Deep NINJA: A new profiling float for deep ocean observation developed in Japan

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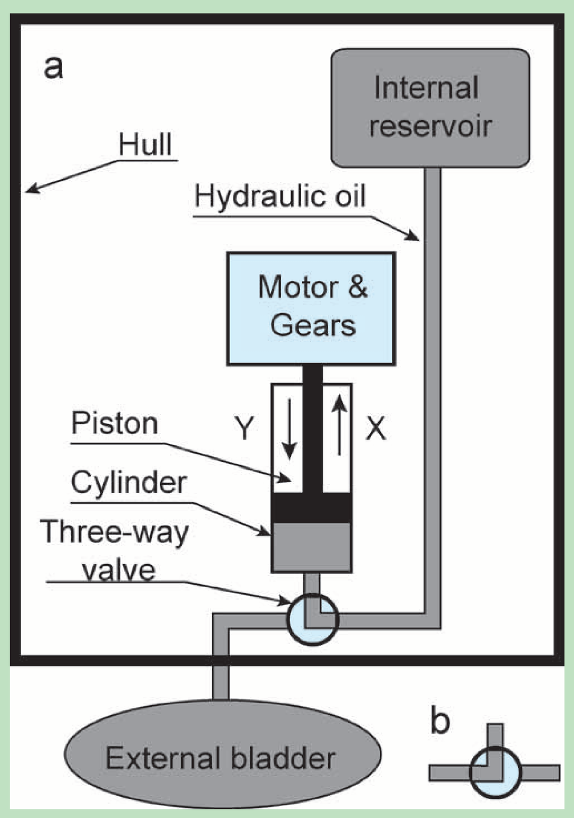
Summary:

We will introduce a Japanese new profiling float for deep ocean, Deep NINJA, which has been developed by Tsurumi Seiki Co. Ltd. and JAMSTEC. Recently, the first prototype was just built up. It is designed to observe the deep ocean up to 4000 m depth everywhere in the global ocean. A multistage aluminum-alloy hull realizes its size of about 210 cm in height (with antenna) and about 50 kg in air weight for easier operation. The Iridium system on board enables the two-way communication with on-land-stations in a short time. Float locations at the sea surface are fixed by GPS accurately. Lithium batteries are loaded to extend the duration of operation in the sea.

One of the key devises of Deep NINJA is the buoyancy engine, which is a hybrid system of the single-stroke piston and the hydraulic pump. The engine was tested at up to 4500 dbar well in laboratory and it can generate significant buoyancy to raise the float to the sea surface from deep ocean. We have carried out several field tests in coastal/shallow waters and the first dive to deep ocean will be planed in 2012.

Buoyancy engine: A key element of Deep NINJA



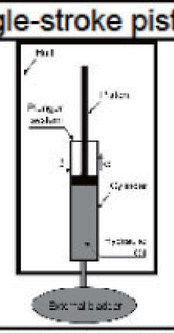
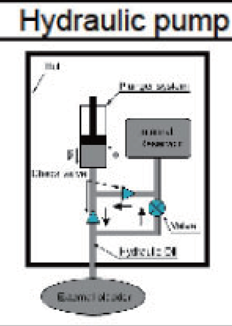
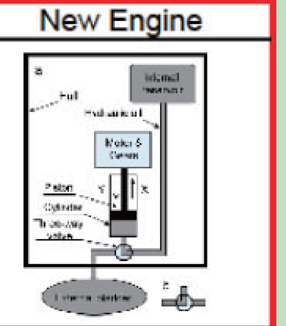
Schematic diagram of the buoyancy engine. The three-way valve can change the hydraulic circuit, which connects (a) the cylinder and the internal reservoir, or (b) the cylinder and the external bladder.

The buoyancy engine is a key device of the deep float. One of the reasons for no available deep floats now is no buoyancy engines which can operate reliably in the great depth. It should be small and light, and must function at great depths using little energy.

The existing engines, single-stroke piston and hydraulic pump, have their own advanages, however, they are not suitable for deep floats: It is difficult for the former to enhance the maximum pressure and to increase the total volume of hydraulic oil. In the hydraulic pump system the valve control of the oil is very difficult under higher pressure.

Deep NINJA has a new buoyancy engine with a hybrid mechanism of the systems and it inherited only the advantages from them.

Comparison of the engine with the previous systems

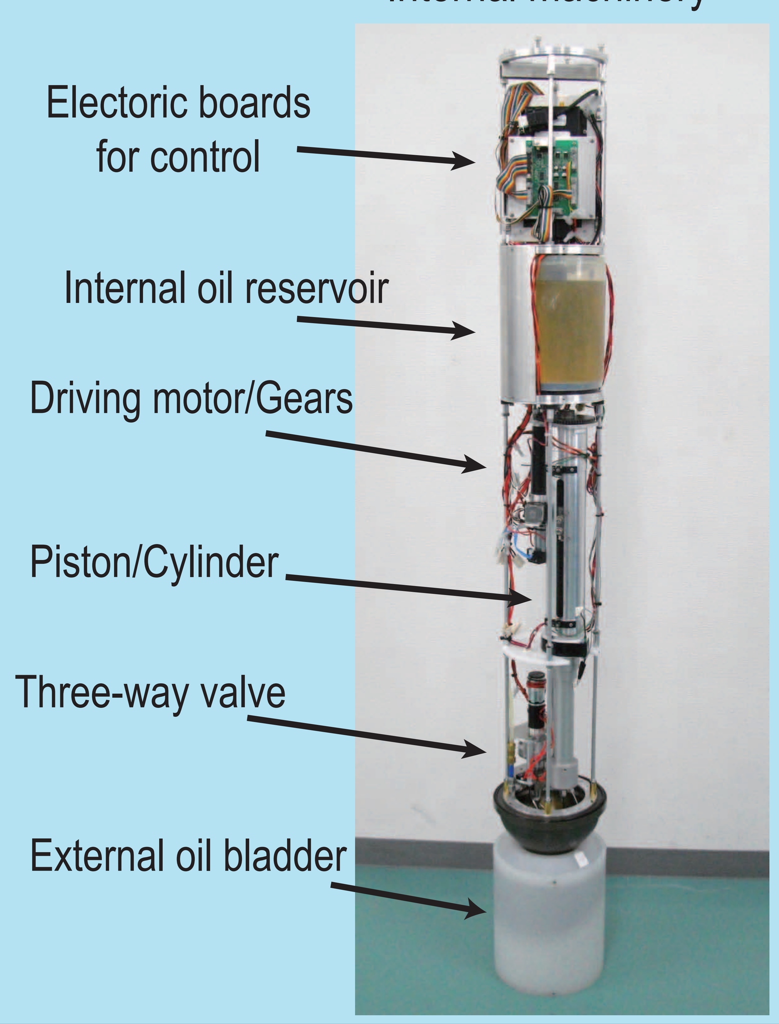
Type	Single-stroke piston	Hydraulic pump	New Engine
			
Typical floats equipped with the system	APEX, NEMO, SOLO	Provor (ALACE)	
Shape of engine	Long, Cylinder-like	Small	Middle, Cylinder-like
Restriction on vehicles' shape	Large	Very little	Small
Generation of buoyancy	Small	Large	Large
Buoyancy control Surfacing / Diving	Excellent / Excellent	Fair / Poor	Excellent / Excellent
Reliability	Excellent	Fair	Excellent
Function at high pressure Reliability / Practical usage	Fair / Poor	Good? / Fair	Good / Excellent

Deep NINJA

Deep NINJA has been developed since 2009 by TSK and JAMSTEC. The first prototype was assembled in 2011.

Specification (the first prototype)
Maximum observing depth: 4000 dbar
(available in the whole ocean)
Sensors: a SBE-CTD for deep float
(enough capacity for additinal sensors)
Size: 210 cm and 50 kg
Pressure hull: Alminum-alloy
(25 cm of Max diameter)
Two-way communication by Iridium
Position is fixed by GPS
Lithium batteries

Internal machinery



Deep NINJA (the first prototype)

Background: Requirement of systematic deep ocean observation

Ocean monitoring by numerous floats, Argo, is limited to 2000 m now because of hardware reasons. Thus, the deeper part of the ocean is observed mainly by research ships as it was done before the advent of the floats.

In recent years, it is reported that observed variations in the deeper ocean were much larger than expected and their influences on the global climate can not be ignored.

Comparisons of accurate hydrographic surveys clarified deep/bottom waters in the global ocean have warmed significantly since 1990s. The heat accumulated in the deeper layers than 3000m depth of the whole ocean is estimated at about 0.4–0.8 × 10^{22} J, about 10–20% of that in the upper layers than 700m depth. The expansion of the deep waters due to their warming resulted in the rise of the sea level: the contribution of the deeper ocean than 3000m depth is about 0.1 mm yr^{-1} rising of the observed sea level rise of 3.1 mm yr^{-1}.

Because of the sparse observations in the deeper ocean, the estimated impacts of the deeper ocean include larger errors than the other components of the global climate. Thus, the deep ocean is increasingly recognized as a major source of uncertainness to predict the future climate.

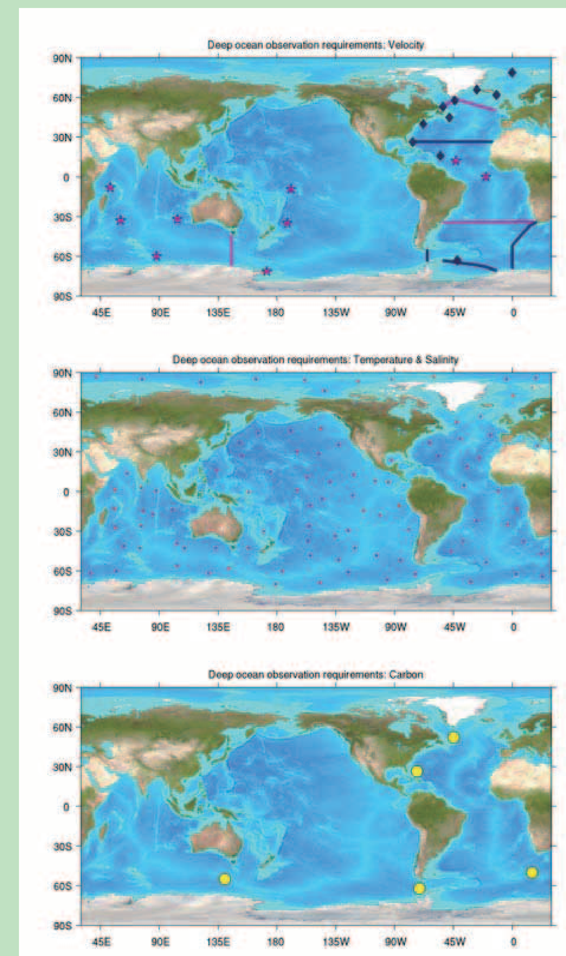
OceanObs'09

To understand and predict the anthropogenic global changes, the importance of the deep ocean monitoring is increasingly recognized also from the viewpoint of the social security.

At OceanObs'09, a proposal of systematic observations for deep ocean by autonomous devices was suggested and then adopted as an international guideline of observational ocean sciences for the next decade (2010–2019). An observing network by numerous "deep floats" should be introduced to monitor temperature and salinity in the deep ocean and to estimate the sea level rise accurately.

The suggestion seemed an extension of Argo toward deeper oceans and the importance of "deep Argo" was recognized commonly among Argo community. However, the development of the network was not set to start yet because of no deep floats.

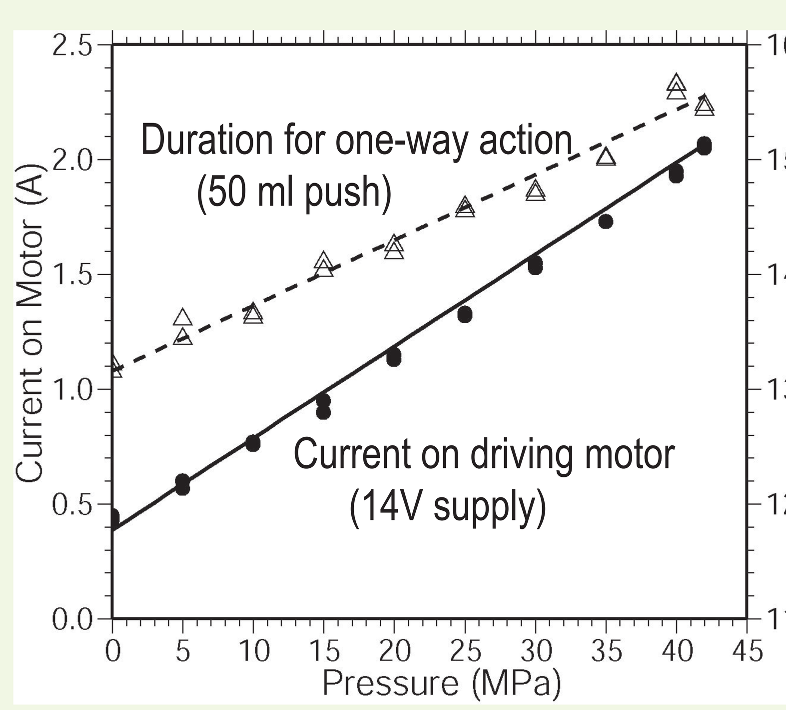
Now, some float makers are interested in the development of a deep float by the increasing requirements of the deep ocean monitoring and some of them have already begun it.



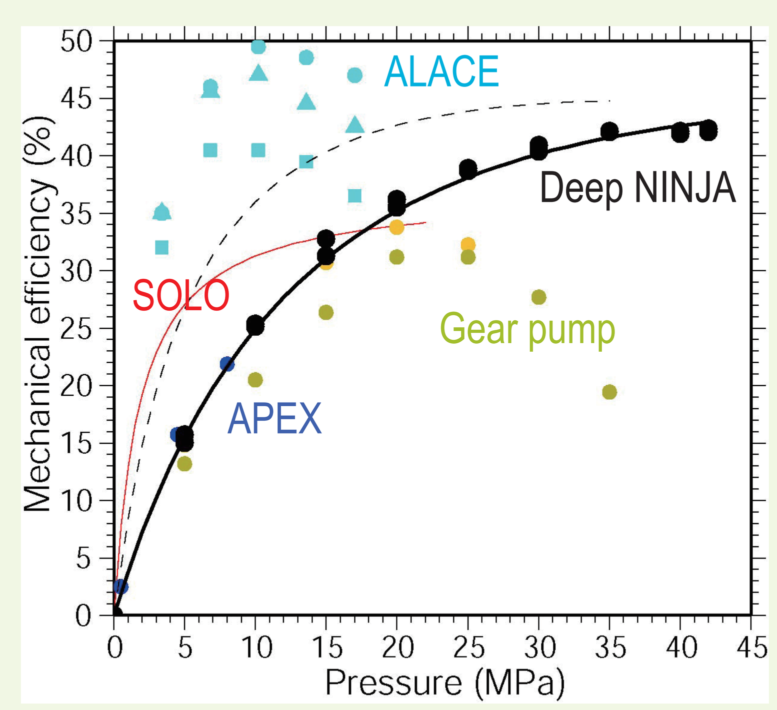
Observing systems for deep ocean approved at OceanObs'09. Middle panel shows the monitoring network by many deep floats.

Performance of the buoyancy engine

The buoyancy engine was verified to function well at the pressure of up to 4500 dbar. Its mechanical efficiency is over 40% in the higher pressure than 3000 dbar, which is almost comparable to the engines used in the previous floats (based on literature).



Test results of the engine used in Deep NINJA. Solid circles show the electric current used for the driving motor and triangles show the duration for one-way action of the piston at pushing up oil of 50 ml. Regression lines are obtained linearly.



Mechanical efficiency of the engine for Deep NINJA (solid circles). Solid line represents the estimation based on the linear regressions and the dashed line represent the results of another engine adjusted for 3000 dbar operation.

Field test in Sagami-Bay (by R/V Kaiyo in August 2011)

Control of Deep NINJA in water is also important and we have developed and improved a control system for Deep NINJA with on-desk simulations. Then, field tests in coastal/shallow waters have been carried out since 2011 spring.

In August 2011, we carried out a field test in Sagami-Bay by R/V Kaiyo, JAMSTEC, to verify reliabilities of the control system for long-term operation. In the test, the prototype tied to surface buoys by a 1000m-long line was designed to continue the observing cycles for as long a period as possible. Unfortunately, the prototype desended to shallower depths than the expected from parameters because it was pulled strongly toward the surface buoys due to strong winds. The control system, however, seemed to be verified to work well.

Maintained the prototype in the intervals of tests.

Final check just before deployment.