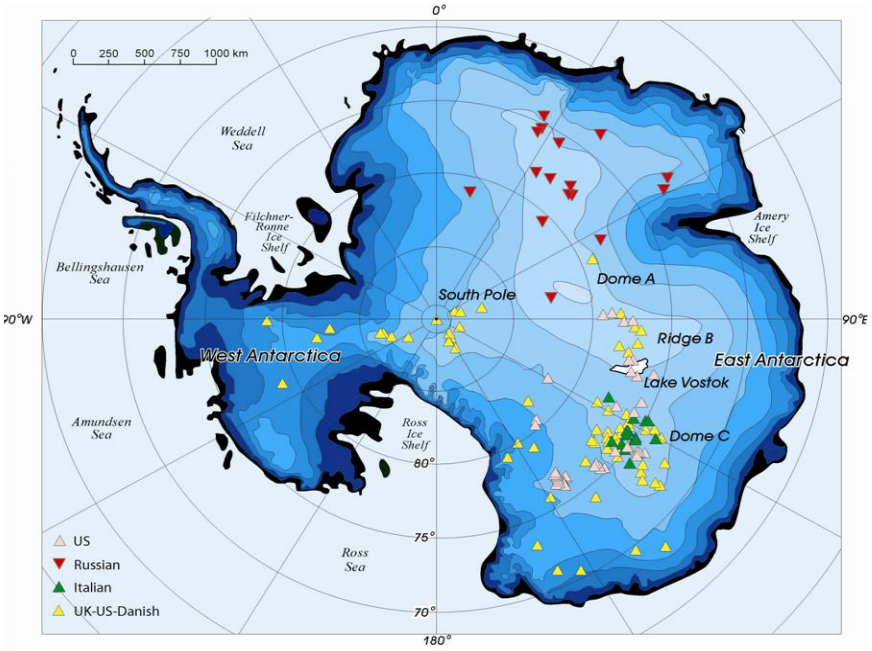
Science and Implementation Plan
for
A SCAR Scientific Research Program (SRP)

"Subglacial Antarctic Lake Environments (SALE)"



M. Siegert, 2004

by the
SCAR Subglacial Antarctic Lake Exploration Group of Specialists (SALEGOS)

Submitted 6 November 2003; Revised and Resubmitted 12 August, 2004

Table of Contents

PROPOSAL FOR A SCAR SCIENTIFIC RESEARCH PROGRAM

Submitted 6 November 2003; Revised and Resubmitted 12 August, 2004

A. Program Description

A.1 Title: Subglacial Antarctic Lake Environments (SALE)

A.2 Submission: Through the Standing Scientific Groups for Life Sciences and Geosciences by the Subglacial Antarctic Lake Exploration Group of Specialists (SALEGOS). Endorsed by the LSSSG and GSSSG in Bremen, July, 2004.

A.3 Program Duration: January 1, 2005 to December 31, 2013. Six years of meetings and planning with two years for final synthesis and reporting.

A.4 Estimated SCAR Funding: Total Core Program: $200,000 ($25,000/year), Expected Total Supplemental Requests: $120,000 ($15,000/year)

A.5 Program Executive Summary: It is proposed to form a Scientific Research Program (SRP) entitled "Subglacial Antarctic Lake Environments (SALE)" to serve as the international focal point of SCAR's activities to promote, facilitate, and champion cooperation and collaboration in the exploration and study of subglacial environments in Antarctica. SALE will be constituted for a period of eight years with twelve members' representative of the disciplines and expertise fundamental to subglacial lake exploration and study. SALE will:

- guide the development and implementation of the SRP's activities including changes in course as indicated by events and progress;
- encourage and facilitate communication and collaboration between scientists and technologists involved in subglacial lake environment exploration and research;
- advise the international community through SCAR on scientific and technology issues including addressing environmental concerns and proposing safeguards;
- promote partnerships, collaboration, data and sample access, common data management protocols and data sharing to facilitate and expedite the advancement of Antarctic science and knowledge;
- summarize and report results to the wider scientific community, policy makers, and the lay public in available venues;
- encourage adherence to the agreed guiding principles for subglacial environment stewardship, exploration, research, and data management;
- advocate subglacial lake environments exploration and research to National Committees, scientific communities, policy makers, and the lay public;
- establish scientific liaisons and logistics cooperation with other Antarctic entities and activities in close partnership and coordination with COMNAP;
- respond to requests from SCAR for expert advice in a timely manner including convening of expert groups when needed:
- maintain an up-to-date inventory of subglacial lakes, develop a standard identification scheme, and maintain a current bibliography;
- provide advice on minimization of contamination for entry, sensor package deployments, and sampling technologies and engage independent third party experts as needed for objective advice and guidance;
- organize and conduct workshops, scientific sessions, and symposia;
- provide a web site with links to activities related to subglacial lake environments including national programs, meetings, reports, and data repositories;
- convene and conduct scientific, methodological and technology workshops;

- provide a centralized focus for outreach efforts including promotional materials, an available speaker and topic list, creation of interactive tools for educating the public, meeting reports, regular press releases, and contact information for the media; and
- develop and promote common protocols and standards for data management to ensure access, quality and comparability across programs including the development of a portal to data repositories held by others.

The overarching scientific objectives of SALE are:

- To understand the formation and evolution of subglacial lake processes and environments.
- To determine the origins, evolution and maintenance of life in subglacial lake environments.
- To understand the limnology and paleoclimate history recorded in subglacial lake sediments.

The proposed SRP for SALE supports SCAR's mission, vision, and goals as outlined in the "First SCAR Long Range Strategic Plan" by providing a venue to ensure SCAR leadership in leading-edge interdisciplinary Antarctic exploration and science. SALE will facilitate and coordinate research among interested nations to develop greater scientific understanding of the nature and evolution of the Antarctic region and its processes, the role of Antarctica in the Earth System with particular reference to changing climate, and provide a basis for understanding the effect of global and human change by deciphering the past evolution of the continent and life over millions of years. The new knowledge gained about the workings of the Earth System will be communicated to policy makers and the lay public in understandable formats. SALE will be an advocate for environmentally sound subglacial lake environment exploration and research. While environmental, logistical and technological challenges are many, SALE will closely coordinate it efforts with COMNAP, national committees, and the ATCM to ensure that the best available knowledge is brought to bear on the varied issues that must be addressed. The SALE network will allow countries to participate at a level commensurate with available national resources while benefiting from a team effort intended increase the capacity of all of its members by sharing of collective expertise, experiences, and knowledge. Subglacial lake environments have already generated great public interest and SALE will capitalize on this interest with a vigorous outreach program that will assist in incorporating Antarctic sciences into the education process from "K-Gray" and communicate findings to the public.

Subglacial lake environments are emerging as a major new frontier theme of the International Polar Year in 2007-2009. The designation of SALE as a SRP will position SCAR to be a leader in the International Polar Year (IPY) in this topical area. SALE provides an international focal point for the exploration and study of subglacial lake environments. Initial plans have been agreed to form an international network of exploration and research programs under the auspices of SALE to coordinate activities during the IPY 2007-2009 and after [**see Appendix D - SALE - UNified International Team for Exploration and Discovery (SALE-UNITED**].

B. Program Plan- Over the past decade a series of international workshops, and meetings of a group of specialists; have developed an interdisciplinary science and technology plan for the exploration and study of subglacial lake environments. The

Subglacial Antarctic Lake Exploration Group of Specialists (SALEGOS) was duly constituted by SCAR in Tokyo in the year 2000 and the membership was agreed upon. By the time of this proposal, SALEGOS will have held six meetings and produced meeting reports for each.

- Meeting 1: Bologna, Italy, November 2001.
- Meeting 2: New York, USA, May 2002.
- Meeting 3: Santa Cruz, USA, October 2002.
- Meeting 4: Chamonix, France, April 2003.
- Meeting 5: Bristol, UK, October 2003.
- Meeting 6: Bremen, Germany, July 2004.

SALEGOS members concluded that the group's Terms of Reference have been met fulfilling the mandate as originally envisioned. SALEGOS members recommended that the Group of Specialists be disbanded in July, 2004. SALEGOS members also recognized that SCAR has an interest in continuing to foster international cooperation in subglacial lake environment exploration and that an organization with the appropriate expertise is needed to continue to serve in an advisory role. As such, SALEGOS recommended the formation of a SCAR Scientific Research Program entitled "Subglacial Antarctic Lake Environments (SALE)".

B.1 Scientific Objectives - To understand the complex interplay of biological, geological, chemical, glaciological, and physical processes within subglacial lake environments an international, interdisciplinary plan for coordinated research and study is essential. The overarching scientific objectives that will guide subglacial lake environment exploration and research are:

- **To understand the formation and evolution of subglacial lake processes and environments.**
- **To determine the origins, evolution and maintenance of life in subglacial lake environments.**
- **To understand the limnology and paleoclimate history recorded in subglacial lake sediments.**

These objectives can only be accomplished by integrated and coordinated phases of discovery and hypotheses-driven research over at least a ten-year period. The scientific objectives will be addressed through a series of projects which form a comprehensive research program for the exploration of subglacial lake environments. Each research project will be defined by its own scientific objectives and requirements for logistics and technology. Together the portfolio of projects advances the overall program. The timing of individual projects, while interrelated, will ultimately be determined by the resources and technologies available and the priorities of individual National Antarctic Programs. The projects are not necessarily sequential and several may be pursued in parallel. However, some later objectives are dependent on the information, results, and technological advances provided by earlier phases of research. Below specific scientific objectives provided for each area of discovery. While there are disciplinary based objectives, in most instances, attainment of the objectives requires an interdisciplinary approach and team effort.

B.1.1 Functional Genomics and Phylogenetics - Examine organisms in terms of their genomes (their full DNA sequences), including gene function as well as

their phylogenetic relationships; search for extinct and extant life signatures in the overlying ice sheet (glacial and accretion ice) to determine the possible origins of biotic constituents to the underlying lakes; and determine the genetic diversity in the water accumulations and benthic sediments of subglacial lake environments.

B.1.2 Limnology - Determine biogeochemical processes and metabolic activities in the water accumulations and sediments of subglacial lake environments and relate these to genomic data; measure vertical density gradients and use these to model water motion; examine the geochemical and isotopic composition of selected lake water constituents to determine their role in biological processes, water column stability, and to establish the age of subglacial lake environments water; and compute the hydrological budget for and hydrological linkages among subglacial lake environments.

B.1.3 Geophysics - Identify and measure subglacial lake surfaces using radio echo sounding; determine the bathymetry of subglacial accumulations of water and sediment thickness from seismic measurements; and understand the tectonic and ice sheet setting of subglacial lake environments through geological analysis of geophysical data.

B.1.4 Glaciology - Measure the flow of ice over subglacial lake environments through direct surface measurements and satellite data; understand the interrelation between ice sheet processes and water circulation; and Identify the formation and evolution of subglacial lake environments using numerical models of ice sheet history.

B.1.5 Geology and Cenozoic Paleoclimate - Understand the origin, transport and deposition of subglacial sediment and relate surface sediment in each sub-environment to extant process; use paleo-environmental data to determine water and ice sheet histories, and evaluate temporal changes in Cenozoic paleoclimate relative to those histories determined from Antarctic marginal sequences and global Cenozoic proxy records; and examine sediment mineral composition and chemistry and sample geological bedrock to establish the basinal tectonic setting and its temporal evolution.

B.2 Background - Beneath the thick East Antarctic Ice Sheet, water has accumulated over millennia forming subglacial environments ranging in size and form from Lake Vostok, an expansive body of water the size of Lake Ontario, to shallow frozen swamp-like features the size of Manhattan. Although similar in size to these more familiar landmarks, subglacial lake environments in Antarctica remain virtually unexplored and unknown. Over 145 features have now been identified suggesting that the subglacial environment may well be an immense interconnected, hydrological system that has previously gone unrecognized. Whereas the full extent and the interconnectedness of this major earth system are not yet fully known, the potential drainage systems identified are as extensive as large continental river basins. These environments have formed in response to a complex interplay of tectonics, topography, climate and ice sheet flow over millions of years and contain a previously unaccounted for reservoir of organic carbon. Sealed from free exchange with the atmosphere for possibly 10 to 35 million years, subglacial lake environments are analogous to the icy domains of Mars and Europa that hold the greatest promise for the presence of life beyond earth. Tantalizing evidence from studies of the overlying ice sheet indicates that unique life supporting ecosystems are likely locked within subglacial lake environments. Such life must have adapted to the temperatures, pressures, gases, and carbon and energy sources, which are akin to the deep ocean coupled with the inordinately slow delivery of constituents (nutrients, organic matter, gases) from the overriding ice sheet. These settings are probably the most oligotrophic on the planet and may harbor specially adapted organisms and ecosystems. Seismic, geochemical and genomic

studies point toward the influence of local tectonics in setting boundary conditions under which these subglacial lake systems have evolved.

At about 35 million years ago, the climate of Antarctica shifted from a tree-covered continent to a region locked beneath ice. Recovery of a comprehensive record of this major climatic shift has remained elusive, especially for the interior of the continent. The region of highest subglacial lake density rings what is likely to have been one of the nucleation points of the East Antarctic Ice Sheet and has tremendous potential for containing paleo-records of these major shifts in climate. Numerous, targeted drilling efforts around the perimeter of the continent have thus far failed to recover continuous paleoclimate sedimentary records that are essential for understanding the evolution of global and regional climate. Subglacial lake environments may provide a signature of past climate as well as limnetic biogeochemical processes. In contrast to the East Antarctic Ice Sheet, the West Antarctic Ice Sheet may have responded dramatically to Quaternary environmental changes. Lakes beneath the West Antarctic Ice Sheet could contain unique records of ice sheet variability over the last few hundred thousand years, which could critically advance our understanding of ice sheet stability.

B.3 Enabling Technologies - Although SALE is structured as primarily a scientific program, the technological challenges and environmental stewardship issues are not underestimated. The stages of exploration, as detailed in the Cambridge workshop (1999), were seen as a useful starting point for further and more detailed consideration of the requirements for subglacial lake environment exploration (SALEGOS Meeting Report 1). Some technologies are already in place and can be used immediately if financial and logistical support is available (i.e., airborne radar, magnetic, and gravity and land based seismic surveys). Conversely, other technologies will require developmental efforts. Operational sensors that could be deployed within lakes exist for some of the more fundamental properties, whereas more complex sensor arrays will require development. Initial discussions suggest that standard oceanographic sensor arrays for pressure, temperature, conductivity, transmissometry (suspended particle detectors), fluorescence detection and current velocity have been developed to meet similar operational requirements of temperature and pressure. Other less mature *in situ* sensors are available for important parameters such as dissolved oxygen, nutrients and geothermal heat flux. More experimental sensor arrays would need to be developed for the detection of other dissolved gases (H_2S, CH_4, N_2O, N_2, Ar), major anions and cations, and bioreactive redox couples such as ammonium and dissolved manganese. Even available sensors will need to be field tested for compatibility with the expected temperature and pressure regimes of subglacial lake environments and environmental restrictions. Another requirement will be the suitability of the size of the sensor packages and the size of lake access holes. The limitations on the borehole size may require miniaturization of existing technologies.

Sample recovery has its own set of challenges. Again, standard oceanographic techniques for remote collection using water sampling bottles (e.g., Rosette Samplers with Niskin bottles) and sediment retrieval by coring devices (piston corers, gravity corers, box corers, grab samplers, etc.) may be compatible with subglacial environments. Other specialized techniques may need to be developed. One suggestion is the use of *in situ* filtering devices to process large volumes of water to concentrate particulates for analysis in a clean surface laboratory following retrieval of the device. Sediment trap technologies and other water particulate collection devices are adaptable to subglacial environments. The use of ROVs and associated sample collection abilities were discussed in an NSF sponsored workshop held on 27 March 2003 in Palo Alto,

California and offered a promising way to sample certain environments over important spatial scales. As with sensor arrays, the size of the entry hole and compatibility with decontamination procedures are additional requirements for sampling devices including ROVs and other technologies. Geological drilling technologies remain to be fully developed; however the current Antarctic Geological Drilling (ANDRILL) Program is establishing technology and techniques (a 2000 m long drill string through up to 300 m thickness of floating ice on the sea) that are moving closer to what is required for subglacial lake sediment recovery.

A critical aspect of subglacial lake exploration and technology development is testing, verification and monitoring for potential contamination during all phases of the scientific program. There must deliberate and careful scrutiny of the methodologies employed, from ice drilling to sample recovery, both from an environmental stewardship and scientific standpoint. Stewardship issues include providing the maximum possible protection of subglacial lake environments by ensuring minimal alteration or change due to the planned scientific studies. From a scientific standpoint, it is essential that uncompromised samples be provided for study and that the presence of human-made devices does not bias the data collected. There is also concern that unusual or previously unknown biological agents be properly handled upon retrieval to avoid an unwanted release to the environment. Contamination may arise not only from the introduction of chemicals (toxic, nutritive, or otherwise) into the lake but also from the potential introduction of non-indigenous microorganisms. In addition, due to the presumed highly oligotrophic nature of the lakes, redistribution of water and sediments within the lakes must be minimized during any *in situ* operation. While these are difficult issues, much can be learned from the history of exploration of the McMurdo Dry Valley Lakes, the Ocean Drilling Program and NASA's experience in planetary protection. There is a need to test contamination procedures at all stages of processing and planetary protection rules serve as a guide for the development and testing of subglacial lake exploration technology.

The general approach of development and testing of technologies in more accessible and less environmentally sensitive analogue locations is crucial for environmental stewardship. Analogues include frozen lakes, ice shelves, and the upper portions of ice sheets in both the northern and southern hemispheres. Existing ice drilling techniques appear to be capable of meeting the field requirements for penetration of 4 or more kilometers of ice, penetrating low temperature (sub-zero) and high pressure regimes. The challenge for ice drilling is demonstration of the ability to do so with minimal and/or acceptable levels of contamination. For example, hot water techniques used with coiled tube drilling technology could replace chemical fluid-based drilling and still be able to maintain bore hole integrity for periods of time ample enough to conduct experiments, introduce sensor arrays and retrieve samples. Techniques are needed to ensure the purity of the drilling water fluid to avoid contamination from surface microbes. There may be solutions to this requirement in methods currently proposed to sterilize (UV radiation, ozonolysis) ballast waters in ships that prevent the introduction of non-indigenous species. And finally, decontamination techniques must be developed for any packages that would be delivered into a lake. The current approaches are sterilization by heat (autoclave) and/or chemical treatment (peroxide). Any instrument packages must be able to survive these decontamination protocols and maintain their operational specifications.

B.4 Program Justification - Over the past decade a series of international workshops and a Group of Specialists have been convened to develop an interdisciplinary science and technology plan for the exploration and study of subglacial

environments. These planning efforts have been supported by the US National Science Foundation (NSF), the US National Aeronautic and Space Administration (NASA), the Russian Antarctic Expedition (RAE), the International Council for Science's (ICSU) Scientific Committee on Antarctic Research (SCAR), and others. Plans resulting from these efforts are extensive, well advanced, and detailed in scope and content. Within the next few years, current survey programs will be expanded to include intensive logistical efforts to survey, penetrate and sample the lakes. The phase of entry into these environments will require significant international collaboration, cooperation and coordination. The creation of a SCAR SRP to aid in facilitating these events and activities is critical and timely.

B.4.1 Links with other proposed SCAR activities - The proposed SALE program will continue to build on past efforts and has elements and objectives that complement two other SRPs being proposed to SCAR; Antarctic Climate Evolution (ACE) and Evolution and Biodiversity in Antarctica (EBA).

The main objective of the ACE Program is the acquisition and compilation of "ground truth" geoscience data and the use of these data in developing a suite of paleoclimate models for the Antarctic region. The paleo-climatic record contained in subglacial lake sediments will provide important new information from the interior of the continent. In addition, the ice sheet history quantified through numerical modeling will offer important constraints on the formation and development of subglacial lake environments.

The proposed SCAR Program "Evolution and Biodiversity in the Antarctic" aims to improve and expand fundamental understanding of the evolutionary history, current biology and biodiversity of Antarctic biota in both a climatic and tectonic context. The evolutionary process of life pervades all levels of biological organization from molecules to ecosystems. Subglacial lake environments offer a unique opportunity to examine biodiversity and evolutionary responses in isolated systems that provide analogues for life on early Earth and other planetary bodies. Novel responses to the environment are likely to be found in these lake systems, which are important end-members for biodiversity and polar community dynamics.

The objectives of ACE and EBA are complementary and supportive of many of the scientific objectives of SALE. The synergy among these SCAR programs will be encouraged and facilitated. Joint planning, meetings and coordination will be ensured by appointing liaisons between the programs.

Subglacial lake environments have been identified as an area of scientific interest for the burgeoning efforts related to the IPY and IGY celebration in 2007-2009. The designation of SALE as a SRP is an important step for SCAR involvement in the IPY. SALE provides a focus for international efforts in subglacial lake environment exploration and study an important element of the IPY theme exploring new frontiers (see Appendix D).

B.5 Preliminary Implementation Plan - An orderly transition from SALEGOS to SALE by 2005 is proposed:

- Submission of the transition plan to the SCAR Executive, May 2003 – **Complete**
- Transition plan considered by the SCAR Executive Committee, July 2003, Brest, France. - **Approved for Final Proposal Submission.**
- SALEGOS Meeting V October 14 and 15, 2003, Bristol, UK. – **Complete**.
- Revision of transition plan based on SCAR Executive Committee response,

October 2003. - **Complete**

- SALEGOS Meeting VI to be held in conjunction with the SCAR Science Conference in Bremen, Germany, July 2004 (final meeting) - **Complete**
- Submission of the SRP Proposal to the SCAR Standing Scientific Groups (SSGs), endorsed by the LSSSG and GSSSG Bremen, July 2004. – **Complete**
- Revise SRP proposal according to new SCAR review **criteria– Complete.**
- SCAR Executive Committee and SSG recommendations to SCAR Delegates Meeting, Bremerhaven, Germany, October 2004 – Final program approval/decline.
- First SALE meeting 2005.

B.6 Program Management - A detailed and specific plan for program management will facilitates wide participation, efficient operation, and the flexibility to evolve as the program matures. Responsibilities are clearly described to ensure that all components of the SALE mission and objectives receive adequate attention and focus. Subcommittees will be formed to concentrate efforts on issues of special importance, such as data management and outreach.

B.6.1 Scientific Steering Committee - The program will be managed by a Scientific Steering Committee (SSC) of twelve members with the scientific and technical expertise and experience necessary to successfully conduct the program. Each member will have a significant and clearly identified role related to a critical scientific discipline, environmental stewardship issues, and/or a technological challenge supportive of the overarching scientific objectives. At the inaugural SALE meeting a Convener, Deputy Convener and Secretary will be elected by the members. The committee would meet at least once a year and conduct the rest of its business electronically. Members would serve for a 4-year term, with the possibility of extension for a second term depending on contribution and performance. The committee membership should ensure the necessary breadth of knowledge to adequately address all relevant thematic/disciplinary/technological/environmental topics. This core of experts will be supplemented as needed by invitation of guest scientists and technologists to SALE meetings, regular review of SALE membership, and through liaison relationships with other organizations such as COMNAP, AEON, complementary SCAR SRPs, and others as appropriate. SALE will actively interact with EBA and ACE as to promote synergy and common interests. SALE will designate representatives to these other programs to ensure synergy, communication and collaboration.

SALE's initial membership should cover the following scientific and technological areas:

- limnology/ecology
- genomics/molecular ecology
- hydrodynamics
- geophysics and survey techniques
- glaciology
- geology/tectonics
- geochemistry
- Cenozoic paleoclimate
- ice drilling techniques/access
- observatories
- remotely operated and autonomous vehicles

- sample recovery and processing
- specialized analytical techniques
- environmental issues and clean technologies

Recognizing the budgetary limits on membership, guest speakers will be invited to committee meetings as needed when expertise beyond that of the committee is required to address an issue.

Table 1. Criteria for Membership on SCAR SRPs

- Appointment is by the SCAR Executive with approval of the Delegates.
- Primarily based on scientific expertise.
- A mix of skills, experience, national representation, and gender should be maintained.
- Terms are 4-years with the possibility of one four-year extension.
- A membership rotation scheme should be adopted that maintains program continuity.
- A mix of expertise commensurate with the issues before the program should be maintained.

Membership on the SALE SRP committee is open to all SCAR nations, targeting those with an interest in subglacial lake environments. The initial SALE membership should draw heavily on the current SALEGOS membership for continuity with a request for each interested National Committee to review its membership on the committee. Appointees should be selected based on a combination of national representation and expertise in relevant disciplines (as outlined below). We note that multiple persons from a single country may be appointed as members of SALE. Importantly, members should be enthusiastic proponents of subglacial lake environment exploration and research. Following the recommendations of SALEGOS, it is expected that each interested nation will form a National Scientific Steering Committee (NSSC). It is strongly recommended that SALE membership include liaisons with these national committees to improve communication, coordination, and collaboration.

B.6.2 Terms of Reference - SALE will operate under the general SCAR Terms of Reference (TOR) for Scientific Research Programs (SRPs) amended with program specific TORs:

- *Oversee and guide the development and execution of the SRP's activities including changes in course as indicated by events and progress.*
- *Encourage and facilitate communication and collaboration between scientists and technologists world-wide involved in the exploration of subglacial lake environments while seeking support for the program through national and international mechanisms.*
- *Advise the international community through SCAR on scientific and technology issues relevant to subglacial lake exploration including environmental protocols, procedures, concerns and safeguards.*
- *Promote collaboration, data access and data sharing to facilitate and expedite the data syntheses needed to develop and revise the science and technology agenda for the exploration of subglacial lake environments.*
- *Summarize and report the results of these efforts to the scientific and wider*

community on an ongoing basis including regular reporting on the use of SCAR funds.

- *Encourage adherence to the agreed guiding principles of exploration and research on subglacial lake environments, especially environmental stewardship.*
- *Be an advocate for exploration of subglacial lake environments in all venues including National Committees, scientific communities, and the public and establish scientific liaisons and logistics cooperation with other Antarctic entities and activities as appropriate.*
- *Respond to requests from SCAR for expert advice in a timely manner including convening of expert groups when needed (i.e., review of CEEs).*
- *Ensure the SRP activities are justified and supportive of the group's TOR.*
- *Interact and coordinate activities with other SCAR SRPs.*
- *Provide a centralized focus for outreach efforts including promotional materials, a web site, an available speaker and topic list, interactive tools for educating the public, a bibliography (including press releases and articles in the lay print and visual media), meeting reports, regular press releases, and contact information for the media.*
- *Develop and promote common protocols and standards for data management to ensure quality and comparability across programs.*

SALE will neither oversee nor manage national or international field and laboratory projects or facilities other than to help guide and coordinate their development as requested. It is suggested that the first meeting of SALE review/revise the TOR for the program.

B.6.3 Plans for Data Management and Outreach - While SALE will not retain data, its web site will serve as a portal to member nations that do, making data widely available. SALE will develop a set of data management protocols and standards that all participants can agree to adhere to, to ensure comparability of data across all projects and programs. The standards will be developed by a SALE Subcommittee for Data Management Protocols and Standards in consultation with JCADM and other relevant organizations. To provide a focus for SALE outreach, a Subcommittee on Communication, Education, and Outreach will be formed to explore outreach and education options and develop a comprehensive communication, education, and information dissemination plan for SALE. SALE's outreach efforts will include, but not be limited to: the creation of promotional materials, developing an available speaker and topics list, creating interactive tools for educating the public, posting of meeting reports, and providing contact information for the media.

B.7 Deliverables - SALE will provide the following deliverables:

- *maintain and make widely available an up-to-date inventory of subglacial lake features;*
- *a standard identification scheme for subglacial lake environments;*
- *a current bibliography of relevant articles from peer reviewed journals, meeting reports and the lay press;*
- *a website with links to all activities related to subglacial lake environments including national programs, meetings, and reports acting as a portal to data held by others;*
- *methodology and technology workshops in response to community needs;*

- *expert groups on clean sampling technologies and other environmental stewardship issues in response to community needs;*
- *workshops, scientific sessions, and symposia;*
- *review of CEEs for SALE projects and field activities as requested;*
- *advice on all aspects of SALE as requested by SCAR including convening of expert groups when additional expertise is needed;*
- *promotional materials, a web site, an available speaker and topics list, interactive tools for educating the public, a bibliography (including press releases and articles in the print and visual media), meeting reports, contact information for the media; and*
- *common protocols and standards for data management that ensure quality and comparability across programs.*

B.8 Milestones - Workshops, symposia and special sessions at major conferences are important for fostering collaboration. The exchange of ideas in the furtherance of planning will be a primary mission of SALE.

- **Year 1** – Program Meeting - I; review/revise terms of reference, metrics of performance, scientific objectives, etc.; elect program officers; and report progress to SCAR.
- **Year 2** – Program Meeting - II; organize and hold a workshop; promote and organize SALE sessions at appropriate scientific meetings; develop a session for the SCAR Science Conference and report progress to SCAR.
- **Year 3** - Program Meeting - III; promote and organize SALE sessions at appropriate scientific meetings; develop a popular science article on SALE, and report progress to SCAR.
- **Year 4** - Program Meeting - IV; organize and hold a workshop; promote and organize SALE sessions at appropriate scientific meetings; develop a popular science article on SALE, develop a session for the SCAR Science Conference; and report progress to SCAR.
- **Year 5** – Program Meeting - V; promote and organize SALE sessions at appropriate scientific meetings, organize a major SALE international symposium.
- **Year 6** – Program Meeting - VI; promote and organize SALE sessions at appropriate scientific meetings; develop a popular science article on SALE, develop a session for the SCAR Science Conference; and report progress to SCAR.
- **Year 7** – Program Meeting - VII, organize publication of a SALE book, promote and organize SALE sessions at appropriate scientific meetings; develop a popular science article on SALE; and report progress to SCAR.
- **Year 8** – Program Meeting - VIII, publish the SALE book; develop a major keynote session for the SCAR Science Conference; and report progress to SCAR.

This timetable and the deliverables should be reviewed and revised as necessary at the first SALE meeting and reviewed at each subsequent meeting.

B.9 Metrics of Success - The measures of success of a program that serves primarily in an advocacy role are difficult to quantitatively define. However, it is important to develop metrics of performance that provide SCAR with some indication of a

program's impact. The following are proposed as possible metrics of performance for the SALE SRP:

- workshops held, attendance, and reports produced;
- sessions focusing on exploration and research of subglacial lakes (number and quality) held at national and international meetings, attendance, and resulting proceedings publications;
- peer-reviewed publications each year (number and quality) related to subglacial lake exploration and research;
- articles in the popular press including numbers of interviews given by SALE members as well as website hits;
- formation of national scientific steering committees; and
- leverage of funds from other sources.

The SALE leadership will regularly canvas the community for these statistics and keep up-to-date records for annual performance reviews. It is proposed that during the first meeting of SALE that these metrics be revisited and a final set of performance criteria be agreed and communicated to the SCAR Executive for final approval.

B.10 References Cited

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Report of the Subglacial Antarctic Lake Exploration Group of Specialists (SALEGOS): Meeting – 2. Lamont-Doherty Earth Observatory, USA, 23-24 May, 2002. 39 pp.

Report of the Subglacial Antarctic Lake Exploration Group of Specialists (SALEGOS): Meeting – 3. University of California at Santa Cruz, USA, 2-3 October, 2002. 19 pp.

Report of the Subglacial Antarctic Lake Exploration Group of Specialists (SALEGOS): Meeting – 4. Chamonix, France, 4-5 April 2003. 38 pp.

Report of the Subglacial Antarctic Lake Exploration Group of Specialists (SALEGOS): Meeting – 5. Bristol University, UK, 14-15 October 2003. 12 pp.

SALEGOS membership. An International Plan for Subglacial Lake Exploration. 2004. Polar Geography, In review.

SALEGOS membership. Subglacial Antarctic Lake Environments: International Planning for Exploration and Research. EOS, In review.

C. **Supporting Information** – The following information is presented to support this application for a SRP for SALE including discussions of the proposed lead investigators, the justification for SCAR support, and national and international partnerships. Extensive lists of potential SALE members with short biographical sketches are provided in Appendices A and B. The budget is for $25,000 per year for eight years with estimated supplemental request of $15,000 each year for special items. Budget details are provided in Appendix C and have been submitted to the finance committee on the appropriate forms for 2005 and 2006.

C.1 Lead investigators - We fully appreciate that it is the responsibility of SCAR to appoint the membership of SALE. For continuity of the program, it is strongly recommend that a significant portion of the SALEGOS membership (listed in Appendix A) be preserved for at least the first few years of SALE. Other scientists identified by SALEGOS who have shown enthusiasm for subglacial lake research and have appropriate knowledge of the subject areas are included in Appendix B.

C.2 Justification for SCAR Support - SCAR is ideally situated to provide a forum for international collaboration in regard to subglacial lake environment exploration and research. SCAR provides the network of National Antarctic Committees that will be needed to collect and communicate information about activities related to SALE. In many countries the cachet of SCAR will be important for teams developing individual subglacial environment programs and projects. It is also important for SCAR to be a major international influence on the direction of SALE science and research. SALE will be an important, large Antarctic science project for at least the next decade. SCAR provides an important third party perspective through SALE when it comes to environmental stewardship issues.

C.3 National and International Partnerships - By the very nature of the proposed research program, international support and cooperation are essential. The SCAR Cambridge workshop recommended that international cooperation be a guiding principle for SALE. As mentioned above international partnerships will initially be encouraged by ensuring that National SSCs are represented on SALE. Also, other organizations such as ICSU (International Council for Science) and COSPAR (Committee on Space Research) will be engaged in SALE activities as appropriate. As mentioned above, ICSU planning for IPY will includes a subglacial lake research component and liaison with IPY planning groups will be encouraged. Plans for coordination were tentatively agreed at the last SALEGOS meeting and are described in **Appendix D - SALE-Unified International Team for Exploration and Discovery. (UNITED**).

C.4 Budget - A program of this scale and scope will require a significant time commitment from the committee members that will be covered by them personally on agreement with their home institutions. The budget request is for basic operational costs to allow the program to meet once a year and to provide seed funding for two workshops and/or symposia each year. The annual estimated budget request from SCAR for SALE (for the first four years, 2 SCAR cycles) is presented in Appendix C.

Appendix A. **Membership of SALEGOS** - It is strongly recommend that a significant portion of the SALEGOS membership be preserved for at least the first few years of the SALE.

Robin Bell. Lamont-Doherty Earth Observatory, Columbia University, New York, USA. Dr. Bell is a senior research scientist responsible for seven major aero-geophysical expeditions to Antarctica. She is interested in the mechanisms of ice sheet collapse, the interactions of tectonics and climate and the study of extreme environments within subglacial lakes. Her research interests are in linking the earth's physical processes with the impacts on biota. She is currently the U.S. representative to the Working Group on Geophysics of the Scientific Committee on Antarctic Research (SCAR), Chair of the U.S. National Academy's Polar Research Board and vice-Chair of the ICSU International Polar Year Planning Group.

Sergey A. Bulat. Division of Molecular & Radiation Biophysics, Petersburg Nuclear Physics Institute (PNPI), RAS, RUSSIA. Dr. Bulat is a Leading Researcher at the Petersburg Nuclear Physics Institute, Saint Petersburg-Gatchina. He earned his Ph.D. in Genetics in 1984 from the Leningrad State University and has worked on molecular microbial diversity, genomics and phylogenetics for the past twenty years. For the last four years his research focuses on studying microbial contents of ancient Antarctic ice and searching for life signatures in extreme environments (subglacial Lake Vostok, East Antarctica) in the Exobiology context.

J. Cynan Ellis-Evans. British Antarctic Survey, Cambridge, UK. He is the former Head of Limnological Research at the British Antarctic Survey (1980-2002) and currently Head of the BAS Program Office (2002-present), which coordinates BAS international polar research activities. He is also biodiversity project coordinator for the SCAR RiSCC program, coordinator of the European Southern Ocean CIRCLE program and has been involved in developing subglacial lake exploration since 1995. Dr. Ellis-Evans has undertaken twelve field seasons in Antarctica and five in the High Arctic. His research interests include aquatic biogeochemistry, microbial ecology, palaeolimnology and life at limits; he has published extensively in these areas.

Mahlon C. Kennicutt II. *Secretary*. Texas A&M University, College Station, TX , USA. Dr. Kennicutt is a Professor of Oceanography, Director of the Geochemical and Environmental Research Group (GERG) and Team Leader of the Sustainable Coastal Margins Program (SCMP) at Texas A&M University. Dr. Kennicutt has more than twenty years of experience in Antarctic and Arctic research related to human perturbations of the environment. Dr. Kennicutt is the US Delegate to SCAR and serves as a member of the SCAR Standing Committee for Antarctic Treaty Matters. Previously Dr. Kennicutt served as a member of the Group of Specialists on Environmental Affairs and Conservation (GOSEAC).

Valery Lukin. Arctic and Antarctic Research Institute, St. Petersburg 199397, RUSSIA. Valery Lukin is Deputy Director of the Institute and Head of the Russian Antarctic Expedition (RAE). He graduated from the Leningrad State University in 1970, in the field of physical oceanography. His research focuses on genesis and evolution of water masses, fine thermohaline water structure and turbulent exchange processes. For the last ten years he has been involved in complex systems analysis of natural environmental compartments of Antarctica where the results of geological, geophysical,

biological and hydrological studies are taken into account. Valery Lukin is one of the first authors of the Russian Comprehensive Program "Study of Lake Vostok".

Jean Robert Petit. Laboratoire de Glaciologie et Geophysique de l'Environnement, CNRS, Grenoble, FRANCE. Dr. Petit is senior scientist in glaciology and paleoclimatology. He earned is Ph.D. in mechanics and geophysics in 1984 from University Joseph Fourier at Grenoble and has worked on the drilling technique and analysis of Antarctic ice cores for the past 20 years. His research focuses on paleoclimatogy as deduced from stable isotopes, mineral dust, geochemistry, electrical properties and bore hole geophysics. He was involved in the international (Russian-US-French) project for deep drilling at Vostok station and participated to eleven field seasons at Vostok station.

Ross D. Powell. Department of Geology & Environmental Geosciences, Northern Illinois University, DeKalb, IL, USA. Dr. Powell earned his Ph.D. from Ohio State University and his Antarctic research includes interpreting geological drill cores for Antarctica's climatic history and being involved with Antarctic drilling technologies, from the Dry Valley Drilling Project, through the Cape Roberts Project to the ANDRILL Program (currently convener of the international science steering committee). Other interests lie in documenting and quantifying modern terrestrial and marine sedimentological processes, including the first scientific research using an ROV below floating glacial ice. Dr. Powell has additional high-latitude research experience in Alaska (twenty six years), Baffin Island (two years), Chile (two years) and Svalbard (three years) involving interpretation of seismic reflection and sediment core records for inferring past glacial and climatic histories, and conducting modern process studies to document environmental change and construct models for interpreting the glacial stratigraphic record.

John C. Priscu*, Convener.* Department of Land Resources & Environmental Sciences, Montana State University, Bozeman, Montana, USA. Dr. Priscu is a Professor of Ecology at Montana State University, Bozeman. He earned his Ph.D. in Limnological Ecology in 1982 from the University of California at Davis and has worked on Antarctic marine and freshwater systems for the past twenty years. His research focuses on biochemical transformations in polar freshwater and marine systems, physiological responses of icy environments, polar microbial biodiversity as it relates to ecosystem structure and function, and the role of polar systems in global change research and Astrobiology. Dr. Priscu is the current U.S. representative on the SCAR Scientific Standing Committee on the Life Sciences, a member of the U.S. Ice Core Working Group (ICWG), a member of the U.S. Ice Core Drilling Services Advisory Committee and a former member of the U.S. NSF Office of Polar Programs Office Advisory Committee.

Martin Siegert. School of Geographical Sciences, University of Bristol, UK. Martin Siegert is Professor of Physical Geography at the University of Bristol. He earned his Ph.D. in numerical ice sheet modeling in 1993 from the University of Cambridge and has worked in the broad subject of Antarctic glaciology since this time. His research focuses on the identification and characterization of subglacial lakes, understanding the physical and chemical processes that operate in subglacial lake environments, and investigating the long-term history of the Antarctic ice sheet. He is co-Chair of the Antarctic Climate Evolution (ACE) SPPG.

Ignazio Tabacco. DST-Geofica, Milano, ITALY. Since 1970 Dr. Tabacco held the position of Professor of Applied Geophysics at the Hearth Science Department of the

University of Milan. In the period 1970-1985 he worked on geophysical exploration applied to hydrogeological research and on crustal exploration in Europe and in North Africa. In the period 1985-1993 he held the position of Professor of Geophysics at the University A. Neto, Luanda Angola (Africa). Dr. Tabacco has made six expeditions to Antarctica and 2 to the Arctic. His Polar activity focuses on geophysical exploration: seismic, electric and radar. He participated in the EPICA project; was member of the steering committee of EIMINT-ESF project; is a member of the consortium BEDMAPSCAR; is a leader of the Italian Group on Subglacial lake research.

Appendix B. Other Potential SALE Members - Other scientists identified by SALEGOS who have shown enthusiasm for subglacial lake research and have appropriate knowledge of the subject.

Edward E. Adams. Department of Civil Engineering, Montana State University, Bozeman, Montana, USA. Dr. Adams is an Associate Professor in the Civil Engineering Department at Montana State University - Bozeman. He earned a Ph.D. in Mechanical Engineering from Montana State University in 1987 and was on the faculty at Michigan Technological University in Houghton, Michigan before returning to MSU in 1992. From graduate work through to the present, his research area has been in the field of ice and snow mechanics, with particular emphasis on the thermodynamics of metamorphism and microstructure. Within the field, studies have included the Dry Valley lake ice and Lake Vostok in the Antarctic, snow structure stability pertaining to avalanches and forecasting highway-icing conditions in topographically complex terrain.

Sridhar Anandakrishnan. Department of Geosciences and EMS Environment Institute, Pennsylvania State University, University Park PA, 16802, USA. Dr. Anandakrishnan is an associate professor of Geosciences at PSU. He earned a Ph.D. in Geophysics at the University of Wisconsin-Madison in 1991 and has worked on characterizing subglacial environments using geophysical techniques, primarily active seismic methods. His research has focused on the role of water in the subglacial environment, including its presence, quantity and interactions with ice dynamics. Subglacial lake studies depend crucially on active (reflection) seismic techniques to determine lake properties, because radar methods do not penetrate water effectively.

Carlo Barbante. Associate Professor of Analytical Chemistry at the University of Venice, ITALY. Prof. Barbante received his Ph.D. in Industrial Chemistry from the University of Padova in 1988. His main field of interest is the trace element determination in environmental matrices by sector field and quadrupole inductively coupled plasma mass spectrometry (ICP- SFMS, ICP-QMS). He has proved experience in ultra-clean procedures for sampling and analysis of trace metals in seawater, snow, ice and in biological materials. Prof. Barbante has been Scientific coordinator during the IX and XI Scientific Italian Expeditions in Antarctica (1993-94 and 1995-96). He is also leader of the research groups on trace elements in the frame of Environmental Contamination and Glaciology projects of the Italian National Program for Antarctic Research. He has been involved in the European Project for Ice Coring in Antarctica (EPICA) funded by the EU. He is referee of several widely known international journals in the field of environmental and analytical chemistry. He is scientific coordinator of Marie Curie Fellowships funded by the EU.

Peter J. Barrett. Victoria University of Wellington, NEW ZEALAND. Dr Barrett is Professor of Geology in the School of Earth Sciences and Director of the Antarctic Research Centre. He earned his Ph.D. degree from Ohio State University in 1968 for a paleoenvironmental interpretation of ancient alluvial strata in the Transantarctic Mountains. Since his return to NZ in 1970 he has studied both modern and ancient sediments in NZ and Antarctica, investigating marine and terrestrial sedimentary sequences as archives of past environments (including climate). This has involved leadership of several offshore drilling projects, most recently the Cape Roberts Project (1993-2002), for investigating climatic and tectonic history of the Antarctic margin over the last 50 million years.

Erik Blake. Icefield Instruments Inc., Whitehorse, Yukon, CANADA. Dr. Blake earned an engineering degree in 1986 from the University of Toronto and a Ph.D. in Glaciology in 1992 from the University of British Columbia. For the past 15 years, Blake has been involved in developing instrumentation for glaciological applications including ice coring drills, ice-penetrating radar systems, automated ice core analysis equipment, and borehole surveying equipment. Current research interests include the development of ultra-clean drilling technology for trace metal analysis, the evolution of millennia-old ice patches in the Yukon that are revealing Holocene archaeological artifacts as they melt, and the development of technology for subglacial lake exploration.

Donald D. Blankenship. Institute for Geophysics, The University of Texas, Austin, Texas, USA. Dr. Blankenship is a Research Scientist at the Institute for Geophysics and a Member of the Graduate Studies Committee in the Department of Geological Sciences at the University of Texas at Austin. He earned his Ph.D. in Geophysics in 1989 from the University of Wisconsin-Madison and has worked on problems in Antarctic glaciology and geophysics as part of sixteen field campaigns in both East and West Antarctica. His research focuses are the geological controls on the variability of terrestrial ice sheets and the evolution of sub-ice water systems on Earth, Mars and Europa. He has been a leader in the development of over-ice seismology and airborne radar sounding techniques for solving problems in Antarctic science. He is currently a Member of the Science Definition Team for NASA's Jupiter Icy Moons Orbiter. He also served as Chairman of the Instrument Definition Team for NASA's Europa Orbiter Radar Sounder.

Brent C. Christner. Department of Land Resources & Environmental Sciences, Montana State University, Bozeman, Montana, USA. Dr. Christner is a postdoctoral researcher in John Priscu's laboratory at Montana State University, Bozeman. He earned his Ph.D. in Microbiology in 2002 from The Ohio State University and has worked on polar and non-polar glacial environments for the past seven years. His research focuses on microbial diversity and ecology, the physiological responses and adaptations of microbes in icy environments, the role of polar systems in global ecology, and Astrobiology.

Peter T. Doran. Department of Earth and Environmental Sciences, University of Illinois at Chicago, Chicago, Illinois, USA. Dr. Doran is an Associate Professor of Hydrological and Aquatic Sciences at the University of Illinois at Chicago. He earned his Ph.D. in Hydrology/Hydrogeology in 1996 from the University of Nevada, Reno, and has worked on ice-covered Arctic and Antarctic lakes and lake sediments for the last twenty years. His research focuses on modern sedimentalogical and biogeochemical processes in perennially ice-covered lakes, lake history, clathrates, geochronology, climate change, extreme environments and their use as planetary analogs.

Paul Duval. Laboratoire de Glaciologie et Geophysique de l'Environnement, CNRS, Grenoble, FRANCE. Dr. Duval is senior scientist in ice physics. He earned is Ph.D. in physical and mechanical science from University Joseph Fourier at Grenoble. He worked on the rheological properties of natural glacier ice at very low strain rate and is interested in the link with the defect in ice and the ice crystal fabrics. Dr. Duval’s work employs both experimental and theoretical approaches.

Richard C.A. Hindmarsh. Physical Science Division, British Antarctic Survey, Cambridge, UK. Dr. Hindmarsh is a Project Leader at the British Antarctic Survey, Cambridge. He is a glaciological modeler, modeling ice sheets and ice-sheet sub-

systems, with a special emphasis on understanding their stability properties. More recently he has been considering the glaciological data assimilation problem over time-scales of decades to tens of millenia, using diverse data sources such as satellite altimetry, radar sounding and geological dating.

Brian D. Lanoil. Department of Environmental Sciences, University of California, Riverside, California, USA. Dr. Lanoil is an Assistant Professor of Environmental Microbiology at the University of California at Riverside. He earned his Ph.D. in Molecular and Cell Biology with an emphasis in Microbiology from Oregon State University in 1998. He studied as a postdoctoral scholar focusing on Astrobiology and Geomicrobiology at the National Aeronautics and Space Administration's Jet Propulsion Laboratory and the California Institute of Technology, and has worked on life in extreme environments and subglacial microbiology since he was a graduate student, with increased emphasis on this area in recent years. His research focuses on the use of molecular biology tools to examine the ecology and diversity of microbes in cold environments, biogeochemistry of microbially-mediated subglacial weathering processes, and the implications of subglacial microbiology for life in extreme environments and life on other planets.

German L. Leitchenkov. Department of Antarctic Geoscience, All-Russia Research Institute for Geology and Mineral Resources of the World Ocean, VNIIOkeangeologia, Ministry of Natural Resources, Russia. Dr. Leitchenkov is a head of Department at the VNIIOkeangeologia, Saint Petersburg. He has worked on the interpretation of Antarctic geophysical data, tectonics and marine geology for the past twenty two years and earned his Ph.D. in Geophysics in 1999 from VNIIOkeangeologia at Saint Petersburg. For the last five years his research focuses also on studying Antarctic interior (mostly the area of subglacial Lake Vostok) in the context of geological interpretation of subglacial environments.

Vladimir Ya. Lipenkov. Department of Geography of Polar Regions, Arctic and Antarctic Research Institute, St. Petersburg, Russia. Dr. Lipenkov is a Leading Researcher at the Arctic and Antarctic Research Institute. He earned his Ph.D. in Cryology and Glaciology in 1988 from the Moscow State University. For the past twenty five years he has been working in the field of polar ice core studies. His research focuses on physical properties of ice and gas hydrate formation as related to ice-core records, ice sheet and sub-ice environment modeling.

W. Berry Lyons. Director and Professor of Geochemistry, Byrd Polar Research Center, The Ohio State University, Columbus, Ohio, USA. He earned his degree in chemical oceanography in 1979 from the University of Connecticut. He has been involved in the investigation of geochemical, biogeochemical processes and climate change issues in polar regions for close to twenty five years. These include the geochemical analyses of ice cores in both polar regions, the hydrological response of Antarctic dry valley landscapes to climate changes and the geochemical evolution of polar lakes. For the past 4 years Lyons has been the lead-PI of the McMurdo Dry Valleys Long-Term Ecological Research program in Antarctica. He is a Fellow of American Geophysical Union and the American Association for the Advancement of Science.

Christoph J. Mayer. Department of Quaternary Geology, Geological Survey of Denmark and Greenland, Copenhagen, DENMARK. Dr. Christoph Mayer is a researcher within the glaciology group of the Geological Survey of Denmark and Greenland in

Copenhagen. He obtained his Ph.D. with a thesis about numerical modeling of the transition between ice sheets and ice shelves in 1996 at the University of Bremen, Germany. Since 1990 he has worked at different institutes in Germany, Austria and Denmark on the ice dynamic response on climatic conditions, both in Antarctica and in Greenland. Moreover, he is involved in several projects about remote sensing of the cryosphere.

Frank Pattyn. Department of Geography, Vrije Universiteit Brussel, Brussels, BELGIUM. Dr. Pattyn is a research associate at the Free University Brussels, Belgium. He earned his Ph.D. in 1998 on the study of ice-sheet dynamics in Dronning Maud Land, Antarctica from the same university. His research focuses on ice dynamics, numerical modeling of ice-sheet and glacier systems, the response of ice masses to environmental changes, and the development of higher-order ice-sheet models (in 2D and 3D).

Sergey V. Popov. Antarctic Division, Polar Marine Geological Research Expedition (PMGRE), RUSSIA. Dr. Popov is a research geophysicist, Group Leader at the Antarctic Division of PMGRE, Saint Petersburg-Lomonosov. He earned his Ph.D. in Geomorphology in 2003 from the St. Petersburg State University and has worked on Antarctic subglacial relief and glaciology for the past eleven years. For the last six years his research focuses on studying the subglacial Lake Vostok area, East Antarctica.

P. Buford Price. Professor of Physics, University of California, Berkeley, CA, 94720. USA. Price has broad interests that include leadership in the AMANDA high-energy neutrino observatory at the South Pole. He is the inventor of the optical dust logger, the biospectral logger, and the ice grain-size logger, which have applications to climatology, volcanology, glaciology, and search for microbial life in ice and permafrost. A miniaturized version of the biologger, which measures fluorescence spectra of microbes and biomolecules, can be used to explore Lake Vostok as well as subsurfaces of Mars and Europa.

Alex R. Pyne. Victoria University of Wellington, NEW ZEALAND. Mr. Pyne is currently Projects Manager of the VUW ARC, and has BSc (Hons) and MSc degrees in Antarctic Gondwana sequence geology. He has over twenty six years experience in Antarctic programs and has a primary interest in the design and management of scientific drilling operations, specifically in Antarctica, that includes specific design and operation of drilling equipment for marine sea floor coring on sea ice and ice shelf platforms (CRP & ANDRILL). Also drilling permafrost and ice cores and associated operations including core processing, core description and immediate core scientific investigations.

Margaret S. Race. Ecologist, SETI Institute (Mountain View CA) and Consulting Professor at Stanford University in the Center for International Security and Cooperation (CISAC), USA. She earned her Ph.D. at University of California at Berkeley and has worked for thirty years on problems involving environmental management and impact analyses in diverse ecological systems (aquatic and coastal, agricultural and natural resources and planetary systems). Her current work with NASA focuses on planetary protection and involves analysis of the scientific, technological, legal and policy issues associated with exploration in extreme environments on Earth and in space (including comparative research planning for Lake Vostok and the icy moon Europa.).

Francesco Salvini. Professor, Universaità Roma Tre, Rome, ITALY. Dr. Salvini is a Professor of Structural Geology at Universaità Roma Tre, Roma, Italia. He earned his

Ph.D. in Geological Sciences from Roma La Sapienza University in 1976. He has published over one hundred papers in referenced major Italian and International Journals and lectures on Geology, Remote Sensing, Geodynamics, Petroleum Geology.

Andrew M Smith. Physical Sciences Division, British Antarctic Survey, Cambridge, UK. Dr Smith is a glaciologist and a Project Leader in the British Antarctic Survey's core science program. He has been a glaciologist and geophysicist since 1983, working on ice sheet and glacier dynamics in both Antarctica and the Arctic, gaining his Ph.D. in 1997. His research is directed towards ice flow control mechanisms and implications for future ice sheet evolution. His work has concentrated on ice streams, fast glacier flow and subglacial conditions and he is particularly experienced in the application of geophysical methods in glaciology.

Michael Studinger. Lamont-Doherty Earth Observatory of Columbia University, USA. Dr. Michael Studinger is a Doherty Associate Research Scientist at Lamont. He earned his Ph.D. in 1998 from the Alfred Wegener Institute for Polar and Marine Research and the University of Bremen. For the past eight years his research has focused on the linkage between tectonics and ice sheet dynamics on the Antarctic continent using aerogeophysical data. His major current research project is about Lake Vostok.

Slawek Tulaczyk. Department of Earth Sciences, University of California, Santa Cruz, California, USA. Dr. Tulaczyk is an Associate Professor of Earth Sciences at UCSC. He earned his Ph.D. in Geology, with specialization in Glaciology, in 1998 at the California Institute of Technology and has worked on Antarctic ice dynamics for the past ten years. His research focuses on physical processes, which control the rate of ice motion and mass balance of ice sheets and ice shelves. Most of his work has focused on quantifying the potential near-future contribution of Antarctica to global sea level rise. More recently, he has been studying the interactions of the Antarctic ice sheet with ocean thermohaline circulation to verify whether near-future changes in ice extent in Antarctica may trigger abrupt climate changes.

Nikolay I. Vasilyev. Department of Deep Drilling Technology and Equipment, Saint Petersburg State Mining Institute (Technical University), St. Petersburg, RUSSIA. Dr. Vasilyev is a Head of the Department at St. Petersburg State Mining Institute. He earned his Ph.D. in Drilling Technology in 1988 from the Leningrad State Mining Institute. For the past twenty five years he has worked on ice coring technologies and drill system design. His research focuses on development of electromechanical drills and equipment for deep coring in cold ice and sub-ice rocks, and the technology for subglacial lake entries.

Mike Williams. National Institute for Water and Atmospheric Research, Wellington, NEW ZEALAND. Dr Williams is a research scientist in the Marine Physics section of NIWA. He completed his Ph.D. in Physical Oceanography in 1998 at the University of Tasmania, Australia and has since worked on numerical models of subglacial lakes and subice shelf ocean systems. His current research focuses on ice-water interaction in Antarctic coastal marine systems, frazil ice formation and circulation in subglacial lakes, and the oceanography of the New Zealand Subantarctic.

APPENDIX C: Four Year Budget Projections for SALE

Year 1:
Travel and accommodation for program members
$ 1800/person for 10 persons $ 18,000
(assuming the host country can fund local needs)
Seed funding for workshop/symposia expenses, $7,000/event.
(e.g., publication of report, some travel assistance) $ 7,000
TOTAL $ 25,000

Year 2:
Travel and accommodation for program members
$ 1800/person for 10 persons $ 18,000
(assuming the host country can fund local needs)
Seed funding for workshop/symposia expenses, $7,000/event.
(e.g., publication of report, some travel assistance) $ 7,000
TOTAL $ 25,000

Year 3:
Travel and accommodation for program members
$ 1800/person for 10 persons $ 18,000
(assuming the host country can fund local needs)
Seed funding for workshop/symposia expenses, $7,000/event.
(e.g., publication of report, some travel assistance) $ 7,000
TOTAL $ 25,000

Year 4:
Travel and accommodation for program members
$ 1800/person for 10 persons $ 18,000
(assuming the host country can fund local needs)
Seed funding for workshop/symposia expenses, $7,000/event.
(e.g., publication of report, some travel assistance) $ 7,000
TOTAL $ 25,000

Note: Supplemental funding requests (above the base monies requested) over the years will be for:

- inviting experts to SALE meetings;
- covering the expenses related to convening topical workshop and inviting key participants;
- funding the development of specialized educational and promotional material;
- allowing for smaller meeting of the SALE program management on a more frequent basis; and
- payment of expenses for the SALE Chief Officer to attend and present SALE activities at important international meetings.

APPENDIX D - Subglacial Antarctic Lake Environments – UNified International Team for Exploration and Discovery (SALE-UNITED) in the IPY 2007-2009

ICSU and various national IPY planning committees include references to subglacial lake environments as a potential IPY 2007-2009 activity under the exploring new frontiers theme. To coordinate the multiple ideas submitted to ICSU and national committees as part of the IPY planning process, SALEGOS proposes that all nations with interests in subglacial lake environments join together under the auspices of the SCAR SALE SRP to promote international collaboration and partnerships. This alliance is referred to as **SALE – UNified International Team for Exploration and Discovery (UNITED)** and its mission and terms of reference are provided below.

Subglacial Antarctic lake environments are emerging as a premier, new frontier for exploration during the IPY 2007-2009. Several coordinated campaigns by various nations are in the early stages of planning and implementation. It is suggested that these efforts be coordinated under the auspices of the SCAR Scientific Research Program (SRP) - Subglacial Antarctic Lake Environments (SALE). Under the leadership of the SCAR SRP SALE, these programs would join together to promote and advance common scientific, technological, and logistical issues in close consultation with COMNAP. The coalition approach recognizes that the ambitious interdisciplinary objectives of SALE, as internationally agreed during a series of workshops, and extensive discussions of the SCAR Group of Specialists (SALEGOS), can only be realized by multiple exploration programs that will investigate exemplars of the diverse subglacial environments over the next decade or more. The IPY provides an opportunity for an intensive period of initial exploration that will advance scientific discoveries in glaciology, biogeochemistry, paleoclimate, biology, geology and tectonics, and ecology to a new level that could not otherwise be achieved by a single nation or program.

Each program will be an independently managed campaign with specific scientific objectives, logistical requirements, and management structure that will contribute to, and accrue added value from, a common international research agenda. Synergy is provided by the pooling of resources were appropriate, the sharing of experiences and expertise, the coordination of logistics and technological developments, and a shared vision. The SCAR SRP SALE will serve as the international science and technology steering committee with a subcommittee structure representing the major scientific disciplines and technological needs. The steering committee (SALE) will be comprised of the leaders of each program supplemented by international experts as needed.

The following are brief summaries of the projects being pursued by groups that have tentatively agreed to join SALE-UNITED:

- **Russia/France –** Lake Vostok accretion ice retrieval, drilling technology development, lake entry and water sampling, eventual sediment sample return,

- **Italy** – Detailed surveys and glaciological investigations of Dome C and the Dome C “Lake District”,

- **France/Italy** – Dome C glaciology, chemistry and ice dynamics studies,

- **Russia** – analogous lake studies for microbiology and genomics,

- **US** – Geophysical surveys, lake evolution studies and modeling, ice sheet interactions concentrating on the Lake Vostok region, accretion ice studies,

- **US/France/Italy/Germany** – Subglacial Lake Concordia as a site for exploration, technology development including lake entry and sampling, and microbiological, geochemical, and genomic studies (in collaboration with the German IDEA traverse project),

- **United Kingdom/US** – UK researchers and partners are conducting a diverse set of projects that are expected to continue during and after IPY 2007-2009 including: numerical models of hydrological processes of subglacial environments; in collaboration with the US, studies of 'accreted' ice particles dynamics and origins in subglacial environments using models; studies of subglacial topography to establish basin origins; surveys and inventory of subglacial lakes continent-wide; and surveys of and entry into Subglacial Lake Ellsworth in West Antarctica to be conducted by a coalition of 9 UK universities and research institutions,

- **US -** ROV development for ice grounding studies including water and sediment sampling, and

- **US –** AUV development for intra-lake surveys that include physical, chemical, and biological efforts.

A common effort will be the development, implementation and promotion of environmentally benign procedures for subglacial lake environment exploration and research programs properly vetted through national and ATCM procedures. With proper planning and careful and methodical technology development and testing SALE can be an exemplar of environmental stewardship.

The concerted multi-target approach will assure the widest possible characterization of subglacial lake environments beneath the East and West Antarctic Ice Sheets. This will advance our understanding of the range of possible lake evolutionary histories; the character of the physical, chemical, and biological niches; the interconnectivity of subglacial lake environments; the coupling of the ice sheet, climate and the evolution of life under the ice; the tectonic setting; and the interplay of biogeochemical cycles. Research and exploration programs spanning the continent will allow for complementary investigations of subglacial lake environments of differing ages, evolutionary histories, and biogeochemical settings providing a holistic view of these environments over millions of years and under changing climatic conditions. While early discoveries and exciting findings are expected during the IPY 2007-2009, a long term sustained program of research and exploration will continue far beyond 2009. For example, development of clean technology for eventual lake entry and sampling of one of one of the larger lakes like Lake Concordia may extend beyond 2009 assuming that the technology is tested first on a smaller lake.

To form a mutually beneficial network of programs, SALE – UNITED will operate under these guiding principles:

- Members retain autonomy to make decisions in the best interests of their program while taking into consideration the interests of other programs and the potential for synergies.
- Programs will pursue funding through their national procedures while looking for opportunities to develop joint funding across programs.
- Open and timely access to data and samples will be provided for other SALE-UNITED programs and the broader scientific community while protecting the intellectual property of individual investigators and programs.
- Participation in inter-comparisons and inter-calibrations of techniques and methodologies will be conducted to ensure quality and comparability of information across SALE-UNITED programs.
- Agreed data management protocols and standards will be adopted.
- Technological developments and “lessons learned” will be shared while protecting ownership and/or proprietary information.
- When appropriate joint publications and presentations will be encouraged when all involved stand to accrue benefits.
- Due consideration of “add-on” or “spin-off” projects by others will be provided when it does not compromise individual programmatic efforts but advances the common SALE-United mission.
- Assist in the promotion and communication of SALE-United goals, accomplishments, and findings.
- Respect and value the contributions of all SALE-UNITED members.