexte des missions complémentaires du NOR-50, dont voici une liste absolument non-exhaustive :

- *Etudes des zones frontales (ex. la zone frontale du courant du Benguela ou celle du courant des Canaries)*
- *Etudes de dynamiques particulières (ex. le phénomène de rétroflexion du courant superficiel dans la zone du CCNE ; la terminaison du CCE dans le fond du Golfe de Guinée)*
- *Etudes ciblées (ex. la production primaire par les effluents de l'Amazone)*
- *Répétitivité (de quelques heures à saisonnière) de mesures faites dans le cadre de l'océanographie de surface le long de trajets prédéfinis (de l'échelle régionale à l'échelle trans-océanique)*

Les types de mesures effectuées dans ce cadre d'utilisations complémentaires du NOR-50 pourraient être de diverses natures, et on en énumère quelques unes ci-dessous (liste non exhaustive) :

1) Mesures d'océanographie physique et de météorologie

Il s'agit là de missions d'océanographie « classique » principalement basées sur l'étude de la dynamique et des propriétés physiques de l'eau de mer :

Un Thermosalinographe de coque sera installé sur le navire permettant des mesures en continu de la température et de la salinité à la surface de la mer. Ces mesures pourront être transmises en temps réel et comparées immédiatement aux mesures satellite de température et (ultérieurement) de salinité de surface

Des lancers de XBT et XCTD pourront être généralisés en route (profils verticaux de température et de salinité de 0 à 1000 m)

Des stations CTD pourront être effectuées (côté bâbord), mais elles seront limitées à une profondeur de 2000 m

Des lancers de ballons-sonde seront possibles à partir des plages avant et/ou arrière

Une station de météorologie haute résolution avec mat instrumenté et système inertiel peut être envisagé (acquisition automatique des données)

A ce stade du développement technologique il n'est pas certain, que compte tenu de la vitesse élevée du navire (supérieure à 20 nœuds en transit) et son faible enfoncement dans l'eau (pour une traînée minimum à haute vitesse), on puisse utiliser un ADCP de coque pouvant mesurer en continu la structure 3-D du courant dans les 300 premiers mètres, et ce à la vitesse de croisière. Une étude de faisabilité devrait être exécutée auparavant

2) Mesures physico-chimiques à la surface de l'océan

Les diverses propriétés mesurées, et qui sont énumérées ci-dessous, confèrent à la surface de l'océan un rôle important dans le cycle du carbone, et en font une cible stratégique pour l'étude de ce cycle. Une approche complémentaire consiste à observer les algues qui ont le pouvoir de photosynthèse dans l'océan, afin d'estimer la fixation biologique de carbone, qui représente une inconnue importante dans le cycle du carbone. L'observation de ces algues, et en particulier de leurs pigments photosynthétiques (tels que la chlorophylle), permet de comprendre la variabilité de la plus grosse partie de la fixation biologique de carbone dans l'océan. La couche mélangée de surface, bien éclairée, réalise en effet l'essentiel de la production primaire marine. Outre l'éclairement et la température, un élément important pour le contrôle de la production primaire est la concentration en nitrate, et autres sels nutritifs. Des prélèvements d'eau de surface peuvent être conservés par congélation puis analysés ultérieurement au laboratoire afin de connaître la concentration en sels nutritifs, et de pouvoir identifier les régions ou les périodes où ces sels nutritifs sont présents, voire abondants, à la surface de l'océan. C'est en effet lorsque ceci se produit que le phytoplancton peut se développer rapidement et qu'ont lieu les épisodes d'exportation massive de carbone vers la profondeur. La possibilité, par l'utilisation du NOR-50, d'effectuer ces différents types de mesures à vitesse élevée, et donc de couvrir de grandes surfaces en un temps synoptique, sera un atout supplémentaire dans notre connaissance des processus mis en jeu :

- *Mesures de la pression partielle de gaz carbonique (pCO_2) en continu et/ou par échantillonnage, soit par méthode classique d'équilibrage air/eau et d'analyse par absorption infra-rouge, soit par capteurs spécifiques tels que celui développé au LODYC en collaboration avec la DT INSU*
- *Mesures en continu de la luminance et de la fluorescence marines. Ces mesures acquises à la surface de l'océan sont d'une grande utilité pour la validation des algorithmes de traitement des données satellite de couleur de l'océan (ex. Programme GeP&CO)*
- *Mesures par échantillonnage et filtration (avec conservation des échantillons à –80°C) de pigments photosynthétiques (tels que la chlorophylle et autres pigments accessoires) qui renseignent sur la nature et l'état de l'écosystème et sur les modalités qui accompagnent son action sur les stocks de carbone de l'eau de mer*
- *Mesures par échantillonnage de la concentration en nitrate, et autres sels nutritifs (avec conservation par congélation)*
- *Mesures de la concentration en fer (un élément important pour la production primaire) sous réserve de possibilité technologique (rendue cependant moins difficile grâce à un navire fabriqué en inox)*
- *Prélèvements phytoplanctoniques et zooplanctoniques de la couche de surface ne nécessitant pas d'enrouleurs de chalut*

Certaines de ces techniques de mesure étant d'une mise en oeuvre délicate, elles ne pourront être effectuées que par des techniciens spécialisés.