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A preliminary design of a movable laboratory for hadal trenches

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HIGHLIGHTS

- A new concept for a movable laboratory for hadal trenches.
- The basic philosophy and the preliminary designs for the manned submersible, unmanned submersible and landers are introduced.
- All the technical problems for the FOD HOV are identified and possible solutions to the key technical issues are discussed.

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ABSTRACT

The hadal trenches and the biology and ecology of the organisms that inhabit them remain one of the least understood marine environments. The study of hadal trenches which is often referred to as hadal science, needs special technical equipment support such as landers, unmanned submersibles and manned submersibles. Sending sampling devices or exploratory vehicles to hadal depths is technically challenging and expensive, consequently, our current understanding of hadal ecological structure is still very much in its infancy. In recognition of the significance that hadal science holds and the unique and challenging requirements that work in the deep ocean presents, Shanghai Ocean University has made a significant commitment to develop operational support for the promotion of hadal science in China. The present authors from the JIAOLONG

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Human Occupied Vehicle (HOV)
Full Ocean Depth (FOD)

development team were invited by Shanghai Ocean University to establish a hadal science and technology research center (HAST). The first focus of HAST is to construct a movable laboratory for hadal trenches which includes a mothership, an Human Occupied Vehicle, an Autonomous and Remotely-operated Vehicle and several landers. The purpose of this paper is to introduce the basic philosophy and concepts for the movable laboratory and the preliminary designs for the manned submersible, unmanned submersible and landers. Through these designs all the technical problems to be solved in the development of the full ocean depth surveying and sampling tools are identified and possible solutions to the key technical issues are discussed.

1. Introduction

Deep-sea trenches have lured explorers for decades, tantalizing them with glimpses of an ecosystem shrouded in darkness. In the latest attempt to pierce the gloom, movie director James Cameron in March 26, 2012 took his privately built one-man submersible 10,898 m down to the deepest point on Earth: the Challenger Deep in the Pacific Ocean's Mariana Trench. Although Cameron's journey to the deepest sea yielded little new scientific data, it whetted the public appetite for information about life in the otherworldly environments of deep-sea trenches.

The great depths of the ocean were known to explorers at the time of the Challenger Expedition (1873–1876) (Brady, 1884); these intrepid scientists took soundings down to 8200 m. Their incidental collections of fourteen different foraminifera shells from sounding tubes suggested that protists might live as deep as 7220 m, although it could not be determined if the foraminifera were truly living at the depth of capture (Brady, 1884). Conclusive evidence of life at depths below 6000 m did not occur until more than half a century later (Belyaev, 1989). In 1948, a Swedish deep-sea expedition aboard the Albatross recovered the first benthic animals (polychaetes and holothurians) from depths between 7625 and 7900 m in the Puerto Rico Trench (Wolff, 1960; Belyaev, 1989). This enlightening discovery spawned a decade of vigorous trench exploration, resulting in some of the most comprehensive biological surveys of the world's deep-sea trenches to date. The Danish Galathea Deep-Sea Expedition (1951–1952) sampled in five trenches and captured animals at depths slightly greater than 10,000 m in the Philippine Trench (Bruun, 1956b). Beginning in 1949, many trench sampling expeditions were conducted aboard the Soviet vessel Vityaz, resulting in the capture of benthic animals from 10,600 m in the Tonga Trench and 10,700 m in the Mariana Trench (Belyaev, 1989). In January 1960, oceanographers Jacques Piccard and Don Walsh took the bathyscaph Trieste to dive into the Challenger Deep of the Mariana Trench. They claimed to have observed an unidentified benthic animal, confirming that all oceanic depths are inhabitable (Piccard and Dietz, 1961). During that decade of discovery, it became increasingly evident that fauna living deeper than 6000–7000 m were distinct from the fauna inhabiting the shallower abyssal depths (4000–6000 m). In 1956, A. Bruun first described depths in excess of 6000 m as a unique ecological realm: the hadal zone (Bruun, 1956a). In recent years these bathymetric parameters have been revised to sublittoral (0–300 m), upper bathyal (300–800 m), lower bathyal (800–3500 m), abyssal (3500–6500 m) and hadal (6500–11,000 m) (UNESCO, 2009; Watling et al., 2013).

Trench sampling campaigns on the scale of the Vityaz and Galathea were never repeated and in the decades following these expeditions, trench sampling became less frequent. During the 1970s the 'free-fall' method of sampling became more popular. This involved the opportunistic deployment of baited cameras and traps in the trenches (e.g. Hessler et al., 1978). The 1990s saw the construction of the first full-ocean depth ROV named Kaiko by the Japan Marine Science and Technology Centre (JAMSTEC). In addition to marking the deepest point on Earth, Kaiko achieved more than 20 scientific