

NASA/TP-2002-210778



Antarctic Exploration Parallels for Future Human Planetary Exploration: A Workshop Report

*Stephen J. Hoffman, Ph.D., editor
Science Applications International Corporation*

THE NASA STI PROGRAM OFFICE . . . IN PROFILE

Since its founding, NASA has been dedicated to the advancement of aeronautics and space science. The NASA Scientific and Technical Information (STI) Program Office plays a key part in helping NASA maintain this important role.

The NASA STI Program Office is operated by Langley Research Center, the lead center for NASA's scientific and technical information. The NASA STI Program Office provides access to the NASA STI Database, the largest collection of aeronautical and space science STI in the world. The Program Office is also NASA's institutional mechanism for disseminating the results of its research and development activities. These results are published by NASA in the NASA STI Report Series, which includes the following report types:

- **TECHNICAL PUBLICATION.** Reports of completed research or a major significant phase of research that present the results of NASA programs and include extensive data or theoretical analysis. Includes compilations of significant scientific and technical data and information deemed to be of continuing reference value. NASA's counterpart of peer-reviewed formal professional papers but has less stringent limitations on manuscript length and extent of graphic presentations.
- **TECHNICAL MEMORANDUM.** Scientific and technical findings that are preliminary or of specialized interest, e.g., quick release reports, working papers, and bibliographies that contain minimal annotation. Does not contain extensive analysis.
- **CONTRACTOR REPORT.** Scientific and technical findings by NASA-sponsored contractors and grantees.

- **CONFERENCE PUBLICATION.** Collected papers from scientific and technical conferences, symposia, seminars, or other meetings sponsored or cosponsored by NASA.
- **SPECIAL PUBLICATION.** Scientific, technical, or historical information from NASA programs, projects, and mission, often concerned with subjects having substantial public interest.
- **TECHNICAL TRANSLATION.** English-language translations of foreign scientific and technical material pertinent to NASA's mission.

Specialized services that complement the STI Program Office's diverse offerings include creating custom thesauri, building customized databases, organizing and publishing research results . . . even providing videos.

For more information about the NASA STI Program Office, see the following:

- Access the NASA STI Program Home Page at <http://www.sti.nasa.gov>
- E-mail your question via the Internet to help@sti.nasa.gov
- Fax your question to the NASA Access Help Desk at (301) 621-0134
- Telephone the NASA Access Help Desk at (301) 621-0390
- Write to:
NASA Access Help Desk
NASA Center for AeroSpace Information
7121 Standard
Hanover, MD 21076-1320

NASA/TP-2002-210778



Antarctic Exploration Parallels for Future Human Planetary Exploration: A Workshop Report

*Stephen J. Hoffman, Ph.D., editor
Science Applications International Corporation*

Available from:

NASA Center for Aerospace Information
7121 Standard
Hanover, MD 21076-1320

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161

This report is also available in electronic form at <http://techreports.larc.nasa.gov/cgi-bin/NTRS>

FOREWORD

“It is not until we come far down into the full daylight of history that we find men setting out with the conscious purpose of exploring the unknown for its own sake. With those early hunters, it was doubtless new ground and new game that drew them on, but they too were attracted, consciously or unconsciously, by the spirit of adventure and the unknown - so deep in the soul of man does this divine force lie, the mainspring, perhaps, of the greatest of our actions. In every part of the world and in every age it has driven man forward on the path of evolution, and as long as the human ear can hear the breaking of waves over deep seas, as long as the human eye can follow the track of the northern lights over silent snowfields, as long as human thought seeks distant worlds in infinite space, so long will the fascination of the unknown carry the human mind forward and upward.”

Fridtjof Nansen, 1861-1930, Norwegian arctic explorer, Nobel Peace Prize (1922), statesman, scientist, and humanitarian. Quotation from In Northern Mists, London: Wm Heinemann, 1911, p6.

TABLE OF CONTENTS

	Page
Foreword	i
Table of Contents	iii
List of Tables	v
List of Figures	vi
Acronyms and Abbreviations	viii
ABSTRACT	x
1. INTRODUCTION	1
1.1 Overview	1
1.2 Background	1
1.3 NBSX Synopsis	4
1.4 IGY Synopsis	4
1.5 Workshop Format and Agenda	6
1.6 Report Outline	7
2. INVITED PARTICIPANTS.....	9
2.1 Charles Bentley	9
2.2 Richard Cameron	10
2.3 Mario Giovinetto	11
2.4 Charles Swithinbank	12
3. DISCUSSION TOPICS AND PARTICIPANT RESPONSE	13
3.1 Discussion Questions	13
3.2 C. Bentley Response	16
3.3 R. Cameron Response	23
3.4 M. Giovinetto Response	29
3.5 C. Swithinbank Response	45
4. OTHER COMMENTS AND OBSERVATIONS	50
4.1 Astronaut Office Training Activities	50
4.2 Development and Testing of EVA Suits for Surface Exploration	51
4.3 Ground Support Operations Planning and Interfaces	53
4.4 Observations from Group Discussions	54
5. CONCLUSIONS AND RECOMMENDATIONS	56
5.1 Conclusions	56
5.2 Recommendations	57
6. REFERENCES	58
7. BIBLIOGRAPHY	60
Appendix A: NBSX Background	61

Appendix B: IGY Background68
Appendix C – Curriculum Vitae for Invited Participants73
Appendix D – Supporting Tables for M. Giovinetto Response84

TABLES

Table Number		Page
1.1	JSC personnel participating in the Antarctic Exploration Parallels Workshop	6
4.1	Recent remote field site EVA test activities	52
B-1	U.S. Antarctic Stations and their locations as established during the IGY	69
B-2	Over Snow Traverses conducted by the U.S. during the IGY	71
D-1	Skill types and mix, scheme based on a crew of five	84
D-2	Skill types and mix, scheme based on a crew of seven	85

FIGURES

Figure Number		Page
1.1	NBSX used three tracked amphibious vehicles (Weasels) to transport people and heavy loads of supplies for extended traverses.	4
1.2	The International Geophysical Year logo.	4
5.1	Tour of the Lunar Sample Laboratory facility. From left to right: Dr. Giovinetto, Dr. Gary Lofgren (Lunar Sample Curator), Mary DiJoseph (NASA Headquarters), Dr. Hoffman, Dr. Swithinbank, and Dr. Cameron.	56
A.1	The NBSX base, Maudheim, was located on the Antarctic coast at 10° 56' west longitude, indicated here within the small box on the upper coastline.	61
A.2	Members of the NBSX wintering party on the day the <i>Norsel</i> departed (February 20, 1950). 1. Gordon Robin, 2. Leslie Quar, 3. Nils Roer, 4. Nils Schumacher, 5. Ove Wilson, 6. Ernest Roots, 7. Charles Swithinbank, 8. Egil Rogstad, 9. Bertil Ekström, 10. Alan Reece, 11. Valter Schytt, 12. Gösta Liljequist, 13. John Snarby, 14. Peter Melleby, 15. John Giæver.	62
A.3	“Weasels” – amphibious tracked vehicles developed by the U.S. Army in World War II – were used to transport people and tow sledges loaded with supplies.	63
A.4	Maudheim, as seen from the air, under construction. The large structure in the upper left is the first of two huts. Just to the right of this are four men digging the foundation for the second hut.	63
A.5	General layout of Maudheim. A. Command hut, B. Kitchen/dining hut, C. Diesel generators and shower stall, D. Workshop, E. Drilling machine hut, I. Meteorological office, 2. Radio office, 3. Darkroom, 4. Kitchen, 5. Dining table, 6. Hydrogen generator cave, 7. Balloon-filling cave, 8. Ramp to workshop, 9. Privy, 10. Garages, 11. Cold lab, 12. Tunnel for dogs, 13. Entrance (1950), 14. Entrance (1951), 15. Blizzard entrance, 16. Storerooms, 17. Window wells. There were hundreds of fuel drums. (Illustration and caption from Swithinbank, 1999).	64
A.6	“Advanced Base” as established under the nunatak “Pyrimid”.	64
A.7	Radio operator Egil Rogstad communicates with the outside world using Morse code.	64

Figure Number		Page
A.8	A seismology traverse. The lead Weasel tows a supply sledge and a mobile shelter for the seismic equipment. The trailing Weasel tows a heavily laden supply sledge.	65
A.9	Dr. Swithinbank surveying topographic features.	65
B.1	The International Geophysical Year logo.	68

ACRONYMS AND ABBREVIATIONS

ANI	Adventure Network International
ASRO	Astronaut – Rover project
ATRV	All Terrain Robotic Vehicle
BAS	British Antarctic Survey
BIO-Plex	Bioregenerative Planetary Life Support Systems Test Complex
CTAE	Commonwealth Trans-Antarctic Expedition
DCP	Dome C Project
DEW	Distant Early Warning
DoD	Department of Defense
DVD	Digital Video Disk
ESA	European Space Agency
EVA	Extra Vehicular Activity
ExPOC	Exploration Payload Operations Facility
GISP	Greenland Ice Sheet Project
GLOCHANT	Group of Specialists on Global Change and the Antarctic
GSFC	Goddard Space Flight Center
HEDS	Human Exploration and Development of Space
HMP	Haughton Mars Project
HQ	Headquarters
IATA	International Air Transport Agreements
ICSU	International Council of Scientific Unions
IGY	International Geophysical Year
ISS	International Space Station
ITSS	Information Technical and Scientific Services (Raytheon)
JSC	Johnson Space Center
LCD	Liquid Crystal Display
LPI	Lunar and Planetary Institute
MCC	Mission Control Center
MIT	Massachusetts Institute of Technology
NAS	National Academy of Sciences
NASA	National Aeronautics and Space Administration
NBL	Neutral Buoyancy Laboratory
NBSX	Norwegian-British-Swedish Antarctic Expedition

NOAA	National Oceanic and Atmospheric Administration
NOLS	National Outdoor Leadership School
NRC	National Research Council
NSF	National Science Foundation
RAF	Royal Air Force
RIGGS	Ross Ice Shelf Geophysical and Glaciological Survey
SAIC	Science Applications International Corporation
SCAR	Scientific Committee on Antarctic Research
SCP	Siple Coast Project
SEI	Space Exploration Initiative
SPQMLT	South Pole – Queen Maud Land Traverse
SPRI	Scott Polar Research Institute
SIPRE	Snow, Ice, and Permafrost Research Establishment
STS	Space Transportation System
USAF	United States Air Force
USAP	United States Antarctic Program
USNC	United States National Committee

ABSTRACT

This report documents the results of a workshop that was held at the NASA Johnson Space Center in June of 2001. The motivation for this workshop was to continue the process of gathering expert assessments of NASA's current best understanding of future human exploration missions beyond low Earth orbit. The experts chosen for these assessment are individuals with relevant real world experience that is as similar as possible to these missions. For this workshop four Antarctic explorers were invited to JSC for three days of activities: Dr. Charles Bentley (University of Wisconsin), Dr. Richard Cameron (Webster University), Dr. Mario Giovinetto (Raytheon Technical Services Company at NASA/GSFC), and Dr. Charles Swithinbank (Scott Polar Research Institute, University of Cambridge).

As a group these Antarctic explorers were active during the period immediately following World War II through approximately the end of the International Geophysical Year; some continued polar exploration activities to the present time. Their perspective, as representative of this generation of explorers, is important for several reasons. First, during this era there were a number of relatively sophisticated and extensive expeditions conducted on this continent, but the level of support infrastructure was relatively sparse or nonexistent. In one case an expedition, co-sponsored by Norway, Britain, and Sweden, spent two consecutive years on the continent with only one planned resupply mission and contingency plans for no resupply missions should sea ice prevent the supply ship from reaching them. Second, there were several traverses across the continent that measured more than 1000 miles in total distance, requiring several months to complete. In most cases these traverses were conducted without benefit of maps (because they did not exist) and relatively few aerial photos of the traverse route. Finally, the size of the crews on several of these long duration and long distance missions was relatively small, varying from six to roughly 15 and was often international in composition. All of these traits are foreseen as potential features of early Mars missions in particular and future human exploration missions in general.

The invited Antarctic explorers were given tours of development, training, and scientific facilities at JSC, as well as documentation describing operational scenarios related to future planetary surface exploration. This group then spent two days discussing their observations relative to these facilities and plans with selected technical representatives from the JSC staff. Participation from JSC included representatives from the Engineering, Space and Life Sciences, and Mission Operations Directorates and from the Astronaut Office. The bulk of the information in this report records the responses provided by each of the invited participants to a series of questions provided to them prior to the workshop. In addition to these written comments, the verbal discussions were videotaped, a copy of which is available in the JSC library.

This workshop successfully accomplished its stated purpose and the information documented in this report represents a valuable contribution to the understanding of how best to explore other planets with human crews. The point of view brought by this group of experts represents another significant facet of this complex problem that needed to be examined by the Exploration Office and the lessons learned incorporated into the overall approach to exploration.

1.0 INTRODUCTION

1.1 Workshop Overview

This report documents the results of a workshop, and the activities leading up to it, that was held at the Johnson Space Center (JSC) in June of 2001. The purpose of the workshop was to discuss plans and preparations for future human planetary surface exploration missions with a select group of Antarctic explorers. The invited Antarctic explorers were given tours of development, training, and scientific facilities at JSC, as well as documentation describing operational scenarios related to future planetary surface exploration. This invited group then spent two days discussing their observations related to these facilities and plans with selected technical representatives from the JSC staff. Participation from JSC included representatives from the Engineering, Space and Life Sciences, and Mission Operations Directorates and from the Astronaut Office.

1.2 Background

The principal motivation for this workshop was to continue the process of gathering expert assessments of NASA's current best understanding of future human exploration missions. The experts chosen for these assessments have been individuals with relevant real world experience that is as similar as possible to these missions. For this workshop Antarctic explorers, whose experience dates from the late 1940's through the late 1950's, were invited to JSC for three days of activities.

The Exploration Office, within the JSC's Advanced Development Office, has been investigating future human exploration missions beyond low Earth orbit since its inception in 1996. This office has studied human missions to the Moon, to near Earth asteroids, and to Mars. Within this range of options, Mars missions have represented the most challenging in terms of technologies and operations for a reasonable planning horizon (c. 2020). As such, Mars missions have received significant attention because they set the upper bound for mission requirements.

To date, much of this work has been based on analysis, limited laboratory and field testing, and intelligent speculation. This includes knowledge inherited from the Space Exploration Initiative (SEI) era (roughly 1988 through 1992; generated by the Office of Exploration at NASA Headquarters and by the Exploration Program Office at JSC) as well as other studies that can be traced back as far as work carried out by Dr. Wernher von Braun in the late 1940's and early 1950's (von Braun, W. 1953).

Immediately following the demise of the SEI in 1992, several internal NASA studies were undertaken to utilize the best of the lessons learned from that Initiative, as well as recommendations from other relevant U.S. government studies (e.g., Synthesis Group, 1991) and non U.S. government studies (e.g., Zubrin, 1991), into a consolidated "reference mission" (Hoffman and Kaplan, 1997). This reference mission established a baseline against which alternative mission architectures, technologies, and operations could be compared. As improvements were identified from subsequent analyses and

assessments, updates to the reference missions were developed and documented; the latest published version was released in 1998 (Drake, 1998).

These reference mission versions were complete in the description and analysis of the transportation system needed to convey crew and equipment between the surface of the Earth and the surface of Mars. However, an equivalent level of detail was not developed for Mars surface activities, and consequently for the necessary supporting systems, that human crews would carry out. An initial workshop to discuss these surface activities was held at the Lunar and Planetary Institute (LPI) in October of 1997 (Duke, 1997). This workshop defined the scope of the surface activities likely to occur and provided an initial description of these activities in the form of a number of vignettes. A more detail description of a surface mission scenario was begun in mid 1998 (Hoffman, 2001). This effort used the Mars reference mission and addenda along with the LPI workshop results as a starting point to complete a detailed description of the functions and activities that were likely to take place during the time a human crew was on the Martian surface. A second workshop was organized to describe this Mars mission (both the interplanetary transportation and the surface exploration) to a group of highly experienced field geologists, biologists, and paleontologists as well as several Apollo astronauts (Budden, 1999). This group was asked to assess these mission plans and descriptions based on their personal experience carrying out similar activities on Earth and the Moon. These assessments were incorporated into the surface reference mission as it evolved during this period of time. Also during this time, a number of field tests were conducted for both EVA and robotic systems that incorporated concepts from these reference missions and workshop reports (e.g., Kosmo, 1998, 1999, 2000, and Stoker, et. al. 2001). Additionally, personnel from the Exploration Office and other supporting organizations took advantage of opportunities to work with scientific field parties (e.g., Long, 1999) to gain first hand experience in analog field sites and field operations. Results from these field exercises were subsequently taken into account, as appropriate, in the reference mission documents.

What became evident, as the surface reference mission was re-evaluated based on these workshop assessments and field exercises, was the fact that there was at least one other highly relevant perspective that should be taken into account. This is the perspective of a group of Antarctic explorers that were active during the period immediately following World War II through approximately the end of the International Geophysical Year (IGY). This perspective is important for several reasons. First, during this era there were a number of relatively sophisticated and extensive expeditions conducted on this continent, but the level of infrastructure in place to support these activities was relatively sparse or nonexistent. In one case (which will be described in more detail below) an international expedition, co-sponsored by Norway, Britain, and Sweden, planned to spend two consecutive years on the continent with only one planned resupply mission and contingency plans for no resupply missions should sea ice prevent the supply ship from reaching them. This mission duration and potential reliance on only those supplies brought with the initial deployment is highly similar to one of the proposed Mars mission scenarios. Second, there were several traverses across the continent that measured more than 1000 miles in total distance, requiring several months to complete. In most cases

these traverses were conducted without benefit of maps (because they did not exist) and relatively few aerial photos of the traverse route. This type of traverse has been mentioned repeatedly by the scientific community as one of the desired means of exploring the Martian surface. Finally, the size of the crews on several of these long duration and long distance missions was relatively small, varying from six to roughly 15 and was often international in composition. All of these traits are foreseen as potential features of Mars missions.

Consequently a third workshop was organized in 2001 to invite explorers from this era of Antarctic exploration to conduct a similar assessment of NASA's plans and descriptions for future Mars missions. Representation by members of both long duration and long traverse distance expeditions was sought among the invited participants. Ultimately, four individuals were identified and accepted NASA's invitation to participate in this workshop:

- Dr. Charles Bentley, University of Wisconsin. Dr. Bentley led or co-led two extensive traverses across the Antarctic continent immediately before and during the IGY (the Little America-Byrd Station traverse, the Sentinel Mountains traverse, and the Horlick Mountains traverse). Dr. Bentley spent two consecutive years in Antarctica while conducting these traverses.
- Dr. Richard Cameron, Webster University. Dr. Cameron was chief glaciologist for Wilkes Station from August 1956 through May 1958. Much of his time was spent at a remote station established 50 miles inland. He was also NSF Program Manager for Glaciology from 1975 to 1985. Among other duties, he acted as the NSF representative at South Pole Station at the beginning of each summer and was responsible for ensuring that winter-over personnel were capable of this technical, physical, and emotional challenge.
- Dr. Mario Giovinetto, Raytheon Technical Services Company (supporting NASA/GSFC). During the IGY, Dr. Giovinetto spent two consecutive years working on the Antarctic continent, first at Byrd Station (1957) and then at South Pole Station (1958). He participated in the Little America-Byrd Station traverse, and worked two summers at a remote field camp 50 miles WSW from Little America.
- Dr. Charles Swithinbank, Scott Polar Research Institute. Dr. Swithinbank's first expedition to the Antarctic was as part of the Norwegian-British-Swedish Antarctic Expedition (NBSX). This was an expedition, mentioned previously, that spent two consecutive years on the ice and conducted traverses extending several hundred miles.

Additional information on all of these gentlemen can be found in Section 2 and Appendix C of this report. Brief synopses of the expeditions in which they participated are presented in the following sections with more extensive descriptions in Appendices A and B.

With the exception of Dr. Bentley, who was unavoidably detained by business at the University of Wisconsin, all of these participants were able to tour relevant JSC facilities

and interact with JSC personnel. Their comments and observations are documented in Sections 3 and 4 of this report. Dr. Bentley was able to provide written comments to a set of questions provided to all of the participants, which are documented in Section 3.

1.3 NBSX Synopsis

[Adapted from [http://www.spri.cam.ac.uk/photo/nbsx/nbsxtext\(mod\).html#S2](http://www.spri.cam.ac.uk/photo/nbsx/nbsxtext(mod).html#S2) accessed on August 16, 2001]

The Norwegian-British-Swedish Antarctic Expedition of 1949-52 was an international expedition with a crew of 15. This expedition spent two consecutive years exploring a portion of the Antarctic continent. The expedition carried out a wide range of scientific investigations in the fields of geology, glaciology, meteorology and medicine. In addition, the crew conducted significant topographical surveys and mapping of the local region. Norway was mainly responsible for meteorology and topographical surveys, Britain for geology and Sweden for glaciology.



Figure 1.1 NBSX used three tracked amphibious vehicles (Weasels) to transport people and heavy loads of supplies for extended traverses.

The expedition base, christened Maudheim, was located on the coast of Dronning Maud Land -- an area lying between the meridians of 20°W and 45°E, in territory annexed by Norway just before World War II. Several huts, for accommodation and housing of research and communication equipment, were assembled at Maudheim and some 450 tonnes of supplies, sufficient for a stay of up to three years, were transported approximately three kilometers inland from the transport vessel *Norsel*. In addition, another camp -- Advance Base -- was sited at 72°17'S, 03°48'W (approximately 320

kilometers from Maudheim), close to a nunatak named the "Pyramid". This camp was not permanently occupied, but consisted of tents, stocks of food and fuel available to support field parties. This team also established a network of expedition-support supply depots away from Maudheim and Advance Base to allow field parties to explore for extended times and at extended ranges from either camp.

A more extensive description of this expedition is contained in Appendix A of this report.

1.4 IGY Synopsis

[Adapted from <http://www.nas.edu/history/igy/>; accessed on September 28, 2001]

In 1952 the International Council of Scientific Unions proposed a comprehensive series of global geophysical activities to span the period July 1957 - December 1958. The International Geophysical Year (IGY), as it was

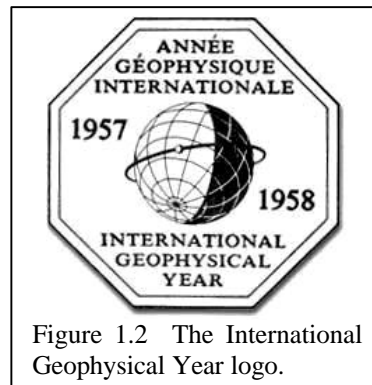


Figure 1.2 The International Geophysical Year logo.

called, was modeled on the International Polar Years of 1882-1883 and 1932-1933 and was intended to allow scientists from around the world to take part in a series of coordinated observations of various geophysical phenomena. Although representatives of 46 countries originally agreed to participate in the IGY, by the close of the activity, 67 countries had become involved.

American participation in the IGY was charged to a U.S. National Committee (USNC) appointed in March 1953 by the National Academy of Sciences (NAS). The core USNC was made up of sixteen members, but the five Working Groups and thirteen Technical Panels that operated under it eventually drew in nearly 200 additional scientists. The technical panels were formed to pursue work in the following areas: aurora and airglow, cosmic rays, geomagnetism, glaciology, gravity, ionospheric physics, longitude and latitude determination, meteorology, oceanography, rocketry, seismology, and solar activity. In addition, a technical panel was set up to attempt to launch an artificial satellite into orbit around the Earth.

IGY activities literally spanned the globe from the North to the South Poles. Although much work was carried out in the arctic and equatorial regions, special attention was given to the Antarctic, where research on ice depths yielded radically new estimates of the Earth's total ice content. IGY Antarctic research also contributed to improved meteorological prediction, advances in the theoretical analysis of glaciers, and better understanding of seismological phenomena in the Southern Hemisphere.

In 1954-55 the United States began investigating sites for stations for the IGY. The following austral summer it established the McMurdo Sound Air Operation Facility. Of the 65 IGY Antarctic research stations established by 12 nations, the United States operated seven, including the prestigious and scientifically valuable, but operationally challenging, site at the geographic South Pole. The National Science Foundation funded IGY work through the National Academy of Sciences, and the Department of Defense separately funded and provided operational support.

Of particular interest for this workshop were the scientific traverses carried out as part of the IGY:

- During the austral summer of 1956-57: the traverse from Little America to Byrd Station (co-led by Charles Bentley and Vernon Anderson).
- During the austral summer of 1957-58: the Filchner Ice Shelf Traverse (led by Ed Thiel), the Ross Ice Shelf Traverse (led by Albert Crary) and the Sentinel Mountains Traverse (co-led by Charles Bentley and Vernon Anderson).
- During the austral summer of 1958-59: the traverse across the Filchner Ice Shelf to Byrd Station (led by Jock Pirrit), the Horlick Mountains Traverse (led by Charles Bentley), and the traverse from McMurdo Station to the East Antarctic ice sheet (led by Albert Crary).

Each of these traverses was carried out by a relatively small number of people (between 5 and 10) and a relatively small number of vehicles (2 to 3). But these traverses averaged

between 500 and 1000 miles through largely unknown terrain. Significant supplies were carried by each of the traverse teams, but they were also occasionally resupplied by air courtesy of the U.S. Navy.

A more extensive description of this initiative is contained in Appendix B of this report.

1.5 Workshop Format and Agenda

The format for this workshop was a series of interactive discussions between the invited participants and a diverse set of JSC personnel, selected to represent those disciplines with a direct interest in the experience base of the invited participants. Table 1.1 lists these JSC attendees.

Table 1.1 JSC personnel participating in the Antarctic Exploration Parallels Workshop

Name	JSC Office Code	Skill type or area of interest
Jean-Loup Chretien	CB	Astronaut. Has flown on several Shuttle missions.
Pat Dickerson, Ph.D.	SX	Planetary geologist; field geology experience. Has helped train astronaut candidates in recent years.
Mary DiJoseph	(GSFC)	Detailed from NASA GSFC to NASA HQ to support advanced planning for future human space missions.
Richard Fullerton	XA	EVA suit engineer. Currently supporting JSC EVA Project Office
Tony Griffith	DV3	Mission Operations Directorate advanced projects. Leading development of mission control elements for future planetary missions.
Don Henninger, Ph. D.	EC	Head of the Advanced Life Support office.
Stephen Hoffman, Ph.D.	EX13	Mission design engineer. Works on advanced program development.
Jeff Jones, M.D.	SD2	Flight Surgeon. Supports the astronaut corps.
Kent Joosten	EX13	Mission design engineer. Works on advanced program development.
Joe Kosmo	EC5	EVA suit engineer. Currently working on development of next generation of planetary surface EVA suit.
Shannon Lucid, Ph.D.	CB	Astronaut. Has flown on several Shuttle missions and spent approximately six months on MIR.
Wendell Mendell, Ph.D.	SX	Planetary scientist. Manages advanced program activities.
Doug Ming, Ph.D.	SX	Planetary scientist. Currently working on plant growth chambers from an applied research perspective.
Doug Rask	DM4	Ascent/descent flight dynamics. Supports advanced mission planning.
Amy Ross	EC5	EVA suit engineer. Supports development of next generation of planetary surface EVA suit.
Robert Trevino	EC5	EVA suit engineer. Has worked austral summers at Siple Dome and Vostok Station.
Terry Tri	EC3	Chief Engineer for Advanced Life Support.
Jean Wall	DV	Crew training.
Brenda Ward, Ph.D.	EX13	Astrophysicist. Deputy manager of the JSC Exploration Office.

The agenda for this workshop was spread over three days. The first day was set aside for the invited participant to tour several relevant JSC facilities that are used for training purposes or that are representative of facilities thought to be relevant for future planetary missions. These facilities include:

- Advanced EVA Suit Development Facility
- EVA Partial Gravity Counterbalance Facility
- Antarctic Meteorite Laboratory
- Lunar Sample Laboratory
- STS Full Fuselage Trainer
- Space Station Mockup and Training Facility
- Mission Control Center
- The Neutral Buoyancy Laboratory (NBL)

Although the facility itself was not toured, this group also received a briefing regarding the BIO-Plex (Bioregenerative Planetary Life Support Systems Test Complex) facility, developed to test advanced life support systems to support long duration human space missions.

The next two days were devoted to the interactive discussions mentioned previously. The first portion of this discussion period was set aside for a series of briefings by NASA personnel describing other activities or facilities not toured by the invited participants. These included:

- NASA participation in Earth analog training and research activities
- “Expedition Corps” activities being carried out by the Astronaut Office
- EVA field tests
- Mission Control Center research activities in support of future planetary missions

The remainder of this portion of the workshop was taken up by a general discussion between all of the participants, guided in general by a series of questions and topics, which are discussed further in Section 3 of this report.

1.6 Report Outline

The remainder of this report is divided into three main sections. Section 2 provides background information for each of the invited Antarctic explorers. Section 3 contains the bulk of the information in this report. This section records the responses provided by each of the invited participants to a series of questions provided to them prior to the workshop. Section 4 records a brief summary of presentations made by NASA personnel at the opening of the workshop and contains additional comments provided by the participants to questions or issues not contained in the set of questions discussed in Section 3. Section 5 summarizes the discussions from this workshop and conclusions are presented based on the original objective of this workshop. Recommendations for future actions are also contained in this section. Finally, a bibliography of additional material

that was found to be relevant in preparing for this workshop, or that was identified by various participants during the course of the workshop, is contained in Section 7.

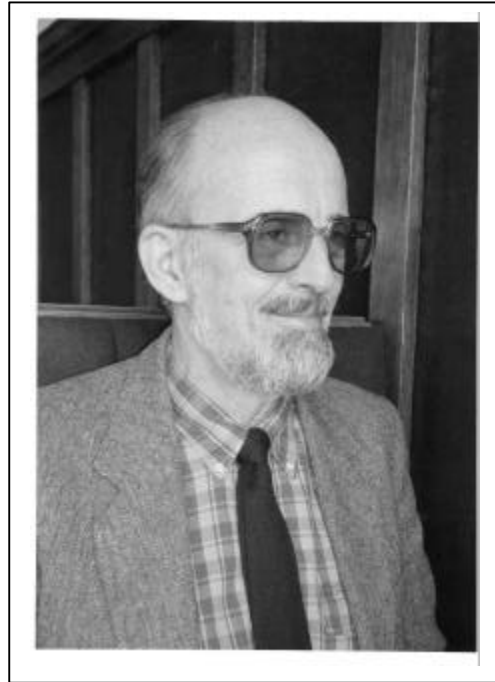
In addition to these written comments, the verbal discussions were videotaped. A copy of this videotape record is available through the JSC library.

2.0 INVITED PARTICIPANTS

The following sections provide a brief description of each invited participant's background and rationale for their attendance at this workshop. A curriculum vita for each of these participants can be found in Appendix C.

2.1 Charles Bentley, Ph.D.

Dr Charles Bentley is the A.P. Crary Professor Emeritus of Geophysics, Department of Geology and Geophysics, University of Wisconsin-Madison. He joined the Arctic Institute of North America in 1956 to participate in IGY-related activities in the Antarctic. He wintered over consecutively in 1957 and 1958 at Byrd Station, a station in the interior of West Antarctica that housed 24 men each winter, 12 Navy support people and 12 civilian scientists/technicians. During the austral summers, he also participated in over-snow traverses, first as co-leader, then leader (the other co-leader went home after the first year). These traverses consisted of six men, three vehicles, and lasted several months on the trail. They covered over 1000 miles of largely unmapped and unphotographed terrain. During these traverses, connections to Byrd Station were by radio (daily, when the transmission conditions were good enough) and roughly every two weeks by resupply flight.

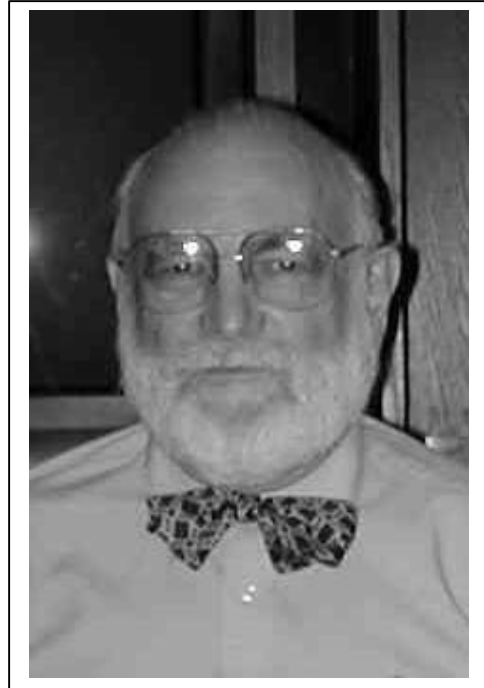


Dr. Bentley was born in 1929 in Rochester, New York. He received a B.S. in Physics from Yale University in 1950 and a Ph.D. in Geophysics from Columbia University in 1959. He has held academic positions ranging from Project Associate through Professor, and finally as A.P. Crary Professor of Geophysics, during his career in the Department of Geology and Geophysics at the University of Wisconsin-Madison (1959 – 1987). Among a variety of other activities, he has been a member of the Polar Research Board, National Research Council (NRC) (1978-1997, chairman 1981-1985) as well as a U.S. member (1981-1997) and vice president (1990-1994) of the Scientific Committee for Antarctic Research (SCAR), International Council of Scientific Unions (ICSU). Dr. Bentley has received many awards from American, British, and Russian organizations for his outstanding contribution to the glaciological and geophysical studies of the polar regions. Among these awards are the Goldthwait Medal from the Byrd Polar Research Center, the Ohio State University; the Seligman Crystal from the International Glaciological Society; and the Bellingshausen-Lazarev Medal from the Soviet Academy of Sciences.

2.2 Richard Cameron, Ph.D.

Dr. Richard Cameron is currently an adjunct professor at Webster University in St. Louis, Missouri.

While completing his undergraduate studies at the University of New Hampshire (B.Sc. in Geology, 1954) he spent the summer of 1953 at the Summer School at the University of Oslo where he had the opportunity of taking a course on Norway in the Polar Regions with Dr. H. U. Sverdrup, a student of the noted polar explorer Fridtjof Nansen. After the course he worked with the Norwegian Polar Institute on glaciers in the Jotunheim. Following graduation he worked with Dr. Valter Schytt (chief glaciologist of the Norwegian-British-Swedish Antarctic Expedition) first in Greenland in the summer of 1954 and then during 1955 at the University of Stockholm.



Dr. Cameron joined the Arctic Institute of North America in 1956 to participate in IGY-related activities in Antarctica. He served as Chief Glaciologist at Wilkes Station, on the coast of East Antarctica. This was a joint Navy-civilian operation consisting of 17 Navy personnel and 10 scientists. Specifically, his glaciological team consisted of two colleagues with whom he had worked before, Olav Loken, in Norway in the summer of 1953, and John Molholm in Greenland in the summer of 1954. This team spent much of its time at a remote station established 50 miles inland, where they conducted both meteorological and glaciological studies. One of the glaciological studies entailed digging a 35-meter vertical pit to study snow densification and stratigraphy.

After completing his doctoral course studies at The Ohio State University in 1961 he accepted the position of Chief of the Geotechnics Branch, Terrestrial Sciences Lab, Air Force Cambridge Laboratories. He returned to Ohio State University in 1963 to finish his dissertation and receive his degree. He then served in a number of positions at the University - Assistant to the Director of the Institute of Polar Studies, Associate Director of The Ohio State University Research Foundation, Assistant Dean of University College, and Assistant Dean of International Programs. In 1973 Dr. Cameron joined the National Science Foundation first as Associate Program Manager and then Program Manager of International Organizations, Division of International Programs. He then moved to the Division of Polar Programs where he was the Program Manager for Glaciology from 1975 to 1985. In this last position he acted as the NSF Representative at South Pole Station at the beginning of each summer. He would go in on the first flight, usually on November 1, with the replacement crew and spend a month or more to monitor how the new crew was doing. Now and then it was necessary to replace a crew

member who was not adequate to handle the job assigned or not emotionally stable enough to spend the whole winter.

Dr. Cameron, has been conducting a number of study tour programs for Webster University during the last few years – Glacier Studies in Austria in 1999, Physical Geography of the Netherlands in 2000 and 2001, and Fire and Ice (glaciology and volcanology) in the Pacific Northwest in 2001.

2.3 Mario Giovanetto, Ph.D.

Dr. Giovanetto has been active in polar research since 1952, participating in projects supported by the U.S. National Science Foundation and other federal research agencies of Argentina and Canada. His field work experiences include three expeditions to high-mountain glaciers in South America and Africa (between 1952 and 1955), winter stays at two stations in Antarctica (Byrd Station, 1957; South Pole Station, 1958), and nine summer-seasons in Antarctica and Greenland (between 1953 and 1978). Overall, he has logged over 2000 miles of over-snow traverse work, made observations at numerous sites on sea-ice and icebergs, and has spent approximately nine years as a member of small, isolated teams working in demanding environments. His



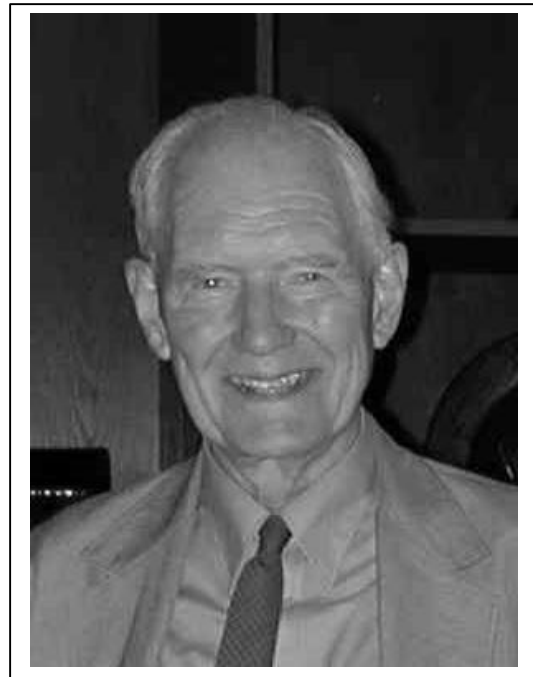
research in glaciology and climatology was performed while affiliated with the Instituto Antartico Argentino (Buenos Aires; 1953-56), Arctic Institute of North America (New York; 1956-59), Institute of Polar Studies (now Byrd Polar Research Center), Ohio State University (Columbus; 1959-61), and the Geophysical and Polar Research Center, University of Wisconsin (Madison, (1961-68). He has produced estimates of mass and energy exchange between atmosphere, ocean (including sea ice) and ice sheets of both hemispheres that are used by others to validate the results of dynamic models applied to global change research. His contributions have been recognized in several awards from government agencies of the U.S. and Argentina.

Dr. Giovanetto was born in Argentina (1933), and is citizen of Canada with permanent resident status in the U.S. He started his education at the Universidad Nacional de La Plata, and received a Ph.D. (1968) in Geography with a minor in Geology and Geophysics from the University of Wisconsin, Madison. He has held academic positions at the University of Wisconsin – Milwaukee (Instructor, 1966-67), University of California – Berkeley (Assistant and Associate Professor, 1968-73), and University of Calgary (Professor, 1973-98). He has served as member of the National Research Council – Earth Sciences Division, U.S. National Academy of Sciences (1971-74); he also served as department head, University of Calgary (1973-83). Since 1998, Dr.

Giovinetto holds appointments of Professor Emeritus, University of Calgary, and Principal Scientist, Department of Geodynamics, Raytheon Technical Services Company - Information Technology and Scientific Services, a subcontractor to NASA-GSFC, Oceans and Ice Branch, Laboratory for Hydrospheric Processes.

2.4 Charles Swithinbank, Ph.D.

Dr Charles Swithinbank is currently a senior research associate at the Scott Polar Research Institute, University of Cambridge, England. He has been conducting research in the Polar Regions since 1947, beginning with his participation in the Oxford University Iceland Expedition. Dr. Swithinbank was the youngest member of the Norwegian-British-Swedish Antarctic Expedition, spending two consecutive years with 15 other researchers and support staff at a Maudheim station. During this expedition he participated in several over snow traverses measuring several hundred miles in extent and lasting for many weeks at a time. His polar expedition record stretches into the 1990's. During these expeditions, Dr. Swithinbank has conducted research at British, U.S., and Russian stations in the Antarctic.



Dr. Swithinbank was born in 1926 in Pegu, Burma. He received a B.A. degree in geography in 1949, an M.A in 1953, and a D.Phil. in glaciology in 1955 from the University of Oxford, Pembroke College. His work with the Norwegian-British-Swedish Antarctic Expedition continued through 1955. He then spent four years as a research fellow at the Scott Polar Research Institute, located at the University of Cambridge. From 1959 through 1963, Dr. Swithinbank was a research associate and lecturer at University of Michigan (where he earned his private pilots license). From 1963 through 1986, he worked for the British Antarctic Survey (University of Cambridge), first as Chief Glaciologist (1963-74) and then as Head of Earth Sciences (1974-86). Since 1986 Dr. Swithinbank has been a senior research associate at the Scott Polar Research Institute, University of Cambridge.

3.0 DISCUSSION TOPICS AND PARTICIPANT RESPONSES

Prior to the workshop, the invited participants were provided with a list of discussion topics prepared by the workshop organizers with input from various JSC organizations that would be participating in the workshop. The original intent of these questions was to provide a framework for the two days set aside for open discussions. As events evolved, all of the participants provided written responses to these specific questions as well as using them as a starting point for additional discussions during the workshop at JSC.

The following section provides a list of the original questions as provided to the invited participants. Their written responses are recorded in the sections that follow.

3.1 Discussion Questions

Interpersonal Aspects

- Conflict resolution – what techniques seem to work the best? Is their effectiveness dependent on the situation or personalities? What techniques should be avoided?
- Gender mix – what ratios seem to work the best? What ratios should be avoided? What other aspects should be discussed as they affect crew effectiveness?
- Cliques – (e.g., military vs. scientist, scientist vs. non-scientist) do they always form?, are they always bad/detrimental?, always good?, how should they be dealt with?
- Cultural differences: impacts at a personal level? Do loyalties to a “home organization” detract from crew effectiveness? If so, how do you deal with it?
- Leadership types and effectiveness: what works? What doesn’t work? Can leadership be split (e.g., a “mission leader” with overall responsibility and a “science leader” with responsibility for mission goals)?
- Selection criteria: what are characteristics/personality traits that should be selected in? What traits should be selected out? Any overt consideration given to balancing traits as the crew is being assembled/selected? Did your criteria change based on experience in the field?
- Coping strategies: how to deal with (a) personal irritations, (b) being away from family, (c) conflicting personalities, (d) perceived “imperfections” in other crewmembers, etc.
- Personal and team motivation: What helped the team to achieve a successful expedition? What hurt? What personal expectations (going into a mission) helped achieve success? If personal expectations were unreasonable or not met, what was the impact on the team?
- Impact of strangers/visitors (even if only by radio/video) – Are there any impacts? If so, what are some examples? What ground rules should be set up, if any, prior to starting the mission?
- Difficulties of reintegration on return from a mission – what are they? How do you deal with them?

Organization/management

- Military versus democratic – what is your experience with each? What are the advantages and disadvantages of each?
- Leadership types and effectiveness (see above)
- What kind and how much support is necessary from a remote group (e.g., “mission control”)? How much and what type of information was communicated to and from this remote support group?
- Public affairs: was this required to accomplish any aspect of the mission? Were you dependent in any way on a public affairs group (e.g., to generate funding or to develop political support)? If Public Affairs was involved during the mission, did they put a “spin” on any of the reports released? If the “spin” was different from the report made by the team, did that affect the team and in what fashion? Did the team feel that any of the “spins” were made for “political correctness” and, if so, how did this affect the team? Any other personal thoughts on the impact of Public Affairs on individuals or the team?

Training

- What level of training fidelity is necessary prior to the mission?
- Of what value are analog sites?
- When does it make sense to go to analog sites?

Planning/logistics

- How were types and quantities of supplies and equipment estimated for very long missions, especially in unknown locations?
- How well (typically) did plans match operations and how much “buffer” was added to account for uncertainties? What criteria were used to decide which spares and the quantity of spares to take along?
- What criteria/process was used to judge when technology/equipment was “good enough” to be relied upon in the field?
- Food: Types? Quantity? Variety? Personal preferences (especially if conflicting)? Cultural preferences: what impact does this have on a multicultural crew?

Operations

- Skill types and mix
- Crew size: maximum, minimum, odd vs. even
- Crew quarters: How much personal/private space allocated per person? How important is environmental control (lighting, sound etc.)? How important is it to be able to personalize this space (e.g., rearrange furniture, add decorations, etc.)
- Medical support needed? If so, what type/skills, facilities, etc.

- Medical care issues: Supplies, training, contingency management, incidence of conditions
- Recreation: how much and what type(s)?

General

- Why take risks to gather scientific data?
- Antarctic infrastructure support: having watched this grow over the years what is better now? What is worse? What should have been left the way it was?
- If you had a chance to go to Mars, what would you do and why?

3.2 C. Bentley Response

INTERPERSONAL ASPECTS

Conflict resolution (What techniques seem to work the best? Is their effectiveness dependent on the situation or personalities? What techniques should be avoided?)

Byrd Station had two leaders, one for the Navy and one for the civilians. Conflicts were worked out between them. There was enough room at the station that individuals with personal differences could, and did, simply avoid each other. The Navy leader the first year was an Irish national living in the US who had been drafted into the medical service and had just received his MD. He had no practical experience in the Navy at all, let alone with command. He had some authority problems, but he muddled through, thanks in part to the excellent civilian leader. The second year not only was the Navy leader (still the doctor) a hard-nosed, wrong-side-of-the-tracks sort, but he had a chief petty officer to help him. Furthermore, the station was better equipped with recreational materials the second year. Conflicts were minimal.

On traverse, we sometimes rubbed each other the wrong way, but there were no real conflicts. We were too busy with our travel and work and too tired at the end of the day to have time or stomach for conflicts.

Gender mix. (What ratios seem to work the best? What ratios should be avoided? What other aspects should be discussed as they affect crew effectiveness?)

Women did not participate in the U.S. Antarctic program during the IGY.

Cliques. (e.g. military vs. scientist, scientist vs. non-scientist) do they always form?, are they always bad/detrimental?, always good?, how should they be dealt with?)

With the military/civilian mix we had at Byrd Station both years, a large degree of separation was inevitable. Living was in separate buildings; interests and activities were different. This led to some conflicts the first year, but few or none the second. I wasn't aware of smaller-scale cliques.

Cultural differences. (Impacts at a personal level? Do loyalties to a "home organization" detract from crew effectiveness? If so, how do you deal with it?)

There certainly was a general cultural/educational difference between military and civilians, but most of the time there was a satisfactory level of mutual respect. There were no "home organization" problems.

Leadership types and effectiveness. (What works? What doesn't work? Can leadership be split (e.g. a "mission leader" with overall responsibility and a "science leader" with responsibility for mission goals?).

With the special circumstance of a personnel roster evenly split between military and civilians, the split leadership worked very well. We had far fewer problems at Byrd Station than were experienced at Ellsworth Station, for example, where the Navy leader was also given scientific leadership (although he wasn't qualified). (But the problems at Ellsworth Station must be attributed to individual personalities much more than to the leadership mode.) Of course, the effectiveness of split leadership depends heavily on the ability of the two leaders to work together.

On traverse in 1957-58, I, as the chief geophysicist, split the leadership with the chief glaciologist. Our duties were largely different and there was seldom need to exercise sovereignty. He was easy-going, although I don't mean a push-over; he had a stubborn streak, just like the rest of us. I see myself as easy to get along with also, but not everybody else does.

Selection criteria. (What are characteristics / personality traits that should be selected in? What traits should be selected out? Any overt consideration given to balancing traits as the crew is being assembled / selected? Did your criteria change based on experience in the field?)

I had nothing to do with personnel selection, so I have no idea what personality traits were sought in the selection. We all had to undergo psychological testing, but I think that was mainly to find people who would weather the strain, not to balance personality traits. I believe the applicant pool was small enough that almost anybody who applied and passed the medical and psychological exams was accepted. Under traverse conditions, the ability to do one's job was the only criterion that mattered. Incompetence is a huge irritant in the field.

Coping strategies. (How to deal with (a) personal irritations, (b) being away from family, (c) conflicting personalities, (d) perceived "imperfections" in other crewmembers, etc.).

In regard to (a), (c), and (d), one simply lived with them. We didn't have "strategies." (b) was greatly relieved by ham radio connections. A major factor in the improved morale the second year at Byrd compared to the first was the much improved ham radio connection to the US.

Personal and team motivation. (What helps a team to achieve a successful expedition? What hurt? What personal expectations (going into a mission) helped achieve success? If personal expectations were unreasonable or not met, what was the impact on the team?).

The excitement of exploring the unknown, in both the scientific and adventuring senses, was motivation enough for the traverse personnel, with whom I was (naturally) most closely associated. I have less idea what motivated the station technicians, who simply read and maintained instruments collecting data they would never see again, although I do believe they were reasonably well paid and, of course, could save up a lot of money by having no expenditures for a year. I believe one motivator for the Navy personnel was a free choice of their next duty stations.

Impact of strangers / visitors (even if only by radio / video). (Are there any impacts? If so, what are some examples? What ground rules should be set up, if any, prior to starting the mission?).

Visitors, both to the station and to the traverse, were welcome because they always brought relief of some kind -- mail, fresh foods, needed supplies. However, my own reaction was also to see them as intruders to a considerable extent (particularly on traverse) -- I was usually glad when they went away again.

Difficulties of reintegration on return from a mission. (What are they? How do you deal with them?).

I had no difficulty. I particularly enjoyed the night, warm weather, and a brief romantic interlude in New Zealand, seeing my family when I got home (to Rochester NY), and going on the New York City subway at rush hour just to experience the crush of the crowds.

ORGANIZATION / MANAGEMENT

Military vs. democratic. (What is your experience with each? What are the advantages and disadvantages of each?)

I think it depends on the size of the group to some extent. The smaller the group the more effective "democracy" is. Nevertheless, even in a group of only 6 men, as on traverse, there must be no doubt about who has the last say, although that "who" can be two people in the split-leadership mode. I believe that more than two leaders wouldn't work well.

Leadership types and effectiveness (see above)

I can't generalize. Our very effective civilian leader the first winter at Byrd Station led "by doing." If there was a job needing to be done he started doing it himself, rounding up help as needed. But the civilian leader the second year did little but his own science job himself, yet he was also effective. My own style was the first -- people can't effectively complain about being worked too hard if one is oneself working even harder (although they certainly can bitch about it later).

What kind and how much support is necessary from a remote group (e.g. "mission control"?). How much and what type of information was communicated to and from this remote support group?).

The traverse group, both in the field and at the station during the winter, was very much on its own. We had only rare radio contact with our Chief Scientist at Little America during the winters, and none on traverse. About the only thing I remember discussing

with him was our mutual plans for traverse routes (he was also leading traverses), to coordinate plans in the region where our plans might overlap.

Public affairs. (Was this required to accomplish any aspect of the mission? Were you dependent in any way on a public affairs group (e.g. to generate funding or to develop political support)? If Public Affairs was involved during the mission, did they put any “spin” on any of the reports released? If the “spin” was different from the report made by the team, did that affect the team and in what fashion? Did the team feel that any of the “spins” were made for “political correctness” and, if so, how did this affect the team? Any other personal thoughts on the impact of Public Affairs on individuals or the team?)

Perhaps because of our remoteness, we had very little sense of public affairs. We did get a nice boost when we heard that our discovery that the bed of the ice sheet was far below sea level was questioned in Washington and our competence was strongly defended by the Chief Scientist. "Political correctness" was an unknown concept in those days.

TRAINING

(What level of training fidelity is necessary prior to the mission? Of what values are analog sites? When does it make sense to go to analog sites?).

In the case of the traverse personnel, a lot of training was necessary (I have no idea what "fidelity" means in this context, so I'm ignoring it). I spent two summers in Greenland learning how to do geophysical exploration on ice sheets (actually, teaching myself). Each chief traverse geophysicist had a PhD. Glaciologists spent a season in Greenland learning their trade also, in addition to their academic backgrounds (they were mostly geologists).

Of what value are analog sites?

Great value for the traverse personnel. Of course, it would be hard to find a more nearly perfect analog situation than Greenland and Antarctica!

When does it make sense to go to analog sites?

Any time prior to embarkation.

PLANNING / LOGISTICS

How were types and quantities of supplies and equipment estimated for very long missions, especially in unknown locations?

This was not difficult for the traverse parties, because our operations were simple and very well constrained. Furthermore, they were made much easier by knowing that we would be resupplied regularly by air and could call for a relief flight at any time in the case of an emergency. Planning for Byrd Station for the winter must have been much

more difficult, because of its greater size, the diversity of operations, and the total isolation for 6 months.

How well (typically) did plans match operations and how much "buffer" was added to account for uncertainties? What criteria were used to decide which spares and the quantity of spares to take along?

Plans generally matched operations pretty well. The biggest problems were ones that couldn't be prevented by planning -- the long delay in finding a safe route from Little America to the station site that set the building of Byrd Station back a couple of months, for example. Or the pirating at Little America of the special non-magnetic panels slated for the magnetic recording station at Byrd and the substitution of panels with steel nails. Somebody had great foresight in designing the "buffer" in that case because we had on site enough copper nails to replace all the steel nails with non-magnetic ones.

What criteria/process was used to judge when technology/equipment was "good enough" to be relied upon in the field?

The traverse seismic equipment had been tried out in Greenland. Other geophysical equipment was simple enough in operation that reliability in the field wasn't really a question. In regard to other equipment the determination came when it was tried out. We soon learned, for example, that our fancy electrical crevasse detectors were essentially useless for routine operation, although they had been used effectively elsewhere in Antarctica under different circumstances. Similarly, our gyrocompasses, which were believed to be necessary because magnetic compasses don't work close to the pole, were unstable on rough surfaces and therefore also essentially useless. On the other hand, a magnetic compass worked just fine; our traverse routes were actually farther from the magnetic pole than Wisconsin is.

Food: Types? Quantity? Variety? Personal preferences (especially if conflicting)? Cultural preferences: what impact does this have on a multicultural crew?

Frozen food was, of course, a natural in Antarctica. Therefore we had an ample supply, both at the station and on traverse, of any food that could be thawed and still be edible. We also had a plentiful supply of dried foods, some of them specially designed for the Antarctic field programs. Because of our resupply capabilities and the large hauling capacities of the traverse SnoCats, we made little effort to travel light in the field. That meant that even in the field we had plenty of variety. Gone were the days of living on hoosh. However, there were no allowances for cultural preferences -- we didn't even think of anything like that.

OPERATIONS

Skill types and mix

Skills were related one-to-one to the tasks that needed to be done, both at Byrd Station and on traverse.

Crew size: maximum, minimum, odd vs. even

Crew size was determined by the scientific tasks to be performed and, at Byrd Station, by the station support necessities. At Byrd, the equal balance of military and civilian was a deliberate additional factor. On traverse, with three vehicles, we needed a minimum of 6 people, so no one would be driving alone, but our space was so limited that even a seventh man created some difficulty. I don't recall that we ever had more than 7.

Crew quarters: How much personal/private space allocated per person? How important is environmental control (lighting, sound etc.)? How important is it to be able to personalize this space (e.g., rearrange furniture, add decorations, etc.)

On traverse there was no private space. Personal space was limited to the shelf in the vehicle on which each man laid out his sleeping bag, and to someplace to stuff our duffel bags. At Byrd Station private space was more extensive during the second winter than the first. The first year we shared sleeping cubicles, whereas during the second winter we had individual spaces. Being able to decorate my own space was important to me when the opportunity arose, although I had thought nothing about it before.

Medical support needed? If so, what type/skills, facilities, etc.

Byrd Station always had an MD in residence. In two years no medical problems arose beyond his capabilities and supplies. The doctor gave us instructions in first aid before we departed on traverse; fortunately, we never had any need to use it. Our traverses were remarkably free of illness and injury. In two field seasons, the only problem we couldn't handle was a broken tooth incurred by biting too hard on a frozen jelly bean. That man continued his work, handling his pain with codeine tablets, until a dentist was flown out to the traverse and pulled the tooth in one of the SnoCats.

Recreation: how much and what type(s)?

On traverse -- essentially none, except reading one's mail when it was delivered. There simply wasn't time for recreation. At Byrd Station, the recreational facilities were pretty much limited to reading and card-playing the first winter. I have a vague recollection of a basketball basket somewhere. During the second, we had a separate recreational building with ping-pong table, mats for judo practice, etc. We also had dogs.

GENERAL

Why take risks to gather scientific data?

Twenty-five-year-olds don't think of risk, they think of adventure. Then, with later seasons, the risks become familiar and well-experienced and it is easy to believe that they are under a control, like driving a car at home.

Antarctic infrastructure support: having watch this grow over the years what is better now? What is worse? What should have been left the way it was?

The vast improvement in infrastructures has vastly increased our capabilities for research in Antarctica. In all practical senses, everything is better. Only a romantic longs for the "good old days." But, of course, there is a considerable amount of the romantic in virtually every Antarctic veteran. If there weren't, he wouldn't keep going back.

If you had a chance to go to Mars, what would you do and why?

Fifty years ago I would have leapt at the chance, for most of the same reasons I leapt at the chance to go to Antarctica. Now I would decline, with thanks, for pretty much the same reasons that I would never winter over in Antarctica again -- too long away from home and family (I never wintered over again after IGY).

3.3 R. Cameron Response

INTERPERSONAL ASPECTS

Conflict resolution (What techniques seem to work the best? Is their effectiveness dependent on the situation or personalities? What techniques should be avoided?)

At Wilkes Station the only real incident during the entire year was when a Chief Petty Officer was going through the chow line and the cook placed chicken on his tray. The petty officer said, "chicken again" and tossed it back in the serving dish and the cook punched him in the nose. The Navy handled this with the cook losing a rank. The cook was cooking three meals a day for 27 men and this incident happened after about nine months. To the civilians, this type of punishment seemed too strong and the after effects lasted too long. It seems that the overall crew of Navy and civilians were able to settle differences rationally and worked extremely well together. The two leaders of the station were able to run the station efficiently and support the various scientific programs fully.

Gender mix. (What ratios seem to work the best? What ratios should be avoided? What other aspects should be discussed as they affect crew effectiveness?)

In the IGY the entire operation was male. Nowadays some stations have both men and women but the predictable problems have arisen with jealousy and pregnancy.

At South Pole Station a female doctor had one friend during the first part of the year and switched to another in the middle of the year. The original partner became so jealous that he attempted to strike partner #2 with a 2x4, but was prevented from doing so by others of the crew. One year the cook at South Pole became pregnant and the National Science Foundation sweated it out until the end of 'winter-over' so they could get the young lady out of there and to New Zealand where the child was born. The U.S. thought if the child was born at the Pole the other Antarctic Treaty countries would believe that this was some sort of planned event to enhance some territorial claim. Seems ridiculous, as the U.S. has no formal claim to any part of Antarctica.

As the mission to Mars is to be such a long mission it would be prudent to avoid a mixed crew and either have all female or all male crew

Cliques. (e.g. military vs. scientist, scientist vs. non-scientist) do they always form?, are they always bad/detrimental?, always good?, how should they be dealt with?)

Cliques never seem to develop although we did have one foursome, 2 Navy and 2 civilians playing bridge regularly. Certainly with a group as large as ours there was a tendency for certain individuals to either drink or otherwise spend time together but none of these groups were ever considered cliques. On a trip to Mars with a 6-man or 6-woman crew I doubt that cliques would develop.

Cultural differences. (Impacts at a personal level? Do loyalties to a “home organization” detract from crew effectiveness? If so, how do you deal with it?)

Each person at the station had a particular job to do and was busy doing it each day. Certainly there was a discrepancy in educational level between the seaman and the young scientists. However, the scientists had respect for the skills that the seaman had and they were called upon frequently to help out on various projects. Classes in mathematics were given and as well as lectures on the scientific work of the station. One foreign national, the Norwegian, was just another member of the crew.

Leadership types and effectiveness. (What works? What doesn't work? Can leadership be split (e.g. a “mission leader” with overall responsibility and a “science leader” with responsibility for mission goals?).

During the IGY the split Navy-civilian leadership plan where there was a Station Leader (Navy) and a Station Scientific Leader (civilian) seemed to work quite well. But these as a rule were large groups of 20 to 100 men. Ellsworth Station was the one station where the leader of the Navy personnel and the civilian scientists was a single individual. This is really the best way to lead an expedition. However in this case the leader was an egomaniac who risked the lives of some of the scientist by allowing them to drive SnoCats hundreds of miles across a heavily crevassed ice shelf without proper radios. He did not want the men to be in communication with any other IGY station to comment on how he was running the station.

I believe a leader who understands the overall objective of the mission, the scientific needs of the scientists and the responsibility he or she has for well being of his crew is a good leader. The leader should not be rigid but rather amenable to ideas and suggestions.

Selection criteria. (What are characteristics / personality traits that should be selected in? What traits should be selected out? Any overt consideration given to balancing traits as the crew is being assembled / selected? Did your criteria change based on experience in the field?)

It seems that a keen interest in the overall project and good training in the scientific discipline to be studied are major factors in selection. In my own case, the psychological exam that I was given at the Chelsea Navy Hospital in preparation for Antarctica was anything but thorough. The appointment was at 11:45 and the doctor must have had a serious lunch date, as these were the two questions and my answers. “Do you like girls?” Yes! Do you chew your fingernails? No! It seemed that I passed my exam and was ready for Antarctica. It seems that the personnel must really know their stuff and are excited by opportunity afforded them to participate in an expedition of exploration. In spite of the careful screening that the National Science Foundation insists on nowadays some people do squeak through and create problems. For a number of years each austral summer season I was the NSF Representative at Pole Station. My job was to go in on the first flight that opens the station on the 1st of November, bringing in the new crew and observe the exchange of duties and monitor how the new crew is adjusting to this new

environment. One year the man selected to be station leader was drinking excessively in the first few weeks and had even threatened a radio operator with a pair of scissors. He was replaced and he left the continent,

For a Mars's mission I would expect selection to be difficult as so many will want to participate in such an historic expedition. The thrill of going to Mars is one thing but the time frame will tax the most dedicated explorer. In some sense one will need to find people who have inner strength and an innate confidence in their own abilities.

Coping strategies. (How to deal with (a) personal irritations, (b) being away from family, (c) conflicting personalities, (d) perceived "imperfections" in other crewmembers, etc.).

On all expeditions there can be minor annoyances of how people eat, how they use foul language, and other personal traits that you might not care to tolerate but one best look at oneself before passing judgment on others. The idea is not to focus on these things. Being away from family can be stressful at times like one fellow at Wilkes whose wife was on a giant spending frenzy for the year. But this is a perturbation of normal behavior and in most distant relationships it was just one person missing the other. In polar expeditions when there might be some sort of disagreement then one person could leave the area until things settled down a bit. Spacecraft do not afford this luxury.

Personal and team motivation. (What helps a team to achieve a successful expedition? What hurt? What personal expectations (going into a mission) helped achieve success? If personal expectations were unreasonable or not met, what was the impact on the team?).

This is the crux of the matter. Luckily on most expeditions that I have participated in all were highly motivated to do their job and to contribute to the overall success of the expedition. I have had two instances leading oversnow traverses where individuals considered their jobs were specifically scientific and that they did not have to help with the mundane tasks of food preparation, and other traverse chores. This was detrimental to the morale of the other crewmembers until they finally agreed to participate. An expedition should be considered as a shared load of responsibilities and if your work or project hits a snag and there is some down time, help someone else.

For Mars, the personnel should be working on projects that they have had a hand in designing so they have some ownership. To merely run an experiment for someone does not afford enough motivation.

Impact of strangers / visitors (even if only by radio / video). (Are there any impacts? If so, what are some examples? What ground rules should be set up, if any, prior to starting the mission?).

Sometimes in isolation the best news from home was no news. In the IGY ham radios were the best means of communications. However, when someone would make a call to his girl friend and she was out for the evening -that never set too well. At Wilkes we never had visitors during the year. Today with e-mail people are in more direct contact

but in my view this takes away from the person's dedication to his work and also importantly, does not let the expedition members bond as well as in days before such fancy communications systems.

Difficulties of reintegration on return from a mission. (What are they? How do you deal with them?).

In general most expedition members have no problem reentering, so called civilization after one or two years on the ice. I do know of at least one fellow who worked on the DEW line for many years as his choice of where on planet earth he wanted to be and being unable to integrate into society that on returning to the States he committed suicide.

ORGANIZATION / MANAGEMENT

Military vs. democratic. (What is your experience with each? What are the advantages and disadvantages of each?)

In a small field expedition I feel that there is hardly any real issue here as there must be a leader and if he is a good leader he will consider views from his team. This can be the case whether the participants are military or civilian. Many a civilian mountaineering expedition has failed because of leadership that was too dictatorial.

Public affairs. (Was this required to accomplish any aspect of the mission? Were you dependent in any way on a public affairs group (e.g. to generate funding or to develop political support)? If Public Affairs was involved during the mission, did they put any "spin" on any of the reports released? If the "spin" was different from the report made by the team, did that affect the team and in what fashion? Did the team feel that any of the "spins" were made for "political correctness" and, if so, how did this affect the team? Any other personal thoughts on the impact of Public Affairs on individuals or the team?)

Much of the work I was involved in as Program Manager of Glaciology at the National Science Foundation did have a public affairs aspect. As we were doing deep ice core drilling in Greenland and Antarctica the media was always interested in our progress and results. One effort to drill through the Ross Ice Shelf (425 meters) became a bit of a problem when the drill got stuck at a depth of 330 meters and all the drill stem was thus lost which was needed for a planned drilling into the sediment below the shelf. This fiasco prevented many scientists from conducting their projects and as they were already in New Zealand I had to fly from McMurdo to Christchurch and tell them that their field season was over. An investigation of this drilling snafu never really cleared up the incident, as the drillers were reluctant to tell the truth. This damaged the ice-drilling program for a number of years. I felt it would have been better for them to own up to their error rather than to stonewall.

As one encourages the media when you are doing great things it seems reasonable that one should be open when things don't go as planned.

TRAINING

(What level of training fidelity is necessary prior to the mission? Of what values are analog sites? When does it make sense to go to analog sites?).

As for my glaciological training before going to Antarctica I worked with (1) the Norwegian Polar Institute on glaciers in Norway in the summer of 1953; (2) the Snow, Ice, and Permafrost Research Establishment (SIPRE) in Greenland in the summer of 1954; (3) Geographical Institute of the University of Stockholm on glaciers in northern Sweden; and (4) a group of international glaciologists preparing to go to Antarctica, in Greenland in the summer of 1956. So my training was thorough before heading to the field for a year. Training in one's scientific discipline is paramount to achieve the maximum benefit of being in a remote part of man's universe.

PLANNING / LOGISTICS

(How were types and quantities of supplies and equipment estimated for very long missions, especially in unknown locations? How well (typically) did plans match operations and how much "buffer" was added to account for uncertainties? What criteria were used to decide which spares and the quantity of spares to take along? What criteria/process was used to decide which spares and the quantity of spares to take along? What criteria/process was used to judge when technology/equipment was "good enough" to be relied upon in the field? Food: Types? Quantity? Variety? Personal preferences (especially if conflicting)? Cultural preferences: what impact does this have on a multicultural crew?)

In planning for the glaciological work at Wilkes I had free rein to select and purchase necessary equipment up to a point. Most glaciological equipment at that time was not particularly sophisticated and was readily available. We had everything we needed except a good theodolite. We worked with what we had. At the IGY stations there was more than enough good food and when we prepared for field operations away from base we were able to select whatever we wanted.

As noted before we had two years supply of food and fuel at Wilkes which was a good safety margin. As for Mars one might consider a major safety margin in food supplies. There will certainly be particular preferences for special foods by international participants. As a young man with a Norwegian expedition I learned to eat codfish roe. Personnel need to be able to expand their tastes in food. As there certainly will be no smoking on a trip to Mars it brings up another vice, habit, tradition, need, or whatever – LIQUOR. With Russian participants vodka would certainly be a must. I think the liquor question might be one of your more vexing ones to handle.

OPERATIONS

The operations and science plans will govern the skill types and mix. There should be as much overlap as possible. Crewmembers should have as much electronic and mechanical

ability as possible. A person who is all thumbs is not recommended. I applied to be an astronaut (I like to think I was not accepted in the program as I was too close to the upper age limit) and it is just as well that I was not accepted, as I am not very mechanically inclined. At Wilkes Station the magnetic, seismological, and aurora programs were run by individual scientists but the glaciological program had three men as there was considerable field work involved, digging snow pits, measuring glacier movement, and there was the safety factor of three men when dangerous areas were to be crossed.

For a Mars mission one could send a crew of four but when one considers traversing the planet by vehicles and the need for back up and safety, a crew of six seems more reasonable. However, having six instead of four requires that the food, water, and oxygen supplies are half again as large.

Crew quarters need not be spacious but they should be private and quiet.

As for medical support it is my opinion that it should be provided by a doctor who is a general practitioner who is already working in a remote environment, rural is good enough. He is the kind of doctor who has to handle all kinds of situations as opposed to the big city doctor who is close to all kinds of cutting-edge instrumentation and specialists. As a rule the big city doctor does not have the confidence of the rural doctor.

As for recreation I do not recommend a swimming pool – unless there is a lot more water on Mars than is supposed. It will be necessary for each of the crew to consider what would they enjoy doing at times when all is going well and they have time for a break. In the Antarctic we had a different movie each week with the old projectors and the big reels. Now with discs that contain movies these should be taken along. Books will be too heavy to take in number so again discs might be used. Certainly some simple lightweight exercise equipment would be advisable.

GENERAL

Many men and women whether they were inventors, scientists, medical researchers, explorers, or astronauts have all taken various risks to gain more knowledge about our planet and its surroundings. As Fridtjof Nansen said “When man loses his thirst for knowledge he will no longer be man.”

The support in Antarctica is better than it has ever been but with more people involved there has been an increase in the rules of engagement of the continent. When I was there in 1957 I was able to decide where and when we would go into the field and I was free to explore at will. Now one can't walk very far from any base for there are limits.

I would certainly go to Mars. Family is certainly important to me but my thirst for exploring the unknown is still with me. Crossing parts of Antarctica where no one had ever been before was such a thrill that I would jump at the chance to go to Mars as a geologist. I believe I have the right temperament, concern for others, and a sense of humor. I am ready to go even at my age of 71.

3.4 M. Giovinetto Response

INTERPERSONAL ASPECTS

Conflict resolution (What techniques seem to work the best? Is their effectiveness dependent on the situation or personalities? What techniques should be avoided?)

Full information should be provided by all individuals involved in a particular conflict. It will follow that whatever resolution is arrived at, it will be the one that produces the minimum amount of resentment between parties, and also provide helpful insight that is likely to help minimize future conflicts.

Unique aspects of a situation and/or personalities have a bearing on any resolution, and therefore there are limits to the generalization stated above. For example, nobody is going to engage in full information exchange during an 'operational' emergency, but the whole group (i.e. those involved as well as those who were not) should discuss it afterwards. In the case of 'personal' conflicts, it would be best if it was discussed only among the affected parties; the discussion could be extended to include a third party if one or both conflicting parties feel that it would be beneficial. Considering the full spectrum of possibilities, should a conflict reach some critical stage, however unlikely, it might be useful if all parties in an international team agree what set of laws will apply (e.g. international maritime law, IATA's, US, etc.).

A practice that should generally be avoided in conflict resolution is for somebody in charge to give instructions to one or more of the parties involved – although clearly a particular situation may necessitate this (see 'Leadership types and effectiveness').

Gender mix. (What ratios seem to work the best? What ratios should be avoided? What other aspects should be discussed as they affect crew effectiveness?)

Concepts of all-male and all-female crews were mentioned by others at the workshop. On the assumption that there will be more than one crew in training, at least one crew should be mixed, if nothing else to learn for future missions. However, it could well be that at the time of final selection, the mixed crew is a better team and then it should be selected for the mission. One hopes that function-dedicated, mission-oriented people would possess the maturity required to control sexual desires and/or emotional needs for 2-3 years. When training time is considered (4-5 years?), the whole project would imply a long association between team members of different gender. Ideally, if each team member was married to -or had a stable relationship with- somebody outside the project, and if couples (and their families) interacted socially (this does NOT imply that friendships need develop), it would allow individuals to have a larger perspective of each other regarding emotional attachments.

In the case of a mixed crew, the gender ratio is of lesser importance than ensuring that a particular gender is represented by at least two individuals. [Personally, I would not be

affected if there were females in a team, or if a female was in charge of the mission or of the particular tasks assigned to me.]

Cliques. (e.g. military vs. scientist, scientist vs. non-scientist) do they always form?, are they always bad/detrimental?, always good?, how should they be dealt with?)

It is hard to conceive cliques (military vs. civilian, scientists vs. non-scientists) developing in a small team. It is probable that groupings may develop between e.g. those who are outgoing and those who are reserved, but associations between outgoing and reserved individuals are also common.

In many cases, it is not that a clique has formed; rather, some individuals might construe that a clique exists simply because they feel excluded from a group regularly sharing some traits. For example, if two or three individuals practice conversational humor in which they ridicule themselves, it is quite probable that other individuals in the team may feel excluded. A first approximation solution to this is for those who feel excluded to “enjoy the show”, or feel positive to the fact that others in the group are having “a good time”, rather than asking that the practice stop, or that it be extended to include those who feel left out. Such an inclusion would normally be out of character, as it would be to recommend that the person who feels excluded attempt joining the group; attempts such as these would normally make the situation worse than it was.

Cultural differences. (Impacts at a personal level? Do loyalties to a “home organization” detract from crew effectiveness? If so, how do you deal with it?)

Cultural differences are very important and have to be given full attention. Reactions to e.g. touch, sound level of voice, body language, body odor, mannerisms, repetitious gestures, etc., would have to be eliminated or minimized as a source of conflict. It is a two-way exercise, with some individuals eliminating or minimizing their ‘offensive’ ways, and others learning to accept parts of the ‘offensive’ behavior in others.

Loyalties, be it to a religion, racial group, nation, political faction, agency, etc. are not a problem unless carried to an extreme where they interfere with the mission. Talking or joking about loyalties may help reduce the possibility of a loyalty becoming an issue. A person not prepared to put on hold a loyalty that may affect others should not be part of the team.

A person that during selection and training sincerely thought that he/she could put a loyalty on hold, but finds that the contrary becomes true during the mission, i.e. the loyalty somehow interferes with the group dynamics, should be prepared to inform others of the change, and whomever is in charge must take the necessary steps, with everybody fully informed, to re-organize activities attenuating the impact of this development as it pertains to operations.

Leadership types and effectiveness. (What works? What doesn't work? Can leadership be split (e.g. a "mission leader" with overall responsibility and a "science leader" with responsibility for mission goals?).

[I do not equate leadership with the position of "being in charge". Ideally the person appointed to be in charge is also a leader i.e. a person who inspires or whose opinion is normally respected as being among the best options.]

In a complex mission, and among reasonable adults, however, it should be possible to accommodate both notions, e.g. a person in charge accepts what a leader in the group proposes on a particular aspect of maintenance, traverse activity, etc. Everybody should be prepared to the possibility that out-of-plan, a leader for a particular activity may emerge during the mission. This should not become an important issue, and should not necessarily require that the change be formalized with a change of designation.

It is possible to conceive a split-leadership mission in which e.g. the pilot is in command of all phases involving space craft operations, and a station chief is in charge of surface operations. However, missions of the type being planned are highly dependent on spacecraft as well as installations and vehicles that are, for practical purposes, 'extensions' of spacecraft, and the group is small – therefore it should not be encumbered with complex hierarchy. In other sections (below) it is suggested that the pilot be in charge of the mission (it follows that if he or she were disabled, then the copilot would take over that responsibility).

As stated in a preceding section, full disclosure as to why a decision is made or will be made is the best recommendation for lasting confidence on leadership. Giving commands or taking the attitude that there is no need to explain a decision cannot be considered anything but arrogance. Persons in charge must know (and if not, learn) that explaining or informing is a show of respect to all participants, not a subservient or demeaning act that undermines authority. As an opposite to this, if anybody in the party thinks that being informed or having decisions explained is a sign of weakness or insecurity on the part of those in charge, then the person should be excluded from participation in the mission.

Individuals in charge must be able to infer a potential conflict (or act on it, however subtly, as soon as it arises, i.e. the moment somebody complains), and proceed to reduce it or help eliminate it. Typically, this requires the ability to look at situations from the perspective of each of those involved. Members of a crew for a mission of this type will be action oriented individuals, and therefore it is not recommended to implement a common managerial style in which the person in charge listens to the complaint and then waits until "it goes away" (it normally does, in appearance, but it accumulates resentment in at least one of the parties, and this is not a positive development for a small, isolated crew).

Selection criteria. (What are characteristics / personality traits that should be selected in? What traits should be selected out? Any overt consideration given to balancing traits as

the crew is being assembled / selected? Did your criteria change based on experience in the field?

The main selection criteria (beyond basic physical and intellectual requirements of each team member's job) should be manual dexterity, "mechanical" ability (i.e. intuition as to how things work for fast, improvised solutions during emergencies), commitment to function(s), and practical "common sense" (the latter in the context of ability to transfer knowledge for application to similar situations).

The commitment to function(s) must be enthusiastic, but not blinding. The notion that at particular times or, more importantly, from a particular time onward, one's function(s) might change, should be an ever present aspect brought up during selection and training.

Selection panels should be wary of anybody who thinks that his/her function is sacrosanct, or that raves about notions of team spirit as if the mission was a sport event (one should be able to continue doing one's work without the need for team spirit). It would be ideal if team spirit existed for all and throughout the mission. As the ideal might not be attained, each member of the crew should be a strong individual capable of performing his/her work without attitude support from other members. Mission managers, and eventually mission leaders, should not rely on "cheerleader" demonstrations as a boost to morale, or productivity, or to reinforce team spirit. This will be a long mission consisting mainly (not exclusively) of tedious, boring work in a drab, exacting environment that at any moment can turn critical or fatal. The person suitable for this is the type that normally possesses a steady, sober mind, and is therefore unlikely to accept mindless "promotion" schemes found in many management manuals.

The reference to practical "common sense" (above) is to the ability to apply what one learns about, e.g. preparing uncontaminated samples, and transfer pertinent parts of that knowledge to the handling of electronic contacts or refilling hydraulic liquid reservoirs. In the same way that 'common sense' is quite uncommon, there are many otherwise accomplished individuals who are incapable of transferring practical experience. The ability is not limited to technical aspects and might involve e.g. housekeeping. If one learns from a good cook not to scrub down to bare metal the upper surface of a well seasoned cast iron frying pan, one should be able to transfer this notion and not scrub to bare metal the inside of a well seasoned metal coffee pot.

[I don't have any suggestions regarding "balancing traits" or experience on "changing selection criteria". However, regarding the first, I expect that there will be a certain randomness that will tend to balance traits on its own. As to the second, I expect that selection criteria will evolve during the selection and training processes. I assume that there will be three teams assembled for training (A-C), with A considered primary for the mission, B as the substitute team, and C mainly to have access to readily trained individuals to substitute for disabled members in the A or B teams (as well as to provide engineers with an available team to perform actual experimentation of equipment, facilities, etc.). Therefore, I also assume that there would be a broad spectrum of

overlapping sets of selection criteria to choose from and modify, each criteria set being revised at a different pace (?)]

Planners should be concerned about domineering-types, prima donnas, etc., regardless if they have been given command posts or not. Also, any person that is into one-upmanship, or needs to satisfy a feeling of self-importance (e.g. some people, even in quiet ways, need 'to win' or perceive that they have "won" points in conversations regardless of content), should be excluded. At the other end, planners should also be concerned about any individual who favors (however low key it might be) apologizing or retreating as ways to achieve conflict resolution. There are persons who are not timid (actually, feel strong) and who prefer to shrug-off issues; this is not a good trait within a small group engaged in a long mission, as it tends to leave others with uncertainty as to what the person really thinks.

Coping strategies. (How to deal with (a) personal irritations, (b) being away from family, (c) conflicting personalities, (d) perceived "imperfections" in other crewmembers, etc.).

Personal irritations, conflicting personalities, and perceived imperfections in others are issues that can and should be elucidated through discussion, humor, etc., each case being possibly unique – so it is difficult to generalize. Being away from family, or other people one loves, is something that each individual should rationalize way ahead of applying for the mission, let alone start training for the mission, or start the mission itself. In any event, coping with this type of stress may pivot on developing associations with those who can cope, instead of association with those who are under the same stress. Sympathy for, or empathy with a particular feeling, is a good thing to find within the team – but it should not lead to piling up, i.e. two people each suffering more than their own original load.

On shorter missions (Earth orbit or moon missions) there is a need to schedule activities in detail possibly because of frequent, real time dealings with or through Mission Control, and to ensure efficient use relatively limited time. In the longer planetary mission there should be more freedom as to when a specialist will work on his / her task (as opposed to those tasks that are part of the mission activities). For example, if there are samples to be studied (specialty function) and geophysical observations to be made on time (part of the team observational load), a specialist may postpone the study of samples but complete the geophysical observations. In other words, there should be no rigid structure that compels a person to appear to be working. Along these lines, one would expect observations to be more structured during outgoing and returning journeys, less so while on Mars. Also, other than perhaps one or two people that may have to do something for particular periods e.g. on Houston time, the rest of the crew should develop their schedule relative to the local solar ephemeris. Given more knowledge on the intrinsic circadian rhythm, physiologists and others will decide on this, but – as it was mentioned at the workshop – moving into longer rather than shorter "days" might not hamper comfortable adaptation to work on local time (sol).

Personal and team motivation. (What helps a team to achieve a successful expedition? What hurt? What personal expectations (going into a mission) helped achieve success? If personal expectations were unreasonable or not met, what was the impact on the team?).

As team members will be we fully informed of every other individual role or function, and the part each play in the whole scheme, individual and group tasks should be accomplished with a minimum of friction and problems. To this end, team members should be prepared to accept partial “failure” (e.g. if a piece of equipment pivotal to his/her most important scientific task becomes inoperable... this person, disappointed as he or she may be for several days, should be able to willingly support other functions.

Impact of strangers / visitors (even if only by radio / video). (Are there any impacts? If so, what are some examples? What ground rules should be set up, if any, prior to starting the mission?).

AND

Public affairs. {from the ORGANIZATION / MANAGEMENT section} (Was this required to accomplish any aspect of the mission? Were you dependent in any way on a public affairs group (e.g. to generate funding or to develop political support)? If Public Affairs was involved during the mission, did they put any “spin” on any of the reports released? If the “spin” was different from the report made by the team, did that affect the team and in what fashion? Did the team feel that any of the “spins” were made for “political correctness” and, if so, how did this affect the team? Any other personal thoughts on the impact of Public Affairs on individuals or the team?)

Participation on these activities should be, for the most part, voluntary. Leaving aside first transmissions after important phases of the mission, such as take-off, landing, docking, etc., one can imagine that the beginning and end of a few traverses may be characterized as being of public interest. These activities on Mars may require (say) once-a-month ‘public’ contacts. But if one or two members do not feel like actively participating in this or that transmission, it should not be obligatory. More importantly, if any embellished or non-factual information is released (by the team or by mission control or others on Earth directly associated with the mission), the purpose of the release must be explained in full to the team. No member of the team has to agree with the reasons for the release or the contents of the release... but they must be fully informed as to why the releases were made. This would apply to any ‘spin’ imposed on releases by Public Affairs people, for whatever reason. Team members normally feel debased when management or parties outside the team produce and release artificial or incorrect info.

Difficulties of reintegration on return from a mission. (What are they? How do you deal with them?).

Excluding physiological issues related to living for extended periods in low gravity, or zero gravity during the return journey, the difficulties of reintegration could be described as ranging between indifference and a deeply felt irritation toward people’s normal

concerns in everyday life (i.e. the same concerns crew members had in normal, everyday life before they left). It may also extend to aversion of simple gestures and manners, e.g. the passing of serving platters around a large table, particularly when every one feels that he or she has something to say about the food; after two years of having direct reach to serving platters, or not using them, and certainly not having much to say about the food that has been rather the same throughout, it is a trying experience to participate in the “ritual”. Similarly, after becoming accustomed to take literally a few steps to reach everything one can possibly need (i.e. there is nothing else to be had), it is a heavy inconvenience having to drive to stores, and once there having to go through a lot of (to one) unnecessary merchandise, before accessing the wanted item. In the same way, there could be a somewhat negative reaction to dealing with individuals from outside the immediate group. Eventually, after several weeks or a few months, these events fail to cause irritation. Ideally, one could also cope by becoming internally amused by the normal activities of people in everyday life [I was never able to achieve this].

ORGANIZATION / MANAGEMENT

Military vs. democratic. (What is your experience with each? What are the advantages and disadvantages of each?)

The difference between military and democratic (civilian?) organization and management tend to dissipate in the case of small groups engaged in special activities. Everything else being equal, one would expect that if a team is made up of all military or all civilian personnel, potential issues would be minimized. Management of a mixed-background crew could increase the potential for issues to develop. For example, a military person in charge may not be able to accept the apparent ‘lack of respect’ or ‘disorganization’ of civilians in the team, and conversely, a civilian in charge might not provide the orderly structure military personnel may equate with efficiency. Differences of this type, i.e. mainly of perception rather than actual, should be overcome in the early phases of training. There is no problem with voting on issues such as at what time fresh coffee would be made, but the practice should not be frequent or extended to important issues that could lead to alliances (cliques?), however small and short lived these may be.

Leadership types and effectiveness (see above). [Comments on these topics appear in the preceding section]

What kind and how much support is necessary from a remote group (e.g. “mission control”?) How much and what type of information was communicated to and from this remote support group?).

Whereas the kind and amount of support necessary from a remote group varies broadly with activity, it should be expected that in the Mars mission and in the scientific area, there would be anywhere from weekly to monthly exchanges with specialists on Earth. At the workshop it was said that scientists in Antarctica operated independently all the time, and as a generalization this is correct. The range of experience, however, is varied. In the case of the British-Norwegian-Swedish Expedition 1949-52 there was a first-rate

scientist available in each discipline (e.g. Dr. Valter Schytt was a senior, respected glaciologist and member of the expedition). At US bases during the IGY in Antarctica, and in the case of practically all disciplines, the training of field workers ranged from undergraduate up to Ph.D. level, and most were far from being senior in their fields (although eventually some did become respected senior scientists). The Mars mission should be based on the expectation that findings in the field will be discussed with experts on Earth, as needed. The mission cannot be limited to the interpretative power of the field workers, particularly given the time constraints as well as the cost and national character of the mission. The issue of credit in terms of potentially important findings does not arise as communications will be automatically recorded, and who did or said what, when, and where will be fully documented. Clearly one would expect that there would be a delay after a finding, i.e. until the observers in Mars have a chance to figure out what is that they are observing, but there should be no holding back of information until a full interpretation is arrived at, particularly if the observing party is on traverse, and the next move depends on the best guess or interpretation of a recent find.

Public affairs. [see preceding section]

TRAINING

(What level of training fidelity is necessary prior to the mission? Of what values are analog sites? When does it make sense to go to analog sites?).

Other than on technical aspects (flight acceleration, weightlessness, and operation of instruments and equipment), each team should be placed in isolation to perform similar work as expected in the mission for as long as it is practical (say, a three-month stay at a small polar or subpolar camp in winter with no physical contact but nearby an existing station for relatively easy and low-cost set up, move-in or- out in case of problems, etc.)

As an analog site (i.e. the Moon) may not be practical, training should be at sites with at least analog terrain, particularly as it pertains the operation of robotic units and traverse vehicles, field equipment such as the drilling unit, field camp construction, etc. It is assumed that robots (as opposed to traverse vehicles) could readily double as emergency (albeit slow) transport for injured field workers (?).

PLANNING / LOGISTICS

(How were types and quantities of supplies and equipment estimated for very long missions, especially in unknown locations? How well (typically) did plans match operations and how much “buffer” was added to account for uncertainties? What criteria were used to decide which spares and the quantity of spares to take along? What criteria/process was used to decide which spares and the quantity of spares to take along? What criteria/process was used to judge when technology/equipment was “good enough” to be relied upon in the field? Food: Types? Quantity? Variety? Personal preferences (especially if conflicting)? Cultural preferences: what impact does this have on a multicultural crew?)

[The US Navy and NSF decided the quantities of supplies and equipment estimated for all of the 1956 – 1959 Antarctic work on which I base most of my responses – I will indicate when the response is not based on this experience.]

Length of mission and whatever was known or unknown about a location or a region were taken into account.

Typically there was a very good match between plans and the actual operations. Both Byrd (1957) and South Pole (1958) bases had an emergency building to which the crews could retreat in case of destructive fire in the main buildings, and in or around it there were sufficient clothes, food, and fuel to wait for summer and airdrops – the only problem would have been crowded quarters (also poor hygiene, no showers or laundry, no sufficient clothing for periodic changes, and no communications [the latter may be an incorrect perception on my part, but I believe that the radios in the traverse vehicles – and these were not very powerful – were stored in base during the winter].

In traverse operations little attention was paid to safety redundancy because the use of multiple vehicles and radios (despite blackouts of some length) ensured the ability to arrange airdrops in case of emergency (otherwise, every vehicle and attached sledge would have had a share of the food, spare clothes, and fuel should any one unit be lost to fire or a crevasse). [The practice would be drastically different in traverses that did not have the same airdrop backup. The traverse activities of the British-Norwegian-Swedish Antarctic Expedition (BNSAE) 1949-52 would not have had the same backup; however, the traverses from their base, Maudheim, were relatively short. A similar expedition of greater scope, the Commonwealth Trans-Antarctic Expedition (CTAE) 1955-1958, led by Vivian Fuchs (deceased) would be a better source on the criteria developed for self-sufficiency, etc. To my knowledge, in the CTAE three people were entrusted with the general area of supplies, equipment, spares, etc.: David Stratton (overall base and satellite camp supplies), David Pratt (vehicles), and John Lewis (aviation). It might be possible to locate them through C. Swithinbank, and if not by contacting the British Antarctic Survey, or the Scott Polar Research Institute, or the International Glaciological Society, all with addresses in Cambridge, UK. I assume the known large presence of the US Navy (also US Air Force, Marines, and Coast Guard detachments) in the Antarctic starting in late 1955 may have provided more “reassurance” for the CTAE planners than to the BNSAE planners. All said, it is doubtful that criteria developed for the requirements of that time would have any applicability now].

Few spares were carried for vehicles, sleds or instruments in the US traverses (again, relying on air drops as needed was the underlying policy).

Most of the criteria and tests used to judge what technology / equipment were reliable for field work were those developed during and post-WWII by the US military in preparation to operate in the Arctic. Different agencies of the three main branches of the services and other entities under the broad umbrella of the DOD provided everything for the IGY 1957-58 Antarctic work (actually, late 1955 to early 1959). After the IGY, principal

investigators, with grants from the NSF, became more involved in the procurement of camp supplies and vehicles, spare parts, etc. – but the reliance on air support throughout the summer was always a given (i.e. not just to obtain spares from a base on the coast, but from the US as well). [R. Cameron would be a good source on how these changes came about, including the eventual removal of large parts of the naval support, and the reliance on support from subcontractors. Other individuals, for example Phil Smith and Ken Moulton, both ex-NSF residing in the Washington DC area, could be good sources for this type of information. In part, their comments on this topic would cover the question posed under GENERAL (Antarctic infrastructure support: having watch this grow over the years what is better now? What is worse? What should have been left the way it was?)]

Some Antarctic bases from a few countries hosted one or two guests from other nations. No special adjustments were made to accommodate cultural preferences regarding food. Cultural differences could be accommodated in terms of food supplies for special occasions, such as national or religious holidays, even personal special days – a few boxes could be so marked. Whereas an effort along these lines could be made (news media will elaborate on it), the daily fare should be whatever is more convenient in terms of nutrition, weight, variety, shelf-time, preparation, waste, etc., rather than cultural aspects. It is hoped that team members will be “space workers” first, and a number of other things a far second.

The idea of team members eating together at least one daily meal should be extended as much as possible to the other two or three daily meals. The main thrust here is to reduce waste rather than enhancing crew-bonding and planning opportunities. As food wrapping is an important part of the waste mass that accumulates during a mission (NASA/TP-2001-209371, p. 53), and as multi-meal wrapping significantly reduces the waste mass, an all-out effort should be made to reduce the number of individual meals sent with the mission. Obviously, break down packaging would have to be provided for the traverse parties, as well as extended EVA activities.

[At Byrd and South Pole stations, being relatively small (15-18 men) we had three scheduled meals a day, everybody seating at the same time. Occasionally, somebody would have to do with a reheated meal, and those of us who worked longer days (e.g. outside projects or in the snow mine at the South Pole) would have a fourth improvised meal sometime between dinner and breakfast. While on traverse (5-6 men, three vehicles) we were also able to have most meals together. Of course, moving in and out of our vehicles was much simpler than the situation expected in Mars traverses (EVA suits, in and out of pressurized space, etc.).]

OPERATIONS

[On Friday, June 08, comments were requested on crew size, composition and skills; leadership; heated / pressurized volume; food; bathing / hygiene; clothing (washing); room temperature. Of these topics, ‘leadership’ has been covered in a preceding subsection, and I cannot add anything substantial regarding food, and clothing (washing)

beyond the contents of NASA/TP-2001-209371. On “crew composition” – if this covers gender and multinational / multicultural mixes, one would have to look at the actual pool of candidates, otherwise the possibilities are too many to comment here.]

Skill types and mix. AND Crew size: maximum, minimum, odd vs. even.

Assuming that two decades from now technology will prove simpler to use, more reliable systems than those available now, and that communications, transferability of parts among different hardware systems, etc., will be improved, it should be expected that personnel responsible for scientific observations would be able to maintain their equipment and instrumentation. Based on these assumptions but in ignorance e.g. as to what degree the EVA suits are fitted to particular individuals, or the assets that may be allocated to growing plants, and the role of the plants/’soil’ in the overall system, two possible “skill types and mix” charts are prepared (Tables 1 and 2, attached [as Appendix D of this report]).

Preference should be given to the smallest possible crew (five?) rather than to large crews (between six and eight?).

Crew mix and specialties are proposed on the knowledge that findings (particularly those from the European Space Agency’s Mars Express 2003 mission / Mars Advanced Radar for Subsurface and Ionosphere Sounding, and from the Netlander 2005 mission / four-unit ground penetrating radar and seismic instrumentation geared to detect ground ice and groundwater) would present a solid base on which to decide specialties and size of the crew, as well as the mix of their abilities.

There are many notations being left out because they are obvious. One such notation would be that the pilot and copilot should not jointly participate on any traverse activity during the stay on Mars, or that the Physician not be involved in injury prone work..

There is need to have a “physician” – ranging from a “medic” (with practice in ‘emergency room’ / ‘trauma ward’ activities so that in case of accidents he or she would be able to handle a large spectrum of injuries), to a surgeon, although limits in the facilities and absence of specialized support staff for advanced surgery impose a limit on the usefulness of the latter.

The geologist, geophysicist and microbiologist should be able, for the most part, take care of their own equipment and instruments. Clearly some specialties can be transferred between members, and many overlapping abilities can be structured into any team. For example, a number of observations will be made in the area of meteorology and microclimatology, but these can be covered by any two or three members of the crew as base and remote site instrumentation would be fully automatic and eventually provide observations over an area of the order of $10^4 - 10^5 \text{ km}^2$ (it is difficult to imagine that the first mission to Mars would undertake traverses over distances common in the Antarctic today). Operational weather forecasting in terms of phenomena such as dust storms

would have to be made with help from specialists on Earth, who would be monitoring areas of the order of $10^5 - 10^8 \text{ km}^2$.

As an extension of 'policies' leading to the protection of crew members with functions critical to the mission (e.g. the pilot and copilot do not participate in the same traverse, the physician does not participate in high risk work), the use of some equipment might could be scheduled with risk in mind. For example, drilling operations could be tackled in three consecutive stages (shallow, intermediate, and deep, from the first to the third semester of the stay) so as to postpone potentially greater risk of injury to crew due to volatile substances, and of irreparable damage to equipment. However, this gradual increment may not be possible as there could be an overriding necessity to go deep early in the stay, such as search for water or a geothermal source.

The "odd" vs. "even" number for the crew does not appear to be important (unless most operations in and out of stations and vehicles are planned to be performed in pairs). Otherwise, specialties required (and the mix thereof) appears be the only set of criteria that should be used to determine the crew size. (See blood type pairing, under "Medical support"..., below).

Something to consider regarding bathing and hygiene, particularly as it indirectly affects efficient use of water, time for bathing, and directly the issue of hygiene, is the length of head and facial hair. As a first approximation, keeping it short, between 0.2 and 0.5 inch, may be best.

Medical support needed. If so, what types, skills, facilities, etc.

These questions should be submitted to medical staff of the armed forces of the US and other nations that have experience with military exercises in the Arctic bare rock areas (these might be snow covered, but not by glacier ice), and of companies with Arctic experience in mining, gas and oil exploration, etc. If the incidence of types and degree of injuries could be established, then a decision could be made about the abilities and facilities the medical support person should have. It is probable, as stated in a preceding subsection, that the real limit to medical support will be imposed by the facilities that can be provided, as well as the absence of multiple expert assistance normally available for major surgery. The mission, crewed by individuals originally in excellent health, could have e.g. appendix, gall bladder, and tonsils removed (?). More importantly, each crew member, his / her family, and the government of each participating country, should provide 'signed' consent at the outset stipulating the categories of injury or disability, and of care and concomitant diversion of assets that would be allocated to each, clearly ending with the stipulation that in the case of prolonged coma or a condition requiring unavailable expertise or facilities, life will be terminated and the body(ies) put to rest in a manner dictated by non-contamination policies (i.e. same as would apply to debris and trash to be secured before liftoff for the return journey). [I assume cremation is not possible due to energy requirements, but if facilities to grow plants exist, incorporation into the 'soil' may be possible (?)].

It would be convenient to have pairs of individuals with compatible blood. Then, stored blood supply would have to be provided only for the person(s) whose blood is incompatible with others. However, medical advances in the next two decades could modify or eliminate these concerns.

Crew quarters: How much personal / private space...environmental control (lighting, sound)... ability to personalize (private) space....

In the outgoing and return journeys it would be hoped that the craft would have personal space of approximately 4 to 6 m³. At the base on Mars personal space of approximately 8 to 10 m³ should be adequate. The acceptable dimensions for personal space are intertwined with the number of individuals in the crew, the size of general-use spaces (for work, recreation, storage, etc.), and the relative location of the personal spaces to the general-use spaces, sources of noise and vibration, etc.

Temperature should be relatively low; between 5 C and 10 C in the work, eating, and sleeping areas (41 F to 50 F), and between 15 C and 20 C in the exercise and personal hygiene areas (59 F to 68 F). Temperature on pressurized vehicle cabins should be no higher than – 5 C (26 F), where use of light gloves would allow easy handling of controls, writing, etc. [At stations in the interior of Antarctica, the large difference between outside and inside temperature created a problem for those who had to work outside in winter, as described at the workshop. That experience is somewhat irrelevant because the EVA suits offer a heated environment.]

The personalization of private space requires very little (e.g. perhaps a “family” picture, and/or a small copy of a favorite painting or cartoon (?). More important would be to have a widely adjustable bed lamp, although in Mars, where books will be uncommon due to volume and mass (?), books would probably be read on a small, personal use equivalent to today’s LCD / DVD player, presumably the same device crew members could take around to read in other areas, privately view films, etc., as opposed to using workstations, or wall mounted, large screens in common-use areas. There should be a widely adjustable, foldable device holder by the head area of each bunk.

Noise reduction would be important, particularly if it is a problem in the common areas, or if the use of e.g. ear plugs and/or protectors in bed is uncomfortable.

(Recreation (how much and what type(s)?)

Music, movies, books (DVD, read on portable LCD, see above). Games, such as cards and chess [not important to me, but very popular with practically everybody else at Byrd and South Pole stations]. Dice should be banned; they are a source of annoyance to those who do not play. The pursuit of hobbies should be evaluated individually, but it would appear hard to justify any volume or mass in a space mission.

Whatever any crew member wishes to do for recreation should not bother others. Unpopular movies could be viewed by the interested party using a portable, personal

screen and earphones rather than a large screen in a common area with open sound. Particular types of music, unless accepted by all, could be listened to using earphones at a level that does not reach others.

GENERAL

(Why take risks to gather scientific data?)

Multiple reasons, quite different for each person or project, motivate persons to take risks in order to collect scientific data, and any generalization is bound to be weak. Some patterns emerge when one considers a number of colleagues. First is the attraction to adventure, to the unusual for which one has no experience (during childhood and perhaps early teens). Then comes the scientific interest that develops only if acquired knowledge is used as a base to support the imagination process and create new knowledge (say, from late teens onward). Persons that develop along these lines will take risks to gather scientific data for sustained periods, even after the sense of adventure is lost, simply because gaining new knowledge becomes the motivation.

A person can learn about the ideas (existing knowledge) developed by others, but cannot be trained to develop his/her own ideas (new knowledge). Individuals who acquire knowledge and who cannot use it to move forward with new ideas may take risks to gather data only while the sense of adventure lasts. Afterward, the field work will continue, but limited by the changed perception of what constitutes reasonable risk. This could result in lost opportunities to develop new sets of observations.

(Antarctic infrastructure support... (see comments under PLANNING / LOGISTICS)

(If you had a chance to go to Mars, what would you do and why?)

I would prefer to answer this question after the preliminary findings from ESA's Mars Express and Netlander missions are made available. Also helpful would be to know the intended landing site, however tentative this might be (e.g. Valles Marineris at low latitude and elevation?). Moreover, any useful commentary on field work on Mars can only be prepared after learning about the possible capabilities of surface robots and traverse vehicles (e.g. their range in terms of operating time (air, food supply), travel distance without major maintenance, cruise speed, power supply for instrumentation, weight carrying capacity, etc.

OTHER

Notes on design: To the extent that it is possible, the interior of spacecraft and surface habitat should provide the longest possible lines of sight. This implies a minimum use of space dividers. Longest possible lines of sight relate also to provide streamline paths from one part of interior space to another, particularly within a single module. Given the close quarters typical of space installations (far more than those experienced in bases in Antarctica and Greenland, but less so than in submarines), efforts should be made to

attenuate the perception of being in small spaces or crowded conditions. For example, if one is alone and moving through a passage, having to adjust motion up or down, left or right (however slightly) makes one more conscious of being in a small space. In the case of two individuals converging toward a relatively narrow passage, being able to adjust direction at a distance of (say) 12 ft from the other person allows both parties to continue moving at the same speed, but if the distance is 6 ft, there will be hesitation, and one or both parties will adjust direction and change speed -- the latter increasing the awareness of being in a crowded space. Descriptions of these events, each in the singular, totally fail to convey their cumulative effect on the crew when the occurrence is tens of times a day per individual, for hundreds of days.

SUMMARY

The following summary is not intended as a brief of the preceding sections, but as a selection of suggestions made (explicitly or implicitly) on issues that appear not to be part of the mainstream discussion.

1. If the crew is international, state the system of law under which it will operate (unlikely it would be needed, but fair to know). As a ‘tool’, it should be in place before it is needed.
2. Have clear guidelines, signed by all individuals, families, agencies, and countries involved, on how injuries, care, death, body remains, even the possibility of no-return, will be handled. As tragic events might unfold, these should not be open to political or news media intervention.
3. Do not encumber the mission with relatively complex hierarchy, such as split ‘leadership’ -- everything is so dependent on craft of one type or another (base installations are more similar to spacecraft than to buildings), that the pilot and copilot, engineers as they are likely to be or become, should be in charge of the mission. In a highly motivated, intellectually compatible crew with a well planned mission highly constrained by the environment, the person in charge would be closer to a “mission chairperson” than to a “mission commander” or the like. It should not matter what the pilot and copilot are in terms of military / civilian, male / female, etc.
4. A first mission (even if it becomes the only one planned for the foreseeable future) should consist of the smallest possible crew. Everything else being equal, it would be best for a smaller team to have more of everything, even if it means that less observations or interpretations will be made.
5. Unless there are physiological arguments to the contrary, those on Mars should operate on local time, and those relatively few doing support work from Earth should adjust their schedules as needed.
6. Mission planners and managers need to detail the distribution of individual functions on a daily or weekly basis to estimate needs in terms of facilities, systems capacity and

supplies. However, caution should be exercised not to allow this planning to become a regulatory model for actual mission activities. Overall, there should be less ‘regulation’ of team activities for the interplanetary journeys than on previous space work (earth orbit, moon surface work), and far less ‘regulation’ of the team activities for the stay on Mars. The schedule of actual activities should be the responsibility of the team as the mission evolves – in any event, any significant change that could be implemented would likely be discussed with specialists on Earth.

7. Mission designers should attempt to provide interior space with the longest possible lines of sight and streamline paths helping to reduce the impact of inherent small space and crowded conditions.

3.5 C. Swithinbank Response

INTERPERSONAL ASPECTS

Conflict resolution (What techniques seem to work the best? Is their effectiveness dependent on the situation or personalities? What techniques should be avoided?)

While there must be a commander, crew relationships should be those of collaborating members of a team. Conflict resolution depends on the personalities of the parties involved. Many leaders would not interfere with minor conflicts between two people. However, Russian stations in Antarctica have an original method which serves to defuse problems. After an incident, the leader convenes a meeting and asks every member of the party who he feels is to blame. After everyone has spoken, one of the combatants realizes that there is a majority against him, and apologizes to the other.

Gender mix. (What ratios seem to work the best? What ratios should be avoided? What other aspects should be discussed as they affect crew effectiveness?)

For Shuttle missions and months on the Space Station, no problem. But for Mars expeditions, I would avoid it. If it is absolutely necessary, make the mix about equal. I have sometimes been asked about homosexuality during long periods of isolation with an all-male crew, but I have never heard of it happening. It is known that male testosterone levels decrease in the absence of women and that may explain why there are no such problems. With a mixed crew, sex and jealousy could well make life difficult in a confined space over a long period.

Cliques. (e.g. military vs. scientist, scientist vs. non-scientist) do they always form?, are they always bad/detrimental?, always good?, how should they be dealt with?)

Should be broken up as soon as possible. They don't always form and do not occur when crews are chosen carefully. Members must acknowledge their interdependence and never risk isolating anyone.

Cultural differences. (Impacts at a personal level? Do loyalties to a "home organization" detract from crew effectiveness? If so, how do you deal with it?)

Live and let live. In my experience with enthusiastic and dedicated people, cultural differences are irrelevant, and remain so even after 2+ years together. There are more important things to worry about. The principal loyalty of the crew must be to NASA rather than to any other home organization.

Leadership types and effectiveness. (What works? What doesn't work? Can leadership be split (e.g. a "mission leader" with overall responsibility and a "science leader" with responsibility for mission goals?).

Have one leader, never a civil *and* a military leader, which can be a sure recipe for conflict. Scientists take offence at being commanded - but they can be led. With a well-chosen crew, very little if any overt leadership should be necessary.

Selection criteria. (What are characteristics / personality traits that should be selected in? What traits should be selected out? Any overt consideration given to balancing traits as the crew is being assembled / selected? Did your criteria change based on experience in the field?)

Tolerance above all. Avoid excitable people. A wide variety of personalities can be successful, from the "life and soul of the party" to the real loner. Good social mixers are OK but not essential. Respect for each other is the most important aspect. Above all, one is respected for doing one's job properly, come hell or high water. Throughout the 2 years (without a break) of my first expedition to Antarctica (1949-1952), we worked a 364-day year, allowing ourselves half a day off for Christmas. Nobody told us to do it. We just knew what a privilege it was to be there, so could not waste time. Apart from watchkeepers, the day's work extended from breakfast to supper, less a short time for lunch. Each member of the group was psychologically self-sufficient and motivated.

Rest days

Days off risk emotional problems - for which one has no time in a busy day. I have seen idleness lead to worry, lethargy and troublemaking. But unnecessarily structured days (such as official working hours) can be counter-productive. NASA may already have learned this, according to page 64 of NASA/TP-2001-209371: "After falling behind schedule in Skylab 4, the crew moved to a looser format. Each member made more choices about what they did and when. The crew enjoyed this and became more productive."

Coping strategies. (How to deal with (a) personal irritations, (b) being away from family, (c) conflicting personalities, (d) perceived "imperfections" in other crewmembers, etc.).

It all boils down to tolerance. Prima donnas should be avoided at all costs. Even if you are disgusted by a colleague who picks his nose, avoid confrontation because you can bet that you too have some awful habit - like eating with your mouth open. Morale is not dependent on square meters per person.

Personal and team motivation. (What helps a team to achieve a successful expedition? What hurt? What personal expectations (going into a mission) helped achieve success? If personal expectations were unreasonable or not met, what was the impact on the team?).

Enthusiasm for the project should provide all the motivation needed. Motivation must be from within each crewmember. Lack of enthusiasm can lead to a desire for entertainment and rest periods.

Impact of strangers / visitors (even if only by radio / video). (Are there any impacts? If so, what are some examples? What ground rules should be set up, if any, prior to starting the mission?).

If you do not know about family crises at home you do not worry about them. This is normally self-regulatory in that neither side wants to worry the other. Nobody can help from a million miles away anyway, so best not to know. Radio, video and music can be a major cause of friction because of differing tastes. Headphones provide for both choice and privacy without infringing on the privacy of others.

What kind and how much support is necessary from a remote group (e.g. “mission control”?) How much and what type of information was communicated to and from this remote support group?).

Interference from “mission control” should be avoided wherever possible, because there is little they can do for you. When necessary, communicate on safety issues, but make your own decisions.

Public affairs. (Was this required to accomplish any aspect of the mission? Were you dependent in any way on a public affairs group (e.g. to generate funding or to develop political support)? If Public Affairs was involved during the mission, did they put any “spin” on any of the reports released? If the “spin” was different from the report made by the team, did that affect the team and in what fashion? Did the team feel that any of the “spins” were made for “political correctness” and, if so, how did this affect the team? Any other personal thoughts on the impact of Public Affairs on individuals or the team?)

As little as possible except to allay fears back home, which can escalate rapidly if not controlled.

TRAINING

(What level of training fidelity is necessary prior to the mission? Of what values are analog sites? When does it make sense to go to analog sites?).

The team should have as much training as possible, but enthusiasm can overcome anything. Analog sites can be useful in ramming home the realities of isolation.

PLANNING / LOGISTICS

(How were types and quantities of supplies and equipment estimated for very long missions, especially in unknown locations? How well (typically) did plans match operations and how much “buffer” was added to account for uncertainties? What criteria were used to decide which spares and the quantity of spares to take along? What criteria/process was used to decide which spares and the quantity of spares to take along? What criteria/process was used to judge when technology/equipment was “good enough” to be relied upon in the field?)

Quantities of supplies must be estimated but plan for the unexpected. Take enough for the planned expedition plus enough to last until help can arrive. Experience is the only criterion when determining spares stocking. Equipment and technology are “good enough” if they do the job, but there must be contingency planning in case they don't.

Food: Types? Quantity? Variety? Personal preferences (especially if conflicting)? Cultural preferences: what impact does this have on a multicultural crew?)

Perhaps mostly dehydrated if water is found. I experienced my worst meals with the Russians – boiled potatoes and nothing else. Sometimes they served up a bone with something clinging to it – about one teaspoon of lean meat. I found the food on American stations to be luxury gourmet standard. But when you are hungry you can tolerate just about anything, including the same menu every day, so long as it is nourishing. On Antarctic journeys we had pemmican, a variety of dried minced beef with lots of fat (against cold) which was made into soup – sometimes thickened with potato powder. We had oatmeal in the morning and hot chocolate as a warm beverage. Every day's meal was the same for up to 6 months on the trail, and I had no complaint.

OPERATIONS

Crew size

Six may be necessary to achieve the right skill mix. Four is the minimum. Three could create a two-against-one situation.

Crew quarters: How much personal / private space...environmental control (lighting, sound)... ability to personalize (private) space....

We found that private quarters of three square meters with a privacy curtain was adequate. Light is important, but unavoidable sound from generator or instruments does not matter. Sound systems are fine if they don't impinge on others. The habitat temperature can also be a factor in comfort. We kept our temperature at around 15 degrees C and wore sweaters. Showers were infrequent because of the energy cost of making water. Lower temperatures avoided body odor, which can create difficulty for those with a keen sense of smell. US Antarctic stations prefer higher temperatures so they can sit around in T-shirts, but this necessitates more frequent showers.

Medical support needed. If so, what types, skills, facilities, etc.

The doctor must be prepared for anything. Accidents and emergencies do happen. A Russian doctor in the Antarctic took out his own appendix and our doctor in 1951 took out a colleague's injured eye. Serious dentistry skills are always needed, not simply temporary fillings. Our doctor even did successful root fillings to save teeth. Because the crew is healthy 99% of the time, the doctor is not generally overworked. With not enough to do, he can become a psychological busybody and interfere in other affairs where he is not wanted. On a Mars mission, medicine must be just one of his skills.

(Recreation (how much and what type(s)?)

Most people will not have much time for recreation. It is a matter of personal choice. Exercising on machines or EVAs must of course be compulsory.

GENERAL

(Why take risks to gather scientific data?)

It is human nature. Curiosity is the driving force of science.

Infrastructure

The crew will be happy in their isolation and will not want much instruction from home. Besides, the guys back home don't understand what you are facing. In my Antarctic experience, infrastructure has steadily improved, but field parties must always be left to take their own decisions. Only on the spot can they evaluate risk versus reward.

Travel

Temperatures of -100 degrees C should not be a problem. That is not much different from the -89 degrees recorded at Vostok station in Antarctica. We have to limit the time out of doors because facemasks get iced up. But that should not happen in an EVA suit. Lightweight vehicles will be needed and dehydrated rations (if water is found) will be best. Avoidable weight will reduce the range of travel. Vehicles must have very generous first-aid kits including morphine. Pots and crockery can be cleaned without water. We used toilet paper to clean our hard plastic utensils and stainless steel pans - never water.

Specialization

Over-specialization can be bad. In Mars missions, the crew must have their eyes in every direction, because there will be many serendipitous discoveries, perhaps in branches of science not represented among the crew. In 1950, our doctor was bored one day and turned over a rock. Underneath he found mites that later we learned were of a new genus and a new species. Now they are named after him.

The first manned Mars mission

It will be the most important voyage of exploration in human history. I would jump at the opportunity to go. In Earthbound exploration we are used to taking risks, but we go to great lengths to minimize them. On Mars the risks will be greater, so we would make greater efforts to minimize them.

4.0 OTHER COMMENTS AND OBSERVATIONS

Personnel from JSC made several presentations during the second morning of the workshop. These presentations were intended to augment the facilities tours conducted the day before. Three of these presentations will be summarized here: relevant astronaut training activities, field testing of surface EVA suits, and development of relevant mission support/mission control techniques and protocols.

4.1 Astronaut Office Training Activities

Shannon Lucid, from the Astronaut Office, discussed a number of training activities being used by this office to prepare crews for long duration space missions. Dr. Lucid spent 188 days on the MIR space station (March 22, 1996 through September 26, 1996); this is currently the longest single mission duration for the U.S. Astronaut Corps experience base. She pointed out that she was one of seven astronauts that flew on MIR as part of the Phase 1 program (“Phase 1” being part of the International Space Station program to reintroduce long duration space mission experience into the Astronaut Corps). Dr. Lucid noted that, even though each of the seven astronauts had a different mission and differing personal experiences, they all agreed that one of the most important training lessons that future crews should experience is how to deal with the interpersonal aspects of the mission. This includes knowing how to deal with the makeup of the crew and the leadership structure of the crew. As a result of this consensus, a training program was started and continues to evolve (Dr. Lucid specifically requested comments or suggestions from the panel). Although astronaut training flow does not always allow for this sequence, the following steps are presented in the order in which they should ideally be experienced:

1. A workshop discussing a variety of background information related to long duration missions. This would include lessons learned from historical missions of exploration on Earth, including specifically those in the polar regions, as well as lessons learned from space flight, including Skylab and the Phase 1 programs. In both of these cases emphasis would be placed on coping mechanisms that can be used by the crew. This comes about because we will never be able to assign the perfect mixture of individuals to make up a crew. Cultural issues would also be discussed to raise awareness of this aspect of interpersonal relations. Finally, the medical aspects of long duration flight would be discussed.
2. An outdoor team building activity. The purpose of this activity would be to develop a sense of teamwork as well as both leadership and “followership” in a busy, fairly high stress environment. Several options were considered for this training, including spending time at the Canadian military’s training facility at Cold Lake, Alberta, during the middle of winter. The Astronaut Office decided that the National Outdoor Leadership School (NOLS) tries to instill a culture that is the closest to that sought by this Office for long duration missions. Several members of the Office have already participated in one of these training courses and this program will continue to be used for the foreseeable future.

3. An indoor team building and personal introspection activity. As a contrast to the intended high activity environment of the outdoor training exercise, an indoor event was also prepared during which there would purposely be a minimum of activity and structure. It was recognized by the Astronaut Office that, while there will certainly be periods of high activity during long duration missions, there is also a probability of extended periods of inactivity that provides a different type of stress on a crew. For this exercise, a group of astronauts was placed in one of the JSC test chambers (previously used for testing life support systems) for one week. They were given a small bag in which to pack any personal items they thought they would need for this exercise. Their only assignment was to prepare a vaguely defined briefing for management describing the training and what they, as a group, learned from the experience. Other than that, the only communication with the outside world was a call once per day to ensure that the group was OK. In addition to experiencing this extended period of loosely structured inactivity, this exercise was intended to give these ISS crew candidates time to think about why they were really going on a long duration mission and to decide how they would deal with this type of environment, particularly a lack of communication with family and friends.

Comments from the invited participants at the conclusion of this briefing indicated that they thought all of these activities were very useful, and that the indoor training exercise in particular was, in their experience, an aspect that commonly occurs but which is given very little consideration prior to an expedition.

4.2 Development and Testing of EVA Suits for Surface Exploration

Joe Kosmo currently directs the development and testing of advanced EVA suits for surface exploration activities at JSC. Mr. Kosmo's experience extends back to the development of the EVA suits used by the Apollo astronauts for lunar surface exploration. The invited participants had visited his shops and indoor testing facilities at JSC on the first day of the workshop. During this presentation Mr. Kosmo described several field tests conducted during the past several years at various locations in the American Southwest and the lessons learned from these tests.

Mr. Kosmo pointed out to this group that the only EVA experience we have on another planet was accumulated during the Apollo missions – 30 years ago – by 14 people, totally 82 hours of actual surface exploration time. This same group covered a total of 59.6 miles (95.4 kilometers) in traverse distance. He went on to remind the group that we have no firm plans to go back to any planet, making it difficult to set goals or milestones for development of these technologies. Mr. Kosmo did indicate that we do have a low level of on-going field-testing and technology development as indicated in the following table.

Table 4.1 Recent remote field site EVA test activities

Date	Location	Objectives
March 1997	Death Valley, CA	Shirtsleeve evaluation of field geologist mobility activities while conducting exploration task exercises in various terrain features.
May 1998	Flagstaff, AZ (various areas, including Apollo training areas)	Baseline space suit mobility validation activities and evaluation of the liquid air backpack (used in lieu of a full portable life support system that would be required on planetary missions).
February 1999	Silver Lake, CA (Mojave Desert region)	Collaborative effort with NASA Ames Research Center in performing remote field studies to identify and define the synergism and interaction between EVA crewmembers and robotic “assistant” vehicles (in this case, the Russian Marsokhod); also known as the ASRO project.
September 2000	Flagstaff, AZ (various areas, including Apollo training areas)	Conduct combined EVA geology traverse and planetary surface deployment tasks with a robotic “assistant” vehicle (in the case, the JSC-developed ATRV Jr.)

A summary of lessons learned from these exercises that are pertinent to this workshop include:

- Site reconnaissance and dry runs. Of the items noted in this category, two ([1] the need to schedule appropriate time in the overall pre-test timeline for on-site inspection, checkout, and corrective action as required in case of damage, and [2] the need to conduct preliminary site investigations and perform necessary “dry runs” to check site features and planned test operations) have equivalent items in operational missions. Allowing time for unscheduled events and performing a preliminary reconnaissance of interesting sites prior to detailed exploration will both be beneficial features of actual planetary missions.
- Field maintenance and support. Carry adequate spares and hardware components for a wide variety of both anticipated and unanticipated repair or replacement operations: “expect the unexpected”. And to the extent possible, design components for interchangeability with other systems. This helps reduce the total stock of spares that must be brought to the test site [or to an operational mission site].
- Robotic “assistants”. Only limited experience has been acquired with these systems, but their utility and benefit has been recognized. Two observations thus far (based on two different “assistants”, both of which should be considered test devices): first, the EVA crewmember should be given command/control authority for the “assistant”; this is in addition to any automated or teleoperated

command/control system on-board, and, second, provide the “assistant” with a variable rate of traverse speed to better keep up with a walking EVA crewmember.

- Mobility aids. Mobility aids tried thus far, such as a walking staff and a modified ice axe, were essential in providing not only stability in ascending/descending slopes and control over rock/rubble surfaces, but also provided a “rest post” support for the EVA crew member. Additionally, a better space suit walking boot (compared with those tested) is needed. Improvements are needed in flexibility and custom fitting to the individual EVA crewmember.

4.3 Ground Support Operations Planning and Interfaces

Tony Griffith leads the Human Exploration Operations Team within JSC’s Mission Operations Directorate. This team supports a number of activities in addition to future human exploration of other planets, but common to all of these activities is their role of developing and documenting integrated advanced operations concepts applicable to each study effort. Specific activities supported by this team include:

- Strategic operations planning and analog site support
- End-to-end design and conceptual analysis for operations
- Track open work and research unknowns
- Plan for exploration impacts to Mission Operations Directorate core competencies, new operations technologies, and required support facilities

To support all of these assigned activities, this group is overseeing the construction of a facility called the Exploration Payload Operations Facility (ExPOC) within the Mission Control Center (MCC) at JSC. This facility and predecessor temporary facilities have been used to support a number of different simulated missions and the relevant portion of the ground control and support function. Among the simulated missions supported by this group has been a NASA Ames Research Center-led activity known as the Haughton Mars Project (HMP). (This particular activity is a scientific investigation of a number of geologic and biologic features at Haughton Crater on Devon Island in the Canadian arctic that are relevant to understanding data being sent back from Mars.) Among the activities or concepts successfully accomplished while interacting with the HMP team are the following:

- Disciplined use of non-synchronous communication (important when considering the time lag that will characterize future communication with crews on other planets, such as Mars)
- Stored, plotted and planned science traverses
- Gained experience with a number of portable electronic devices (technologies representative of those likely for new support concepts)
- Transmitted nearly 1 Gigabyte of information in just over two weeks supporting the HMP field team

- Routinely supported HMP planning meeting at the remote site – with mixed success
- Tracked and predicted depletion points for selected consumables
- Tracked and accurately forecasted weather at Devon Island
- Successfully worked an in-flight maintenance activity with no advanced coordination (important in helping crews resolve problems in the field for which no advanced training or planning has been conducted)

This experience has been valuable in helping this team validate or modify plans and concepts that otherwise would exist as studies based on past experience and supposition about future crew support needs. However, further work will be necessary to refine and expand these concepts. Future activities likely to be supported by this team and from this facility include:

- EVA field tests as discussed in the previous section, with the remote test site typically located in the American Southwest, although other sites are possible;
- Other analog test facilities or sites, such as the underwater Aquarius facility, located in the Florida Keys and operated by the University of North Carolina at Wilmington for the National Oceanic and Atmospheric Administration (NOAA).

Tests at these sites and facilities will be used to compare and contrast results already obtained from previous tests, thus helping to strengthen the applicability of mission support and mission control concepts developed by this team.

4.4 Observations from Group Discussions

Some selected observations extracted from the oral discussions (the order of these items is more chronological and grouped by subject matter than implied relative significance):

- There seemed to be a general consensus among the invited participants that crewmembers should be selected based on tolerance (both of the behavior of others and of the physical environment) and an “easy going” personality. This tends to minimize the number or severity of personal conflicts. However, crewmembers should be highly motivated by the mission, specifically people with a stake in the outcome of the research or mission objectives. Comments indicated that Antarctic crews with these characteristics rarely took days off or suffered from the lack of diversionary entertainment. Charles Swithinbank specifically commented that the crew at Maudheim took off a half day to celebrate Christmas but otherwise worked every day they were on the ice. This internal motivation also minimized the need for a command structure to ensure that mission objectives were met.
- This group also distinguished between leadership and command. This group indicated that the assumed group of highly motivated people chosen for the crew would respond better to individuals that lead the team based on attributes of mutual respect and, to the degree possible, consensus. This did not, however,

eliminate the need for an organization structure in which specific responsibility was assigned to individuals.

- The volume set aside for individual use did not seem to be as important a metric as the need for a place and time where one could be alone. Another comment indicated that a means of volume control was highly desirable – for conversations, personal music, etc.; the use of headphones to listen to recorded media was cited as an example of this.
- Mention was also made of keeping the temperature of heated spaces relatively cool to help minimize body sweat and thus body odor. This in turn helped reduce the need for frequent personal bathing and the resources needed to generate and dispose of bathing water. The two contrasting examples cited were Maudheim where temperatures were kept reasonable low (40 – 50s F) and some U.S. facilities used during the IGY where temperatures were maintained at a level where it was comfortable to walk around in stocking feet. The temperature gradient in the latter case was sufficient to make it quite warm at the height of one's head. The heating plant necessary to maintain these temperatures was, however, quite capable of melting snow and ice for potable water via a heat exchanger.
- Variety and freshness of food did not seem to be a particular concern. With the possible exception of special foods for special occasions, a bland and/or repetitive diet was deemed acceptable.
- The issue of the legal system to be followed by the crew, particularly an international crew, was raised. This was not felt to be a particularly high priority issue but one that should be resolved and agreed to before the mission starts.
- Also raised was the potentially highly emotional issue of injury, illness, and death among the crew. As stated earlier by Mario Giovinetto, there should be “clear guidelines, signed by all individuals, families, agencies, and countries involved, on how injuries, care, death, body remains, even the possibility of no-return, will be handled”. Resolving this issue prior to the mission will help it from becoming divisive or debilitating should it occur during the mission.
- Regarding the question of whether it was better to explore with humans or robots, there seemed to be a consensus that a combination of both was the best solution. Robots are typically better at making measurements that require significant time or precision while humans are better at observing and making serendipitous discoveries. Gathering meteorological data was cited as an example where, during this era, a human being gathered most data in situ, roughly every four hours, by reading an instrument; none of the invited participants would argue with turning this task over to automated devices. However, Charles Swithinbank illustrated the value of serendipity with the example of his camp medical doctor turning over a rock, for no particular reason, and discovering what turned out to be a new species of insect (a mite that was subsequently named for the doctor).

5.0 CONCLUSIONS AND RECOMMENDATIONS

To summarize, the purpose of the workshop described in this report was to discuss plans and preparations for future human planetary surface exploration missions with a select group of Antarctic explorers and obtain an assessment from them based on their experience. To accomplish this, the JSC Exploration Office provided these Antarctic explorers with tours of development, training, and scientific facilities at JSC, as well as documentation describing operational scenarios related to future planetary surface exploration. This invited group then spent two days discussing their observations and assessments related to these facilities and plans, as well as a set of discussion questions prepared before the workshop, with selected technical representatives from the JSC staff. In this regard, the workshop achieved its purpose with the results documented here and on video tape.

5.1 Conclusions

The obvious conclusion that can be drawn from the information in this report is that this workshop represents a valuable contribution to the understanding of how best to explore other planets with human crews. The point of view brought by this group of experts represented another significant facet of this complex problem that needed to be examined by the Exploration Office and the lessons learned incorporated into the overall approach to exploration. The information in this report will contribute to that goal.

To summarize the assessment and recommendations of this invited group:

- As a group, they were impressed with the amount of planning and extent of the training facilities that are being applied to the problem of human planetary exploration.



Figure 5.1. Tour of the Lunar Sample Laboratory facility. From left to right: Dr. Giovinetto, Dr. Gary Lofgren (Lunar Sample Curator), Mary DiJoseph (NASA Headquarters), Dr. Hoffman, Dr. Swithinbank, and Dr. Cameron.

- Both the planning and training being prepared by NASA go well beyond what they experienced for Antarctic exploration. However, they had more opportunities to gain practical experience through on-going programs of polar exploration in advance of their Antarctic expeditions.
- They recommend continuing with as much of this training, both in simulated and analogous environments, as is practicable. Such experience will help reduce the risk to the crews and improve the scientific return from the missions.

5.2 Recommendations

Based on the information gathered during this workshop and the conclusions just discussed, the following recommendations are made:

1. That NASA, and the Exploration Office in particular, maintain direct contact with the invited participants. They represent a valuable source of expert advice and could serve in a consultative role in the future.
2. The Exploration Office should continue to research historical examples of relevant human exploration and incorporate lessons learned into the planetary exploration “reference missions”.
3. The Advanced Programs Office of NASA Headquarters/Code M or the Exploration Office should establish direct contact with the NSF Department of Polar Programs and its supporting organizations (e.g., the Scientific Committee on Antarctic Research – SCAR). This direct contact would be primarily for the purpose of identifying cooperative, mutually beneficial areas of “exploration research”.
4. These same two offices should investigate establishing direct contact with other U.S. government or international organizations with comparable relevant and on-going programs similar to NASA’s human exploration program. Examples include, but are not limited to, NOAA (U.S.), DoD (U.S.), and SPRI (U.K.)
5. The Exploration Office should include periodic reviews/assessments of its mission plans, training program, and facilities by outside experienced personnel as a regular part of the on-going development in this area of human planetary exploration.
6. As an element of items 3. and 4., establish and maintain (where feasible) direct participation by NASA personnel in analogous field research/exploration opportunities. The purpose for this participation is to build relevant direct experience among those charged with planning and developing the tools and operations that will be needed for future planetary exploration.

6.0 REFERENCES

- Budden, N. (1999), Mars Field Geology, Biology and Paleontology Workshop: Summary and Conclusions, LPI Contribution Number 968, Lunar and Planetary Institute, Houston, Texas, 1999.
- Bull, C. (1971), “Snow Accumulation in Antarctica” pp. 367-421 in Research in the Antarctic, AAAS Pub. 93, Washington, D. C., 1971, 768p.
- Drake, B. (1998), Reference Mission Version 3.0; Addendum to the Human Exploration of Mars: The Reference Mission of the NASA Mars Exploration Study Team, Report No. EX13-98-036, NASA Johnson Space Center, Houston, Texas, June 1998.
- Duke, M. (1997), Mars Surface Mission Workshop, LPI Contribution Number 934, Lunar and Planetary Institute, Houston, Texas, 1997.
- Hoffman, S. and Kaplan, D., (1997), Human Exploration of Mars: The Reference Mission of the NASA Mars Exploration Study Team, NASA Special Publication 6107, NASA Lyndon B. Johnson Space Center, Houston TX, July, 1997.
- Hoffman, S. (2001), The Mars Surface Reference Mission: A Description of Human and Robotic Surface Activities, NASA Technical Publication 2001-209371, NASA Lyndon B. Johnson Space Center, Houston TX, August, 2001.
- Kosmo, J. (1998), “Remote Field Site Space Suit Mobility Study Test Report; Flagstaff, AZ, May 2-17, 1998”, JSC 39096, NASA Johnson Space Center, Houston, TX, June 3, 1998. (Available from J. Kosmo only at JSC)
- Kosmo, J. and et. al. (1999), “Results and Findings of the Astronaut-Rover (ASRO); Remote Field Site Test Silver Lake, CA (Mojave Desert), Feb. 22-25, 1999”, JSC 39261, NASA Johnson Space Center, Houston, TX, March 3, 1999. (Available from J. Kosmo only at JSC)
- Kosmo, J., and Ross, A. (2000), “Results and Findings of the Representative Planetary Surface EVA Deployment Task Activities; Remote Field Site Test Location Flagstaff, AZ (Sept. 2-15, 2000)”, JSC 40106, NASA Johnson Space Center, Houston, TX, October 25, 2000. (Available from J. Kosmo only at JSC)
- Long, M. (1999), “Mars on Earth”, National Geographic, Vol. 196, No. 1, July 1999, pp. 34-51.
- Sharp, R. P. (1956), “Objective of Antarctic Glaciological Research”, pp. 27-35 in Antarctica in the International Geophysical Year, American Geophysical Union, Washington, D. C., 1956.

Stoker, C. R. et. al. (2001), "The 1999 Marsokhod rover mission simulation at Silver Lake, California: Mission overview, data sets, and summary of results", *Journal of Geophysical Research - Planets* - Vol. 106, No. E4, April 25, 2001.

Stuster, J. (1996), Bold Endeavors: Lessons from Polar and Space Exploration. Annapolis, MA: Naval Institute Press, 1996.

Swithinbank, Charles (1999), Foothold on Antarctica: The First International Expedition (1949 – 1952) Through the Eyes of its Youngest Member, The Book Guild, Ltd., Sussex, England, 1999. (ISBN 1-85776-406-4)

Synthesis Group (1991), America at the Threshold: Report of the Synthesis Group on America's Space Exploration Initiative, U.S. Government Printing Office, Washington D.C., May 1991.

Von Braun, W. (1953), The Mars Project, University of Illinois Press, Urbana, IL, 1953.

Zubrin, Robert (1991), "Mars Direct: A Simple, Robust, and Cost Effective Architecture for the Space Exploration Initiative," AIAA 91-0326, 29th Aerospace Sciences Meeting, held in Reno, NV, 7-10 January 1991.

7.0 BIBLIOGRAPHY

Behrendt, John C., Innocents on the Ice: A Memoir of Antarctic Exploration, 1957, University Press of Colorado, 1998. (ISBN 0-87081-551-2)

Gjaever, John, The White Desert: the Official Account of the Norwegian-British-Swedish Antarctic Expedition, Chatto & Widus, Ltd. (now Random House, UK), London, 1954.

Swithinbank, Charles, Foothold on Antarctica: The First International Expedition (1949 – 1952) Through the Eyes of its Youngest Member, The Book Guild, Ltd., Sussex, England, 1999. (ISBN 1-85776-406-4)

APPENDIX A: NBSX Background

[The following was copied from [http://www.spri.cam.ac.uk/photo/nbsx/nbsxtext\(mod\).html#S2](http://www.spri.cam.ac.uk/photo/nbsx/nbsxtext(mod).html#S2) accessed on August 16, 2001]

Section 1: Introduction

The Norwegian- British- Swedish Expedition (NBSX) of 1949-52 was the first in Antarctica involving an international team of scientists. Its base was located on the coast of Dronning Maud Land -- an area lying between the meridians of 20°W and 45°E which was territory annexed by Norway just before WWII. [see map at right]

Apart from surveys and mapping the main objective was to carry out a wide ranging programme of scientific investigations with particular interest in discovering whether climatic fluctuations similar to those observed in the Arctic were also occurring in Antarctica.

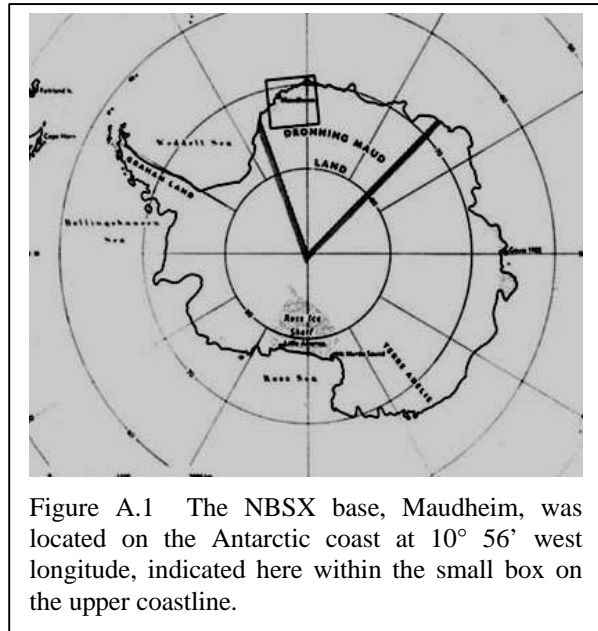


Figure A.1 The NBSX base, Maudheim, was located on the Antarctic coast at 10° 56' west longitude, indicated here within the small box on the upper coastline.

Norway was mainly responsible for meteorology and topographical surveys, Britain for geology and Sweden for glaciology.

Most of the [picture] selection shown here are on glass slides and were taken by Charles Swithinbank.

Section 2: Personnel

The international team consisted at the outset of personnel from Norway, Sweden and the British Commonwealth.

John Giæver (49), Norwegian, leader of the wintering party
Valter Schytt (30), Swedish, chief glaciologist, second-in-command
Gordon de Quetteville Robin (27), Australian, geophysicist, third-in-command
Nils Jørgen Schumacher (30), Norwegian, chief meteorologist
Gösta Liljequist (35), Swedish, assistant meteorologist
Ernest Frederick Roots (26), Canadian, chief geologist
Alan Reece (27), British, assistant geologist
Charles Swithinbank (22), British, assistant glaciologist
Nils Roer (34), Norwegian, topographic surveyor

Ove Wilson (28), Swedish, medical officer
Bertil Ekström (29), Swedish, mechanical engineer
Egil Rogstad (41), Norwegian, radio operator
Peter Melleby (33), Norwegian, in charge of dogs
Schølberg Nilsen (46), Norwegian, cook



Figure A.2 Members of the NBSX wintering party on the day the *Norsel* departed (February 20, 1950). 1. Gordon Robin, 2. Leslie Quar, 3. Nils Roer, 4. Nils Schumacher, 5. Ove Wilson, 6. Ernest Roots, 7. Charles Swithinbank, 8. Egil Rogstad, 9. Bertil Ekström, 10. Alan Reece, 11. Valter Schytt, 12. Gösta Liljequist, 13. John Snarby, 14. Peter Melleby, 15. John Giæver

Some additional members (e.g., Stig Hallgren, Leslie Quar [radio mechanic], John Jelbart, John Snarby [cook; replaced Nilsen before the first winter-over]) joined later on.

Section 3: Transport

The expedition ship *Norsel* was a 600-ton ocean-going sealer powered by a German U-boat diesel engine. On this expedition the ship sailed to Antarctica three times. Since the *Norsel* was too small to transport all men, equipment and supplies from Oslo to the Antarctic base, five of the team and some of the heavier equipment sailed on a large whaling factory-ship, the 24,000 ton *Thorshovdi*, together with 60 dogs (only 40 of which survived the voyage).

In addition, a small five-man RAF group together with two light Auster aircraft accompanied the expedition on the *Norsel*. These planes were intended for reconnaissance.

On subsequent visits of the *Norsel*, a Norwegian and then a Swedish flying unit arrived to carry out a programme of aerial photography.

Heavy transport on the ice used [W]easels -- powerful amphibious tracked vehicles -- which could pull sledges capable of carrying over three tons (see Figure A.3). They were used, for example, to transport hundreds of tons of stores from *Norsel's* unloading dock to the main base on the coast and also to the inland base.



Figure A.3 “Weasels” -- amphibious tracked vehicles developed by the U.S. Army in World War II -- were used to transport people and tow sledges loaded with supplies.

On expeditions to the interior transport was by means of dog teams or [W]easels or occasionally both.

Although no specific use was planned for them, two small boats were brought out. In the event, one did prove its worth when Stig Hallgren, a newly-arrived member of the expedition, was rescued from an ice floe. Unfortunately, three of his companions (Bertil Ekström, Leslie Quar, John Jelbart) were drowned.

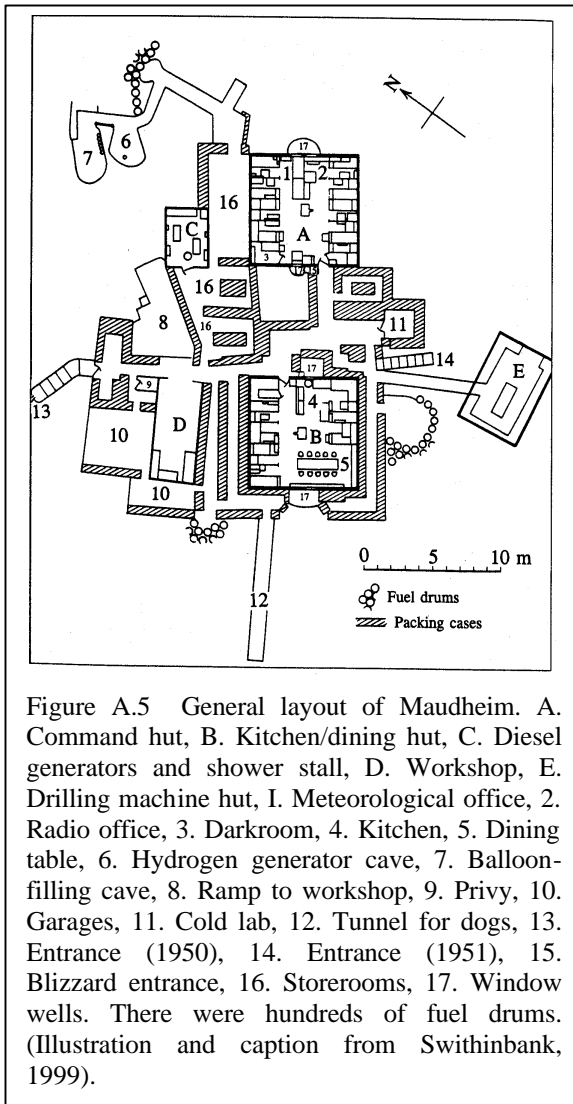


Figure A.4 Maudheim, as seen from the air, under construction. The large structure in the upper left is the first of two huts. Just to the right of this are four men digging the foundation for the second hut.

Section 4: Bases

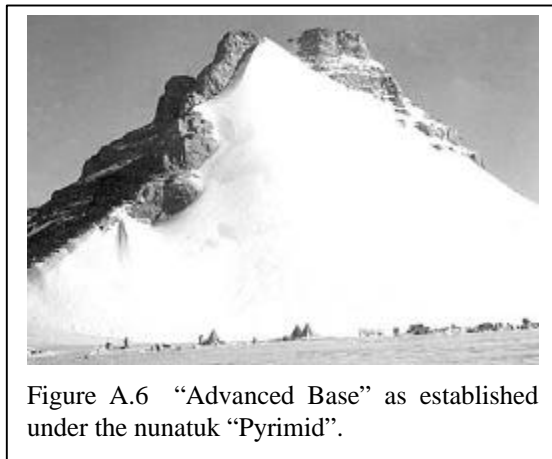
For the full duration of the expedition, Base Camp was established at a location named Maudheim -- $71^{\circ}03'S$, $10^{\circ}55'W$ -- on a floating ice shelf some 3km from an inlet used as an unloading quay for *Norsel*. Several huts for accommodation and the housing of research and communication equipment were assembled there and some 450 tonnes of supplies, sufficient for a stay of up to three years, were transported by [W]easel from the *Norsel*. (See Figures A.4 and A.5.)

About 200 miles from Maudheim, another camp -- Advance Base -- was sited at $72^{\circ}17'S$, $03^{\circ}48'W$, close to a nunatak named the "Pyramid" -- not permanently manned but with tents, stocks of food and fuel available to support field parties (see Figure A.6). In addition, a network of expedition-support depots storing supplies was established away from Maudheim and Advance Base.



main objectives were:

- Reconnaissance: on one of the first of these the location for Advance Base was established.
- Finding crevasse-free routes: this was an important objective.
- Depot laying: for the support of field parties, particularly at Advance Base and at positions along the routes from Maudheim.
- Seismology: possibly the most significant expedition covered a distance of some 800 miles over 80 days during which many measurements were taken of, for instance, ice and rock thickness and ice accumulation. (See Figure A.8)



Section 5: Communications

Radio contact was regularly maintained (generally using telegraphy; see Figure A.7) with Norway and South Africa; and with teams during their journeys into the interior. Conditions could be variable making contact difficult, but overall weather reports were transmitted to Cape Town routinely for the whole duration of the expedition.

Section 6: Expeditions/Journeys

Numerous journeys were undertaken, the longest being of 80 days duration. The





Figure A.8 A seismicology traverse. The lead Weasel tows a supply sledge and a mobile shelter for the seismic equipment. The trailing Weasel tows a heavily laden supply sledge.

- Glaciology: placing and subsequent observation of markers to evaluate glacier movement, snow build-up and temperature levels; drilling out ice-cores to investigate ice formation and temperature.
- Geology: in one instance a joint team journeyed 300 miles carrying out a programme of measurements and rock sampling. (During this

trip Alan Reece sustained damage to an eye, which subsequently had to be removed by the medical officer, Ove Wilson, at Maudheim.)

- Topographical survey: an area of 60,00 sq. km. was mapped by ground survey. The use of aerial photography extended this area to 100,000 sq. km. (See Figure A.9)

Section 7: Scientific Results

In all the above disciplines (and others) a vast amount of data was obtained which yielded much important information.

In addition to the main areas of interest, medical observations were carried out of the reactions of team members to the polar conditions -- of particular value due to the prolonged length of time spent in Antarctica.

Section 8: Conclusions

These are some of the more significant ideas which were eventually generated by the expedition's work:

Glaciology: the proposition that world sea-level was principally controlled by the state of the Antarctic ice-sheet.



Figure A.9 Dr. Swithinbank surveying topographic features.

Meteorology: an improved understanding was developed of the importance of the Antarctic ice-sheets in regulating the world's climate.

Geology: based on the geological findings it was suggested that Dronning Maud Land was once joined to Southern Africa.

Organization: NBSX paved the way for international co-operation in manning and running Antarctic expeditions. It proved to be particularly successful and showed that effective organization was possible with minimum conflict between groups. Such co-operation was a very important feature of the scientific teams active during the International Geophysical Year of 1957-58.

Section 9: Bibliography

Of these, the most well-known published accounts of the expedition are:

GIÆVER, J.
The White Desert
New York, Dutton & Co., 1954, 256p.

A translation from the Norwegian with contributions from other members of the expedition. Well written narrative style.

SWITHINBANK, C.
Foothold on Antarctica
Sussex, England, The Book Guild Ltd., 1999, 260p.

An absorbing and lively narrative account of NBSX by its youngest member. Excellent photographs covering all aspects of the expedition.

ROBERTS, B.
Norwegian-British-Swedish Antarctic Expedition, 1949-52
Polar Record, 1950, Vol. 5, No. 39, pp. 463-466.

ROBIN, G. de Q.
Norwegian-British-Swedish Antarctic Expedition, 1949-52
Polar Record, 1953, Vol. 6, No. 45, pp. 608-614.

ROOTS, E. F.
The Norwegian-British-Swedish Antarctic Expedition, 1949-52
Science News, 1953, No. 26, pp. 9-32.

Text by Claude Cowan based on published sources, edited by Oliver Merrington and Sally Stonehouse, March 2000. HTML by Oliver Merrington. Updated 7 September 2000.

APPENDIX B: IGY BACKGROUND

The following background material was compiled from two sources:

1. From <http://www.nas.edu/history/igy/> accessed on September 28, 2001
2. Unpublished manuscript from Richard Cameron

In 1952 the International Council of Scientific Unions proposed a comprehensive series of global geophysical activities to span the period 1 July 1957 to 31 December 1958. The International Geophysical Year (IGY), as it was called, was modeled on the International Polar Years of 1882-1883 and 1932-1933 and was intended to allow scientists from around the world to take part in a series of coordinated observations of various geophysical phenomena. Although representatives of 46 countries originally agreed to participate in the IGY, by the close of the activity, 67 countries had become involved. Ultimately some 30,000 scientists conducted research at over 1,000 sites including land-based stations, research ships, a floating ice island, and drifting pack ice stations, during the IGY.

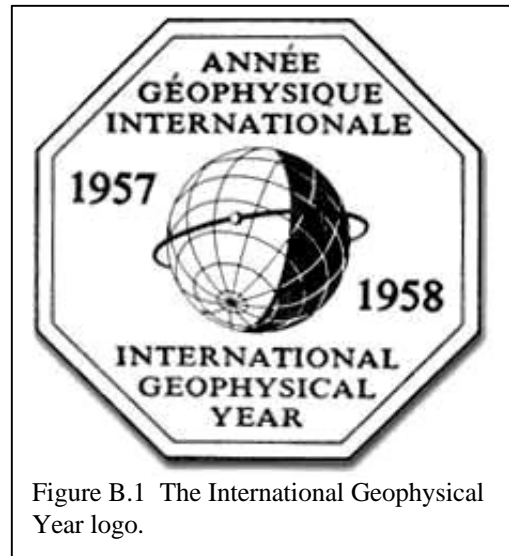


Figure B.1 The International Geophysical Year logo.

American participation in the IGY was charged to a U.S. National Committee (USNC) appointed in March 1953 by the National Academy of Sciences (NAS). The core USNC was made up of sixteen members, but the five Working Groups and thirteen Technical Panels that operated under it eventually drew in nearly 200 additional scientists. The technical panels were formed to pursue work in the following areas: aurora and airglow, cosmic rays, geomagnetism, glaciology, gravity, ionospheric physics, longitude and latitude determination, meteorology, oceanography, rocketry, seismology, and solar activity. In addition, a technical panel was set up to attempt to launch an artificial satellite into orbit around the Earth.

IGY activities literally spanned the globe from the North to the South Poles. Although much work was carried out in the arctic and equatorial regions, special attention was given to the Antarctic, where research on ice depths yielded radically new estimates of the Earth's total ice content. IGY Antarctic research also contributed to improved meteorological prediction, advances in the theoretical analysis of glaciers, and better understanding of seismological phenomena in the Southern Hemisphere.

In 1954-55 the United States began investigating sites for stations for the IGY. The following austral summer it established the McMurdo Sound Air Operation Facility. Of the 65 IGY Antarctic research stations established by 12 nations, the United States operated seven (Table B-1), including the prestigious and scientifically valuable, but

operationally challenging, site at the geographic South Pole. The National Science Foundation funded IGY work through the National Academy of Sciences, and the Department of Defense separately funded and provided operational support.

Table B-1. U.S. Antarctic Stations and their locations as established during the IGY

Station Name	Latitude	Longitude
Byrd	80° 00' S	120° 01' W
Ellsworth	77° 43' S	41° 08' W
Hallett	72° 18' S	170° 18' E
Little America	78° 11' S	162° 10' W
McMurdo	77° 50' S	166° 36' S
South Pole	90° 00' S	N/A
Wilkes	66° 15' S	110° 31' S

The remainder of this Appendix focuses on the activities of the U.S. glaciology program, as these activities were characterized by extensive traverses and exploration of diverse sites across the continent. As such, these activities required planning, preparation, and operations closer to those expected for future planetary missions.

Prior to the IGY, there was but one modern scientific expedition to the continent and that was the Norwegian-British-Swedish Expedition of 1949-52. This expedition is notable in that it undertook ice thickness measurements using seismic methods, made extensive surface glaciological studies of ice movement and snow accumulation, and drilled ice core on the Maudheim Ice Shelf for depth-density and ice fabric studies. This expedition was the model for the U.S. IGY glaciological program. It is also worthy of note that the three young glaciologists on that expedition were to make glaciology their life's work-- Valter Schytt, Gordon Robin, and Charles Swithinbank – each to make major contributions to the discipline.

The U.S. planning for the Antarctic glaciology program was summarized by Sharp (1956) in his article "Objectives of Antarctic Glaciological Research," noting that the program should be guided by the following principles:

1. investigations should concentrate on items which are peculiar to the Antarctic and which cannot be studied efficiently and effectively in more accessible areas;
2. attention should be given, insofar as possible, to basic principles and matters of world-wide significance;
3. efforts should be made to learn as much as possible about the physical state, environment and behavior of Antarctic ice bodies.

Guided by these principles, these were the investigations that were recommended:

1. measurement of ice thickness leading to a reliable calculation of the volume of Antarctic ice primarily by seismic-reflection procedure and gravimetric surveys;
2. observations of variations in the volume of Antarctic ice in the past and measurement of current rates of change;

3. deep core drilling as a means of obtaining data to a depth of 300 meters in the inland ice and the Ross Ice Shelf;
4. determination of firn stratigraphy;
5. studies of thermal regime;
6. studies of crystal fabric;
7. measurement of glacier movement;
8. measurements of rates of accumulation and wastage to determine Antarctic glacier regime;
9. micrometeorological studies;
10. determination of climatic fluctuations as recorded by changes in the size of Antarctic glaciers.

The tasks were therefore set for the glaciology program under the overall direction of Dr. Albert Crary, and glaciologists headed to the Antarctic late in 1956. It was decided that there would be both station glaciology programs as well as oversnow traverse glaciology. Of the seven U. S. IGY stations established in 1955-56, and 1956-57, (Table B-1), only Hallett and McMurdo were not assigned glaciologists.

The station glaciology programs were modified to suit each site as some were on ice shelves (Little America and Ellsworth), some on the inland ice (South Pole and Byrd) and one on the coast where the inland abutted a group of low lying islands (Wilkes). The only one of these stations not situated on the ice was Wilkes but the glaciologists had ready access to the inland ice via an ice ramp. The programs at these stations involved measurement of snow accumulation both by stake and pit studies, ice temperature measurements, determination of the depth-density relationship by excavation of a deep pit (30 m) and general observation of local surface conditions (sastrugi, etc.). An outlet glacier near Wilkes station, the Vanderford Glacier, was accessible to the glaciologists for ice movement studies and at some inland sites ice movement was laboriously calculated from measurements of the deformation of geometric patterns.

Traverses of the inland ice were conducted with two or three Tucker SnoCats and from five to six men. The scientific equipment, food, and fuel were hauled in 2 ½ ton sleds. Logistic support for these field parties was provided by the U. S. Navy flying R4-Ds [the U.S. Navy version of the Douglas DC-3] and the DeHaviland Otter.

The traverse program undertook a diverse scientific program. The surface properties of the snow were studied via pits and coring. The properties at depth, the thickness of the ice, and the nature of the underlying bedrock were determined by exploration geophysics-seismics, gravity and magnetics. In addition, traverse work included reconnaissance geological mapping, collection of lichens, daily weather observations, measured magnetic intensity and declination, gravity observations for geodetic purposes, surface slope measurements and surveying of geographic features for mapping. The workload on such a small party of men for a period of several months was indeed heavy.

The IGY traverses are listed in Table B-2.

Table B-2. Over Snow Traverses conducted by the U.S. during the IGY

Year of Traverse	Traverse Route	Traverse Leader(s)
1956-1957	From Little America Station to Byrd Station	Charles Bentley and Vernon Anderson
1957-1958	From Byrd Station through Marie Byrd Land to Ellsworth Highland and back to Byrd Station.	Charles Bentley and Vernon Anderson
1957-1958	From Little America Station--a circuit of the Ross Ice Shelf	Albert Crary
1957-1958	From Ellsworth Station--exploration of Filchner Ice Shelf	Edwin C. Thiel
1958-1959	From Filchner Ice Shelf to Byrd Station	Jock Pirrit
1958-1959	From Byrd Station to Horlick Mountains	Charles Bentley
1958-1959	From McMurdo Station up Skelton Glacier to East Antarctic ice sheet	Albert Crary

In addition to the station and traverse glaciological program there were two special efforts made during the IGY--they were the Ross Ice Shelf Deformation Project and the ice core drilling at Byrd station and at Little America.

In reviewing the results of this overall glaciology program, one is struck by the great amount of work that was done and by the major contributions it made to our basic knowledge of Antarctica.

- Antarctica was shown to be two distinct geographical entities. East Antarctica, a continental shield, and West Antarctica, an archipelago with vast areas of ice-rock contact well below sea level. At a site 160 m east of Byrd Station the ice measured 4,270 m thick and here the elevation was only 1,780 m so the ice-rock contact was 2,490 m below sea level.
- Snow-accumulation measurements made at the stations and on traverses, and combined with measurements of other nations permitted the preparation of an accumulation map of Antarctica. The average accumulation value of 14 g cm⁻² was calculated for the continent. This compares favorably with the most recent calculation by Bull (1971) of 15.5 +/- 2.0 g cm⁻².
- The mean annual surface air temperature map of Antarctica was prepared from station, traverse and other country observations. It showed that the "cold pole" was in East Antarctica (average temperature of -57° C to -59° C and the lowest recorded temperature of -89° C).
- Ice movement measurements of ice shelf and outlet glaciers were made. The Vanderford Glacier near Wilkes Station was found to be moving 2.1 m/day, the fastest moving glacier to be measured during the IGY.
- At Wilkes Station, the Dry Valleys near McMurdo, and at numerous nunataks evidence of greater ice cover were found.

- The deformation of the Ross Ice Shelf into a series of anticlines, crevasses, and shearing features near Roosevelt Island, not far from Little America, provided insight on ice dynamics of the ice shelf.
- Ice core drilling at Byrd Station (309 m) and at Little America (255 m) provided data on snow accumulation rates, ice fabrics, and records of volcanic activity.
- The thermal conductivity and thermal diffusivity of glacial ice was determined for ice near Wilkes Station.
- Depth-density profiles of firn to 30 m depth were measured at 5 stations.

This program produced a great deal of information but what it really did was to begin the modern scientific study of the entire continent.

APPENDIX C – CURRICULUM VITAE FOR INVITED PARTICIPANTS

C.1 Charles Bentley

PERSONAL DATA

Born December 23, 1929, Rochester, New York

EDUCATION

B.S. Physics, Yale University, 1950

Ph.D. Geophysics, Columbia University, 1959

PREVIOUS POSITIONS

Columbia University...1952 to 1956

Research Geophysicist

Arctic Institute of North America...1956 to 1959

Antarctic geophysical traverse leader

University of Wisconsin-Madison...1959 to 1998

Project Associate from 1959 to 1961; Assistant Professor from 1961 to 1963;

Associate Professor from 1963 to 1968; Professor from 1968 to 1987; A.P. Crary

Professor of Geophysics, Dept. of Geology and Geophysics from 198 to 1998;

A.P. Crary Professor Emeritus of Geophysics, Dept. of Geology and Geophysics from 1998 to present.

PROFESSIONAL AFFILIATIONS

American Association for the Advancement of Science

American Association of University Professors

American Geophysical Union

American Polar Society

American Quaternary Association

International Glaciological Society

Geological Society of America

Oceanography Society

Sigma Xi

Society of Exploration Geophysicists

NATIONAL AND INTERNATIONAL ACTIVITIES

Member, Polar Research Board, National Research Council (1978-1997, chairman 1981-1985)

U.S. member (1981-1997) and vice president (1990-1994), Scientific Committee on Antarctic Research, International Council of Scientific Unions

Vice President, International Commission on Snow and Ice (1987-1995)

Convener, SCAR Group of Specialists on Global Change and the Antarctic (GLOCHANT) (1992-1997)
Chairman, GLOCHANT Programme on Ice Sheet Mass Balance (1993-1996)
Member, Committee on Earth Gravity from Space, NRC (1996-1997)

HONORS AND AWARDS

Nominated for "Young Man of the Year" by National Junior Chamber of Commerce (1963)
National Science Foundation Senior Postdoctoral Fellow, MIT (1968-69)
Bellingshausen-Lazarev medal from the Soviet Academy of Sciences (1971)
Academies of Sciences exchange fellowships to Soviet Union (1977; 1990)
Commemorative medal of 25th anniversary of Soviet Antarctic Expeditions from Arctic and Antarctic Research Institute, Soviet Academy of Sciences (1981)
Commemorative medal of "100 Years of International Geophysics" from Arctic and Antarctic Research Institute, Soviet Academy of Sciences (1985)
A.P. Crary Professor of Geophysics Chair Award, University of Wisconsin Graduate School (1987)
Seligman Crystal, International Glaciological Society (1990)
Fellow of American Association for the Advancement of Science (1990)
Fellow of American Geophysical Union (1991)
Fellow of Arctic Institute of North America (1992)
Honorary Fellow, American Polar Society (1997)
Hilldale Award, University of Wisconsin-Madison (1998)
Goldthwait Medal, Byrd Polar Research Center, Ohio State University (1998)

Official place names in Antarctica: Mount Bentley and Bentley Subglacial Trough.

EXPEDITION RECORD

1956-59 Antarctica; 25 continuous months, including field seasons in 56-57 (traverse from Little America Station to Byrd Station), 57-58 (traverse from Byrd Station to the Sentinel Mountains and back to Byrd Station), and 58-59 (traverse from Byrd Station to Horlick Mountains and back to Byrd Station)
1960-61 Antarctica; traverse from Byrd Station to Bellingshausen Sea
1962-63 Antarctica; geophysical/glaciological survey of Roosevelt Island
1964-65 Antarctica; South Pole - Queen Maud Land Traverse (SPQMLT) I
1967-68 Antarctica; SPQMLT II
1969-70 Antarctica; radar sounding experiments at Byrd Station
1973-74 Antarctica; Ross Ice Shelf Geophysical and Glaciological Survey (RIGGS) I
1976-77 Antarctica; RIGGS III

1978-79 Antarctica; Dome C Project geophysical survey (DCP) I
1981-82 Antarctica; DCP II
1984-85 Antarctica; Siple Coast Project (SCP): Crary Ice Rise and Upstream B
1987-88 Antarctica; SCP: Downstream B
1988-89 Antarctica; SCP: Upstream C
1991-92 Antarctica; SCP: Upstream B
1993-94 Antarctica; SCP: The Unicorn (between ice streams B1 and B2)

C.2 Richard Cameron

PERSONAL DATA

Born in Laconia, New Hampshire, 1930

EDUCATION

University of Oslo, Norway Summer School, 1953

Bachelor of Science Degree in Geology from the University of New Hampshire, 1954

Graduate studies in Quaternary Geology at the University of Stockholm, 1955

Doctorate in Geology from Ohio State University, 1963

PREVIOUS POSITIONS

Webster University...September 1993 to Present

Webster University...July 1999 to June 2000, Academic Director, Leiden Campus,
Netherlands

Webster University...January 1999 to May 1999, Acting Chairman, Science Department

St. Louis Community College System...September 1991 to 1998

Belleville Area College...September 1991 to 1995

McKendree College...June 1991 to 1995

Adjunct Professor teaching astronomy, Earth science, geology and meteorology.

Harris Stowe State College...January 1988 to August 1991

Associate Professor teaching geology, geography and physical sciences.

National Science Foundation...August 1973 to August 1985

Program Manager for Glaciology in the Division of Polar Programs from
December 1975 to August 1985 and Associate Program Manager for International
Organizations, Division of International Programs from August 1973 to
November 1975.

The Ohio State University, Columbus, Ohio...January 1963 to July 1973

Assistant Dean for International Programs, Office of Academic Affairs from
August 1969 to July 1973; Adjunct Associate Professor of Geology from August
1968 to July 1973; Assistant Dean of University College from August 1968 to
July 1969; Associate Director for Development, University Research Foundation
from August 1966 to July 1968; Assistant to the Director, Institute of Polar
Studies from January 1963 to July 1966.

Air Force Cambridge Research Laboratories, Bedford, Massachusetts. June 1961 to
September 1962

Chief of the Geotechnics Branch, Terrestrial Sciences Laboratory

The Ohio State University, Columbus, Ohio...June 1958 to December 1960

Director of IGY Glaciological Data Reduction Center

Wilkes Station, Antarctica... August 1956 to May 1958

Chief Glaciologist, U.S. IGY Antarctic Expedition

HONORS AND AWARDS

Scholarship -University of Oslo Summer School
United States Antarctic Service Medal
Invited Guest of Soviet Academy of Sciences -September 25 to October 10, 1985
(Leningrad, Moscow, Alma Ata, and Tashkent)
Vice-President of the American Polar Society

Official place names in Antarctica: Cameron Island.

EXPEDITION RECORD

1953	Norway, Svartisen Ice Cap and Storglacieren
1954	Greenland
1955	Sweden, Kebnekaise
1956-58	Wilkes Station, Antarctica
1963-64	Antarctica
1964-65	Antarctica
1965-66	Antarctica
1968	St. Elias Mountains, Alaska

Each austral season from 1976-77 to 1983-84 made site visits to glaciological field parties in Antarctica and for six of those years was also the NSF Representative at South Pole Station.

During the operation of Greenland Ice Sheet Program (GISP 1) visited Greenland each summer from 1981 to 1984.

1986	McCall Glacier, Brooks Range, Alaska
1988-89	Antarctic Peninsula, MS <i>World Discoverer</i>
1989-90	Antarctic Peninsula, MS <i>Illiria</i>

C.3 Mario Giovinetto

PERSONAL DATA

Canadian citizen, born 1933 (La Plata, Provincia de Buenos Aires, Argentina)

EDUCATION

Bachiller de Ciencias, 1952, Colegio Nacional, Universidad Nacional de La Plata, La Plata

MSc, 1966, Geography (Geomorphology), University of Wisconsin, Madison

PhD, 1968, Geography (Climatology)--Minor in Geology and Geophysics, University of Wisconsin, Madison

PREVIOUS POSITIONS

Raytheon ITSS (Lanham, MD)...June 1998 to present

University of Calgary (Calgary, Alberta, Canada)...July 1973 to June 1998

Department Head (Geography) from 1973 to 1983; Professor from 1973 to 1998;
Professor Emeritus from 1998 to present

University of California, Berkeley...1968 to 1973

Assistant Professor from 1968 to 1969; Associate Professor from 1969 to 1973

University of Wisconsin, Madison and Milwaukee... June 1961 to January 1968

Instructor (Milwaukee campus) from 1966 to 1968; Research Associate (Madison campus) from 1961 to 1966

Ohio State University (Columbus)...December 1959 to June 1961

Research Associate; Antarctic research programs supported by the U.S. National Science Foundation

University of Michigan (Ann Arbor)...September to November 1959

Research Associate; Antarctic research programs supported by the U.S. National Science Foundation

Ohio State University (Columbus)...May to September 1959

Antarctic research programs supported by the U.S. National Science Foundation

Arctic Institute of North America, New York...October 1956 to April 1959

Antarctic research programs supported by the U.S. National Science Foundation

Instituto Antartico Argentino (Buenos Aires, Argentina)...November 1955 to March 1956

Antarctic research programs supported by the Instituto Antártico Argentino

Dirección Nacional del Antártico, Ministerio de Defensa Nacional (Buenos Aires, Argentina)...November 1953 to March 1955

Antarctic research programs supported by the Instituto Antártico Argentino

Military Service [included above]...December 1953 to February 1955

Antarctic research programs supported by the Instituto Antártico Argentino

Compañía Swift de La Plata (Buenos Aires, Argentina)...January 1951 to November 1953

PROFESSIONAL AFFILIATIONS (Past and *Present)

American Association for the Advancement of Science
American Geographical Society
American Quaternary Research Association
American Water Resources Association
*American Geophysical Union
American Meteorological Society
Arctic Institute of North America
Association of American Geographers
*International Glaciological Society
Society of the Sigma Xi

HONORS AND AWARDS

Special Appointments

Member, U.S. National Research Council, Earth Sciences Division, 1971-74

Honors / Distinctions (Originating Agencies)

Secretaria de Ciencia y Tecnologia, Presidencia de la Nacion, Argentina, 1996
U.S. State Department, 1974
U.S. Department of Interior, 1961
U.S. National Academy of Sciences, 1959
U.S. National Academy of Sciences, 1958

Official place names in Antarctica: Mount Giovinetto.

EXPEDITION RECORD

Dec. 1952 - Feb. 1953: Member; expedition to high mountain glaciers in the central Andes, Argentina.

Nov. 1953 – Mar. 1954: Assistant to scientific staff; Argentine Antarctic Expedition (South Orkney Islands, South Shetland Islands, and Antarctic Peninsula).

May – Sep. 1954: Member; Army-Navy expedition to Andes Fueguinos, Tierra del Fuego.

Nov. 1954 – Mar. 1955: Assistant to scientific staff, Argentine Antarctic Expedition (South Shetland Islands and Antarctic Peninsula).

Jun. – Sep. 1955: Co-leader; expedition to high-mountain snow fields and glaciers in the Mawenzi-Kilimanjaro and Ruwenzori areas.

Nov. 1955 – Mar. 1956: Assistant to scientific staff; Argentine Antarctic Expedition (Filchner Ice Shelf, Antarctic Peninsula, Shag Rocks, and

South Sandwich Islands).

- May – Jun. 1956: Assistant to scientific staff; expedition to the Upsala and Moreno glaciers in southwestern Argentina, organized by the Instituto Nacional - Hielo Continental Patagónico.
- Jul. – Aug. 1956: Participant; polar glaciology training program held in northwest Greenland, organized by U.S. Army's Corps of Engineers-Cold Regions Research and Engineering Laboratories.
- Nov. 1956 – Mar. 1957: Glaciologist; U.S.-IGY oversnow traverse in the Ross Ice Shelf-Marie Byrd Land area of Antarctica.
- Mar. – Nov. 1957: Glaciologist; U.S.-IGY Byrd Station glaciology program, Antarctica.
- Nov. - Dec. 1957: Glaciologist; U.S.-IGY Ross Ice Shelf deformation project, Antarctica.
- Jan. - Nov. 1958: Senior Glaciologist; U.S. IGY Amundsen-Scott (South Pole) Station glaciology program, Antarctica.
- Nov. 1958 - Feb. 1959: Glaciologist and Party Leader; U.S. IGY Ross Ice Shelf deformation project, Antarctica.
- Nov. 1960 - Feb. 1961: Senior Glaciologist; U.S. Antarctic Research Program oversnow traverse McMurdo Sound - South Pole, Antarctica.
- Nov. 1961 – Mar. 1962: Co-principal Investigator and Party Leader; U.S. Antarctic Research Program ice flow studies, Roosevelt Island, Antarctica.
- Nov. 1977 – Mar. 1978: Chief Glaciologist; Argentine Antarctic Expedition - Weddell Sea pack-ice and drifting iceberg project.

C.4 Charles Swithinbank

PERSONAL DATA

Born in Pegu, Burma, 17 November 1926

EDUCATION:

Bryanston School, 1939-44

Royal Navy (Sub-Lieutenant) 1944-46

University of Oxford, Pembroke College, 1946-49 (B.A. 1949)

University of Oxford, Pembroke College, 1953-55 (M.A. 1953; D. Phil. 1955)

PREVIOUS POSITIONS:

Scott Polar Research Institute, Cambridge-Senior Research Associate, 1987-present

British Antarctic Survey, Cambridge-Head of Earth Sciences, 1974-86

British Antarctic Survey, Cambridge-Chief Glaciologist, 1963-74

University of Michigan, Ann Arbor-Research Associate and Lecturer, 1959-63

Scott Polar Research Institute, University of Cambridge-Research Fellow, 1955-59

Norwegian-British-Swedish Antarctic Expedition, 1949-55

PROFESSIONAL AFFILIATIONS:

International Commission on Snow and Ice (Vice-President 1979-83)

American Association for the Advancement of Science-Life Member

Swedish Society for Anthropology and Geography-Life Member

International Glaciological Society (President 1981-84)

Arctic Institute of North America-Life Fellow

American Geographical Society-Life Fellow

The Society of the Sigma Xi-Life Member

The Antarctic Society-Honorary Member

Royal Geographical Society-Life Fellow

National Geographic Society-Member

The Antarctic Club-Member

The Arctic Club-Member

HONORS AND AWARDS

1952 King Haakon VII of Norway-Medal of Merit

1953 Scott Polar Research Institute-Watkins Award

1954 Royal Geographical Society-Ness Award

1956 Queen Elizabeth II-Polar Medal

1960 Federal Aviation Administration-Private Pilot

1964 Pictures of the Year Competition-Second Prize

1966 King Gustav VI of Sweden-Retzius Medal

1970 American Geographical Society-Honorary Fellow

1971 Royal Geographical Society-Patron's Medal

1974 United States Antarctic Service Medal

1989 Milwaukee School of Engineering-Honorary Ph.D.
1990 Royal Scottish Geographical Society-Mungo Park Medal
1997 International Glaciological Society-Honorary Member

Official place names in Antarctica: Swithinbank Range and five other features

EXPEDITION RECORD

1947 Oxford University Iceland Expedition
1948 Oxford University Expedition to the Gambia
1949 Stockholm University Kebnekajse Expedition
1949-52 Norwegian-British-Swedish Antarctic Expedition
1952 Northeast Greenland
1957 Northwest Passage, HMCS *Labrador*
1959-60 Antarctica (USAP)
1960-61 Transantarctic Mountains (USAP)
1961-62 Transantarctic Mountains (USAP)
1963-65 Soviet Antarctic Expedition
1966-67 Antarctic Peninsula (BAS)
1967-68 Antarctica radio-echo sounding (USAP)
1969 Northwest Passage, SS *Manhattan*
1971 North Pole, HMS *Dreadnought*
1971 Greenland, *Thule/Narsarssuaq*
1971-72 Antarctic Peninsula (BAS)
1974-75 Antarctic Peninsula (BAS)
1976-77 Antarctic Peninsula (BAS)
1978-79 Antarctica, Byrd Glacier (USAF)
1979-80 Antarctic Peninsula (BAS)
1983-84 Antarctic Peninsula/South Pole (BAS)
1985-86 Antarctic Peninsula (BAS)
1986 Ellsworth Mountains, Antarctica (ANI)
1987 Antarctic Peninsula, MS *World Discoverer*
1987 Ellsworth Mountains, Antarctica (ANI)
1988 Antarctic Peninsula, MS *World Discoverer*

1988 Northwest Passage, MS *Society Explorer*
1988-89 South Pole/Queen Maud Mountains (USAP)
1989 Spitsbergen, MS *World Discoverer*
1990 Antarctic Peninsula, MS *World Discoverer*
1990 Greenland/Canada, MS *Society Explorer*
1991 Ross Sea, Antarctica, MS *World Discoverer*
1992 Antarctica, MS *Explorer*
1993 Ellsworth Mountains, Antarctica (ANI)
1993 Greenland, MS *Kapitan Khlebnikov*
1994 Antarctica, MS *Explorer*
1994 North Pole, MS *Yamal*
1996 Antarctica, Queen Maud Land

APPENDIX D – SUPPORTING TABLES FOR M. GIOVINETTO RESPONSE

The following two tables were provided by M. Giovinetto to help illustrate his response to the questions raised regarding skill types and mix as well as crew size.

Table D-1. Skill types and mix, scheme based on a crew of five.

19 categ. / 5 crew	Pilot	Copilot	Physician	Geologist	Geophysicist
SpaceCraftOp	X	X			
SpaceCraftOpAssist		X			X
StaSys	X	X	X		
SurfCraftOp	X	X	X	X	X
SurfCraftSys	X	X		X	X
EVA Op	X	X	X	X	X
EVA Sys	X	X	X	X	X
Medicine		X	X		
Geomorphology				X	
Sedimentation				X	
StructuralGeology				X	X
Micropaleontology			X	X	
Hydrology				X	X
GeochemAnalyses			X		X
PlanetaryPhysics	X				X
Microbiology			X	X	
Met/Microclim	X		X		X
OtherProjAssist		X	X		
MissionChief	X →	→ (X)			

A. This table shows a simplified first approximation distribution of the areas of responsibility / skills that could be covered by a crew of five (possibly the smallest viable crew). The ‘label’ for each category of responsibility or function, as well as the ‘designation’ for each crew member, are descriptive and not intended as definitions. For example, the Pilot and Copilot designations cover mechanical and electrical/electronic engineer skills (complemented by those of the Geophysicist).

B. The first seven rows oversimplify the complex function-listings that include all the support operations and systems; relative to this, the last twelve rows show excessive break down of functions.

C. The “Xs” suggest possible crossover and overlap in the abilities and training of crew members (many changes should be expected as crew members actual abilities and training experience become known).

D. The Pilot and Copilot are responsible for the bulk of the ‘technical support’ workload, and as practically everything depends on it, they could be in charge of the mission, while the Geologist and Geophysicist, as well as the Physician, are responsible for most of the ‘scientific observations’ workload.

E. The advantages of a small crew (everything else being equal) are more space, water, and energy available per person, more ‘spare’ parts, and reduced stress due to less crowded quarters. The disadvantages are less safety, particularly in the case of any crew members’ permanent or temporary disability, possibly less efficient and/or incomplete work in each category, possibly less rest time and therefore more stress(?).

Table D-2. Skill types and mix, scheme based on a crew of seven.

19 categ. / 7 crew	Pilot	Copilot	Engineer	Physician	Geologist	Geophys.	Microbiol.
SpaceCraftOperation	1	2					
SpaceCraftOpAssist		1	2				
StationSystems	2		1				
SurfCraftOperation	3	3	4	7	8	8	8
SurfCraftSystems	4	4	3	8			
EVA Op	5	5	5	5	5	5	5
EVA Sys	6	6	6	6	6	6	6
Medicine				1			2
Geomorphology					1		
Sedimentation					2		
StructuralGeology					3	4	
Micropaleontology				4	4		4
Hydrology						1	
GeochemAnalyses				3		2	3
PlanetaryPhysics					7	3	
Microbiology				2			1
Met/Microclimatology			7			7	
OtherProjectsAssist		7					7
MissionChief	7 →	→ (7)					

A. This table shows a simplified first approximation distribution of the areas of responsibility / skills that could be covered by a crew of seven (possibly the largest crew that is necessary). The ‘label’ for each category of responsibility or function, as well as the ‘designation’ for each crew member, are descriptive and not intended as definitions. For example, the Pilot and Copilot designations cover mechanical and electric/electronic engineer skills (these are either a complement to, or complemented by, the skills of the Engineer).

B. The first seven rows oversimplify the complex function-listings that include all the support operations and systems; relative to this, the last twelve rows show excessive break down of functions.

C. The digits in each box suggest “priorities” in the abilities and training of each crew member (many changes should be expected as crew members actual abilities and training experiences become known).

D. The Pilot, Copilot, and Engineer are responsible for the bulk of the ‘technical support’ workload, while the Geologist, Geophysicist, and Microbiologist are responsible for most of the ‘scientific observations’ workload. The Physician’s load on either

category is largely open to change. The Pilot and Copilot could be in charge of the mission as practically everything depends on the “technical support” that is their charge.

E. The advantages of a large crew (everything else being equal) are a larger margin of safety in case of any crew members’ permanent or temporary disability, possibly more efficient and complete work in each category, possibly more rest time and therefore less stress (?). The disadvantages are less space, water and energy available per person, less ‘spare’ parts, and increased stress due to crowding.
