Ocean Outpost

The Future of Humans Living Underwater

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Preface

In an era in which satellite photographs chart even the most remote land masses in astonishing detail, the vast majority of our planet lies unrevealed beneath the ocean. In this watery wilderness, an environment every bit as inaccessible as space, humans have rarely ventured more than a few hundred meters below the waves. At a time at which most people think of space as the final frontier, we should remind ourselves that a great deal of unfinished business remains here on Earth and as robots crawl on the surface of Mars, we should remember that most of our own planet has never been seen with human eyes.

One of the greatest scientific and technological achievements of the twenty-first century will be to cast a light on the eternal darkness of the deep ocean. Life, say the experts, began in the ocean, and if the way many people spend their vacations is any indication, there are few activities we enjoy more than revisiting our submerged origins. Whether cavorting with dolphins, harassing sharks from the protection of titanium cages, or photographing exotic aquatic species through the portholes of tourist submarines, humans have a natural affinity with what lies beneath the surface of the ocean. But despite having had the technology to establish permanent settlements under the ocean for more than five decades, of the 100 billion humans who have ever lived, not a single one has lived permanently underwater.

Ocean Outpost traces the future of man underwater, describing how technology will allow humans to adapt to a permanent life underwater. This book also unveils the challenges that will be faced by twenty-first-century aquatic pioneers and, ultimately, colonists, in what may in due course prove to be one of the greatest human adventures in history.

To realize the goal of a permanent human presence underwater, a wealth of new technologies will need to be developed and qualified, including new manned and unmanned submersibles, advanced propulsion systems, underwater rescue systems, decompression methods, and revolutionary physiological intervention strategies ranging from liquid ventilation to artificial gills. Some of the technology development and medical intervention will require quantum leaps in innovation, while others may be nothing short of radical, appearing to be more science fiction than science. Step by step, *Ocean Outpost* describes how the technology will evolve,

how crews will be selected and trained, and what a typical underwater mission will entail. The book also chronicles the frontiers of underwater technology that will eventually take humans into the midst of a world we could once only guess at.

This book is dedicated to those who accept the dangers and challenges of furthering the human dream to establish a permanent human presence under the ocean and to all those who support them.

Acknowledgments

In writing this book, the author has been fortunate to have had five reviewers who made such positive comments concerning the content of this publication and to Clive Horwood and his team at Praxis for guiding this book through the publication process. The author also gratefully acknowledges all those who gave permission to use many of the images in this book, especially Jeff Parker of Ambient Pressure Diving, world-record No Limits freedivers Herbert Nitsch, Patrick Musimu, and Tanya Streeter, scientists Dr. Robert Freitas, Dr. Phil Nuytten, Alan Bodner, and Erika Shagatay, Will Kohnen, President/CEO of SEAmagine Hydrospace Corporation, open-circuit scuba world record-holder, Mark Ellyat, and Hawkes Ocean Technologies.

The author also expresses his deep appreciation to Christine Cressy, whose attention to detail and patience greatly facilitated the publication of this book, to Jim Wilkie for creating the cover of this book, and to Stewart Harrison, who sourced several of the references that appear in *Ocean Outpost*.

Once again, no acknowledgment would be complete without special mention of our cats, Jasper and MiniMach, who provided endless welcome distraction and entertainment.

About the author

Erik Seedhouse is an aerospace scientist whose ambition has always been to work as an astronaut. After completing his first degree in Sports Science at Northumbria University, the author joined the legendary 2nd Battalion the Parachute Regiment, the world's most elite airborne regiment. During his time in the "Para's", Erik spent 6 months in Belize, where he was trained in the art of jungle warfare and conducted several border patrols along the Belize–Guatemala border. Later, he spent several months learning the intricacies of desert warfare on the Akamas Range in Cyprus. He made more than 30 jumps from a Hercules C130 aircraft, performed more than 200 abseils from a helicopter, and fired more light anti-tank weapons than he cares to remember!

Upon returning to the comparatively mundane world of academia, the author embarked upon a Master's degree in Medical Science at Sheffield University. He supported his Master's degree studies by winning prize money in 100-km ultradistance running races. Shortly after placing third in the World 100 km Championships in 1992 and setting the North American 100-km record, the author turned to ultradistance triathlon, winning the World Endurance Triathlon Championships in 1995 and 1996. For good measure, he also won the inaugural World Double Ironman Championships in 1995 and the infamous Decatriathlon, the world's longest triathlon, an event requiring competitors to swim 38 km, cycle 1,800 km, and run 422 km. Non-stop!

Returning to academia once again in 1996, Erik pursued his PhD at the German Space Agency's Institute for Space Medicine. While conducting his PhD studies, he still found time to win Ultraman Hawaii and the European Ultraman Championships as well as completing the Race Across America bike race. Due to his success as the world's leading ultradistance triathlete, Erik was featured in dozens of magazines and television interviews. In 1997, *GQ* magazine nominated him as the "Fittest Man in the World".

In 1999, Erik decided it was time to get a real job. He retired from being a professional triathlete and started his post-doctoral studies at Vancouver's Simon Fraser University's School of Kinesiology. While at Simon Fraser University, Erik established the Simon Fraser Freediving Program in association with Performance

Freedivers. In 2005, the author worked as an astronaut training consultant for Bigelow Aerospace in Las Vegas and wrote *Tourists in Space*, a training manual for spaceflight participants. He is a Fellow of the British Interplanetary Society and a member of the Aerospace Medical Association. Recently, he was one of the final 30 candidates of the Canadian Space Agency's Astronaut Recruitment Campaign. Erik currently works as an aerospace project manager – a job that includes such duties as acceleration training officer for the Canadian Forces, manned centrifuge operator, and flight director for manned hyperbaric operations. In his spare time, he also works as a manned spaceflight consultant, triathlon coach, and author. He plans to travel into space with one of the private spaceflight companies.

In addition to being a triathlete, skydiver, pilot, and author, Erik is an avid scuba-diver and has logged more than 200 dives in more than 20 countries. His favorite dive destinations are Moorea and Tasmania. His favorite diving movies include *The Big Blue*, by Luc Besson, the director's cut of *The Abyss*, by James Cameron, and the classic 1989 Norwegian film, *Dykket* (*The Dive*), by Tristan DeVere Cole. His favorite underwater science fiction novels include *Starfish* by Peter Watts and *OceanSpace* by Allen Steele. *Ocean Outpost* is his sixth book. When not writing, he spends as much time as possible in Kona on the Big Island of Hawaii and at his real home in Sandefjord, Norway. Erik lives with his wife and two cats on the Niagara Escarpment in Canada.

Figures

Tables

Panels

Abbreviations and acronyms

AAT	Aquatic Ape Theory
ABE	Autonomous Benthic Explorer
ABS	American Bureau of Shipping
ADME	Absorption, Digestion, Metabolism, and Elimination
ADS	Atmospheric Diving Suit
AIP	Air Independent Propulsion
AMS	Atmospheric Monitoring System
ARDS	Acute Respiratory Distress Syndrome
ARS	Air Revitalization System
ATB	Acoustic Transponder Beacon
ATCS	Active Thermal Control System
AUV	Autonomous Underwater Vehicle
BCD	Buoyancy Control Device
CCR	Closed Circuit Rebreather
CMBB	Center for Marine Biotechnology and Biomedicine
CNS	Central Nervous System
COTS	Commercial off the Shelf
CSA	Canadian Space Agency
CT	Computed Tomography
CWS	Caution and Warning System
DCS	Decompression Sickness
DDIA	Dubai Development and Investment Authority
DND	Department of National Defence
DSRV	Deep Submergence Rescue Vehicle
DWA	Drop Weight Assembly
EU	European Union
FDA	Federal Drug Administration
FPB	Fixed Positive Buoyancy
HA	Hydroxyapatite
HOT	Hawkes Ocean Technologies
HPNS	High Pressure Nervous Syndrome

HUD	Head-Up Display
IND	Investigational New Drug
ISS	International Space Station
JAMSTEC	Japan Marine Science and Technology Center
LARS	Launch and Recovery System
LiOH	Lithium Hydroxide
LBL	Long-baseline
LSS	Life Support System
MBT	Main Ballast Tank
MDR	Mammalian Diving Reflex
MMS	Minerals Management Service
MOD	Maximum Operating Depth
MRDF	Marine Resources Development Foundation
NAUI	National Association of Underwater Instructors
NDT	Non-Destructive Testing
NMRI	Naval Medical Research Institute
NOAA	National Oceanic Atmospheric Administration
NRC	National Research Council
OBS	Optical Backscatter
OWTT	One Way Travel Time
PADI	Professional Association of Diving Instructors
PEM	Polymer Electrode Membrane
PFC	Perfluorocarbon
PI	Principal Investigator
PIT	Pilot in Training
OCS	Outer Continental Shelf
OWC	OceanWorks International Corporation
RHOV	Replacement Human-Occupied Vehicle
RLV	Residual Lung Volume
ROV	Remotely Operated Vehicle
SAS	Sub Aviator Systems
SIO	Scripps Institute of Oceanography
SMS	Seafloor Massive Sulphide
SOR	Strategic Oil Reserve
SRC	Submarine Rescue Chamber
SRDRS	Submarine Rescue Diving and Recompression System
TCCS	Trace Contaminant Control Subassembly
THCS	Thermal and Humidity Control System
TLC	Total Lung Capacity
UNCW	University of North Carolina Wilmington
VBS	Variable Ballast System
VBT	Variable Ballast Tank
WHOI	Woods Hole Oceanographic Institution
WMS	Waste Management System

Section I

Diving

In June 1913, the *Regina Margherita*, flagship of the Italian Navy, anchored in Picadia Bay, Karpathos, in the Aegean Sea. In a heavy storm, the ship dragged its anchor, which eventually broke and was lost in 77 m of ocean. Since it would have been a disgrace for the captain to return to the home port without the anchor, several attempts were made to salvage it. After many unsuccessful days spent trying to recover the anchor, one of the divers died, the Italian Naval Archives describing his death as the result of a blackout.

In desperation, the captain sought help from a group of Greek sponge fishermen renowned for their diving abilities and offered a substantial reward to the diver who could recover the ship's anchor. Several divers offered to help, among them a rather feeble-looking fisherman by the name of Georghios (Yorgos) Haggi Statti, who boasted he could hold his breath for 7 min and would have no trouble diving down and recovering the anchor. At 1.75 m tall and weighing 60 kg, Yorgos did not look the part of a diver capable of descending to 77 m on one breath of air and because of his sickly appearance, the captain was initially quite skeptical and requested that the ship's doctor perform a medical examination.

The results of the examination did little to convince the captain, since it was discovered that Yorgos was suffering from pulmonary emphysema, a debilitating condition of the respiratory system. Secondary symptoms associated with this condition do not help a breath-hold diver, since both the resting heart rate and the breathing rate are elevated. In the case of Yorgos, his breathing rate was measured at between 20 and 22 breaths per minute (a normal rate being about 12 breaths per minute), and his heart rate at between 80 and 90 beats per minute (compared with a normal rate of 70 beats per minute). However, Yorgos did appear to have one advantage, since his lack of an auditory membrane permitted him to dive without having to equalize using his hand. The doctors recommended that given the illness, Yorgos should not be allowed to dive. Fortunately, Yorgos, not being a fan of current medical practice, chose to ignore the doctors, and began training for the dive anyway. Within a period of 4 days, he made 21 practice dives to depths of between 45 and 84 m – performances that astounded the doctors. These depths are particularly remarkable given that in 1960, the Cousteau team declared that in

their estimation, a depth of 55 m was the absolute limit for human breath-hold diving.

Yorgos dove down to 77 m on three occasions and succeeded in passing a rope through the anchor's eye that allowed the crew to retrieve it. It should be noted that during these dives, Yorgos wore neither a mask nor fins. For his trouble, he received five pounds of sterling and given permission to fish with dynamite – a practice usually reserved for the Italian Navy. He also passed into the annals of breath-hold-diving legend and became the subject of numerous articles, his story being mentioned in books written by future breath-hold-diving athletes.

Strangely, each account of Yorgos's feat sidesteps the obvious question: How did he do it? The answers can be found in testimonies and statements made by the doctors who examined him, which are preserved in the archives of the Italian Navy in Rome. The explanation lies in a simple but, at the time, ingenious technique used by Yorgos. He descended in the vertical head-up position after first tying a rock weighing about 45 kg to his ankles. This ballast allowed him to descend to the bottom at a phenomenal rate. Once there, he simply cut the rope with a knife, passed it through the anchor's eye, and allowed the surface crew to pull him back to the surface.

Today, athletes still practice a version of the diving technique pioneered by Yorgos in a discipline known as No Limits, which is the subject of the first chapter of this book. Section I begins by describing the challenges of modern No Limits freedivers as they set their sights on dives to 300 m on just one breath of air. Chapter 2 ventures deeper by exploring the world of technical and saturation divers and identifies the factors that determine life or death for divers working at extreme depths. Section I concludes by assessing future science and technology that will be required by divers seeking to extend the human diving envelope by venturing into previously impenetrable depths.