R/V *Mirai*, her missions, facilities and special project "BEAGLE 2003"

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***Abstract*-The R/V *Mirai*, with its large ice-strengthened sturdy hull, was launched in 1997 (Dimension; Lx B x D = 128.58 m x 19 m x 13.2 m; 8,687 Gross tons). The ship, in particular, with its large size and its anti-rolling device of special design, is capable of undertaking missions to high-latitude and Polar Regions exposed to the extremely harsh weather and sea conditions. The ship is equipped with many state-of-the art oceanographic and marine meteorological instruments and is expected to act as a floating platform for sophisticated interdisciplinary researches, emphasizing on global change. One advantage of *Mirai* is that highly trained marine technicians with many observation and data analysis devices support the scientists onboard. This arrangement allows the scientists to develop onboard research results efficiently.**

The missions of *Mirai* include making clear the role of the oceans on heat transport, material cycle and marine ecosystems as well as seafloor plate dynamics. The R/V *Mirai* surveyed vast sea areas ranging from the Arctic Ocean, the Pacific Ocean to the eastern tropical Indian Ocean during1997 to 2003. This year we will have a round world trip survey mainly in the southern hemisphere called "BEAGLE 2003" cruise after Charles Darwin's voyage of Beagle. The R/V *Mirai* will start from Brisbane and end at Fremantle, Australia via Papeete (Tahiti), Valparaiso (Chili), Santos (Brazil), Cape Town (South Africa), Tamatave (Madagascar) and Prot Luis (Mauritius). The BEAGLE cruise will focus on the studies of three main theme: the heat and material transports and their variability in the general ocean circulation, the basin-scale biogeochemical changes of the chemical properties and chemical interaction between air and sea water, and the paleo-environmental changes in the ocean. The cruise is designed to revisit WOCE (World Ocean Circulation Experiment) Hydrographic Program (WHP) lines in the southern hemisphere to detect the long term change in the hydrographic structure and the Antarctic overturn by surveying WHP lines in the Pacific, the Atlantic and the Indian at one cruise. This southern hemisphere circum navigation was highlighted at POGO (Partnership Of Global Observation)-3 (December 2002) as a following up actions of San Paulo Declaration announced by POGO-2 (January 2001) that encourages and promotes both oceanographic studies and scientific capacity building in the southern hemisphere. It is expected that many oversea scientists and young trainee will be onboard as well as Japanese scientists.

Fig. 1. Photograph of research vessel *Mirai*.

TABLE 1
Main parameters of the R/V *Mirai* General Specifications

Length Over All : 128.68 m
Length Over : 118.00 m
Perpendiculars Breadth : 19.00 m
Draft : 6.92 m
Gross Tonnage : 8,687 t
Sea Speed : 16 knot
Range : 12,000 NM
Ice Class : Class NK IA

Propulsion Plant :
Diesel-Electric combined driving system.
Twin controllable pitch propellers and Twin rudders.
Thrusters : Bow 2, Stern 1
Max Complement : 80 persons
Scientists : 28
Technicians : 18
Crew : 34

I. GENERAL ARRANGEMENT OF R/V MIRAI

Fig.1 shows the recent photograph of the JAMSTEC R/V *Mirai*, which was reformed from the *Mutsu*, 1996. The seven characteristic features of the R/V *Mirai* are as follows;

(1) **Possible for longer survey voyages and wide area observation:** Cruising range is approximately 12, 000 NM with ship's speed 16 knots. Endurance total 60 days includes research days.

(2) **Superior navigation under rough weather with ice strengthened hull:** Large class vessel in the world as research vessel, equipped with Hybrid type anti-rolling systems. Also its hull structure is ice strengthened for the voyage to the Arctic Ocean area in the summer seasons.

(3) **Ability to carry large types of observation instruments on board, and deployed and retrieval of equipment in research areas:** Transport, deployment and retrieval of ocean observation buoy (TRITON buoy) developed by JAMSTEC is effectively handled. Further, CTD/water sampling systems, 20 m length piston core sampler system etc. are possible to be installed and operated on board.

(4) **On board, assembling, maintenance and repair of observation instrument s are possible:** In order to keep longer voyages and observations to be efficient and successful, it is essential to have space and facilities for assembling, maintenance and repair of observation instruments on board.

(5) Sample processing and analysis are possible on board with adequate space and facilities: There is an abundance of laboratories equipped with data processing systems, treatment and analyzing systems for various samples collected in the ocean.

(6) Outstanding maneuverability upon observation: Twin shafts, controllable pitch propeller (CPP) and twin rudders diesel-electric combined propulsion systems are installed. Also bow and stern thrusters are equipped. For these configured operations, joystick control systems are employed for easy and accurate auto-heading and positioning.

(7) Synergy type research vessel: In order to achieve observatory research through cooperation in various fields, this vessel is designed in synergy with flexibility depended on the requirements of researchers from different fields such as ministries, agencies, universities, government related corporations and international collaborations. Therefore, a general-purpose laboratory is prepared to adapt its usage for new observatory activities, and is capable to mount container laboratories on board.

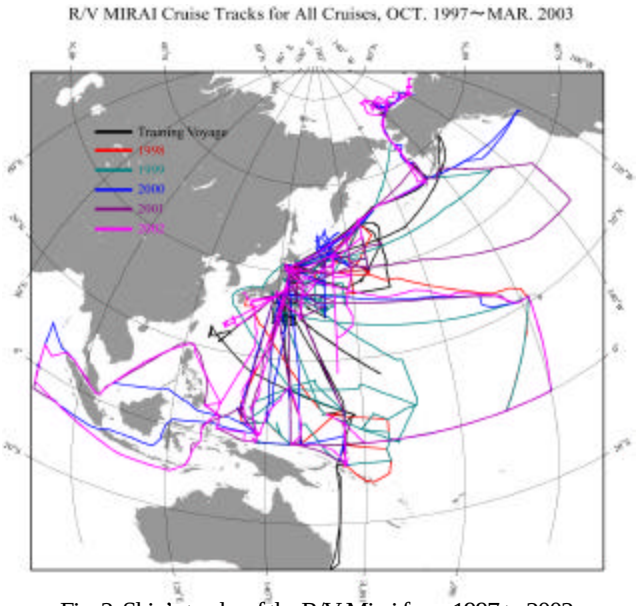

Fig. 2. Ship's tracks of the R/V Mirai from 1997 to 2002.

II. SCIENTIFIC MISSIONS OF R/V *MIRAI*

The *Mirai* has a special mission for ocean science because of her having several superior characteristic features. The six main missions are as follows:

1) Observation at high latitude, Arctic region for interaction among atmosphere, ocean and sea ice:
Investigation of an interaction between the ocean and sea ice at high latitude zone will be held. Sea ice distributed over a high latitude area works as a lid, which controls the energy transportation between the atmosphere and the ocean. A global climate change will be supposed by ice reduction in a result of global warming. We investigate the interaction between sea ice, ocean and atmosphere.

2) Material cycle in ocean:
Investigation of CO_2 flux between the atmosphere and the ocean will help to predict a global warming.3) Geodynamics of seafloor:
To analyze the history of the environmental change and activity of the Earth, topography and geological structure are observed..

4) Primary production of phytoplankton at the subtropical zone:
Carbon dioxide, which causes a green house effect, is consumed in photosynthetic process of phytoplankton. To predict a comsumption of CO2 , carbon cycle is investigated.

5) El Niño:
To investigate the mechanism of El Niño, Japanese buoys are installed along the Equator. Interactions between the atmosphere and the ocean, heat flux in the ocean is observed using the buoys.

6) Paleoclimatology and Paleoceanography:
The past climate of the earth has a long cycle. To predict the climatic change of the future, past climate is investigated.

III. INSTRUMENTATIOS AND LABORATORIES

Instrumentations and facilities on board the R/V Mirai are shown in Figs. 3 and 4, and the cartoon of their location and operational system on the general arrangement is shown in Fig. 5. Several instrumentations were already mentioned above. They are classified into several branches based on their usage.

Atmospheric Laboratories and Observation research facilities:
Atmospheric laboratories and observation facilities are Doppler radar system, Doppler radar room, a radiosonde (balloon launching container), satellite data receiving room and atmospheric gas observation room, Ceilometer, SOAR, and other general meteorological observation room
Doppler Radar Dome is installed for the measurement of cloud volume and distribution.
Cielometer is used for the estimation of the clouds by the use of the lazor light.
Radiosonde is used for the physical conditions of the troposphere and stratosphere up to 25 km above the vessel.
SOAR (Shipboard Oceanic and Atmospheric Radiation) is a shipboard observation system for measuring the radiative energy budget. This comprehensive atmospheric observation system of the R/V Mirai is the only one that of the Japanese research vessels.

Oceanographic Laboratories and Observational Facilities:
As for the chemical oceanography, large and small CTD/water sampler and biological/chemical sample processing room, seawater processing room, CTD room, low temperature laboratory, biological/chemical sample analyzing room, surface seawater analyzing room and analyzing dark room. The chemical compositions of seawater, especially nutrient, highly trained marine technicians routinely analyze on board chlorophyll, total carbonate, alkalinity, pH and so on.

As for the physical oceanography, Acoustic Doppler Current Profiler (ADCP), XCTD, XBT, XCP, moored buoy system and TRITON buoy and small buoys are available for the dynamic analysis of seawater circulation.

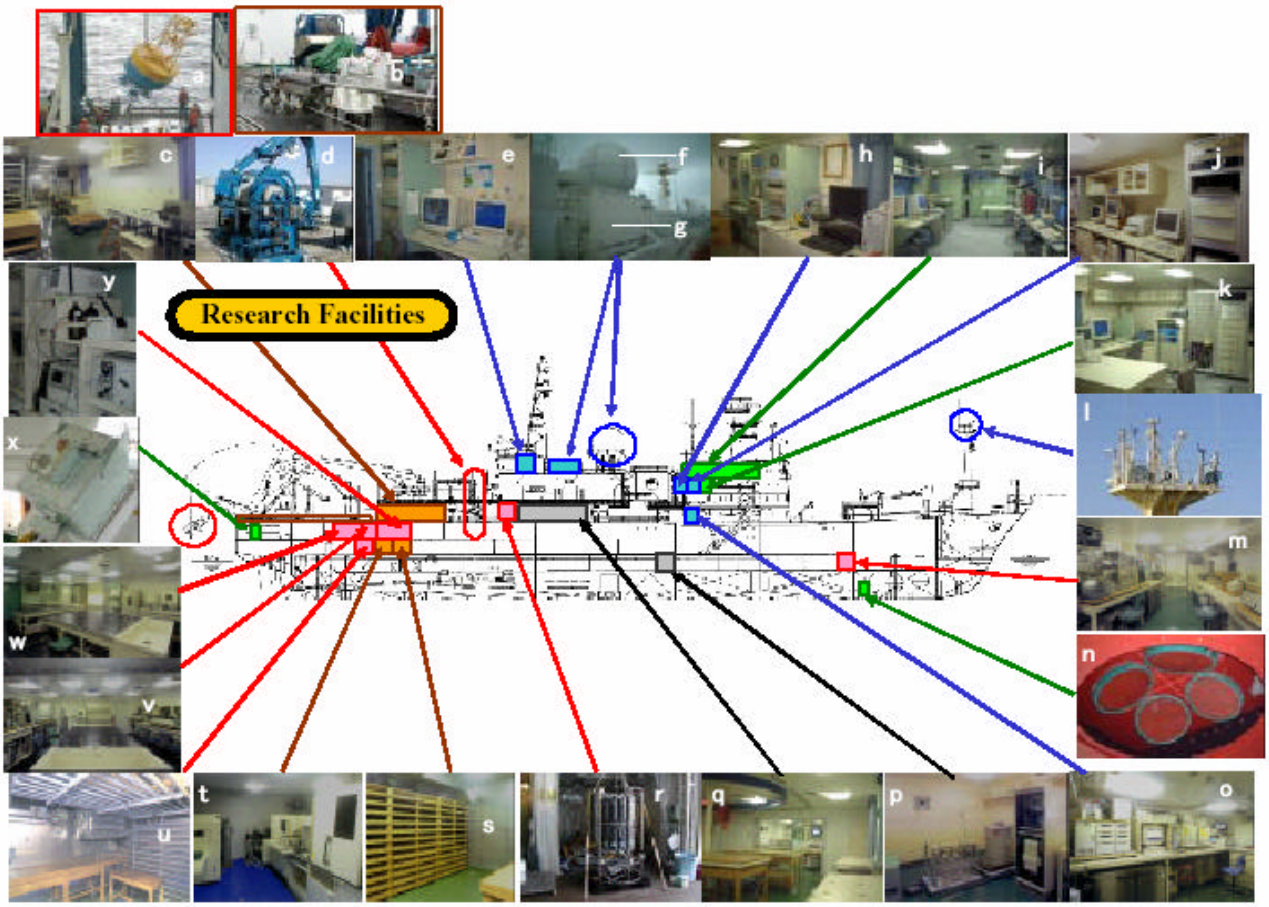

Fig. 3. Research facilities of the R/V Mirai.
a: Triton buoy operation, b: Piston corer, c: Wet lab, d: CTD crane winch system, e: Doppler radar room, f: Doppler radar, g: Balloon launching container, h: Meteorological observation room, i: Research and command room, j: Satellite data receiving room, k: Network control room, l: Foremast, m: Surface water monitoring room, n: ADCP Transducer, o: Atmospheric gas observation room, p: Gravity meter, q: Dry lab, r: CTD room, s: Sediment core repository, t: X-ray room, u: Low temperature lab, v: Biological / chemical sample processing room, w: Biological / chemical sample processing room, x: XCTD / XBT auto launcher, y: Analyzing Dark room

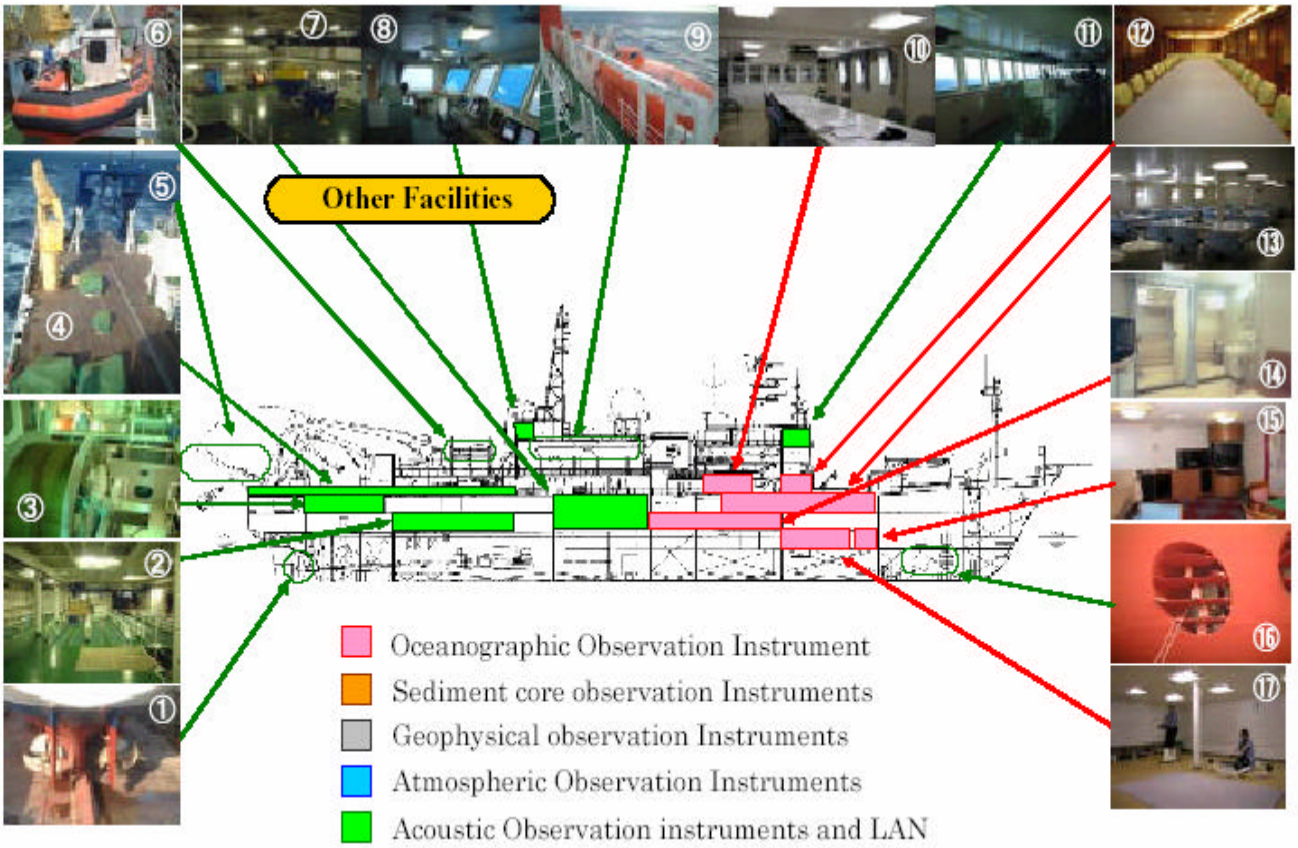

Fig. 4. Other facilities of the R/V Mirai
①: Controllable Pitch Propeller, ②: Rope store, ③: Winch room, ④: Observation deck, ⑤: A-Flame crane, ⑥: Rubber boat, ⑦: Buoy Shed, ⑧: Aft wheel house, ⑨: Life boat, ⑩: Library & Meeting room, ⑪: Wheel house, ⑫: Conference room, ⑬: Dining Saloon, ⑭: Living quarter, ⑮: Recreation room, ⑯: Bow thruster, ⑰: Gymnasium

Paleocenographic observation facilities:
As for the paleoclimatic and paleoceanographic studies piston corer, gravity corer and multiple corer are available. A wet and semi-dry rooms are prepared for the handling of long piston core samples. X-ray diffractometer, X-ray fluorescent analyzer, soft X-ray radiograph are available for the minor structure, chemistry and mineralogy of he recovered sediments.

Geophysics:
As for the geophysical studies gravimeter room, Proton magnetometer and three-component magnetometer are available for the deep structure and magnetic properties of the seafloor. In order to handle all the data , Data processing room and network control room are prepared for all the scientists and technicians on board.

IV. TECHNICAL SUPPORT SYSTEM OF R/V *MIRAI*

The outstanding technical support system for the R/V Mirai on board observation and analyzing system is a technicians system of JAMSTEC. The JAMSTEC has three family corporations. Nippon Marine Enterprises, NME, Marine Works Japan, MWJ and Global Ocean Development Incorporation, GODI. Each corporation has 10 to 100 young technicians for the marine technical support. Their major tasks are maintenance, technical support and management of ship's operation. This system is really outstanding for the oceanographer to work at the sea.

V. OUTLINE OF THE BEAGLE 2003

The R/V *Mirai* has been surveyed mainly northern hemisphere, Arctic Ocean, NW pacific, Bering Oceans as well as Equatorial areas as seen in Fig. 2. This year the vessel will survey down to the southern hemisphere for the round trip of the world on the 30° latitude. The cruise nickname was BEAGLE 2003 after Charles Darwin's cruise "BEAGLE" from 1831 to 1836 mainly surveyed on the southern hemisphere round trip. He established two major scientific results, "Origin of Species" and "Origin of Coral Reefs". Scientists who will join the BEAGLE 2003 eagerly intend to establish internationally great works through this cruise; therefore the cruise was named after Voyage BEAGLE. The term BEAGLE means in our case Blue EArth GLobal Expedition.

The major missions of the BEAGLE 2003 are to make clear the oceanic circulation at the southern hemisphere special references to the overturn of the Antarctic circulation of cold current, decadal change on the line of WOCE (World Ocean Circulation Experiment) held on 1991 to 1996 again to get more precise data by using the much more sophisticated technique and instrumentations, and the paleoceanographic study on both Arctic and Antarctic area on the climatic and environmental changes, whether they have similarity and synchronity or not.

The R/V Mirai will start from Brisbane, Australia on Aug. 3 and will end at Fremantle Australia on February 19.

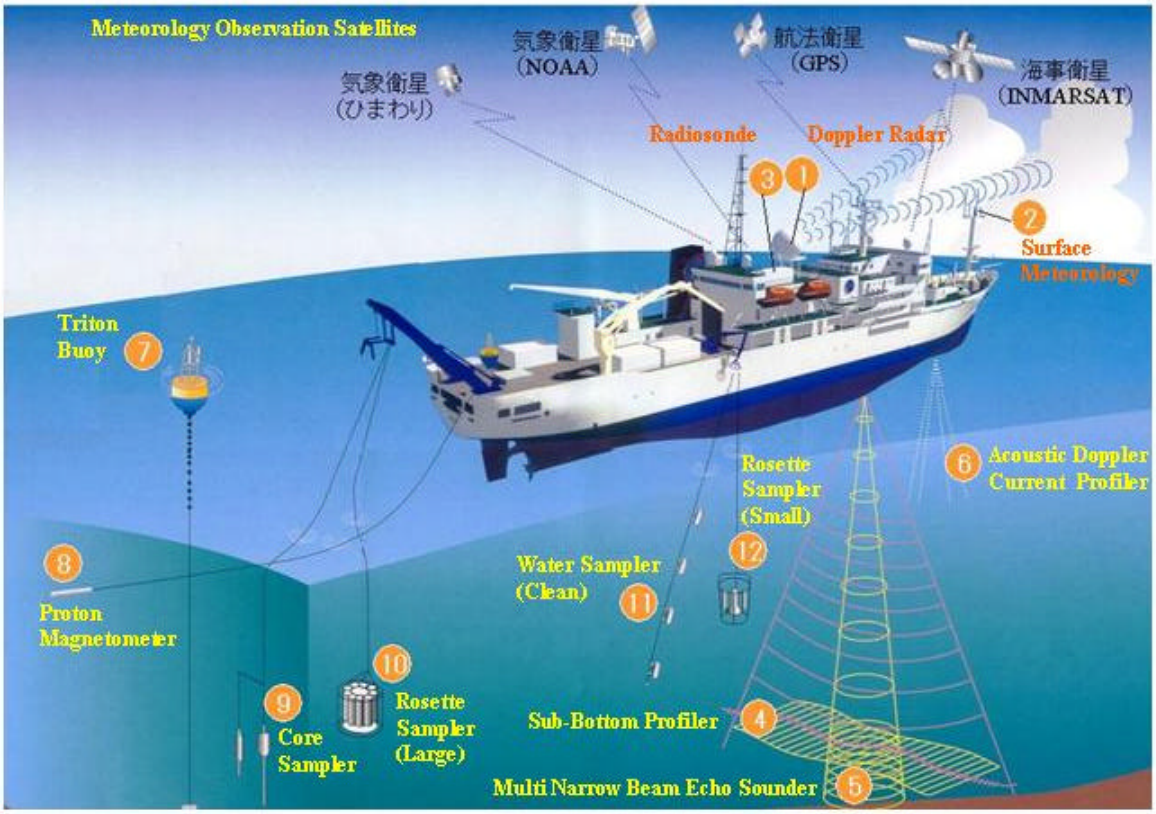

Figure 5. Cartoon of the instrumentations on board R/V *Mirai* with their operational arrangement

VI. SUMMARY

Newly reformed R/V Mirai started the oceanographic study from 1997 mainly to the Arctic and Equatorial regions of North Pacific Ocean. She has several specific facilities and missions. Above all technical support system and atmospheric observation systems are excellent. This year BEAGLE 2003 will start to survey to the southern hemisphere to investigate decadal change and Antarctic overturn system along the 30° line.

Acknowledgments

During the preparation of this manuscript we refer the leaflets that were published by JAMSTEC on the major part of the outline of Mirai because no precise explanation written in English were published so far except Japanese short explanation and leaflets. We thank to Capt. Masaharu Akamine and his crew of R/V Mirai for their kind support of our scientific missions. Thanks are also due to Masao Fukasawa, Hiroyasu Monma, Shozo Tashiro, Toshio Furuta, Naokazu Ahagon, Katsunori Kimoto, Kazuhiko Kashiwase and Masanori Kyo, JAMSTEC, Kazuhiro Sugiyama, MWJ and Akio Nakagawa, Tasuku Naito, GODI and Satoshi Ueda, IHI for their warm support and giving us important information on the R/V Mirai during the preparation.

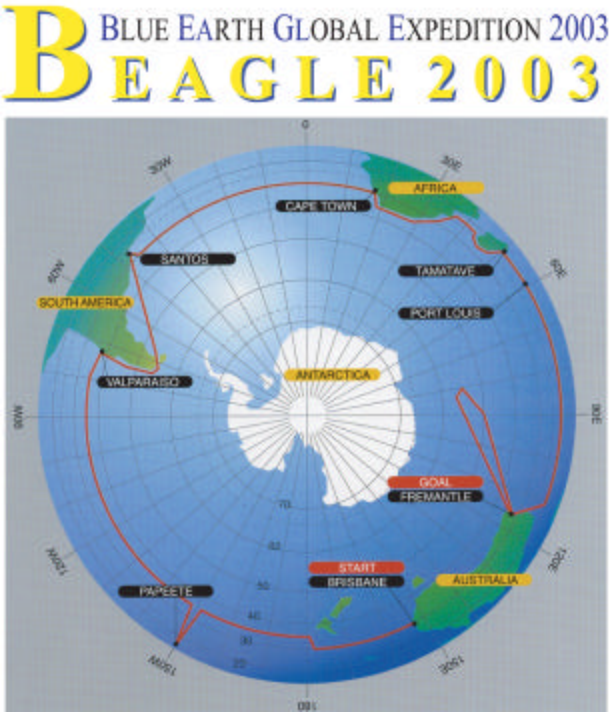

Fig. 6. Logo of the BEAGLE 2003.