

2026 第九届 IEEE 国际无人系统大会 特邀专题简介表

特邀专题名称

深海柔性运载装备前沿理论与装备应用

组织者

- 1.李国瑞，教授，哈尔滨工程大学
- 2.黄桥高，教授，西北工业大学
- 3.陈云赛，教授，哈尔滨工程大学
- 4.李宏源，副研究员，北京大学
- 5.王豪，讲师，哈尔滨工程大学

个人简介



李国瑞，哈尔滨工程大学教授，国家高层次人才。入选“中国十大科技新锐人物”，人民日报“自立自强青年科学家”，“中国力学学会青年人才蓄水池计划”。研究方向：软物质与柔性结构力学、深海电液柔性运载装备、软体水下机器人、深海柔性探测系统等。承担国家自然科学基金、国家重点研发计划课题等科研项目多项。面向深海装备、水下仿生机器人领域的基础理论、器件设计、系统集成等问题，发展了软体机器人及柔性智能装备设计理论、系统集成及应用方法。研制了首套电液驱动深海柔性机器人等系列装备，已在马里亚纳海沟、海马冷泉、海山区等多个海域实现探测应用。以第一/通讯作者在 *Nature*（封面论文）、*Science Robotics*、*Nature Communications*、*Science Advances* 等知名期刊发表论文多篇。电液驱动深海柔性机器人作为代表性工作，入选“非凡十四五”智能机器人跨越式发展案例（2025），被中央电视台-《新闻联播》、*Science* 官网首页、国家自然科学基金委等官方机构报道。研究成果获选 2021 年度中国科学十大进展、教育部自然科学一等奖等。



黄桥高，西北工业大学教授、博导，长江学者特聘教授、国家“万人计划”青年拔尖人才，入选西北工业大学“翱翔青年学者”、“翱翔新星”支持计划，西北工业大学第三届学术委员会委员，首届海洋强国青年科学家，任《中国舰船研究》《数字

海洋与水下攻防》《空气动力学学报》等多个期刊编委/青年编委。主要研究方向水下航行器总体设计、水下推进水动力学、水下减振降噪等，主持国家自然科学基金“叶企孙”基金重点项目、科技委基础加强计划重点项目、中央高校青年教师科研创新能力支持项目（U40）等 20 余项。近 5 年以第一作者/通讯作者在 *Journal of Fluid Mechanics*、*Physics of Fluids*、*Ocean Engineering*、*力学学报* 等期刊上发表高水平论文 80 余篇，授权发明专利 16 项，出版专著 2 部，获国家技术发明二等奖（R3），军事技术发明一等奖（R5），国防科技进步一等奖（R8），陕西省自然科学二等奖（R2），中国造船工程学会技术发明特等奖（R5），中国造船工程学会科技进步二等奖 2 项（R1、R2）。



陈云赛，哈尔滨工程大学教授、博士生导师，哈尔滨工程大学青岛基地副主任，国家级青年人才，泰山学者青年专家，山东省优秀青年基金获得者，第五届中国科协青托计划入选者。长期从事自主水下航行器技术研究，在新概念海洋机器人、深海作业技术、有人/无人跨域协同和深潜器智能运维等方面取得了系列突破，担任国家某重点项目首席科学家。近 5 年以第一作者或通讯作者发表 SCI 论文 40 余篇，申请国家发明专利 50 余项。担任中国造船工程学会深海装备技术学术委员会委员，中国宇航学会无人飞行器专业委员。主持国家自然科学基金、国家重点研发计划等国家级项目 10 余项，主持研发了多型深海机器人系统，成果应用于国家重大工程、国家大洋航次任务。



李宏源，国家级青年人才，北京大学海洋装备与工程研究所副主任，副研究员。主要从事跨介质海洋装备与流固耦合力学领域的研究，在 *JFM*、*PNAS*、*PoF*、*OE* 等国际权威期刊发表 SCI 论文 51 篇，授权国家发明专利 40 项。作为项目负责人主持国家自然科学基金、国家重点研发计划重点专项课题、装备预研项目等国家级项目共 14 项。兼任中国造船工程学会理事、中国指挥与控制学会大模型与决策智能专业委员会委员、第十一届中国仪器仪表学会气象水文海洋仪器分会委员、中国力学学会水动力学专业组组长、《海洋技术学报》和《材料开发与应用》期刊青年编委等多个学术职务。获“首都前沿学术成果奖”、“Wiley 中国

高贡献作者奖”、“JFM/FLOW Symposium Outstanding Poster Prize”。



王豪，哈尔滨工程大学讲师，硕士生导师。主要研究方向为深海高保真采样装备与深海柔性机电系统。主持国家自然科学基金项目、省部级基金项目以及各类横向项目十余项，系统性开展了深海/深渊生物与环境样本高质量采集与处理技术与装备研究，多次参与我国大洋科考航次，获得了一系列研究成果，所研制的全海深系列采样器在年西太平洋马里亚纳海沟科考航次中取得了万米级沟虾保压样品。主持研制了 3000m 级深海视觉伺服柔性运载器和 6000m 级液压驱动柔性运载器，发表 SCI 学术论文 20 余篇，授权国家发明专利 20 余项。

特邀专题简介

深海机器人作为深海探测的核心载体，在资源勘查、极端环境救援及精细化作业中发挥着不可替代的作用，体现了国家深海工程的核心竞争力。近年来，强适应、高柔顺的仿生柔性智能装备作为特种机器人领域的关键突破口，在深海低扰动探测与柔性交互作业等方面展现出广阔的应用潜力，为实现水下复杂环境及深海极端工况下的精准、高效作业提供了新范式。

然而，深海柔性运载装备在工程化应用进程中，仍面临亟待攻克的关键科学与技术挑战。高静水压下柔性材料的非线性耦合变形机制尚不清晰，动态表征方法的缺乏直接导致装备机动性能受限与驱动效能衰减。同时，极端环境下柔性运载装备的驱动与适应机制极具挑战，需对复杂柔性装备的性能分析和系统设计开展系统性探索。此外，深海多模态柔性感知机理的缺失，使得现有装备难以实现高保真状态感知与闭环控制，进而严重制约了其在复杂任务场景中的作业可靠性与自主化水平。因此，探究深海柔性机器人在驱动、感知、通信及控制等领域的基础科学问题，探索深海柔性新质装备的设计理论与作业新方法，提升深海柔性系统的环境适应性与作业完备度，可为深海低扰动探测与作业装备的技术革新提供理论支撑与工程参考，推动其在深海科考、资源开发及应急保障等领域的应用。

本特邀专题诚邀相关领域的学者提交包含创新理论、关键技术突破或新颖应用场景的原创性研究论文，主要征集（但不限于）以下方向：

- 深海仿生柔性运载装备的总体设计
- 新型深海柔性驱动器设计及构型优化
- 深海环境下柔性运载装备流固耦合驱动机理
- 深海柔性装备跨域运动规划与控制策略
- 极端静水压条件下柔性材料的非线性力学行为与变形机制
- 深海多模态柔性感知机理与仿生传感器件研发
- 深海柔性运载装备的能源管理与长效续航技术
- 深海柔性系统轻量化水下通信技术与装备
- 深海柔性系统的集群作业方法
- 深海柔性装备的工程应用方法与可靠性评估

IEEE ICUS 2026
Invited Session Summary

Title of Session

Deep-Sea Flexible Vehicles: Bridging Foundation, Frontiers, and Deployment

Organizers

1. Prof. Guorui Li

Harbin Engineering University, China

2. Prof. Qiaogao Huang

Northwestern Polytechnical University, China

3. Prof. Yunsai Chen

Harbin Engineering University, China

4. Prof. Hongyuan Li

Peking University, China

5. Dr. Hao Wang

Harbin Engineering University, China

Biosketches of Organizers



Guorui Li, a professor of in Naval Architecture and Ocean Engineering at Harbin Engineering University, National Young Talent of China. Since joining Harbin Engineering University in 2022, Guorui has established the “Deep-Sea Flexible Vehicle” research group. Guorui has long focused on interdisciplinary research at the frontier of deep-sea soft robotics, making several contributions that span from the mechanics of soft materials, deep-sea electrohydraulic robots, and deep-sea vehicles. These vehicles have been deployed in diverse deep-sea explorations, including the Mariana Trench, Haima Cold Seeps, and deep-sea seamounts. As the first or corresponding author, he has published multiple high-impact papers in journals such as Nature (cover article), Science Robotics, and Science Advances. These works were highlighted on the homepage of Science and named a Milestone Achievement in Robotics under China’s 14th Five-Year Plan. He have led several research projects from NSFC and National KeyR&D Program of China.



Qiaogao Huang, Professor and Doctoral Supervisor at Northwestern Polytechnical University, Distinguished Professor of the Changjiang Scholars Program, National "Ten Thousand Talents Plan" Young Top-Notch Talent, selected for the "Aoxiang Young Scholar" and "Aoxiang Rising Star" support programs at

Northwestern Polytechnical University, member of the Third Academic Committee of Northwestern Polytechnical University, and one of the first "Maritime Power Young Scientist". He serves on the editorial boards of several journals, including Chinese Journal of Ship Research, Digital Ocean & Underwater Warfare, and Acta Aerodynamica Sinica. His main research directions include overall design of underwater vehicles, underwater propulsion hydrodynamics, and underwater vibration and noise reduction. He has led over 20 projects, including key projects of the National Natural Science Foundation of China (Ye Qisun Fund), key projects of the Science and Technology Commission's Basic Strengthening Program, and the Scientific Research Innovation Capability Support Project for Young Faculty (U40). In the past five years, he has published over 80 high-level papers as the first/corresponding author in journals such as Journal of Fluid Mechanics, Physics of Fluids, Ocean Engineering, and Chinese Journal of Theoretical and Applied Mechanics. He has been granted 16 invention patents, published 2 monographs, and received numerous awards, including the Second Prize of the National Technological Invention Award (R3), the First Prize of the Military Technological Invention Award (R5), the First Prize of the National Defense Science and Technology Progress Award (R8), the Second Prize of the Shaanxi Provincial Natural Science Award (R2), the Grand Prize of the China Shipbuilding Engineering Society's Technological Invention Award (R5), and two Second Prizes of the China Shipbuilding Engineering Society's Science and Technology Progress Award (R1, R2).



Prof. Yunsai Chen is a professor and Ph.D. supervisor at Harbin Engineering University, and serves as Deputy Director of the Qingdao Campus of Harbin Engineering University. He is a recipient of the National Young Talent program, a Taishan Scholar Young Expert, a recipient of the Excellent Youth Foundation of Shandong Province, and a selected participant of the 5th Young Elite Sponsorship Program by the China Association for Science and Technology. His research focuses on autonomous underwater vehicle technologies, achieving a series of breakthroughs in novel marine robotics, deep-sea operation technologies, manned/unmanned cross-domain coordination, and intelligent maintenance of deep-sea submersibles. He currently serves as Chief Scientist of a major national key project. Over the past five years, Professor Chen has published more than 40 SCI-indexed papers as first or corresponding author and filed over 50 Chinese invention patents. He serves as a member of the Deep-Sea Equipment Technology Committee of the Chinese Society of Naval Architects and Marine Engineers, and a member of the Unmanned Vehicle Committee of the Chinese Society of Astronautics. He has led more than 10 national-level projects, including the National Natural Science

Foundation of China, and the National Key Research and Development Program of China. He has also led the development of multiple types of deep-sea robotic systems, with outcomes applied to major national projects and national oceanographic expedition missions.



Dr. Hongyuan Li is a recipient of the National Young Talent Program, serving as an Associate Researcher and Deputy Director of the Institute of Marine Equipment and Engineering at Peking University. His research primarily focuses on cross-domain marine equipment and fluid-structure interaction mechanics. He has published 51 SCI papers in prestigious international journals such as JFM, PNAS, PoF, and OE, and holds 40 authorized national invention patents. As a principal investigator, he has led 14 national-level projects, including those funded by the National Natural Science Foundation of China, the National Key Research and Development Program of China, and national equipment pre-research programs. He also holds multiple academic positions, serving as a Council Member of the Chinese Society of Naval Architects and Marine Engineers, a Committee Member of CICC Technical Committee on Large Models and Decision Intelligence, a Committee Member of the 11th Meteorological, Hydrological and Marine Instruments Branch of the China Instrument and Control Society, a member of the Hydrodynamics Professional Group of the Chinese Society of Theoretical and Applied Mechanics, and a Youth Editorial Board Member for the Journal of Ocean Technology and Development and Application of Materials. Dr. Li has been honored with the Capital Frontier Academic Achievement Award, received his Ph.D.



Hao Wang, Ph.D. in Engineering, is a Lecturer and Master's Supervisor at Harbin Engineering University, primarily specializing in deep-sea high-fidelity sampling equipment and deep-sea flexible electromechanical systems. He has served as the principal investigator for more than ten research initiatives, including projects funded by the National Natural Science Foundation of China, various provincial and ministerial-level funds, and industrial collaborations, through which he has conducted systematic research on high-quality collection and processing technologies for deep-sea and hadal biological and environmental samples. Having participated in numerous national oceanographic expeditions, Dr. Wang has achieved a series of significant milestones; notably, the full-ocean-depth sampler series he developed successfully retrieved pressurized amphipod samples at a depth of 10,000 meters in the Mariana Trench, marking a first

for China. He has also led the development of a 3,000m-class deep-sea visual-servo flexible vehicle and a 6,000m-class hydraulically driven flexible vehicle, published over 20 SCI-indexed academic papers, and been granted more than 20 national invention patents.

Details of Session

Deep-sea robots, which serve as the primary platforms for deep-sea exploration, play an indispensable role in resource prospecting, search and rescue operations in extreme environments, and delicate manipulation tasks. They embody the core competitiveness of a nation's deep-sea engineering capabilities. In recent years, highly adaptable and compliant bionic flexible intelligent equipment has emerged as a critical breakthrough in specialized robotics. This technology holds broad application potential for low-disturbance deep-sea exploration and flexible interactive manipulation, offering a novel paradigm for achieving precise and efficient operations in complex underwater environments and extreme deep-sea conditions.

However, the engineering application of Deep-Sea Flexible Carrier Equipment still faces critical scientific and technological challenges that urgently need to be addressed. The nonlinear coupled deformation mechanisms of flexible materials under high hydrostatic pressure remain unclear, and the lack of dynamic characterization methods directly restricts maneuverability and degrades actuation efficiency. Meanwhile, the actuation and adaptation mechanisms of flexible carrier equipment in extreme environments are highly complex, necessitating systematic investigations into performance analysis and system design of such advanced flexible equipment. Furthermore, the absence of deep-sea multimodal flexible sensing mechanisms prevents existing equipment from achieving high-fidelity state estimation and closed-loop control, severely limiting their operational reliability and autonomy in complex mission scenarios. Therefore, investigating the fundamental scientific issues related to the actuation, perception, communication, and control of deep-sea flexible robots, exploring novel design theories and operational methods for advanced deep-sea flexible equipment, and enhancing the environmental adaptability and operational completeness of deep-sea flexible systems will provide theoretical support and engineering references for technological innovation in deep-sea low-disturbance exploration and manipulation equipment, ultimately promoting their practical applications in deep-sea scientific research, resource development, and emergency support.

This special invited session warmly welcomes scholars from related fields to submit original research papers presenting innovative theories, significant

technological breakthroughs, or novel application scenarios. Topics of interest include, but are not limited to:

- Overall design of deep-sea bionic flexible carrier equipment
- Design and configuration optimization of novel deep-sea flexible actuators
- Fluid-structure interaction actuation mechanisms of flexible carrier equipment in deep-sea environments
- Cross-domain motion planning and control strategies for deep-sea flexible equipment
- Nonlinear mechanical behaviour and deformation mechanisms of flexible materials under extreme hydrostatic pressure
- Deep-sea multimodal flexible sensing mechanisms and the development of bionic sensor devices
- Energy management and long-endurance technologies for deep-sea flexible carrier equipment
- Lightweight underwater communication technologies and equipment for deep-sea flexible systems
- Swarm operation methods for deep-sea flexible systems
- Engineering application methods and reliability evaluation of deep-sea flexible equipment