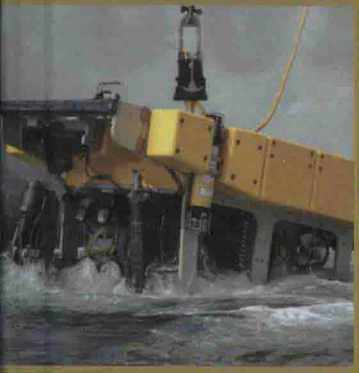
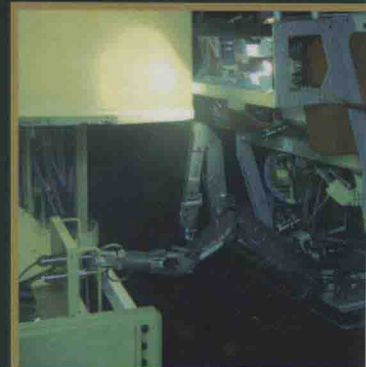
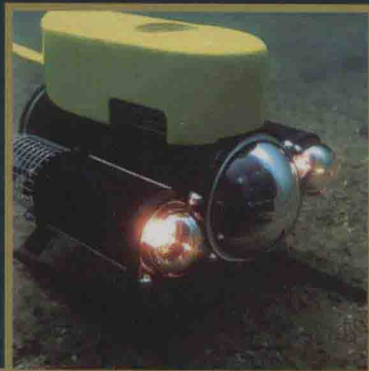


Second Edition

# THE [REDACTED] ROV MANUAL

A User Guide for Remotely  
Operated Vehicles



Robert D. Christ  
Robert L. Wernli Sr



# The ROV Manual

## A User Guide for Remotely Operated Vehicles

Second Edition

**Robert D. Christ**

**Robert L. Wernli, Sr.**



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# The ROV Manual

## A User Guide for Remotely Operated Vehicles



# Foreword

The world watched in horror in September 2005 as the video feeds from the hurricane-ravaged city of New Orleans were broadcast worldwide. As the city was struggling to recover from Hurricane Katrina, Hurricane Rita delivered the final blow to both the people on the coast of the Northern Gulf of Mexico as well as to the oilfield infrastructure. In the aftermath, close to 200 oil and gas production structures lay on the sea floor. The remaining structures fortunate enough to still stand incurred heavy damage.

In the midst of this crisis, we were busily trying to complete the first edition of this manual to meet an April 2006 publishing deadline. But the world changed for us on January 1, 2006 when the phone rang demanding Bob Christ's immediate travel to survey an oil barge that struck one of those 200 unmarked submerged platforms, which resulted in it spilling 72,000 barrels of fuel oil on the sea floor. Then a platform damage inspection was needed... dive support for decommissioning... structural repairs due to wind and wave stresses from hurricane force winds and seas... the publication deadline passed and yet Bob was still in the field. Bob Wernli was juggling his consulting, at-sea test support and a publication deadline for his second novel. Time was running out for both of us so we quickly buttoned up the first edition, although it was not as complete as we had originally envisioned.

In this second edition, we have come closer to our goal of producing a broad overview of ROV technology. Through the help of leaders and companies from throughout the industry, we have produced a solid survey of the current state of this capability. Our sincere gratitude and thanks go out to those who contributed to our quest. These contributors are recognized in the Acknowledgements section. What we envisioned from the beginning for this manual is a basic *How To* for ROV technology. The US Military has this type of top-level technology manual in their "Dash 10" series. The aviation industry has what is commonly known as the "Jeppesen Manual" (named for the company that wrote the original manual). We hope that we have achieved this goal through this edition of *The ROV Manual*.

This manual is a living breathing entity. Every book is a piece of history upon the publication date; therefore, we welcome comments on this edition. We hope to revise this manual in the future as the technology evolves and would like your comments for further refining this text if/when we put forth another edition. Each subject within this manual could fill an entire book in and of itself. We struggled with editing this manual (with a nominal word and text cap) to include all subjects in as short and succinct a manner as possible while still getting the point across. Although, due to the size constraints, we could not address the larger work-class ROVs as much as we desired, the technology, sensors, tools, manipulators, and related equipment apply across the board to all systems. We hope that this text will whet the reader's appetite for further research into the technologies, equipment, and systems discussed.

The entire body of knowledge encompassing ROV technology is evolving rapidly and the lines between ROV and AUV are quickly occluding as the field of robotics morphs from space to land to sea. The subsea oilfield is firmly embracing the land-based model of network interconnectivity bringing man (remotely) back into the harsh environment of the subsea world. The easy *finds* for the world's minerals have already been achieved and exploited. The frontier has moved from the

29% of the Earth covered by land to the 71% of the Earth covered by sea. The mineral riches of the world are hidden beneath those waves. The only way to get to them is with robotics. And that is where the fun starts!

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# Acknowledgments

In the first edition, the authors performed all of the basic research with some participation from industry in the form of recommendations and figure submissions. However, in this edition we elicited considerable industry participation—and we certainly received it!

Arnt Olsen of Kongsberg again participated with the contribution of Kongsberg’s seminal work on acoustic theory. Stephen Dodd of GRI Simulations contributed to Chapter 4. Tyler Schilling along with Peter MacInnes, Steve Barrow, and Matt Whitworth of Schilling Robotics were instrumental in the production of both the manipulator as well as the tooling chapters. Alasdair Murray and Steve Stepinoff of Sub-Atlantic and Chris Roper of Saab SeaEye supplied a plethora of materials for mid-sized vehicles and Jim Teague, J. Teague Enterprises, contributed to the chapter on floatation.

And a special thanks to pioneers of the cables and connector industry, Cal Peters, Kevin Hardy, and Brock Rosenthal, who completely drafted Chapter 8. Kevin Hardy is President of Global Ocean Design, specializing in free vehicle component technologies. He retired from the Scripps Institution of Oceanography/UCSD after 36 years in ocean engineering. Hardy’s instruments have successfully operated from the Arctic Circle to the southern oceans, and from the Arctic surface to the deepest ocean trenches, including James Cameron’s dive to the bottom of the Mariana Trench. Cal Peters is the Director of Engineering for Falmat (San Marcos, CA), a manufacturer of custom cables for the offshore industry and other markets. He has 32 years experience in the design and manufacture of EM, signal, power, faired, and neutrally buoyant underwater cables for diverse applications, including towed instruments, moorings, ROVs, and manned vehicles. Brock Rosenthal is the President and founder of Ocean Innovations (La Jolla, CA), a distributor of underwater connectors, cables, and other quality oceanographic hardware. Rosenthal has helped numerous end users clearly define their operational requirements before selecting their underwater equipment. Their support in this endeavor is truly appreciated.

But it did not stop there. Practically all of the titans of this industry volunteered their time and resources to this project. It is difficult to express our thanks in broad enough terms. All contributors are listed alphabetically by chapter below.

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# Introduction

This edition of *The ROV Manual* substantially expands upon the previous edition. This text is divided into five logical parts covering the industry and environment, the basics of ROV technology, payload sensors, intervention tooling as well as practical field applications. In the last chapter of the book, we look into the future in order to examine what industry analysts feel is the direction subsea technology is heading with a specific focus on the field of subsea robotics.

It is often said that *for every mathematical formula within a book, the population of book purchasers is halved*. As authors we certainly appreciate that thought, but seek to go from general terms to specific (as well as from simple to complex) toward reaching a broad readership for this subject. Some of the chapters are heavily focused on theory (e.g., Chapter 14 on underwater acoustics is heavily math-based) while others (e.g., Chapters 21 and 22, which focus on field applications and procedures) contain little or no mathematics. The general technology user should feel free to skip over the math-based sections, while those with a more academic bent or specific application should delve into the technical aspects of theory.

Chapters 1 and 2 (Part 1) seek to paint a background picture of the industry, as well as the environment, where ROVs operate and this technology applies. Chapters 3–11 (Part 2) drill down to the actual vehicle in a good bit of detail while Chapters 12–18 (Part 3) branch out into the broad subject of payload sensors. It is often said in this industry, “It is not about the vehicle, it is about the sensors and tooling.” Therefore, we additionally break out Part 4 (Chapters 19 and 20) to address the manipulators and tooling aspects of ROV technology while the final section (Part 5—Chapters 21–23) focuses on both practical applications and standard operating procedures, then closes with the authors’ take on the future of this technology.

While this text casts a wide net over the entire field of Remotely Operated Vehicle technology, we focus specifically on the classes of vehicle (narrowly defined in Chapter 3) in the observation class ROV (OCROV) and mid-sized ROV (MSROV) categories. The only subject missing to cover the full gamut of vehicles (i.e., the Work Class ROV, WCROV) is high-pressure hydraulics. And that subject will be left for a future iteration of this manual as we continue to refine this work while the industry (and technology) continues to evolve.

The divisions (parts) of this manual each address a separate readership. Part 1 is geared towards the business side and should be applicable to project managers making use of this technology while Part 2 focuses specifically on the ROV technician. Part 3 is addressed to the project manager but should also be of interest to the survey team as well as the ROV technician for gaining a general understanding of deployed sensor technologies. Part 4 is directed toward intervention technicians over a broad range of users (from Project Manager to Corporate Executive to Regulatory Officials to, of course, ROV Technicians). And Part 5 wraps it all up with both practical considerations and a look into the future.

No text of this size can do any measure of justice to the field of ROV technology. The authors have carefully carved out individual subjects in order to form an introduction into each field. We hope that you, the reader, come away with a general understanding of this industry and its advanced technologies, thus encouraging further investigation into your specific field of interest.

Welcome to the exciting field of subsea robotics!

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