The Deep See Vehicle Technology in the New Century

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1. Introduction

- The 21st century is the century of ocean.
- Among land, ocean, sky and firmament,
  the only treasury of resources that has not yet been sufficiently exploited.

To reach and stay in the deep sea space,
To comprehend and recognize the globe,
To exploit and utilize the ocean resources,
To preserve and improve the ocean environment.

Need the support of the advanced deep submergence vehicles and equipments

To do the survey, measurement, investigation, test, exploration, production, reserve, transportation and maintenance etc.
1. Introduction

The composition of deep submergence vehicles and equipments

- Manned deep submergence Vehicles
- Unmanned deep submergence Vehicles
- Assorted Accessory Tools

ROV — the remotely operated vehicles,
1. Introduction

The composition of deep submergence vehicles and equipments

- Manned deep submergence Vehicles
- Unmanned deep submergence Vehicles
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- ROV — the remotely operated vehicles,
- AUV — the autonomous underwater vehicles
1. Introduction

The composition of deep submergence vehicles and equipments

- Manned deep submergence Vehicles
- Unmanned deep submergence Vehicles
- Assorted Accessory Tools

- ROV — the remotely operated vehicles,
- AUV — the autonomous underwater vehicles
- Glider —
1. Introduction

The composition of deep submergence vehicles and equipments

- Manned deep submergence Vehicles
  - ADS

- Unmanned deep submergence Vehicles
  - ROV
  - AUV
  - Glider

- Assorted Accessory Tools

ADS — the atmospheric diving systems.
One man atmospheric suits (OMAS)

Depth $\leq 450\text{m.}$
1. Introduction

The composition of deep submergence vehicles and equipments

- Manned deep submergence Vehicles
  - ADS
  - HOV
- Unmanned deep submergence Vehicles
  - ROV
  - AUV
  - Glider
- Assorted Accessory Tools

HOV — the human occupied (deep submergence) vehicle

Displacement $\leq 30$ tons,
Working duration for each dive $\leq 12$ hours, Max.
Submerging depth $1000m \sim 11000m$, Total passengers $\leq 3$. 
1. Introduction

- The composition of deep submergence vehicles and equipments

◆ Examples of the famous HOVs

Nautile 6000m, France

Shinkai 6500m, Japan

Alvin 4500m, USA

Jiaolong 7000m, China
1. Introduction

The composition of deep submergence vehicles and equipments

DSSS — the deep sea space station

- Displacement: 200 ~ 23000 tons,
- Working duration (each dive): 10 ~ 90 days,
- Max. submerging depth: 150m ~ 3000m,
- Total passengers: 10 ~ 60 persons.
1. Introduction

The composition of deep submergence vehicles and equipments

- Manned deep submergence Vehicles
  - ADS
  - HOV
  - DSSS

- Unmanned deep submergence Vehicles
  - ROV
  - AUV
  - Glider

- Assorted Accessory Tools
1. Introduction

The deep submergence vehicle and equipment technology gained great progress during the past decades in the world.

The manned deep submergence vehicle “Jiaolong 7000” is an example of the advanced HOVs produced recent years.

Supported by the Ministry of Science and Technology of China,

- Started the R & D of “Jiaolong 7000” — in 2002,
- Dived onto the seafloor of depth 7062m — in August 2012,
1. Introduction

◆ “Jiaolong 7000” started its regular service — in June 2013 compositing of three voyages to South China Sea and Pacific Ocean for scientific investigations.

◆ This evidently exhibited an imported breakthrough of the deep submergence vehicle technology in China.
2. The roles and development trends of deep submergence vehicle and equipment technology
2. The roles and development trends of DS Vehicle Tech.

2.1 The enhancement of ocean resource exploitation requires faster growth of deep submergence operation technology

Exploitation of ocean oil and gas resources is extending into the deep sea during the past decades.
2. The roles and development trends of DS Vehicle Tech.

2.1 The enhancement of ocean resource exploitation requires faster growth of deep submergence operation technology

The oil and gas production systems have more and more transferred from the water surface (dry mode) to the seabed (wet mode) to meet the challenges presented by deeper waters, harsher environment conditions and higher costs.

The subsea power distribution system

The world’s first all-electric subsea production System in the Dutch North Sea installed in 2008
In the future the exploitation and production systems of deep sea oil and gas will largely be laid down on the seabed.

The vehicles and equipments for assembling, testing, operating and maintaining etc. of these systems need to be further developed.
The traditional deep submergence underwater operations usually rely on ROVs carried, released, and controlled by operators on a surface vehicle or a platform.

To reduce the difficulties induced by bad climate, high waves and large depth in exploiting deep sea resources, and in inspecting, maintaining and repairing subsea systems by the traditional way of operations, the great attention has been paid by Russia, Norway and Canada to the investigation of DSSSs.
Since early 1990s, **Russia** has investigated a series of **nuclear** powered deep submergence DSSSs:

- A 23,000 t for seafloor drilling
- A 20,000 t for energy supply
- A 15,000 t for shipping
- A 7,000 t for production
- A 1,050 t for survey
- A natural gas transfer platform
2.1 The enhancement of ocean resource exploitation requires faster growth of deep submergence operation technology

- The corresponding researches on DSSSs in Russia

A 23,000t nuclear powered deep submergence drilling station

The underwater drilling, subsidence separation and storage
2.1 The enhancement of ocean resource exploitation requires faster growth of deep submergence operation technology

- The corresponding researches on DSSSs in Russia

- **Dimensions**: $140 \times 56 \times 21$m
- **Displacement**: 20000t
- **Power**: 35MW
- **Depth**: 50~150m

A 20,000t nuclear powered energy supply station
2.1 The enhancement of ocean resource exploitation requires faster growth of deep submergence operation technology

- The corresponding researches on DSSSs in Russia

A 15,000t nuclear powered deep submergence shipping vessel
2.1 The enhancement of ocean resource exploitation requires faster growth of deep submergence operation technology

- The corresponding researches on DSSSs in Russia

A 7,000t nuclear powered deep submergence production station,

- Hull Diameter: 7.2/9m
- Displacement: 7000t
- Depth: 400m, 32 persons
- Power 6000kW, Speed 10kn
- 2xROV, Diving Sys., Pipe repair sys., Bulldozer, Transport container
2.1 The enhancement of ocean resource exploitation requires faster growth of deep submergence operation technology

- The corresponding researches on DSSSs in Russia

A 1,050t nuclear powered deep submergence survey station

- **Displacement**: 1,050t
- **Dimensions**: $32.3 \times 5.2 \times 9.2$ m
- **Depth**: 600m
- **Speed**: 6.2kn
- **Nuclear power**
- **Duration**: 60 days
- **Crew**: 8 persons
- **Researchers**: 4 persons
2.1 The enhancement of ocean resource exploitation requires faster growth of deep submergence operation technology

- The corresponding researches on DSSSs in Russia

A nuclear powered natural gas transfer platform
2.1 The enhancement of ocean resource exploitation requires faster growth of deep submergence operation technology

In Norway the schemes of a 1,600t offshore submergence workstation, an 800t seafloor workstation and a 300t large depth submergence workstation were proposed in 1990s.

- **Displacement:** 1600t
- **Dimensions:** L47 m, B8.5m
- **Depth:** 450m
- **Payload:** 25t
- **Max. speed:** 10kn
- **Near floor speed:** 2kn
- **Working diameter:** 200nmile
- **underwater cruise duration:** 21days
- **Region:** North Sea
- **Functions:** Transport of persons, devices and parts; underwater inspect, maintenance and repair
The investigation of an 1,500t “Arctic Ocean submergence workstation” was investigated for assembling and maintaining the subsea production systems on the seafloor was reported in 2012.
2. The roles and development trends of DS Vehicle Tech.

2.2 The development of ocean survey and research capabilities needs the support of advanced deep submergence vehicles

- A variety number of researches on front sciences and high-technologies have to be investigated in the deep sea

  for example,
  - the origination of lives,
  - the actions of the mid-ocean ridge and hydrotherm,
  - the genes of deep-sea organisms etc.

- A new upsurge of researches on the earth system science has been created since late last century in the world.
2. The roles and development trends of DS Vehicle Tech.

2.2 The development of ocean survey and research capabilities needs the support of advanced deep submergence vehicles

- The present manned deep submergence research vehicles (HOVs) are not enough to support the deep submergence, seafloor observation and deep sea drilling etc. for scientific research. 

  - due to their
  - short endurance,
  - short underwater cruise and working duration
  - weak energy supply
  - limited operating ability etc.
2. The roles and development trends of DS Vehicle Tech.

2.2 The development of ocean survey and research capabilities needs the support of advanced deep submergence vehicles

Comparing with the ocean surface survey vessels, JAMSTEC et.al concluded in 2000 that the manned deep submergence vehicles would provide major means and great potentials in the future for ocean science research.

This is because that in controlling ROV to operate in deep sea, a manned deep submergence vehicle has higher efficiency in a way of less influence from the wave conditions and less repeated unloading and loading of ROV from the deck of a surface ship.
2. The roles and development trends of DS Vehicle Tech.

2.2 The development of ocean survey and research capabilities needs the support of advanced deep submergence vehicles

As a result, the schemes of the DSSSs of the submerging depth ranging from 500m to 2000m, and the small HOVs of the submerging depth ranging from 4000m to 11000m were proposed in Japan.
2.2 The development of ocean survey and research capabilities needs the support of advanced deep submergence vehicles

Later around 2010, supported by the national program of the civil ocean technology development, a 6000t nuclear powered multi-function workstation (DSSS) for deep-sea science research was investigated in Russia.

- Displacement: 5900t
- Dimensions: 117 × 15 × 16.2 m
- Depth: 400m
In the 21st century the attention of ocean technology investigations and applications in the world are mostly focused on the problems about resources, environment and sovereignty.

The major challenges that the ocean vehicles and equipments encountered are about
- the adaptability to extreme environment conditions,
- the reliability of their functions,
- the economic efficiencies when operating in deep seas.
2. The roles and development trends of DS Vehicle Tech.

2.3 The ocean engineering industry needs to be promoted by the innovative deep submergence equipment technology

The deep submergence vehicles and equipments embody many front technologies:

(1) The fundamental scientific and technical problems:

- extreme environment loads and dynamic responses,
- loads and motions control,
- fluid-structure interactions,
- non-linear dynamics,
- structural safety and risk analysis,
- underwater operation mechanics, ……etc.
2. The roles and development trends of DS Vehicle Tech.

2.3 The ocean engineering industry needs to be promoted by the innovative deep submergence equipment technology

The deep submergence vehicles embody many front technologies:

(2) The key technologies:

- Optimization of ultra-deep large-scale submerged structures,
- Precise forming and welding of thick titanium alloy plate,
- Applications of composite materials,
- Condensed high energy power supply, the undersea power station, the all-electric propulsion and powering,
- Long distance undersea navigation/positioning/communication,
- Deep submerged underwater connection of independent cabins,
- Underwater wet-metled connection of cables,
- Release and retrieval of ROV/AUV by submergence workstation,
- Manipulation and control of motions, positions and attitudes of cable connected multi-vessels,……etc.
3. The future development of the deep submergence vehicles and equipments
3. The future development of the deep submergence vehicles

- The rapid growth of ocean oil and gas productions in 1970s and 1980s urged the commercial applications of the unmanned submergence vehicles ROVs and AUVs and promoted their technology maturity.
3. The future development of the deep submergence vehicles

The utilization of manned submergence vehicles has the history of more than half a century. It is not until 1980s that the HOVs got deeper than 6000m and gained more and more applications.

<table>
<thead>
<tr>
<th>No.</th>
<th>Names</th>
<th>Owner</th>
<th>Country</th>
<th>Max. Depth</th>
<th>Year</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>Jiaolong 7000</td>
<td>State Oceanic Administration</td>
<td>China</td>
<td>7000m</td>
<td>2009</td>
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<td>2</td>
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<td>JAMSTEC</td>
<td>Japan</td>
<td>6500m</td>
<td>1989</td>
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<td>3</td>
<td>New Alvin</td>
<td>WHOI</td>
<td>USA</td>
<td>4500m, 6500m</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Consul</td>
<td>Russian Navy</td>
<td>Russia</td>
<td>6000m</td>
<td>2009</td>
</tr>
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<td>5</td>
<td>RUS</td>
<td>Russian Navy</td>
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<td>France</td>
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<td>WHOI</td>
<td>USA</td>
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<td>Japan</td>
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<td>USA</td>
<td>2000m</td>
<td>1971</td>
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<td>Johnson Sea-1000 Link I, II</td>
<td>HBOI</td>
<td>USA</td>
<td>1000m</td>
<td>1973</td>
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</table>
Along with the fast development of technologies in the fields of material, manufacturing, artificial intelligence, hydroacoustics and image processing etc., as well as the urgent needs of cognition, utilization, protection of oceans, the development of deep submergence vehicle technology in the 21st century in China will face three important tasks.
3. The future development of the deep submergence vehicles

3.1 The systematic development of manned and unmanned deep submergence vehicles and auxiliary equipments

- About 99% of the global ocean is shallower than 7000m.

> 250 hydrothermal sites
> 50 currently actively venting
3. The future development of the deep submergence vehicles

3.1 The systematic development of manned and unmanned deep submergence vehicles and auxiliary equipments

For strengthening the ocean science & technology research in China, the first task is to make the utmost of the existing “Jiaolong 7000” and other deep submergence vehicles and equipments.
3. The future development of the deep submergence vehicles

3.1 The systematic development of manned and unmanned deep submergence vehicles and auxiliary equipments

The way is to improve their operation management and allocate the necessary instruments.

Including:
- the new surface supporting vessels
- a 4500m HOV
- more ROVs, AUVs, gliders
- the corresponding accessory tools.

To achieve a more efficient, more reliable and more complete system and capacity of deep submergence operations.
3. The future develop. of the deep submergence vehicles

3.1 The systematic development of manned and unmanned deep submergence vehicles and auxiliary equipments

— To achieve a more efficient, more reliable and more complete system and capacity of deep submergence operations.

◆ 4500〜7000m ROV
◆ 4500m AUV
◆ Gliders
◆ 4500m HOV

◆ Tows
◆ 500m ADS
◆ accessory tools
3. The future development of the deep submergence vehicles

3.2 The preferential development of deep sea space station

- It could be expected that in many years to come, the ocean energy and resource exploitations and other ocean utilization activities will be carried out mostly in the sea shallower than 3000 m.
The second task is to enhance the effort and capability of building and utilizing the DSSSs.

DSSSs are potent instruments of ocean exploitation and exploration projection.

A DSSS may
- avoid the influence of harsh wave and wind conditions on water surface,
- several or several tens of operators, scientists and engineers
- traveling or staying underwater in the depth of 900m～3000m
- working duration 15 to 90 days.
3. The future development of the deep submergence vehicles

3.2 The preferential development of deep sea space station

Comparing with the existing HOVs, the DSSSs have several distinguishing features:

- The first — do not chase large diving depth, usually no more than 3000m, but pursue longer traveling endurance, wider working extent, heavier payload and greater power supply.
- The second — can carry out long-period, high-efficiency ocean resource exploitations and deep sea in-site investigations.
- The third — not only can float in the depth up to 1000～3000m, and also can release and control one or more ROVs and AUVs to even deeper places for science and engineering purposes.
3. The future develop. of the deep submergence vehicles

3.2 The preferential development of deep sea space station

Since 2001 China Shipbuilding Industry Corporation (CSIC) started investigations on the key technologies of DSSSs.

China Ship Scientific Research Center (CSSRC) proposed in 2008 a nuclear powered multi-function (survey and operation) DSSS.

Displacement 2600t, Maxi. depth 1000m.

The onboard physical, chemical and biological transducers and measuring instruments.

carrying and controlling 1 AUV, 1 underwater crane, 2 ROVs, and other electromechanical devices.
3. The future develop. of the deep submergence vehicles

3.2 The preferential development of deep sea space station

The multi-function (survey and operation) DSSS proposed by CSSRC.

- Displacement: 2600 tons
- Working depth:
  - 1000m (High strength steel)
  - 3000m (Titanium)
- Max. crew & passengers: 45
- Self-sustaining duration: 60 days
- Underwater cruise duration: 30 days
- Max. underwater speed: 12 kn
  - Cruise speed: 6～8 kn
3. The future development of the deep submergence vehicles

3.2 The preferential development of deep sea space station

The key technologies and the important research subjects:

◆ the emergency detaching and escaping,
◆ the interactions of float-state-operating bodies,
◆ the habitability and life insurance,
◆ the tools and devices for deep submerged operations etc.

High strength materials and applications
◆ Structure tests
◆ Structural optimizations
◆ Float-state operation
◆ Model tests
3. The future development of the deep submergence vehicles

3.3 Investigation of ultra-deep submergence vehicles

The ultra-deep regions of the ocean that are deeper than 7000m cover no more than 1% of the global ocean area.

The third task is to develop the technologies of the ultra-deep submergence vehicles and the accessory equipments for operating especially in these regions in the depth from 7000m to 11000m in an adequately future time.

J. Piccard and D. Walsh at the beginning of 1960

- dived down to the Mariana Trench at the depth of 10913m.
- taking the “Trieste” manned deep submergence vehicle.
- unable at that time to do the deep-ocean explorations.
- marked a milestone of mankind in challenging the extreme water depth.
3. The future development of the deep submergence vehicles

3.3 Investigation of ultra-deep submergence vehicles

The development of working-type ultra-deep vehicles require the technologies:

- the safety and reliability of ultra-deep submerged structures,
- the ultra-high-pressure-resistant and low-specific-gravity buoyancy materials
- the integrated hydraulic pumping devices and thrusters
- the high-pressure watertight cables and connectors
- the ultra-high-pressure-resistant acoustic and optic devices
- the integrated design and optimization
- the information transfer in ultra-deep water
- etc.
4. Concluding Remarks
4. Concluding Remarks

- For sustainable development of the global economy and the human society in the 21st century the mankind has to largely devote their efforts to understand, utilize and protect the ocean.
- The deep sea science research will bring to ever brilliant light of knowledge about the earth and the lives.
- The exploitations of deep sea resources and the managements of ocean environment are even urgent tasks for the present world.
- The deep submergence vehicles and equipments will play more and more important roles in this century.
- The technology development in this field is speeding up. It should be recognized that traveling and operating in the deep sea is no less difficult, valuable, important and great than the aerospace missions.
Thank you for your attention!