

**Collaborative AUTOSUB Science in Extreme Environments (CASEE) Bursary Report
Justin E. Manley**

- Destination(s):** Southampton, London and Oxford England - November 12-20, 2006
Aberdeen Scotland - June 18-21, 2007
- Purpose:** Build collaborative relationships with UK Colleagues, research risk management in the field
- Activities:**
1. Visit with UK researchers at National Oceanography Centre & National Environmental Research Council
 2. Meet with members of the undersea technology community in the UK
 3. Develop concepts and analysis on role of risk in AUVs
 4. Attend IEEE OCEANS 2007 to share ideas on the role of risk in AUVs.
- Deliverables:**
1. Trip Report to U.S. National Oceanic and Atmospheric Administration (NOAA) on November visit, attached
 2. IEEE OCEANS 2007 Conference Paper, "The Role of Risk in AUV Development and Deployment" Abstract below, see conference proceedings for full paper.
 3. IEEE OCEANS 2007 Conference Presentation, attached
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Synopsis:

The CASEE Bursary allowed me to make two visits to the UK. In these visits I was able to build new relationships, and foster existing ones, with members of the undersea technology community in the UK. These meetings discussed many topics of interest and improved my understanding of the research sponsorship mechanisms and philosophy in the UK. They also included a significant focus on Autonomous Underwater Vehicles (AUVs). By focusing on risks in AUV development and deployment I was able to formulate some ideas on how best to manage such risks. In the UK I gained valuable knowledge about the AUTOSUB program. Back in the US I worked with two AUV programs I was familiar with to complete three case studies. These formed the basis of a conference paper on the subject. I traveled to the IEEE OCEANS 2007 Conference in Aberdeen Scotland to present the paper. There I met additional new contacts in the undersea technology field and presented my paper.

Acknowledgments:

The financial support of the CASEE bursary was instrumental to this effort and supported my two trips to the UK. The National Oceanic and Atmospheric Administration, my client, kindly allowed me to engage in these trips and supported my labor during these activities.

Many individuals provided important contributions and were generous with their time. I would like to recognize Dr. Gwyn Griffiths (National Oceanography Centre), Simon Edwards (Leviathan Facility) Ian Gallet (Society for Underwater Technology) and Dr. Paul Newman (Oxford University).

Special thanks go to Dr. Ken Collins for his guidance in administering the CASEE Bursary and his warm hospitality during my visit to Southampton. A proper pint after walking the dog was also an enjoyable collaboration I enjoyed during this effort.

Deliverable:

Please see:

J. Manley, "The Role of Risk in AUV Development and Deployment," *Proceedings of Oceans 2007*, IEEE, Aberdeen, Scotland, June 2007.

Abstract:

The marine environment is immensely challenging to all technologies, thus risk is ever present in ocean engineering. In the case of autonomous underwater vehicles, however, risk takes on new dimensions. Engineers must evaluate and overcome technical risks to ensure reliable functioning of an AUV. Operators must develop and rigorously apply standard operating procedures to ensure both the safety of the AUV and the people and vessels around it. AUVs can, and must, be viewed through the eyes of designers and operators and their varied perspectives on risk. A third party, with an altogether different view of risk is the insurance community. Finally, the role of lawyers and regulators must be considered. Despite these disparate viewpoints risk can be clearly seen to influence both the development and deployment of AUVs.

This paper examines the role of risk in AUV development and deployment and presents case studies. The Autosub Under Ice research program administered by the U.K. National Oceanography Centre, AUV pilot programs in the U.S. National Oceanic and Atmospheric Administration and the acquisition of an AUV by an academic team are all explored. In each case study the role of technology and operational risks is described. Liability and regulatory issues are also discussed. In each case risk can be clearly identified as a driver behind technical or operational decisions, or both.

This paper concludes with some recommendations for both AUV developers and operators. These recommendations are designed to reduce risk and open a dialog across the AUV community in the hopes of generating interest in a commonly developed code of best practices. The need for and path towards such a code is also described.

Conference Presentation Slides Follow

November Trip Report Follows



The Role of Risk in AUV Development and Deployment

Justin E. Manley

Battelle Applied Coastal and Environmental Services

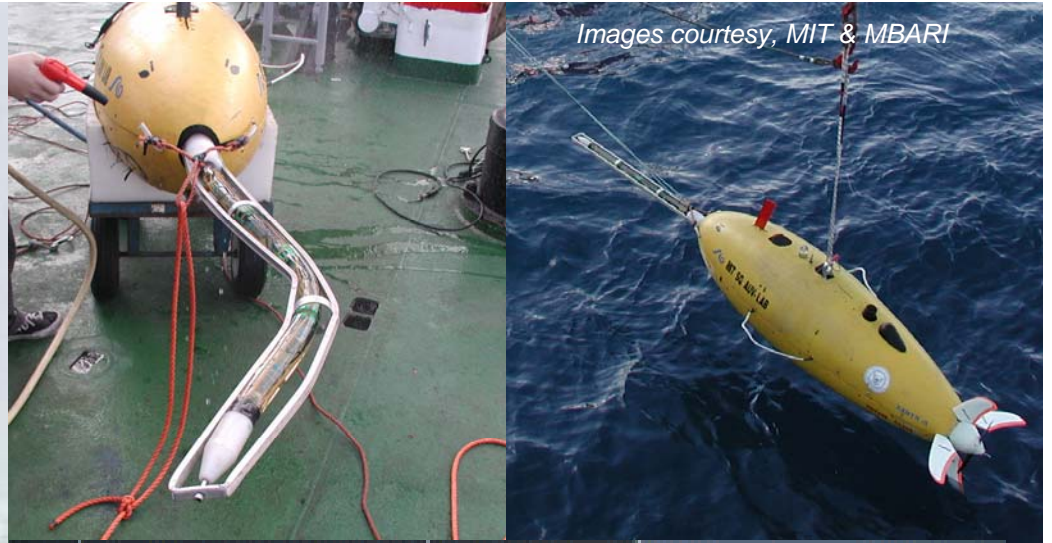
NOAA Office of Ocean Exploration

Objectives

- Consider risk and how it impacts both the development and deployment of AUVs
- Review case studies for lessons learned
- Offer some thoughts on moving the field forward and effectively managing risk
- Open a discussion amongst the community

Personal Experience

- AUVs get lost
 - Monterey Bay
 - Mediterranean
 - Charles River
- AUVs “meet”
 - Ferries
 - Seafloor
 - Objects
 - Law enforcement

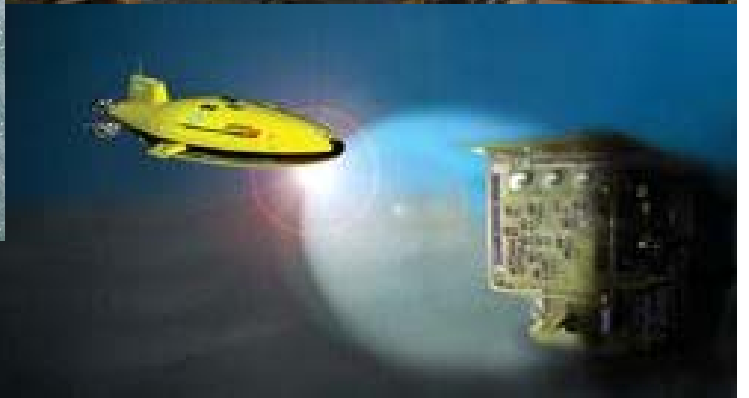
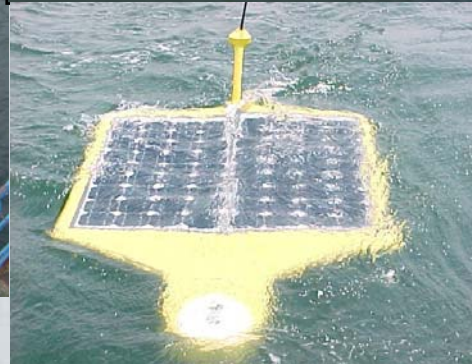
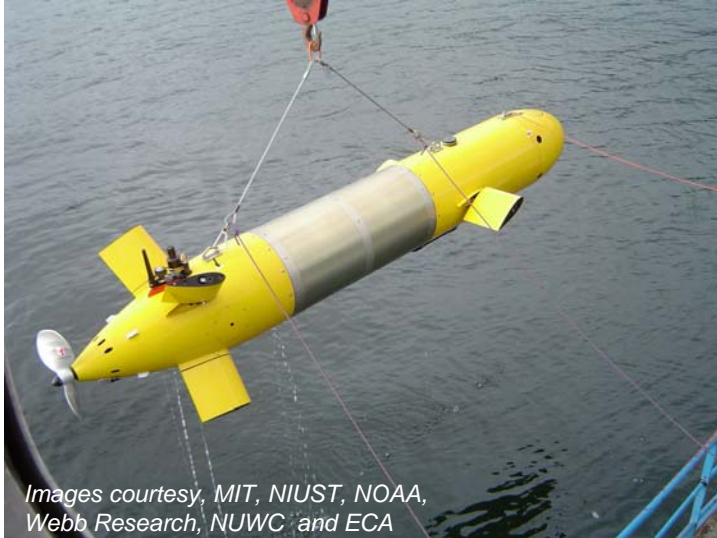
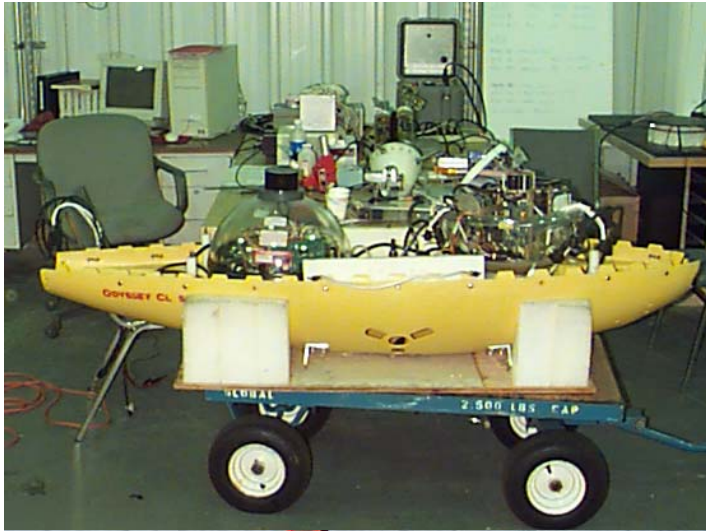


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The Business of Innovation

J. Manley, OCEANS 2007



Images courtesy, MIT, NIUST, NOAA, Webb Research, NUWC and ECA

AUVs have evolved dramatically!

Risks

- Technical
 - Mechanical
 - Energy
 - Navigation
 - Control
 - Not a major insurance liability
- Operational
 - User “error”
 - Launch and recovery
 - Environment
 - Personnel are key
 - Legal regime is uncertain



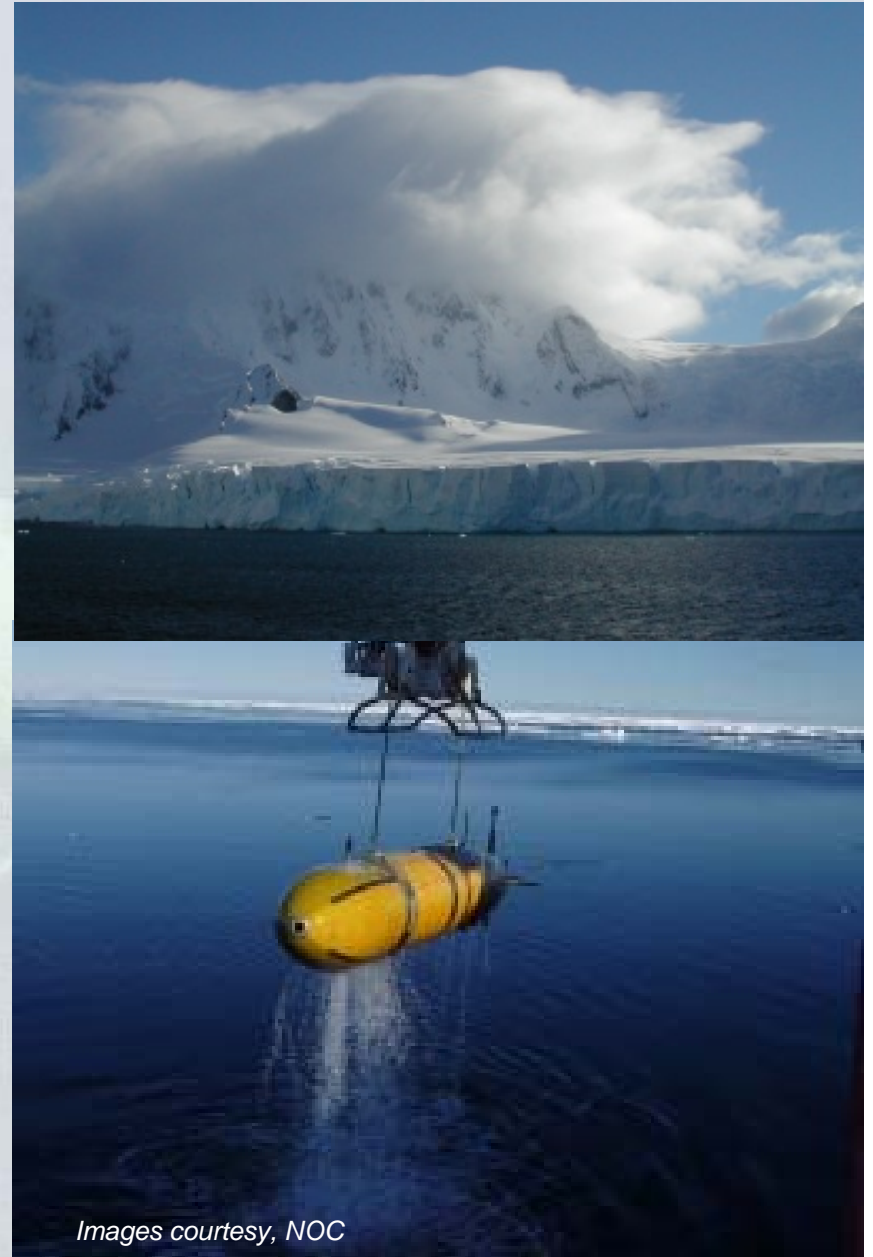
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Case Study: AUTOSUB

- Mission under Antarctic Ice
 - Data was of high value
 - High operational risk
 - Insurance = vehicle cost
 - Self-insure, replacement AUV
 - Vehicle was “lost”
- Outcomes
 - CASEE Program was launched
 - International Masterclass
 - Robust risk management protocol instituted, and evolving
 - New research focus on reliability of autonomous systems



Images courtesy, NOC

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Case Study: National Oceanic and Atmospheric Administration

- Experienced Marine Operations group
 - Not familiar with AUVs
 - Requires multiple units for force multiplication
- Pilot Projects, spiral approach
 - Develop operational procedures
 - Educate user community
 - Evaluate AUV capability and required improvements

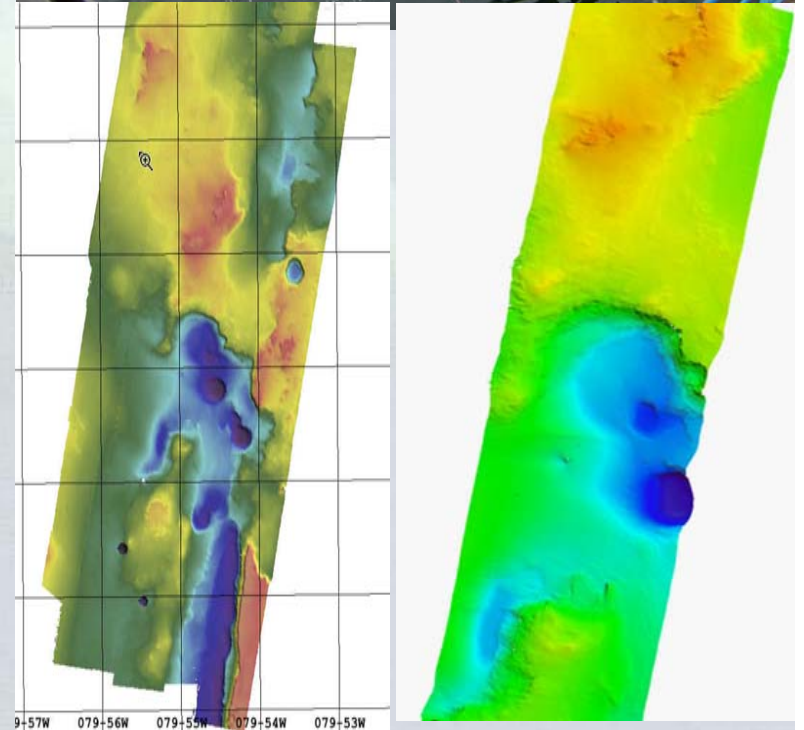


Images courtesy, NOAA



Case Study: National Institute for Undersea Science and Technology

- Reduce technical risk
 - Acquire commercial AUV
 - Work closely with vendor during construction
- Manage operational risk
 - Partner with experienced operations team
 - Establish advisory board
 - Phased entry into service



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Managing Technical Risk, Recommendations

- Small scale operators with few AUVs
 - Might consider UVTC approach, Procure “off-the-shelf” AUV
 - May sacrifice some capability for reliability
- Larger efforts and fleet operators
 - Might consider the spiral approach
 - Higher initial costs and longer procurement cycle yield better return over time

Successful AUV Ops use the contents of these



Not these

Managing Operational Risk, Recommendations

- Careful focus on program goals
 - AUVs must be considered a means to an end
- New entrants encouraged to learn from their peers
 - e.g. UVTC advisory board and teaming concept
- Personnel development is key
 - Prime factor in insurance
 - Requires time to develop staff
 - Community engagement helps

Enhancing the Global AUV Community

- Expand community interactions
 - Operational lessons are as valuable, or greater, than technical developments
 - Plan (budget) for conference and workshop participation
- Professional societies
 - Should coordinate amongst themselves
 - “code of practice” under development
 - Standards can be powerful tools in the growth of an industry

Questions

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Acknowledgments

Collaborative AUTOSUB Science in
Extreme Environments (CASEE)
Program & National Environmental
Research Council (U.K.)

Leviathan Facility (U.K.)

NIUST Undersea Vehicle Technology
Center (U.S.)

NOAA AUV Working Group (U.S.)

NOAA Research/Office of Ocean Exploration
Travel Report for November 12-20, 2005

Traveler: Justin Manley

Destination: United Kingdom, Southampton, Oxford and London.

Purpose: Meet with UK R&D community to discuss technology and ocean science issues

Objectives:

1. Gain knowledge on UK R&D funding systems
2. Meet individuals involved in AUV development, and ocean exploration in UK
3. Identify new developments in subsea technology
4. Learn more about risk evaluation of AUVs and high tech programs

Preparation:

1. Applied for and was awarded a bursary (fellowship) to travel to the UK and investigate policy and program management issues in advanced marine technology. Coordinated with my host at the National Oceanography Centre (Dr. Ken Collins) to arrange travel and meetings in the UK
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Participants:

Various from across the UK ocean science and technology community.

Background:

Autosub Under Ice was a £5.86 million (~\$12M) program to explore the marine environment beneath floating ice shelves using an Autonomous Underwater Vehicle. Funded by the [Natural Environment Research Council](http://www.nerc.gov.uk) (similar to the U.S. NSF), the program brought together oceanographers, geologists, glaciologists, biologists and engineers from fourteen UK institutions to investigate the role of sub-ice shelf processes in the climate system. See <http://www.soc.soton.ac.uk/aiui/aiui.html> for more. A sub-component of this program was the collaborative autosub science in extreme environments (CASEE) project. Click on the "CASEE Web Site" link in the AUI page. CASEE included an opportunity for researchers to request travel funds for international exchange.

I wrote a proposal (which was funded by NERC) to visit the UK twice to develop a greater understanding of how their agencies and researchers pursue the development and deployment of advanced technologies such as AUVs. I was particularly interested in the role of risk management, which is a fundamental concept to the UK R&D efforts I was familiar with. By Learning more about U.K. programs and comparing that to efforts in the United States my goal is to write a concept paper on "the role of risk in unmanned vehicle development and deployment." I plan to make my second visit to the UK (also sponsored by the CASEE bursary) to present this paper at OCEANS 2007 in Aberdeen Scotland in June 2007.

This trip report provides a synopsis of the day-to-day activities and a summary of the key ideas or conversations that came out of the many meetings I had in the UK.

Trip Synopsis:

Daily Activities

Monday November 13, 2006: I arrived in the UK and travelled to Southampton. I checked in at the National Oceanography Centre (NOC) with Dr. Ken Collins and obtained my visitor credentials. In my conversations with Ken I learned about the structure of the UK Fiscal year and how their research community often runs into "odd" spending patterns late in the year. I had a very productive discussion with Martin Marsters who is a member of the outreach team at NOC. We discussed OE and its programs and I introduced him to our website, especially the lesson plans. We also had a good discussion about how to use "telepresence" in education and outreach. Martin gave me a copy of a DVD produced by the "SERPENT" program which teams ocean scientists with commercial ROV operators. The results seem to be of some value and certainly represent an efficient use of resources. I concluded my day's research activities by watching the "Gadget Show" on television in the evening. Consumer technology interests in the UK seem to be identical to those in the U.S. Not a major surprise.

Tuesday November 14, 2006: My first meeting was with Jon Adams a Professor of Marine Archaeology at the University of Southampton. I described OE, its programs and in particular the Phaedra expedition of 2006. Jon had good insights about the technology demands of archaeology and interdisciplinary exploration. He was interested in the results of some of our technology demonstrations, especially the imaging of the wreck of the *Paul Palmer* in the Stellwagen Bank National Marine Sanctuary. I also invited Jon to contribute to the Marine Technology Society **Journal** (I am the Editor and always on the lookout for a good paper).

I had lunch and an extended meeting with Gwyn Griffiths who leads the autosub team at NOC. I provided him with updates on AUV activity in the U.S. and NOAA. He helped me understand the existing funding regime in UK ocean sciences and introduced me to Oceans 2025, which is a combined vision/proposal from the major UK oceanographic programs. The overall concept was intriguing and the concepts within his technology development work program (particularly improved reliability of AUVs, a 5000km range AUV and air deployed conventional AUVs) also sounded exciting. Funding decisions are anticipated soon and Gwyn promised to send me detailed information on his technology work program once its funding level is determined. We also discussed how Autosub 3 was transitioned from a technology effort into an operational asset now available to the UK science community.

In the afternoon I met with Steve McPhail to get an update on the development of Autosub 6000. The core technology developments are valuable but it is fundamentally an evolution of the existing design. Once ready for testing and operations, in early 2008, this asset will be of great interest to Bram Murton, an oceanographer I met at NOC. Bram has some exciting ideas about technology, including low cost deep ROV approaches and his own ideas on a hybrid ROV. We also discussed the possibility of a joint AUV based expedition to the Cayman Trench. It might be possible to coordinate Autosub 6000 and Sentry (WHOI's new AUV) for an expedition to explore this deep water just off the U.S. Coast. I showed Bram the OE website and described how he could go about submitting a proposal for the 2008 cycle. This holds great promise for a collaborative exploration using the latest tools from both the UK and US.

Wednesday November 15, 2006: My primary activity today was a long visit with Mike Webb of NERC. Mike is the senior program manager over the Autosub Under Ice program and other NOC efforts. On my part I shared information about NOAA in general and ocean exploration in particular. The *Okeanos Explorer* and ROV were of great interest to Mike, as was the HROV project at WHOI. A primary conversation topic was the possibility of including *O. Explorer* in the international barter system developing amongst ship operators. Currently NSF participates but NOAA is not effectively engaged. In concept we might be able to swap time on our vessel for other ships operated by the barter participants. Thus we might see the cost savings of keeping the vessel in one region but also be able to use other ships and tools to explore wider regions of the ocean. I assured Mike I would bring this concept back to OE for discussion. We also discussed developing strong collaborations amongst our ROV operators and technology suites. I will make sure we invite representatives from the UK community to our planned technology workshop that will discuss our ROV payload plans. The other core concept I took away was that the funding base and outlook in the UK is much different from that in NOAA. NERC sponsors research programs for five years at a time. Once funds are awarded and committed they are quite stable. This allows large bodies of work (e.g. Autosub Under Ice at over \$10M) to be conceived and executed. While the burden of justification is higher than OE's peer review panel the stability and results speak for themselves. The Autosub program truly explored an unknown region with the latest technology. It incurred great risk (even the loss of one AUV) but yielded exceptional data. Obviously the Government funding mechanisms are different but these lessons are worth considering as OE develops programs and sees its budget stabilize.

Thursday November 16, 2006: I opened my day with a meeting with Colin Day and Geraint West both of whom are engaged in the operations side at NOC. Once again I described the *O. Explorer* and ROV. We discussed the barter system and including their representatives in the OE ROV/technology workshop. We also discussed the Cayman Trench idea and its possible logistics. Much will depend upon the trials of Autosub 6000. A strong discussion and excellent contacts with the UK vessel operations community.

Later in the day I travelled to Oxford. I met with Paul Newman who was a post-Doc at MIT while I ran the AUV Lab there. Paul is now a Fellow of New College (similar to tenured faculty) where he teaches engineering. He conducts most his research in robotics. In addition to learning about the fascinating history of Oxford and the quirks of its education system I also saw further impacts of the UK R&D approach. Paul described how he just finished a series of proposals that would provide funding for three to six years of his work. As a researcher he appreciates the stability and duration of the funding. This is especially true for his technology development efforts. We also discussed the idea of an undersea "grand challenge" to spur the development of undersea robotics. Paul pointed out that the cost of entry is much higher than the land version (where an automobile and laptop are all on needs). It is unclear if that means the prize must be larger or if it will simply exclude the amateurs from such an event.

Friday November 17, 2006: I met with Ian Gallet executive director of the Society for Underwater Technology. In addition to discussing ways SUT and the Marine Technology Society might collaborate we also discussed the legal and policy efforts his society is leading in the UK. A working group there is attempting to develop updated legal studies of AUVs and eventually hopes to develop a code of “best practices” for the operation of AUVs. Both of these efforts are intended to help those who actually use AUVs manage their liability as they use ever greater numbers of AUVs offshore. This discussion was followed by a visit to the Leviathan Facility, specialty underwriters for Lloyds of London. Leviathan exclusively works in the area of marine equipment and have written policies on many AUVs. I met with Simon Edwards who founded the group. Simon described the critical importance of the crew and vessel experience in AUV operations. All of the claims Leviathan has paid out have been a result of launch and recovery incidents. While they have not found themselves in a liability situation (e.g. an AUV surfacing under a jet ski injuring the rider) but Simon assured me he was concerned about this incident. From his perspective it is a matter of when not if and that only such an incident will initiate the legal events required to truly understand the liability regime for AUVs. He encouraged me to work with Ian Gallett on the code of best practices and suggested that development and use of such a code would help AUV operators manage their risks more effectively.

Saturday and Sunday November 18-19, 2006: I spent the weekend visiting a friend at the University of Birmingham who is completing a Ph.D. in advanced techniques for data visualization. Staying the Saturday night significantly reduced my air travel costs and allowed me to see a Rugby Game. Definitely in the spirit of international exchange. I spent Sunday travelling back to Boston.

Key Contacts:

All of the individual meetings described above can be considered key contacts. For further information or contact information please see Justin.

Reference Materials:

These are materials were collected on this trip and are retained by Justin

1. SERPENT Program DVD
2. An overview of the Oceans 2025 initiative proposed to NERC.
3. Industry publications from the Society for Underwater Technology including two issues of their Journal and a magazine on underwater vehicles.