# THE APPLICATION OF SUBMARINE EXPERIENCE AND TECHNOLOGY TO THE SPACE ENVIRONMENT

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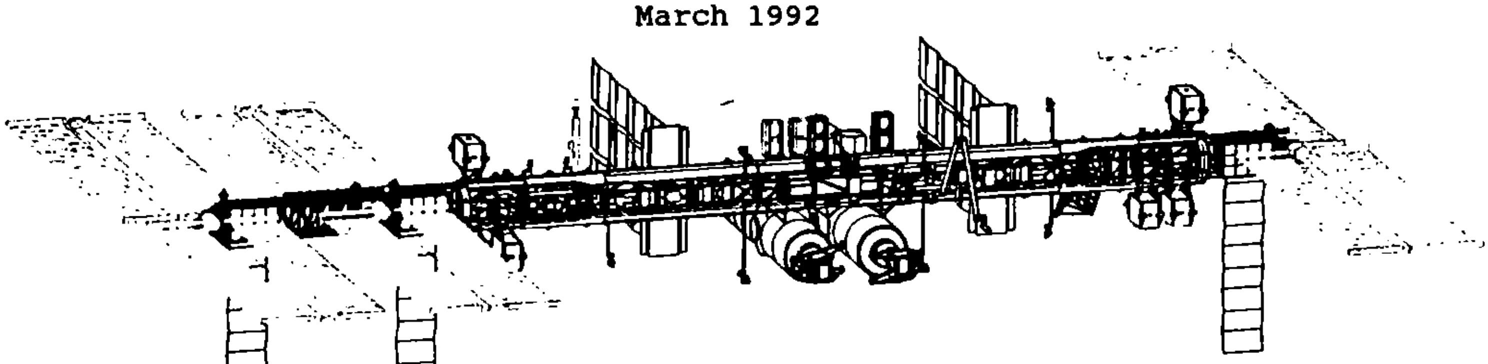

STAGE 17

Permanently Manned Capability

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## TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

## LIST OF TABLES

LIST OF FIGURES

# CHAPTER I

# THE APPLICATION OF SUBMARINE EXPERIENCE AND TECHNOLOGY TO THE SPACE ENVIRONMENT

## INTRODUCTION:

As the United States embarks upon the frontiers of "outer space" voyage in the future, it should call upon the wealth of knowledge generated from eighty years of journeys into "inner space" by the United States Submarine Force. There are many parallels that can be drawn between operating submerged, isolated from the world in a nuclear submarine, and operating in a space station or space ship on a long term voyage to Mars or beyond. Obviously gravity is the major disparity between them, but their similarities outnumber their differences.

Operation in a closed environment involves a number of common factors regardless of the location. These include: (1) atmospheric control, (2) long term mental and physical effects on personnel due to the isolation, (3) casualty procedures which are adapted to the hostile environment, and (4) specially designed equipment.

In controlling the atmosphere, carbon dioxide and trace contaminants must be removed and oxygen must be replenished. Extensive submerged operations have resulted in well-tested limits for oxygen and carbon dioxide, not only for short one-hour and 24-hour periods but also for longer periods such as 90 days.
Trace contaminants have also been analyzed in detail to determine

their effects.

No area has been more fruitful than the investigation into mental and physical effects upon personnel as a result of long term life in a closed environment. The effects of microgravity must be taken into account, but the long term mental effects caused by isolation and the stress it generates are well known factors to submariners.

An area which may be the most important of all is the knowledge of well tested casualty procedures in closed spaces. For decades the men on submarines have fought fires, toxic gas and flooding in peace and in combat to keep their ships at sea. Our experience in the art of survival at sea isolated from all assistance may be a factor in the survival of men and women in space during unforeseen casualties.

The "silent service" also has numerous equipment applications which can provide new ideas without incurring the new system research and development costs. This area has many possibilities as diverse as the ring laser gyro navigation system to the software architecture necessary to control advanced fire control systems.

The premise of this research is that the knowledge gained by years of experience at sea in the submarine fleets of the United States and the national wealth expended upon their construction and operation should be applied to the space effort. This knowledge of life under the oceans can be utilized to further the efforts of the United States to explore the solar system at reduced costs and on a more rapid schedule. The technologies developed and the data collected by the Submarine Force should be mobilized and applied to our national efforts to explore and utilize space as the next frontier for demonstrating American excellence.

# CHAPTER II

# SUBMARINE PHILOSOPHIES ADAPTABLE TO SPACE:

Years of operational experience in the submarine force will change your philosophy of daily life. Things which seem strange to non-submariners are second nature when you operate submerged. What are some "second nature" philosophies of the submarine force?

## SYSTEM REDUNDANCY:

The redundancy of submarine systems is legendary. Backup systems are provided for all systems critical for life support and ship's control while submerged. This redundancy is the result of (1) the type of operations normally done by submarines and (2) the environment in which we operate.

Surface warships normally cruise in formations or act as part of a larger task force with supplies and assistance readily available. On the contrary submarines normally operate singly, independent of any other friendly forces, in far forward isolated areas. This is a similar situation to the space station which can not expect ready supply or assistance.

The second factor requiring redundancy is the submerged environment. As in space, the submerged environment is unforgiving. The failure of life support systems while submerged means either aborting the mission or the death of the crew. When operating under the polar ice cap there is no method of ventilating the ship if it fills with smoke. When operating submerged in the mid-Atlantic, where the average depth of the ocean is about two miles, the failure of the systems that permit maintaining depth control could result in catastrophe. Therefore, backup systems are built into those that control the ship's depth. Normal planes operation is by one hydraulic system called "the Lead system." If the "Lead" pump is secured, the "Main" hydraulic system automatically carries the hydraulic load. If the "Main" system fails, the system power transfer valve automatically shifts the planes to the "Vital" system. If none of the normal systems are available, the planes may be isolated from the hydraulic header and operated locally by a small DC powered hydraulic pump. If no hydraulics are available such as due to a leak on the planes ram packing, planes may be positioned by chain fall. Every system does not have the same redundancy that is built into the planes' operating system, but almost every critical system for life support or ship control has one or two levels backup.

The idea of redundancy holds true not only in the equipment area. A favorite example occurred when my ship exhausted the supply of flour before we completed the patrol. The Mess Specialists produced an approved Navy standard recipe for making bread from instant ice cream mix. The bread was actually good!

The redundancy philosophy that has protected the submarine force from many disasters submerged has developed from the maximum utilization of all available assets and the development of casualty procedures in advance. The operators of the space station and future space missions should thoroughly analyze this system of backups and "what ifs" to guard against disaster.

## WORK ORGANIZATION:

Submarines operate with two parallel paths of authority while at sea. For operation, maintenance and training the crew is divided into departments and subdivided into divisions by rating. This provides a ready method of management to track the individual progress of each man. It also provides the work force necessary to schedule and do the large volume of maintenance activities necessary to keep the complex ship systems operational at maximum efficiency. This organization through the Department Head, the division officer and the leading petty officer is not sufficient to combat major casualties such as fire or flooding. A parallel watch section does the actions necessary for operating the ship and for fighting casualties.

The watch section is led by the Officer of the Deck who gets his authority directly from the Captain. He is responsible for directing casualty control actions and for controlling ship depth, speed and course. Roughly one third of the crew is on watch at a given time. The off-going watch section responds to all casualties as the "casualty assistance team." They are the men manning the fire hoses and rushing the damage control equipment to the scene of the casualty to help the on-watch personnel.

The necessity of these parallel paths of authority in space as well as in submarines will be explained in the section concerning casualty control in a closed environment.

## PERSONNEL QUALIFICATION:

The submarine force has stressed personal submarine qualifications by all crew members for many years. The basis for this submarine qualification program is damage control knowledge. Rapid response to casualties is of vital importance during submerged operations. If only one man is in the compartment when the flooding occurs, he must be able to locate and isolate the source or the submarine may not survive. The space station can operate with one module isolated if it doesn't contain critical life support equipment, but a submarine cannot normally stay afloat or maintain submerged control of depth with a compartment completely flooded. Only the bow compartment can be totally flooded and the ship remain off the bottom on the 627 Class SSBN. With this compartment full the ship must maintain a significant speed to generate dynamic lift or it will sink with a severe down angle.

The survival of the entire crew may depend on the knowledge level of any individual. An extensive training program for all hands, officer and enlisted, exists to complete this effort. This same standard of knowledge level must be applied to the space program. Mission specialists need the same casualty control knowledge as pilots and copilots. If survival is too dependent upon a single individual, the entire crew may be placed in danger. The submariner's motto is "always train your relief."

# CHAPTER III

# MAN'S ADAPTATION
# SUBMARINE EXPERIENCE

## SUBMARINE PERSONNEL KNOWLEDGE BANK

Many questions are presently being asked in the press about the capability of men to endure the isolation and rigors of space travel. An excellent article in the 5 February 1992 edition of The Wall Street Journal discusses this very issue. The title of the article reads "Russian Psychiatrist Tries to Make Sure Cosmonaut Stays Up" by Adi Ignatius. The single remaining Soviet cosmonaut is Sergei Krikalev who has been aboard the MIR space station for eight months. Imagine returning home after these events occurred since blasting into space on May 18, 1991 -the disintegration of the Soviet Union as a nation, the ousting of Mikhail Gorbachev, the coup attempt in the former Soviet Union, and the changing of one's hometown's name from Leningrad to St. Petersburg.[1]

On a submarine, the psychological aspects of isolation are more severe that the physical aspects. Many of the techniques used by submariners to deal with family separation and stress are readily adaptable to the space environment.

## FAMILY AND PERSONNEL STRESS DURING EXTENDED DEPLOYMENTS:

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[1]. Adi Egnatius, "Russian Psychiatrist Tries to Make Sure Cosmonaut Stays Up", The Wall Street Journal, 5 February 1992, p.1.

Extended deployments at sea place great stress on the family as well as on the crew member. Captain Colon Jackson, USN(ret), the former Chaplain of Submarine Group Six in Charleston, South Carolina has dealt extensively with the stress caused in the families of the submarine crews deployed from Charleston and made this the subject of his doctoral dissertation. He observes:

> "Another stress that wives experience during deployments is the feeling of isolation and aloneness. Many wives shared with me that when their husbands deployed, the only people they felt at ease with were other waiting wives. Although married, many women stated they were treated as singles. She does not fit in the single community nor does she feel accepted by couples. As a matter of fact, most said that even friends abandoned them."[2]

The stress also extends to the children, an especially difficult problem. In an article titled "Military Daddy: Now You See Him Now You Don't" by Katharine Kersey and Janet Schwenke we get this assessment of that stress.

> "First of all, it's important to realize that young children may not fully understand the reasons behind Daddy's departure. They may feel abandoned. In their minds, Daddy may *choose* to go away. They may feel guilty: "He's going away because of something I did." They may feel unlovable or worthless: "If I was *really* good enough, he would stay." These feelings may be reflected in anger, hostility, a desire for revenge, or a desire to be punished for having such feelings."[3]

The care of the families of submarine crews is a well defined program. One or two experienced wives designated as "Ombudsmen"

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[2]. Captain Colon Jackson, USN(ret), "Stress in the Navy Family", Chapter IV, "Dynamics of Stress", (Doctorate Dissertation,1983), p. 80.

[3]. Katharine Kersey and Janet Schwenke, "Military Daddy: Now You See Him Now You Don't", Ladycom, June 1982, p. 65.

attend the "Ombudsman Training Academy." Here they learn the resources necessary to help families solve various problems from finance and health care to counselling. Extraordinary efforts are made by submarine families to bridge the separation of crew member and friends and loved ones. A strong wives' organization which can look after the needs of the families and provide assistance in emergencies is essential.

An excellent way to prepare the astronauts for the isolation of the closed environment of space would be to send them on a standard ballistic missile submarine patrol. The advantages of this program would be the insights gained in the philosophies of dealing with isolation, family separation, and stress relief in a high technology environment. Invariably experienced submarine personnel develop their own methods of dealing with these issues. Some keep journals to their wives, others actively pursue advancement and qualifications. Frequently it's the wife who cannot adjust to the submarine career instead of the husband at sea. The wives and families of temporary duty personnel are made a part of the dependent family support group when the submarine deploys. This "trial mission" would give the astronaut wives a chance to observe and learn the techniques used by experienced submarine wives to cope with isolation.

The military wife's effect on her husband's performance appeared in an article by Dr. Edna J. Hunter in the Military Family magazine:

> "In discussing the personal and emotional adjustment of military wives, a number of major issues come into focus.

Just as the military organization provides the national security of the United States, similarly, the security and psychological or mental health of military personnel often times rests with the nuclear family. Studies suggests that when there is peace at home, there is a greater likelihood of the serviceperson doing a more proficient, effective job."[4]

The submarine force can offer extensive experience in the adaptation of personnel to the stresses of deployment. It would be unwise to send personnel on a three-year deployment who had no experience in handling the isolation and stress of that environment.

## SHIPBOARD STRESSES:

Aboard ship a different set of problems are encountered than those seen by the families at home. One of these is boredom. The Soviets encountered this same difficulty in the MIR space station. Ignatius expresses it this way,

"Boredom is a big problem. The two men work most of their waking hours, taking some time off for meals and a spin on the exercycle. "Free time basically consists of looking out the window," says Victor Blagov, deputy director of the space flight."[5]

Other than not having any windows, the submarine problem is similar. The boredom problem comes during the off watch times of the crewmen. Extensive efforts are made to overcome this negative effect on morale. The primary defense against this problem is a good relationship with other members of the crew. On submarines

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[4]. Dr. Edna J. Hunter, "Military Wife Adjustment: An Independent Dependent", Military Family, May-June 1982.

[5]. Ignatius, "Russian Psychiatrist Tries to Make Sure Cosmonaut Stays Up," The Wall Street Journal, 5 February 1992.

the departments are broken up into smaller division units of men of similar training such as electricians or machinist mates. A "sea dad" program is frequently used in the training program. A more experienced man is assigned as being responsible for the training and indoctrination of a junior man. By keeping track of how men are using their time, we can tell when men start to withdraw due to depression over lack of progress or just loneliness for home. Senior personnel are trained to look for the signs of potential psychological problems, especially in terms of withdrawal or depression which could drive men to suicide.

The Submarine Force has an active program for suicide prevention. Submarine Group Six of Charleston, South Carolina has published a "Supervisor's Guide to Suicide Prevention". This lists a number of items as suicide warning signs. Some of these will automatically be generated by the positioning of astronauts in the space station or moon base. Some of the applicable signs are:

"-Talk about feeling worthless.
-Decline in job performance and /or personal appearance.
-Changes in sleep patterns and/or appetite.
-Unusual withdrawal, isolation, aggression, disinterest, moodiness, or crying spells."[6]

To counteract these same problems during patrol each man is made aware of the importance of his submarine's strategic mission. In the Fleet Ballistic Missile Submarine Fleet we stress (1) our operations are the basis for the first line of defense of the United States against nuclear attack, and (2) the importance of

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[6]. U.S. Navy, Commander, Submarine Group Six, "Supervisor's Guide to Suicide Prevention", p. 1.

each individual in the completion of the ship's mission. Each man is led through the qualification program which teaches him the damage control knowledge which might mean the difference between life and death for the entire crew. The importance of each individual is reinforced by making the members of the crew responsible for the quality of the qualification program. A man must pass a board of his peers in order to complete the submarine qualification program.

The short patrol of up to a month doesn't seem to significantly affect most crew members. After that period, "worry" sets in about the family back home. It would be easy to deduce from this that the solution is to send only single astronauts on long missions. In my three-year tour as Captain of USS Daniel Boone, of eight suicide attempts, the majority were by single individuals. The stable family man who has a supportive wife seems to be the best choice.

Individuals sometimes become depressed or homesick but wholesale depression of the crew is rare. Many lessons in stress management were learned while at sea during Hurricane Hugo. The hurricane destroyed the communications facilities which normally forward family messages to the submarine crews operating from Charleston, South Carolina. The hurricane hit Charleston on the 21st of September 1989. We waited until 10 October to receive status reports about all family members and property. The wait generated deep depression in the crew. At one point I even had a chief petty officer, one of my senior enlisted men, in my stateroom in tears.

In dealing with this high level of stress one factor came through clearly. The crew had to be able to believe the information passed to them. The extensive communications suite aboard a modern submarine will permit interception of many types of signals. My policy of passing information became one of total honesty. We searched all airways until we finally found news reports on "Radio Free Africa". The remoteness of our location and interference from the storms limited our capability to get any information. The reports obtained were passed on to the crew even though they gave frightening numbers of 11,000 homeless and dozens missing in Charleston. The men already knew the news would be bad and to withhold the information would have destroyed my future credibility.

From the Ignatius article concerning the MIR cosmonauts we find a similar stress situation.

> "When anti-reform elements in Moscow launched the coup attempt in August, Mr Krikalev, 32, was noticeably upset. After hearing the news, he refused to make contact with mission control for two consecutive orbits. Finally, Mr. Krikalev spoke in a bitter, metallic tone. "Yes," he said. "We've heard the news."[7]

The stress during the Hurricane Hugo patrol was mitigated by several other methods. Church prayer services were held regularly which gave the crew a feeling of unity against the problem. Supervisors were directed to watch their men carefully for signals of excessive depression. The ship's training schedule was stepped

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[7]. Adi Ignatius, "Russian Psychiatrist Tries to Make Sure Cosmonaut Stays Up", The Wall Street Journal, 5 February 1992.

up to a higher level of drills. This kept everyone busy and lessened time for introspection and worry.

The importance of physical exercise should not be minimized in the relieving of stress. Using exercise equipment such as a rowing machine or an exercycle will relieve acute stress and generate an outlet for frustration.

Setting and achieving personal goals can be another constructive use of time. The completion of college level correspondence courses is an excellent example. Not only does it give the person the feeling of achievement in completing the course, but also, as he immerses himself in study to meet the deadline of completion, he loses the anxiety of thinking about the time remaining. It's frequent to find yourself wishing that there were just a few more days left to complete a certain paper or project. From an article published in 1981 entitled "Work and rest on nuclear submarines", we find this evaluation:

> "The workload of submariners on deployment is substantial, although individual differences in workload are pronounced. For all ranks, study constitutes a significant proportion of the workload. In general, men average about 4.5 hours of non-watch work and study daily, in addition to standing watch for 6 to 8 hours."[8]

Extremely long space missions such as the proposed Mars mission of three years will require the planning of leisure and goal oriented activities. It is unrealistic to think that

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[8]. Arthur N. Beare and Kenneth R. Bondi of the Naval Submarine Medical Research Laboratory, Robert J. Biersner of the Naval Medical Research and Development Command, and Paul Naitoh of the Naval Health Research Center, "Work and rest on nuclear submarines", ERGONOMICS, VOL 24, NO. 8, 593-610, 1981.

astronauts can "look out the windows" for that long without developing psychological problems. Engaging astronauts in such activities as manufacturing processes and experiments to take advantage of the zero gravity environment will greatly aid in their psychological health.

The confinement, isolation and stress involved in the operation of a nuclear submarine on an extended patrol is similar to that which will be encountered in the long space voyages of the future. A number of documented studies have been conducted in the submarine force to determine the medical and psychological effects of submarine operations.

One such study addressed the "Mental Health of Nuclear Submariners."[9] This analysis utilized the Minnesota Multiphasic Personality Inventory (MMPI) profiles of 1,013 nuclear submariners. It concluded that "the mental health of nuclear submariners as a whole is excellent."[10]

Another study looked at the attitude changes during and after long submarine patrols. The objectives of this study were to answer four questions. "(1) What kinds of attitudes are affected most and least (and in what direction) by submarine conditions, e.g., confinement, isolation, long exposure to revitalized atmosphere, etc.; (2) which attitudes do and do not revert to pre-mission levels during the rehabilitation period after each mission; (3)

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[9]. Benjamin B. Weybrew and Ernest M. Noddin, The Mental Health of Nuclear Submariners in the United States Navy, (Groton: NSMRL 851, 1979).

[10]. Ibid, p. summary.

what differences in attitude levels and changes occur during the submerged and rehabilitation period among selected subgroups within the submarine crew; and (4) within the framework of existing theories of attitude change, what shipboard procedures might be recommended to prevent undesirable attitude changes during protracted submarine missions?"[11]

One of the conclusions of the attitude study was the importance of adopting measures to prevent negative changes in attitude during both the patrol and the subsequent rehabilitation period.[12] Another finding may hold important applications to the space program. This finding was also supplemented by older confinement studies reference in the attitude study. It was that "stimulus invariance (the sameness of things) *vice* the level of stimulation itself may be a crucial factor in adjustment to the isolation and confinement during these missions(Weybrew 1963)."[13]

## IN SUMMARY:

> "Space psychology, which is just starting to take shape, poses many questions for which there are as yet no answers. Most concern interplanetary travel in cramped quarters with little chance of rescue, if things go radically wrong. Behavioral scientists currently strive to determine how specific individuals and small groups would likely react to various types of stress in space,

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[11]. B.B. Weybrew and H. B. Molish, "Attitude changes during and after long submarine missions", Undersea Biomedical Research, Submarine Supplement 1979, p. 176.

[12]. Ibid, p. S187.

[13]. Ibid, p. S187.

identify probable limits of endurance, and develop ways to ensure effective performance. Progress is slow and study results will be tenative until manned space flights greatly expand the available data base."[14]

The behavioral scientists of the space program have a data base of the effects of closed environments on the performance of individuals in high stress situations but it is not being utilized. That data base exists in the submarine forces of the United States and the years of experience in combat, in casualty situations and in the boredom of patrolling the waters of the world's ocean depths isolated from home and family. To wait upon experience in manned space flight to determine the effects of isolation for long periods in closed spaces is to send our astronauts into the unknown unprepared to deal with the situation.

Prior to deployment, submariners must develop confidence in their ship and in their ability to combat casualties. Before departure for sea, the ship is sealed and all equipment is tested. Numerous drills are completed by the crew to practice the basic skills required for combating the major casualties possible at sea including fire, flooding, toxic gas and reactor shutdown. This simulated "at sea" period called "Fast Cruise" takes place with the submarine tied to the pier.

Just like the submarine, a breach of the spacecraft hull integrity means the loss of the crew unless casualty procedures are effective. In discussing the attitudes of the MIR cosmonauts this

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[14]. John M. Collins, Senior Specialist in National Defense, Congressional Report for Congress - Military Space Forces-the Next Fifty Years, (Washington, D.C.: Congressional Research Service, 1989), p. CRS-121.

same thought is evident after several months in space.

> "But soon after, problems begin to develop. "The constant anticipation that something bad is going to happen begins to work at their subconscious," says Dr. Slyed. "Every one of them knows that three millimeters separates him from a vacuum. If, God forbid, those three millimeters were to be punctured, there is basically nothing that could save them."[15]

Many of the physiological effects of space travel are due to the microgravity of space. These medical effects of weightlessness are summarized by John M. Collins in a CRS Report for Congress:

> "Earth's gravity exerts great force. Humans need strong bones and muscles merely to sit or stand. Hearts and lungs must work hard to distribute blood and oxygen. "Weightlessness," manifest when spacecraft neutralize gravity's force during flight, produces opposite effects. Physical dexterity, bone density, muscle tone, blood circulation, and bodily fluids all decrease." [16]

This is one area of research which has no parallel in the undersea world and the submarine data base is of no assistance.

The Navy Submarine Medical Research Laboratory (NSMRL) in New London, Connecticut has done years of research on the medical issues of living in closed environments. Many of these studies are associated with the atmosphere. These effects will be discussed in Chapter V of this research paper. Many studies concern psychological effects of isolation. When men are placed in a metal confinement and kept for long periods of time in a controlled environment, whether it is in space or underwater, many of the same effects will be seen.

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[15]. Adi Ignatius, "Russian Psychiatrist Tries to Make Sure Cosmonaut Stays Up", The Wall Street Journal, 5 February 1992.

[16]. Ibid. p. CRS-35.

# ADJUSTMENT TO A NEW "CIRCADIAN RHYTHM" AT SEA:

This Congressional Research Service Report to Congress fails to take into account submarine operations and the data collected over the last 40 years.

> "The absence of identifiable day and night, which disrupts human habit patterns, causes psychophysical problems. Crews in low earth orbit repeat the light-dark-light cycle several times every 24 hours; clock hands seem to stand still in the HEO(*high earth orbit*). Effects derange work-rest routines like jet lag magnified many times. Results range from emotional instability, fatigue, and poor attention span to impaired vital functions, such as pulse, heart beat, brain activity, body temperature, endocrine activity, and metabolism. Low resistance to infection may even be manifest."[17]

Both submarine and space environments are without the cycles of sunrise and sunset that determine our body's inner biological rhythms. Submariners go to great lengths to create their own "time zone." The ship operates on a six hour "watch rotation." Every six hours a new watch section relieves and the on-watch section begins their twelve hour off period. The normal three section at-sea watch bill places most men in an 18-hour day. A meal is served every six hours. Berthing spaces are darkened around the clock to simulate night for those watch standers. Upon departure for sea all clocks are normally shifted to Greenwich Mean Time to conform to the time scale used in submarine routing messages. This new time configuration and the great longitudinal changes encountered on

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[17]. Collins, "Military Space Forces", p. CRS-36.

most patrols mean that sunrise and sunset have no bearing on time of day by the clock.

Studies concerning the work-rest schedules of submarine personnel and the disruption of circadian rhythms were conducted by Naval Submarine Medical Research Laboratory teams of physicians in 1981 and 1982. These studies found none of the drastic results postulated in the Congressional Research Service study. The submarine 18-hour "day" rotates around the watch bill instead of rotating around the solar 24 hour day schedule. My experience shows that "clock hands seem to stand still"[18] only when personnel are not gainfully employed. The at-sea schedule with frequent training drills, administrative deadlines for personal qualifications and operational requirements doesn't permit time to stand still. In fact, many people complain that they don't have enough time to complete the tasks assigned and come to the executive officer for extensions of deadlines.

The 18-hour no-day-or-night schedule does generate a number of problems. These problems are not the ones which were expected in the CRS report. Many of the problems with the lack of day and night are merely scheduling difficulties. Drill periods requiring periscope depth operations during darkness, are not popular when the darkness occurrs at 2130 at night. These problems, however, are not of the magnitude of the difficulty expected. Just as a person moving from one part of the country to another part has to adjust, personnel first entering this environment have an adjustment

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[18]. Ibid

period. There are problems to overcome but they are not insurmountable. You have to learn to eat chili and sandwiches at 0100 in the morning even though your body tells you it supposed to be breakfast. There are difficulties when you awaken from a long sleep on your day off and can't determine if it's 0600 or 1800. Many submariners wear watches with 24 hour Navy time capability for this very reason.

Trying to keep track of local time when the ship is traversing great longitudinal distances can become extremely confusing. To relieve this confusion most submarines shift to Greenwich Mean Time upon departure from home port for long patrols. This shift is accomplished quickly and usually eliminates an entire watch section and a meal. By shifting the clocks ahead by five hours as a single event, the adjustment is accomplished quickly and is much less painful. A two-day off period is sometimes inserted into the schedule also to break with the inport schedule, to get the men acclimated to sea life again and to permit a needed rest from the rigors of inport maintenance and the goodbyes of loved ones.

Without the normal methods of determining the passage of time while at sea, submarine personnel have developed numerous ways to count the days until the end of patrol. The weekly schedule revolves around two axes. First, the operational schedule. If operations dictate a full day on Sunday, then the schedule is rotated and Sunday may become Monday by the schedule. The other axis is that of the training plan. The complexity of the equipment and of the operations of the nuclear submarine require extensive training to raise the level of knowledge of the junior personnel and to maintain the proficiency of the experienced personnel. Usually, four or five days a week are reserved for drills for qualification and proficiency. Other days are reserved for training lectures and discussions. The entire patrol training plan is scheduled before the departure for sea.

These formal plans work to ensure the training gets finished. The informal personal plans keep the morale high and demonstrate much more creativity. Various plans which are used for time keeping in the timeless submarine environment are listed below.

-Calendars abound-both published and hand drawn. Some count days, others laundry days, field-days, pay days, drill sessions, etc.

-Men ration "care packages" from home and count cokes and candy bars.

-Paper chains are made by families and one link is removed each day until the return home.

-Wives send one letter a week post-dated in patrol packages and the "end of the patrol date" corresponds to the last letter.

-Extensive "half-way" night programs are held with talent contests and beauty pageants.

-Charts of the entire ocean are posted with miniature submarines moved along the track to and from the patrol areas.

-Quartermasters post "miles to home" figures which are counted down as the ship progresses down the track home.

The key to all of these ways of counting the time until the end of patrol is the breaking up of the endless environment into segments which the mind can grasp and finishing each segment one at a time. Personnel can plan for future times and can see the light at the end of the tunnel approaching.

## SOCIAL INTERACTION

## THE TEAM EFFORT:

Why would men volunteer for duty which involves long periods of time away from family and friends, in an alien world without grass, trees or sun, without the living area alloted even to prisoners in jail? A study completed by B.B. Weybrew and H.B. Molish of the Naval Submarine Medical Research Laboratory addressed this question with the following results.

> "One common finding based upon the questionnaire and interview data contained in these studies was that 70-80% of both officers and enlisted men who volunteer for this branch of the service apparently do so mainly because of the status and prestige associated with a high-morale, closely-knit group of men engaged in what appears to them to be a meaningful military enterprise."[19]

An extremely important part of dealing with the stress and isolation of patrol on a submarine is the team effort. The espirit de corps of the submarine force has become legendary. The main factor in generating this feeling is the type of operation normally

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[19]. B.B. Weybrew and H.B. Molish, "Attitude changes during and after long submarine missions," Undersea Biomedical Research, Submarine Supplement, 1979, p. S176.

given to submarines. Where surface ships usually operate as part of larger battle groups or surface action groups, submarines normally operate as single units. Fleet ballistic missile submarines operate in remote areas far from land with their exact position not even known to the land-based operational commander. One of their primary missions is to remain undetected by friend or foe. Attack submarines are frequently assigned to far forward areas in enemy territory. They attack enemy forces and survive based only on their own expertise at warfare and their stealth and cunning. One of the best examples of the team effort of a submarine crew comes from the recalling of the war patrols of USS Tang by Rear Admiral Richard H. O'Kane, USN (ret).

> "I believe the whole ship's company breathed out in unison, though we were not hanging on the ropes below. True, the air conditioning had been off all day, and most fans as well. The heat from the night's battery charge had nowhere to go but up into the living spaces above the batteries, and we were hot and sweaty. Some would have given a buck for a cigarette, but in spite of our CO2 absorbent they would not have lighted anyway. A healthy "submarine smell" was undoubtedly present, but since we were all in the same boat none of us noticed it. We had all been too busy to become over apprehensive, but as of this moment there was never a happier submarine crew."[20]

Even though this recounts a submarine war patrol, the same feeling is still evident in today's submarine fleet. During casualties at sea reliance on others generates unity within the crew. We see this pride coming through in the embroidered patches unique for each shuttle flight. We also see it in the elation over the team effort to capture and repair the Solar Max satellite. In

[20]. Richard H. O'Kane, Clear the Bridge!-the war patrols of USS Tang, (Chicago: Rand McNally & Company, 1977), p. 116.

the casualty procedures for the space station, a chain of command with a controlling station has been recommended. This will generate a coordinated effort with team members assigned to jobs just like positions on a basketball team. This is not only more efficient in handling casualties but also is a major factor in the psychological defense against problems with isolation.

# CHAPTER IV

# MEDICAL ASPECTS-THE SUBMARINE LABORATORY

## NON-ATMOSPHERIC RELATED PHYSIOLOGIES:

Many studies have been completed by the Naval Submarine Medical Research Laboratory (NSMRL) which deal with the non-atmospheric effects of life aboard submarines for extended patrols. These studies include vitamin deficiencies due to lack of exposure to sunlight[1], Carbohydrate metabolism[2], motor and cognitive performance changes during patrol[3] and the relationship of personality factors and some social habits to cardiovascular risk in submariners.[4] Hundreds of studies have been conducted to investigate the problems or potential problems to submarine personnel due to the closed environment of submarine duty. A list of the studies conducted since 1979 which in this author's opinion were applicable to space related duty is included in the

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1. Christine L. Schlichting, Ph.D.,and David J. Styer, Lt, MSC, USN, "Vitamin D Status of Submariners During Patrol," (Groton: Naval Submarine Medical Research Laboratory, 1989).

2. E. Heyder, L.W. Mooney and D.V. Tappan, "Carbohydrate Metabolism in U.S. Navy Submarine Personnel," (Groton: NSMRL 997, 1985).

3. C. Schlichting, D. Styer, andP. Gray, "Motor and Cognitive Performance Do Not Change During a Ten-Week Submarine Patrol," (Groton: NSMRL 1150, 1989).

4. D.V. Tappan and B.B. Weybrew, "Relationship of Personality Factors and Some Social Habits to Cardiovascular Risk in Submariners," (Groton: NSMRL 952, 1982).

Bibliography of this research paper.

## MEDICAL DIAGNOSIS PROGRAMS:

Submarines,. especially those of the Fleet Ballistic Missile force, carried doctors on board during the fifties and sixties. With the scarcity of doctors in the Navy after that time and the data gathered from previous patrols, this requirement was no longer felt warranted. Presently, independent duty corpsmen are assigned to each submarine. These corpsmen are trained in multiple areas as varied as filling teeth to treating appendicitis. They are responsible for the medical well being of the 150-man crew and for being the on board expert to advise the Captain of emergencies requiring medical evacuation. A conservative approach is always taken in peacetime. Even with this conservatism the long distances in the mid-atlantic and in the pacific might require a number of days delay before a seriouosly ill person could be evacuated by helicopter or small craft.

To assist these corpsmen in their duties the Naval Submarine Medical Research Laboratory has developed several extensive Medical diagnosis computer programs. These programs have gone through at sea testing. Programs exist for acute abdominal pain[5], acute chest

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[5]. Caras, Southerland, and Fisherkeller, MEDIC-Abdominal Pain-A decision support program for the management of acute abdominal pain-User's Manual, (Groton: NSMRL 1146, 11 October 1989).

pain[6] and acute dental pain.[7] The on-going program is in the process of adding eye disorders to the list of diagnostic programs. Further integration into the shipboard data base is being accomplished and expanded treatment information is being added.[8]

Computer programs are also in effect which assist the corpsman in the handling of appropriate medical supplies for patrols. This program is continually being updated to ensure that submarines at sea carry adequate amounts of antibiotics and other medications. This type of program has a good data base of usage which should be utilized by the space forces as a baseline of the supplies required for long voyages.

The crews of the space station and of future space flights must be able to diagnose and treat medical problems with on board equipment and supplies. The submarine force has programs and supply lists tested by at sea utilization in the closed environment of numerous patrols. These programs can give the space health and medical treatment teams a headstart in the development of viable procedures for deployment of astronauts on extended missions. The extensive data base developed from years of submarine duty can be adapted to include the necessary zero gravity additions.

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6. Caras, Southerland, and Fisherkeller, MEDIC-Chest Pain-A Decision support program for the management of acute chest pain-User's Manual, (Groton: NSMRL 1144, 5 October 1989).

7. K. Fisherkeller, C. Burgess-Russotti, Ralls, and D. Hamilton, A Computer assisted program for the management of acute dental pain-User's Manual, (Groton: NSMRL 1143, 28 June 1989).

8. Naval Submarine Medical Research Laboratory, Indoctrination Briefing Slide Presentation.

# CONTINUING RESEARCH:

Continuing research programs are underway by the Naval Submarine Medical Research Laboratory. The focus of these programs is centered on five areas: Diving physiology concentrating on submarine escape and rescue, environmental physiology looking at submarine atmospheres, psychology dealing with submariner screening and the support of corpsmen at sea, visual research looking at white light, periscope and sonar displays and finally, auditory research concentrating on sonar performance and diver hearing.[9]

A number of these areas of research are applicable to space related areas. Diving physiology is the same physiology used in the wearing of Extra Vehicular Activity (EVA) suits. Data from the Navy Submarine Medical Research Laboratory was a factor in the decision to lower the pressure in the Man Tended Configuration (MTC) of the space station. The lower pressure prevents the necessity of prebreathing and limits danger from the "bends." Both of these procedures were developed from diving physiologies.

The development of computer and control displays which are less tiring to individuals and which are more easily read are the same for astronauts as they are in the enclosure of the submarine. The testing required to determine the acceptability of personnel to duty in a closed environment is similarly applicable.

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[9]. Naval Submarine Medical Research Laboratory, Indoctrination brief presentation, slide 5.

# CHAPTER V

# THE ATMOSPHERE AND LIFE SUBMERGED

The greatest adjustment to life in a closed environment is the development of an appreciation for clean air. After patrol when the hatches are opened for the first time in more than two months, the first comment of the crew is usually about the foulness of the smell of the outside world.

## CONTAMINANTS:

Many things which are taken for granted to people living in other environments are prohibited to those in closed environments. Chlorine bleach for laundering clothes is not permitted. The small amounts of chlorine given off by this liquid could mask the ability to detect chlorine being given off by the ship's lead-acid storage battery due to a leakage of seawater into the battery compartment. Most cleansers are prohibited. The most widely used antiseptic cleanser is probably vinegar. Ammonia used frequently to clean glass in most homes could put all hands into emergency breathing masks for hours if spilled submerged. Any aerosols propelled by carbon dioxide or freon are prohibited including deodorants, shaving cream, air fresheners and many other products which are used daily by the normal American. Most glues and high power adhesives are prohibited. This gets to be a real problem when something breaks which normally could easily be fixed with just a drop of "superglue". Sometimes this broken part is in a vital piece of equipment.

Included as an appendix to this paper is a list taken from the Navsea, Atmosphere Control Manual of chemicals and substances which are prohibited aboard submarines due to their potential as atmosphere contaminants. Other categories of substances are Restricted, Limited and Permitted. The four categories are defined as:

"Prohibited - Not allowed on board submarines at any time except under specific exemptions.

Restricted - Not allowed on board submarines while underway, except under specific exceptions, although may be used on board in limited quantities while in port and ventilating outboard.

Limited - May be used while underway for a specific purpose and for which no completely non-toxic substitute exists. Shall not be carried on board in excess of required quantities.

Permitted - No restrictions."[1]

An Atmosphere Contaminant Log is maintained of all atmospheric contaminants which are brought on board the submarine and a tag is required on each container. The location of each container must be logged. Special casualty procedures are specified for the different contaminants in Chapter 9 of the NAVSEA, Atmosphere Control Manual.

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[1]. U.S. Navy, Naval Sea Systems Command, Submarine Atmosphere Control (U) Manual S9510-AB-ATM-010, p. 7-1 - 7-2.

## RADIOACTIVITY:

There is also a problem with radiation buildup in a closed environment. Before you jump to conclusions about "the reactor" let me explain. The radiation buildup comes from luminous dial watches not from the reactor plant. Many luminous dial watches, especially those used by divers, have radioactive dials. For example the Seiko watch given to me for Christmas measured 310 counts per minute on a Beta-Gamma detector. Radium dial watches give off radon gas which builds up to an equilibrium level in a closed environment. The extremely sensitive atmospheric monitoring systems for airborne radioactivity used on nuclear submarines can easily pick up this source of radiation. This prohibits the use of these watches on board because of the problem with the masking of real reactor problems by these false indications.

Another problem is the chance of a broken crystal yielding loose surface contamination in the ship. This contamination would be detected on routine surveys and would require an investigation and a determination of the source. The diver's watches which are required to be carried on the ship are sealed in double plastic bags and are locked in a safe to prevent unauthorized usage.

Similar offenders causing radioactive contamination are vacuum tubes used in radar equipment and other high power electronics. These tubes must be accounted for and stored for disposal ashore if they are replaced at sea. They are controlled and tagged while installed and while in spare parts storage.

# ATMOSPHERIC LIMITS:

It is interesting to look at the differences in the atmospheric limits for the proposed space station and for the nuclear submarine force.

The limits presently used in the submarine force have been formulated from years of operational data backed up by numerous medical studies by doctors associated with the Naval Submarine Medical Research Laboratory. This explanation of the limits imposed on submarines is from the "Background" section of the Nuclear Powered Submarine Atmosphere Control Manual:

> "The atmosphere specifications in this manual represent the best available information within the present scope of medical and technological expertise. In some cases they represent a carefully evaluated compromise between what is medically desired and that which is technically obtainable. In all cases the operator should recognize that the prescribed upper limits of atmosphere contaminants do not represent a clear demarcation point or "go, no-go" line between potential damage to personnel or equipment and the area of continued safe operation. The goal must be to maintain atmosphere contamination at a level which approaches -- as closely as practicable -- the composition of clean air in the atmosphere."[2]

A comparison of the submarine atmospheric contaminant limits presently used with those proposed by the Submarine Atmospheric Contaminant Workshop held at the Naval Submarine Medical Research Laboratory in September 1983 illustrates the evolution of the limits. Some contaminants have been totally dropped from the

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[2]. U.S. Navy, Commander Naval Sea Systems Command, Nuclear Powered Submarine Atmosphere Control Manual (Technical Manual S9510-AB-ATM-010)/(U), (Washington, D.C.: Naval Sea Systems Command, 15 October 1988), p.1-2.

present submarine limits such as Acetylene, Ethanol, and Xylene. Some limits have become much more restrictive such as Acetone and Methyl Chloroform. Continuing efforts by the submarine force to protect its personnel but also to permit the maximum flexibility of operations have resulted in the refinement of the levels of contaminants permitted.

ATMOSPHERIC CONTAMINANTS(ppm by vol)

| COMPOUND | SUBMARINE LIMIT | | WORKSHOP LIMIT | |
|---|---|---|---|---|
| | 90-DAY | 24-HR | 90-DAY | 24-HR |
| Acetone | 200 | 1000 | 300 | 2000 |
| Ammonia | 25 | 50 | 25 | 50 |
| Benzene | 1.0 | 2.0 | 1.0 | 100 |
| Carbon dioxide | 5000 | 39,475 | 5000 | 10,000 |
| Carbon Monoxide | 15 | 50 | 25 | 200 |
| Chlorine | 0.1 | 0.5 | 0.1 | 1.0 |
| Hydrogen | 10,000 | 10,000 | 3,000 | 3,000 |
| Hydrogen chloride | 0.5 | 20 | 1.0 | 4.0 |
| Methane | 5,000 | 5,000 | 5,000 | 5,000 |
| Methyl Chloroform | 2.5 | 10 | 200 | 500 |
| Nitrogen Dioxide | 0.5 | 1.0 | 0.5 | 1.0 |
| Ozone | 0.02 | 0.1 | 0.02 | 0.1 |
| Sulfur Dioxide | 1.0 | 5.0 | 1.0 | 5.0 |
| Toluene | 20 | 100 | 50 | 100 |
| Vinylidene Chloride | .15 | 10 | 2.0 | 25 |

(This comparison lists only those contaminants which appear on both lists)

Machinery upgrades have also been performed to lessen the danger to personnel and equipment. Original R-11 air conditioning plants have been replaced with R-114 air conditioning units. The contamination limit for R-11 is 5 millitorr while the limit for R-114 is 100 millitorr. Old electrostatic precipitators which were almost impossible to clean have been replaced with new modular units which may be immersed in the electrosonic sink. Many machinery upgrades have been performed to either limit leakage of contaminants or to improve the capability of the atmosphere control equipment to purify the atmosphere.

# OXYGEN LEVELS:

A major medical effort was sustained to verify the feasibility of lowering the oxygen levels during submerged operations. This effort enabled the submarine force to operate with improved fire safety. The previous limit for oxygen on board submarines was 140-160 TORR (mmHg) but not greater than 21% $O_2$. This limit is illustrated in the attached chart from the Atmosphere Control Manual.[3] The new limit permits lowering $O_2$ levels to 17%. This change greatly reduces the chance of fire. You will notice from the provided table that the oxygen level is maintained in a region of the chart and not at an absolute level. The pressure fluctuations of the ship cause the partial pressure of oxygen to continually change while submerged.

A significant difference exists in the allowable atmospheric pressure limits on submarines and those on the proposed space station. The submarine limits of pressure extend from 810 to 700 Torr (760Torr=one atmosphere)(1 Torr=1mm Hg)[4]. The proposed space station limits are 770 to 750 Torr (14.7+or-.2 psi).[5]

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[3]. Ibid, p. 4-6.

[4]. Ibid

[5]. J. Waligora, Closed Life Support Systems Study Presentation-Barothermal Physiology Req., (Houston: NASA Johnson Space Center, 12 June 1990), p. 6.

The station pressure will be maintained by the supply of air from the repressurization banks or oxygen sources and the relief of air overboard by automatic relief valves.[6] There will also be a reduction in pressure due to the removal of carbon dioxide until the carbon dioxide reduction processes are perfected. Even without the operation of the diesel generator, submarines could not maintain a pressure limit this restrictive. They would not want to maintain it if it were possible. Submarines use air for the operation of numerous pneumatically controlled systems. They also continuously pump carbon dioxide overboard and bleed oxygen into the atmosphere to replace that which has been used. Pressurized air is also used as the mover of liquids from water for ballast to sewage discharge. Air pressure continually fluctuates up and down as it is used and recharged into the main ship's air banks. Therefore, a bounded region of allowable oxygen concentrations is used instead of an absolute limit. This system of a relatively large area of allowable pressure limits is presently not possible on the space station due primarily to the lack of any air compressor capability.

The space station operational limit for oxygen is 2.83-3.35 psi (146 Torr-173 Torr).[7] When the space station oxygen limits are superimposed on the submarine atmospheric graph, the tight

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[6]. National Aeronautics and Space Administration, <u>Environmental Control and Life Support System Architectural Control Document-SSP 30262 Revison D</u>, (Reston: NASA Space Station Freedom Program Office, 1991), p. 3-7.

[7].Waligora, <u>Closed Life Support Systems Study Presentation-Barothermal Physiology Req.</u>, p. 4.

restrictions are easily illustrated. A second factor is also apparent. More than half of the space station allowable zone is above the submarine zone. The upper limit of the submarine zone is for fire suppression. This statement appears in the Atmosphere Control Manual, "Routine operations should not be conducted with oxygen concentrations in excess of 21%, since abnormally high concentrations promote the propagation of flames and conflagrations."[8]

[8]. NAVSEA, Atmosphere Control Manual, p. 4-9.

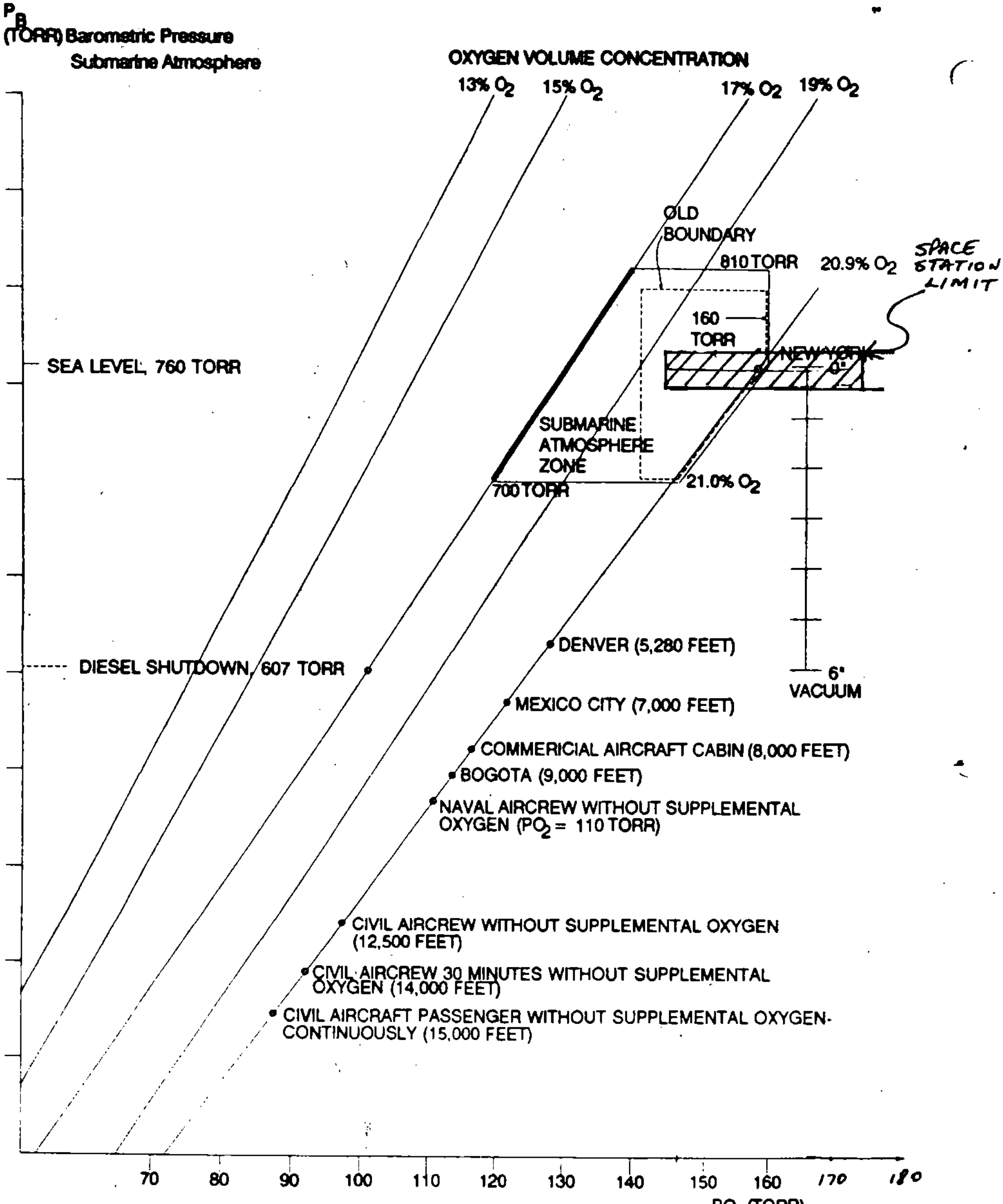



FIGURE 4-1 RELATIONSHIPS OF OXYGEN PARTIAL PRESSURE AND VOLUME CONCENTRATION TO TOTAL PRESSURE ($P_B$), WITH ILLUSTRATED SUBMARINE ZONE.

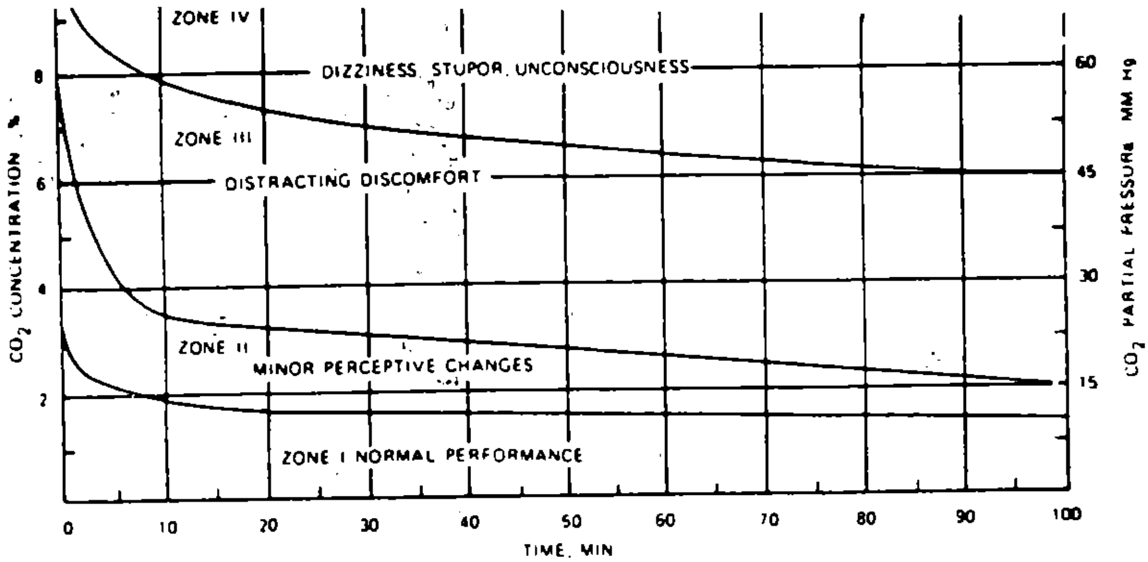
[9].NAVSEA, Atmosphere Control Manual, p. 4-6.

An extensive air system maintenance capability exists aboard submarines. To assume the air systems aboard the space station will be leak free for the 30-year life span of the station is unrealistic. A small air leak in one of the repressurization air valves will drain the banks due to no recharge capability. The excess air will be relieved overboard automatically.

Submariners by procedure dive with the air banks at maximum pressure and the ship's atmospheric pressure at 760 Torrs (14.7 psi). If this is not done, as the ship's air compressors charge the air from the ship into the air banks the atmospheric pressure drops out of the allowable range. The only solution is to come to periscope depth and raise the snorkel mask and take air into the ship to raise the atmospheric pressure back to normal. In the space station the lack of an air compressor capability results in an eventual situation of zero air bank pressure and one remaining atmosphere of pressure in the station. An enlarged pressure band and a compressor capability would permit the conservation of much of the air from a small leak and would greatly extend the ability of the station to maintain the reserve air in the repressurization air bank for emergencies.

## CARBON DIOXIDE LIMITS:

Carbon dioxide limits on submarines are divided into two categories "short-term exposure" and "long-term exposure". The short term limits are divided into zones I, II, III and IV. Zones one through three produce effects which are reversible by breathing fresh air for an adequate period. Zone IV can cause permanent damage and even death.[10] The chart below illustrates these zones.



[11]

Long-term exposure limits for submarines are divided into three areas. These are 0.5-0.8% (where there are no significant effects on the body), 0.8% to 3.0% (where impaired mental functions and slowed physical activities result) and 3.0% and above (where increased mental and physical and mental impairment result).[12] The normal 90-day limit is maintained 3.8 Torr(0.5%) for ships having new generation scrubbers and 6.1 Torr(0.8%) for ships with older units. The monoethanol amine scrubbers used by submarines are not capable of lowering carbon dioxide very much below 0.4% due to submerged back pressure on the outlet and due to the

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10. NAVSEA, Atmosphere Control Manual, p. 4-11.

11. Ibid

12. Ibid

characteristics of the units. The molecular sieve $CO_2$ removal units for the space station can lower $CO_2$ to the 3.0 Torr (0.39%) specification for the space station.

Numerous studies have been conducted by the Naval Submarine Medical Research Laboratory on the effects of Carbon Dioxide levels upon submariners. These studies have looked at various aspects of the body and the response of each to raised levels of $CO_2$. This partial list of some of the studies gives an indication of the depth of knowledge in this area of living in a closed environment. Only studies conducted after 1979 are listed.

Douglas, W.H.J., K.E. Schaefer, A.A. Messier, and S.M. Pasquale, Proliferation of Pneumocyte II Cells in Prolonged Exposure to 1% $CO_2$ (Groton: NSMRL 848 September 1979).

Messier, A.A., E. Heyder, W.R. Braithwaite, C. McCluggage, A. Peck and K. E. Schaefer, Calcium, Magnesium and Phosphorus Metabolism and Parathyroid-Calcitonin Function During Prolonged Exposure to Elevated $CO_2$ Concentrations on Submarines, MR041.o1.01-0125.06, (Groton: NSMRL 802 September 1979).

Sack, D.M., M. Holick and K.R. Bondi, Calcium and Vitamin D Metabolism in Submariners: Carbon dioxide, sunlight and absorption considerations, (Groton: NSMRL 1037 15 January 1986).

Schaefer, K.E., S.M. Pasquale, A.A. Messier, and H. Niemoller, CO2 Induced Kidney Calcification, (Groton: NSMRL 847 September 1979).

Schaefer, K.E., Physiological Stresses Related to Hypercapnia During Patrols on Submarines, MF041.01.01-125.05, (Groton: NSMRL 799 September 1979).

Schaefer, K.E., W.H.J. Douglas, A.A. Messier, M.L. Shea and P.A. Gohman, Effect of Prolonged Exposure to 0.5% CO2 on Kidney Calcification and Ultrastructure of Lungs, (Groton: NSMRL 868 September 1979).

Wilson, A.J., K.E. Schaefer, Effect of Prolonged Exposure to Elevated CO and CO2 Levels during Submarine Patrols on Red Blood Cell Parameters, MR041.01.01-125.07, (Groton: NSMRL 813 September 1979).

The sum of the results of these studies is that operation between 0.5% and 0.8% $CO_2$ generates few if any major non-reversible effects upon personnel. There are, however, numerous effects which are still under investigation for prolonged exposure to levels of $CO_2$ from 0.5% to 3.0%. These excerpts from the above studies indicate some of the effects which require further investigation.

> "The role of $CO_2$ in the etiology of lung damage caused by exposure to increased oxygen has been the subject of some debate in the literature and has not yet been determined(Wood 1975). Further experiments are required to answer this question. The findings of this study establish new criteria for the evaluation of low levels of chronic $CO_2$ toxicity that may occur in submarine and space craft environments."[13]

> "The mechanisms involved in the cyclic bone $CO_2$ and calcium and phosphorus changes during chronic hypercapnia are far from clear. It is difficult to understand how a small elevation in $PCO_2$ of a few mmHg could cause such cyclic changes, based on a $PCO_2$-dependent saturation mechanism."[14]

Extensive data gathering has already been performed on the effects of $CO_2$ concentrations on personnel in closed environments. All of these studies should be equally applicable to the closed environment of a space craft.

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[13]. W.H.J. Douglas, K.E. Schaefer, A.A. Messier, and S.M. Pasquale, "Proliferation of pneumocyte II cells in prolonged exposure to 1% CO2," Undersea Biomedical Research, Submarine Supplement 1979, p. S141.

[14]. A.A. Messier, E. Heyder, W. R. Braithwaite, C. McCluggage, A. Peck, and K.E. Schaefer, "Calcium, magnesium, and phosphorus metabolism, and parathyroid-calcitonin function during prolonged exposure to elevated CO2 concentrations on submarines," Undersea Biomedical Research, Submarine Supplement 1979, p. S68.

# OTHER ANALYZED GASES:

A number of studies have been performed on gases in addition to oxygen and carbon dioxide. These studies look at many trace contaminants and their long and short term effects while submerged. One such study looks at the body burden levels of volatile organic compounds while in a moored submarine.[15] Another at the same compounds exhaled by tested individuals before and after a 70-day patrol submerged. Studies have also been completed on the effects of carbon monoxide[16] and of nitrogen dioxide[17].

# CONCLUSIONS:

The exhaustive atmospheric studies conducted by the Naval Submarine Medical Research Laboratory and the extensive data base provided by decades of submerged operations in a closed environment can provide the life sciences program with valuable insight and experience into living in the closed environment of space. There is little difference in living in a space confinement and living in a submarine except for the aspects of microgravity.

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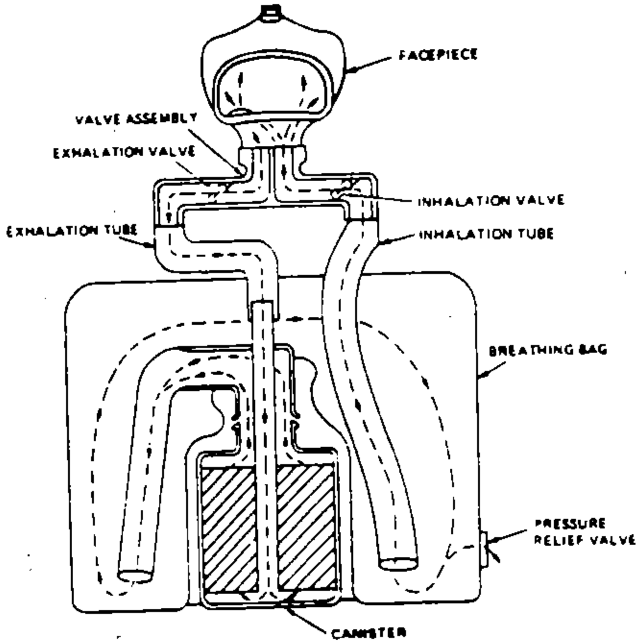
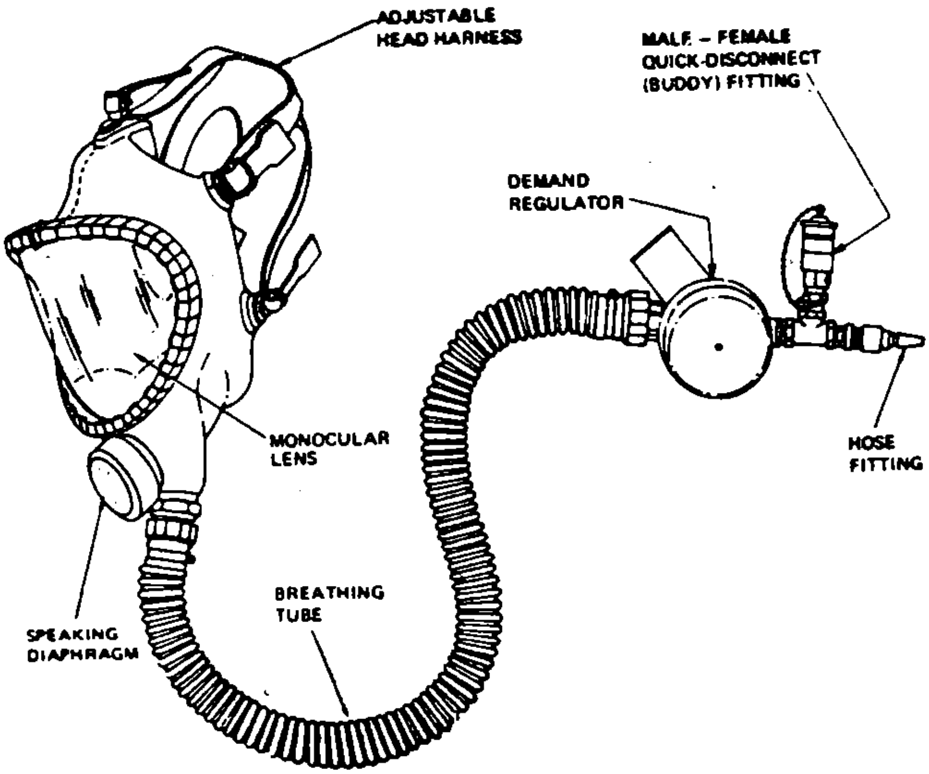
[15]. Knight, D.R. et al, Body Burden of Organic Vapors: Trial Measurements aboard a Moored Submarine, (Groton: NSMRL Memo 84-4 of 19 December 1984).

[16]. Bondi, D.R., Current Submarine Carbon Monoxide and Estimated Carboxyhemoglobin Levels and Interpretation of their Possible Effects on Mental Performance and Health Risk, (Groton: NSMRL 883 of 27 November 1978).

[17]. Bondi, K.R., M.L. Shea and R.M. DeBell, Nitrogen Dioxide Levels Aboard Nuclear Submarines, (In Nov 83 issue of J.Am. Ind. Hyg. Assoc.), (Groton: NSMRL 988 of 1 December 1983).




18.
Figure 5-11. Type A4 OBA Air Flow Diagram




19.
Figure 5-10. EAB Mask

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[18]. NAVSEA, <u>Atmosphere Control Manual</u>, p. 5-38.

[19]. NAVSEA, <u>Atmosphere Control Manual</u>, p. 5-32.

# CHAPTER VI

# RADIATION EFFECTS AND SHIELDING

"Regardless of the mission duration, radiation protection from solar flare events and galactic cosmic rays are a critical issue for crewed missions."

America on the Threshold
Synthesis Group[1]

Do our plans for the space station and for space travel provide for adequate protection of the crew members from radiation in the space environment? Can the submarine force provide expertise in the area of shielding to improve the safety of the program?

In the present submarine force, the major portion of which is nuclear powered submarines, the reduction of radiation exposure to the crew members is an issue of the maximum importance. Every effort is made to reduce personnel exposure during operations and maintenance activities. The effectiveness of these efforts has resulted in very low dose rates to submarine crews. Often these dose rates are lower than those of the civilian public living in areas of high solar exposure such as Denver, Colorado.[2]

The national limits for radiation exposure for non-radiation workers are 500 millirem per year or 300 millirem per quarter. The

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1. Thomas Stafford, Chairman, Synthesis Group, America At the Threshold, (Arlington: The Synthesis Group, May 1991), p. 79.

2. U.S. Navy, Naval Nuclear Propulsion Program, Occupational Radiation Exposure From U.S. Naval Nuclear Propulsion Plants and Their Support Facilities (Report NT-91-2), (Washington,D.C.: Naval Nuclear Propulsion Program, 1991), p. 35.

radiation exposure limit to radiation workers is 5000 millirem per year.[3] The exposure allowed by shuttle astronauts as reported in the Synthesis report is 50 Rem per year or 50,000 millirem per year.[4]

## RADIATION SOURCES:

The space radiation level unlike the submarine radiation level is not constant. High radiation levels in space come from several different sources. The total dose encountered by the astronauts is a sum of these sources. The sources include Galactic Cosmic Rays (GCR) and Solar Particle Events (SPE). "Life threatening solar flares from Anomalously Large (AL) events occurring during a solar maximum are readily detected, but not reliably predicted."[5]

TABLE 2 Anomalously Large (AL) Solar Particle Events. [6]

| Date | rem (BFO)a) |
|---|---|
| 23 Feb 56 | 60 |
| 9 Feb 58 | 30 |
| 10 May 59 | 48 |
| 10, 14 July 59 | 114 |
| 12, 14 Nov 60 | 102 |
| 4, 7 Aug 72 | 498 |
| Sept, Oct 89 | 200 |

[3]. Ibid, p. 34.

[4]. Ibid, p. 23.

[5]. Dr. Thomas E. Ward, Synthesis Group Member, Space Radiation Issues, Shielding Requirements, and Enabling Science, (Washington: Department of Energy, 1991), p. 1.

[6]. Ibid, p. 5.

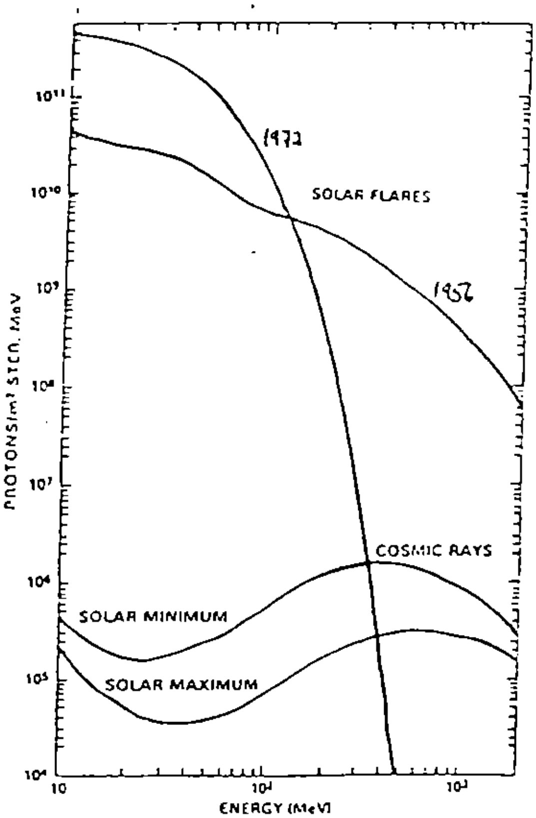


FIGURE 4 Comparison of the 1956 and 1972 AL SPE Energy Spectra With the Proton GCR.

The radiation to the astronauts can be countered if they are provided a shielded volume that can be used as a retreat during those times of maximum dose rate. During the other periods the dose rate is acceptable without significant shielding. The highest levels of radiation are due to Solar activity. This shows that shielding might only have to be used to attenuate radiation from a single source direction, that of the sun. In this logic Van Allen Belt radiation sources and other non-solar sources fall into another category.

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[7]. Ibid

# RADIATION RISKS:

The radiation environment is reasonably well defined. Studies have been conducted such as "Galactic Cosmic Radiation: Constraints on Space Exploration," by the Naval Research Laboratory[8] and "Space Radiation Issues, Shielding Requirements, and Enabling Science," by Dr. Thomas E. Ward, a Synthesis Group Member at the Department of Energy[9]. These studies indicate extensive data gathering and give a well defined breakdown of the radiation composition and level to be expected on space missons. The nuclear submarine force has more experience and technical ability in the design of shielding and in the areas of personnel radiation protection and monitoring than any group of scientists in the United States. The Naval Reactors branch of the Naval Sea Systems Command publishes each two unclassified reports. One report, "Environmental Monitoring and Disposal of Radioactive Wastes from U.S. Naval Nuclear Powered Ships and Their Support Facilities" covers all the environmental effects from operating our fleet of over 100 nuclear ships and their support facilities. The second report, "Occupational Radiation Exposure From U.S. Naval Nuclear Plants and Their Support Facilities," discusses all of the radiation effects to personnel due to the operation of hundreds of reactors and the subsequent

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[8]. Galactic Cosmic Radiation: Constraints on Space Exploration-NRL Publication 209-4154, James H. Adams, Jr, editor, (Washington, D.C.: Naval Research Laboratory, 1991).

[9]. Thomas E. Ward, Synthesis Group Member, Space Radiation Issues, Shielding Requirements, and Enabling Science (unpublished), February 6, 1991.

refuelings and overhauls since the 1950's. This is over 40 years of radiation related personnel monitoring. The extent of the personnel database is indicated in this exerpt from the "Occupational Radiation Exposure Report" by Naval Reactors:

> "Of particular interest to workers in the Naval Nuclear Propulsion Program are studies of groups occupationally exposed to radiation. A recent survey of radiation-worker populations in the U.S. shows there are about 350,000 workers currently under study. For more than a decade, Naval Nuclear Propulsion Program personnel, including those at shipyards and in the Fleet, have been included among populations being studied."[10]

There are differences between the energies of the particles of cosmic sources and those of submarine reactors. These differences are documented. There are also extensive documented studies of the 100,000 atomic bomb survivors.[11] The extremely high levels of expertise in radioactive shielding and monitoring developed over years of operation of naval reactors should not be ignored by the space program. Statements such as this from the Congressional Research Service concerning the effects of radiation on the astronaut corps are disturbing to this experienced submarine captain in the nuclear submarine force.

> "Cumulative effects make total exposure time a critical factor. There is, however, no consensus concerning safe levels. Even means of measuring dosages are under review. Better understanding is obligatory, because early disablement could cause mission failures. Delayed results that could include leukemia, solid tumors, cataracts, and infertility would retard recruitment and

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[10] Naval Nuclear Propulsion Program, Occupational Radiation Exposure From U.S. Naval Nuclear Propulsion Plants and Their Support Facilities, p. 40.

[11]. Ibid, p. 37.

retention of military personnel."[12]

Taking just one of the effects listed here for use as an example we demonstrate the extent of the knowledge level in the effects of radiation on personnel which is available in the nuclear naval forces. The effect is that of cataracts being generated by radioactive exposure. Nuclear trained personnel are required to have nuclear physicals on a regular basis. One of the inspection points of the physical concerns the susceptibility to cataracts. This data is taken from the Naval Nuclear Propulsion Program report titled "Occupational Radiation Exposure From U.S. Naval Nuclear Plants and Their Support Facilities," of February 1991.

> "Radiation induced cataracts have been observed in atomic bomb survivors and persons treated with very high doses of x-rays to the eye. Approximately 20 years ago, potential cataract induction was considered a matter of concern. However, more recent research indicates the induction of cataracts by radiation is considered to require a high threshold for a vision-impairing cataract under conditions of protracted exposure is thought to be no less than 800 rem, which greatly exceeds the amount of radiation that can be accumulated by the lens through occupational exposure to radiation under normal working conditions."[13]

The radiation risks to the astronauts can be defined with some degree of accuracy if the radiation levels and components can be defined. In the Naval Research Laboratory report, "Galactic Cosmic Radiation: Constraints on Space Exploration," this conclusion was reached.

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[12]. Collins, Military Space Forces, p. CRS-35.

[13]. Navy Nuclear Propulsion Program, Occupational Radiation Exposure From U.S. Naval Nuclear Propulsion Plants and Their Support Facilities (Report NT-91-2), (Washington, D.C.: Naval Reactors NAVSEA 08, 1991), p. 38.

"Nuclear rockets, however, may deliver their own radiation dose equivalent to the crew, so it is unclear at this time whether nuclear propulsion will reduce the total radiation hazard."[14]

Nuclear propulsion whether it is in space or under water uses nuclear fuel. This fuel usually consists of either uranium 235 or Plutonium 238 and a fission process. The radiation emitted from this fission process is extremely well defined and documented. Yes, shielding will be required if we operate space nuclear reactors. The high power densities generated by the nuclear reactor make launching of shielding material feasible and cost effective just as it makes the launching of the reactor feasible and cost effective.

The radiation risks encountered by the astronauts from Galactic Cosmic Rays, Solar Particle Events and from Van Allen Belt radiation sources make the risks to the astronauts high. The submarine force would not think of operating the reactor on a nuclear ship without adequate shielding for the personnel. In 1972 there was a Solar Particle Event which generated 498 rem total dose over the period 4 to 7 August.[15] The untrained person doesn't grasp the danger involved in this event. The table below is provided from the article, "Management of Irradiated and Contaminated Casualty Victims," written by Dr. William C. Milroy, Ph.D., while Commanding Officer of the Naval Submarine Medical Research

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14. Galactic Cosmic Radiation: Constraints on Space Exploration, James H. Adams, Jr., editor, (Washington, D.C.: Naval Research Laboratory, 1991), p. 3.

15. Ward, Space Radiation, p. 5.

**Table 3. *Acute Radiation Syndrome*** [16]

| DOSE RANGE (rem) | SYNDROME TYPE | SYMPTOMS | LYMPHOCYTES (Day 3) | PLATELETS (Day 30) | TREATMENT | PROGNOSIS |
|---|---|---|---|---|---|---|
| 0–25 | None | None | Normal | Normal | None | |
| 25–100 | None | Mild prodromal | Normal or slightly depressed relative to base line | Normal or slightly depressed relative to base line | None necessary | |
| 100–200 | Hematopoetic (mild) | Prodromal nausea and vomiting | 50% reduction | 25–50% reduction | Symptomatic | Recovery expected |
| 200–400 | Hematopoetic (moderate) | Prodromal; latent period; definite hematologic derangement; some nausea and vomiting | 75% reduction | 50–75% reduction | Supportive antibiotics, blood products | Some mortality; most recover |
| 400–600 | Hematopoetic (severe); some gastrointestinal | Marked prodromal; latent period; marked hematologic derangement; nausea, vomiting, diarrhea; prostration; bleeding; infection | 90% reduction | 90% reduction | Supportive fluids, antibiotics; blood products; marrow transplants; stem cell transfusion | 50% or more mortality |
| 600–1000 | Gastrointestinal | Marked prodromal; shortened latent period; marked nausea, vomiting, diarrhea; prostration; coma, death; hematologic derangement depends on survival time | Essentially absent | Essentially absent | All of above or expectant | Mortality increases to 100% above 900 rems |
| 5000 | Central nervous system | N/A | N/A | N/A | N/A | Death within 2 days |

This table indicates that an acute dose of 498 rem will yield numerous serious side effects and a "50% or more mortality rate" of the patient. This same effect could be generated by a 50 rem dose rate over a ten hour period of exposure. The terms "acute" or "long-term" are associated with doses of radiation and generally mean whether the body has time to biologically recover from the radiation exposure damage before subsequent doses. The three day dose in August 1972 would be termed "acute".

The consideration of sending astronauts into space without shielding due to the costs of launching the weight of the shielding into orbit is not a wise determination. The radiation shielding section of this research paper includes multiple designs for

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16. William C. Milroy, Ph.D., "Management of Irradiated and Contaminated Casualty Victims," Emergency Medicine Clinics of North America-Vol.2, No.3, August 1984, p. 674.

shields for the space station and recommendations for protection of astronauts from radiation problems. The entire station or space craft does not need to be shielded as long as a shielded shelter is provided to the personnel during the times of high radiation exposuree to the spacecraft.

## DOSE REDUCTION:

The basic theory for reducing radiation exposure can be delineated in three words: Time, Distance, and Shielding. The accumulated dose can be reduced by any single factor or by any combination of the three factors. Using the Mars trip as an example as specified in the Synthesis study, the length of the trip is a major factor in the dose.[17] A faster trip will yield a lower dose to the astronauts. This is a good case for the development of the nuclear thermal engine with its much faster transit time to Mars. It is not possible to affect significantly the distance to the solar source. Avoidance of Van Allen belt sources and other known radiation sources is significant.

The final factor is shielding. The only factor which can successfully protect the astronauts from an unexpected solar event during the transit to Mars or the Moon is shielding. In fact, this disturbing statement appears in the Synthesis report, "Solar flare events may be incapacitating or lethal for an unshielded

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[17]. Ibid, p. 24.

astronaut."[18]

What kind of radiation levels are acceptable to the astronauts? This is a debatable issue. The Navy submarine crew radiation limits are designed for no biological damage over the life of the crew member in excess of the radiological damage due to background radiation sources.[19] The limits for the astronauts are based upon a different standard. "The career depth dose-equivalent is based upon a maximum 3% lifetime risk of cancer mortality."[20]

TABLE 4 Career Whole Body Dose Equivalent Limits Based on a Lifetime Excess Risk of Cancer Mortality of 3%.

| Age (years) | Female (rem)a) | Male (rem)a) |
|---|---|---|
| 25 | 100 | 150 |
| 35 | 175 | 250 |
| 45 | 250 | 320 |
| 55 | 300 | 400 |

a) 100 rem = 1 Sv

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18. Ibid.

19. Naval Nuclear Propulsion Program, Occupational Radiation Exposure From U. S. Naval Nuclear Propulsion Plants and Their Support Facilities, p. 36.

20. National Aeronautics and Space Administration, Johnson Space Center, Closed Life Support Systems Study, "Radiological Health Requirements," by Donald Robbins, Ph. D., NASA/JSC, of June 11-14, 1990, p. 3.

21. Ward, Space Radiation Issues, p. 2.

The shorter term limits are given in Table 2 where the life-threatening limits are set by the dose to the Blood Forming Organs (BFO). Shielding estimates should be made for the protection of BFO.

TABLE 5 Short-term Dose Equivalent Limits and Career Limits (rem)[a].

| Time Period | BFO [b] | Lens of Eye | Skin |
|---|---|---|---|
| 30 day | 25 | 100 | 150 |
| annual | 50 | 200 | 300 |
| career | see Table 1 | 400 | 600 |

The problem with shielding is weight due to the constraints on the launching of heavy payloads into orbit. There is a weight penalty to be paid to shield the entire spacecraft. The real question is, "How much shielding is enough?" Presently the shielding for the space station consists of about 7cm of aluminum. The submarine force has a demonstrated expertise in shielding. In submarine construction many materials are used for shielding including lead, water, lead glass, and canned polyethylene. The cyclic nature of the radioactivity shows that the astronauts could perform most of their duties unshielded if provided with a "shielded retreat area" for safety during solar events. Since most of the solar flare activity will be coming from a single direction only one side of the space craft needs shielding if it can be maintained in a set attitude toward the source of the radioactivity. This may not be possible on the space station due to the orientation of the station toward the earth and the propulsion expenditure required to keep a shield pointed toward the sun. On a Mars mission however the use of a one sided shield might

22. Ibid.

be possible and preferable.

If a polyethlene segmented shield was used, the shield would start to be effective as it was being assembled. After one side of the retreat was layered, the shield would be operational as long as that side was pointed toward the source of the radiation. The shield could be transported into space one segment at a time as shuttle loading permits.

## SHIELDED HABITATION MODULE:

If we take the habitation module as the retreat area and shield it with a 12 inch polyethylene shield, we would provide one tenth thickness of neutron protection or an order of magnitude decrease in the neutron dose and reduce the gamma dose by a factor of three. The "very slow attenuation" of the proton dose mentioned in the Adam's article is due to the use of aluminum as a shield inappropriately. Aluminum is not a good shield for proton or neutron radiation. Aluminum is a good shield for Beta and Gamma radiation and will attenuate the heavy particles of the Cosmic sources. The size of the proton and neutron particles makes water or a substance such as polyethylene which is high in hydrogen a much preferable shielding material. By placing the aluminum shield outside of this polyethylene, the heavy particles from the Cosmic rays would be attenuated before entering the poly and the neutron flux would be generated outside of the poly shield.[23] This could be reduced by layering borated polyethylene on the inside of the 12 inch polyethylene shield. The borated polyethylene contains boron 10 which absorbs thermal neutrons and forms metastable boron 11 which immediately decays to Lithium and an alpha particle. The alpha particle, a helium nucleus, will be effectively trapped in the polyethylene. The unborated poly also attenuates neutron radiation by three processes: elastic scattering, photoelectric effect and Compton scattering.

The poly will also attenuate gamma radiation. One tenth thickness for gamma radiation for polyethylene is 24 inches. The tenth thicknesses for water shielding and polyethlene shielding are very similar.

Other shielding can be provided by strategic placement of the water storage tanks. If these tanks are designed to be relatively flat and configured to conform to the shape of the pressure hull, they will effectively become shields when filled with water. Again they would need to be situated between the crew and the source of the radiation.

The canned polyethylene shield could also serve another important function. The structural rigidity and flexibility of the polyethylene would make it a good shock absorbing medium to prevent puncture of the module pressure hull by impingement of space debris or meteorites. This problem is addressed in the Congressional

23. James H. Adams, Jr. ed., Galactic Cosmic Radiation: Constraints on Space Exploration (Washington: Naval Research Laboratory, 1991), p. 3.

Research Service study by John M. Collins,

> "Multicellular construction probably will characterize large space vehicles, because bulkheads distribute structural loads and provide multiple stress paths. Self sealing pressure chambers moreover might serve much the same purpose as watertight compartments on ships. Vehicles could survive, if mertoroids or enemy weapons punctured one or more."[24]

In future missions to the moon and to Mars canned poly segments could be used as shielding against radiation while on the surface. If the polyethylene was used in this manner, it would require protection from temperatures higher than about 180 degrees at which it begins to soften. The combined use of polyethylene, water tanks and layers of lunar or Martian earth should provide adequate protection for our astronauts during their extended missions.

There is one drawback to the polyethylene shield in addition to the weight penalty. It would act as an insulator preventing the radiating of heat from the module. If the rejection of heat is required through the pressure hull, other systems using heat radiating panels or other options would be required. The protection of the astronauts from radiation and from collision with space debris makes this option of shielding worthy of further investigation.

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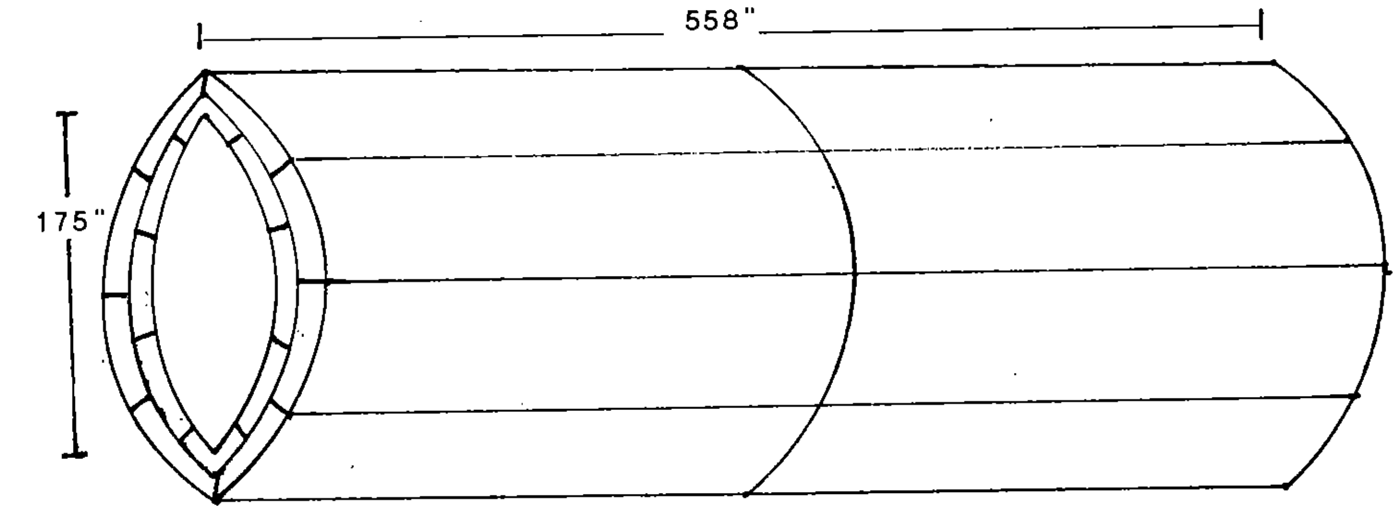
[24]. Collins, Military Space Forces, p. CRS-118.

# SEGMENTED POLY SHIELD




## JUSTIFICATION FOR POLYETHYLENE

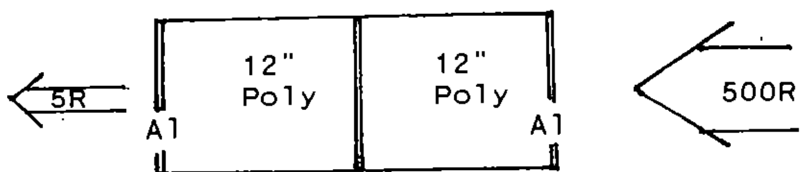
Proton and Neutron attenuation requires hydrogen rich shielding material. Water and poly are similar in their shielding properties and densities. Poly is easier to mold to shape and more durable for shielding the modules from impact from space debris, a secondary function of this radiation shield.

The shield will be formed from aluminum canned poly segments. The shield will consists of two layers of 12 inch segments overlapped to prevent channelling of radiation between segments. The inner layer will be of poly doped with boron 10. The boron will provide additional neutron attenuation by the reaction:

$B_{10}$ + neutron = metastable $B_{11}$ = $Li_8$ + alpha

Both the Li and the alpha particle will be trapped in the poly.

## DOSE ATTENUATION




1972 SPE
Dose
Rate(DR)= 498 R/4days
DRavg= 5.2 R/hr
DRw/24"poly= /.052R/hr

Solar Minimum Dose rate = 64 Rem/yr
With only 12" of poly shield this would be reduced to 6.4 Rem/yr almost within specification for radiation workers of 5 Rem/yr.

## VOLUME AND WEIGHT

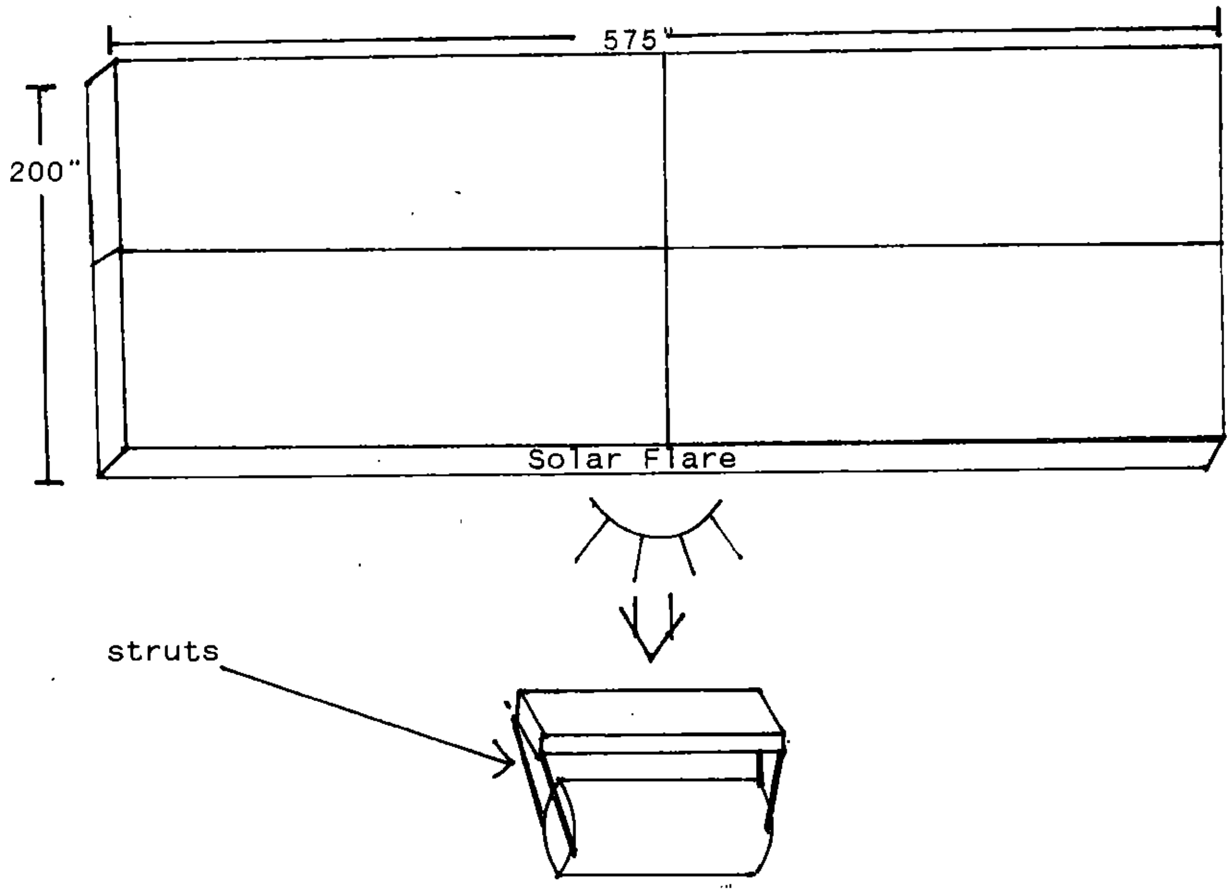
Volume=$\pi r_2^2 h - \pi r_1^2 h$, h= 558" $r_1$=87.5" $r_2$=111" density = 65#/$ft^3$
Volume= 4730 $ft^3$ weight= 307,441#
Poly applied in 32 segments at avg of 9607# each

# MOVEABLE EMERGENCY SHIELD

This shield is designed to be a flat movable shield which may be positioned between the habitation module and the source of the radiation which is most probably the sun. The shield will be positioned in the same method as the solar thermal shield used over the Skylab station to prevent overheating.

If properly positioned between the personnel and the source of the radiation, this shield will be just as effective as the circular shield. This shield will not provide debris impact protection to the module unless the debris happens to be from the same direction as the radiation source. The shield will also not be effective against radiation from multidirectional sources such as from the Van Allen Belt.

The shielding material is polyethylene coated with a highly reflective coating of aluminum foil for heat rejection. The shield consists of eight panels 12" thick measuring 100" by 287". The shield when assembled must be positioned to shadow the entire habitation module. Movement of the shield will be necessary to ensure protection.




no protection from multidirectional sources

# CHAPTER VII

# CASUALTY PROCEDURES

One area of experience in submarine operations which can make a significant contribution to the space program is that of dealing with various casualties in the closed environment. This study will deal with the contrasting of the submarine techniques of fighting casualties with the space station casualty procedures as outlined in the "Contingency Operations Scenarios Study" by J. Steve McLendon, JSC, on July 26, 1990.[1]

Seven Contingency Scenarios were examined in the referenced study. These included: Depress, Fire, Toxic spill, Loss of H2O, Loss of Control, Loss of Power, and Loss of Thermal Control.
It is obvious that some of these scenarios are more closely related to the submarine environment than others.

## SUBMARINE CONSTRUCTION AND PROCEDURES:

To analyze these scenarios from a submarine viewpoint, some background knowledge of submarine equipment and procedure needs to be discussed. Submarines are constructed with several water tight compartments separated by water tight doors (hatches). The number of compartments depends on the class of submarine. The SSBN 627 Class submarine has five water tight compartments while an SSN 688

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[1]. J. Steve McLendon, Contingency Operations Scenarios Study, (Houston: Johnson Space Center, 26 July 1990), p. 4.

class ship has only two. The water tight doors can withstand the pressure differential designed into the bulkhead between the compartments. This can vary but may be up to several hundred pounds per square inch. The water tight doors have an O-ring seating surface and two closed positions. The doors may be shut "on the latch" or they may be "dogged" shut. The doors also have an open latch. When shut on the latch the doors may be opened by operating the spring latch handle. The doors are not air tight when latched due to seat leakage. To put the door at full strength it must be "dogged" by spinning the center handle to engage the four seat dogs located around the circumference of the door.

During normal operation the water tight doors remain on the open latch to permit easy equalization of air pressure between compartments. In rig for battle and in casualties the doors are immediately placed on the latch to isolate the atmospheres of the compartments and to improve the watertight integrity of the ship. The main bulkhead ventilation flappers are also isolated in the standard casualty rig which is called rig for General Emergency. In main compartments containing numerous hull penetrations there are emergency flood control accumulators. These accumulators provide a single lever which when activated shuts all hull and backup valves in the space with hydraulic pressure from the emergency accumulator source. These actuators are effective even if normal hydraulic pressure has been lost.

# DEPRESSURIZATION:

There is a definite similarity between the depressurization scenario and the submarine flooding scenario.

"Assumptions:

1. All internal hatches are open during nominal operations.

2. Leak location is unknown and not detectable by audible means.

3. The equalization valves on the hatches are already closed.

4. Flying debris not considered-equipment tolerates rapid depress." [2]

I have two comments about the initial assumptions of this casualty procedure. First "leak location unknown and not detectable by audible means."[3] I do not agree with this assumption. Submariners are very sound conscious and we continually make tours of spaces searching for sound discrepancies. Any leak large enough to cause a pressure decrease in a module will undoubtedly be audible. It is a frequent occurrence to detect minute air and steam leaks on submarines audibly even though we have a large amount of rotating machinery. The astronauts can definitely be trained to be as proficient as submarine watchstanders in detecting small leaks of air or other gases.

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[2]. Ibid, pp. 5-6.

[3]. Ibid, p. 5.

After routinely touring my submarine for a couple of weeks on a daily basis, it was possible not only to locate leaks but also to walk into a space and to detect sound discrepancies from the normal levels. Bearing degradation on rotating machinery and improper system lineups are easily detected by experienced watchstanders by sound abnormalities.

The second comment on the assumptions concerns flying debris.[4] I have observed the lifting of a 4500 psi air relief in a closed space in which a crew member was physically blown out of the compartment through the open hatch. Meticulous storage of all tools and equipment is a submarine necessity which prevented any significant flying debris. Obviously a catastrophic 12 inch hole caused by impact of a piece of space junk would cause not only rapid depressurization but would also cause debris to be generated. If we are to guard against this scenario, the hatches should always be shut during operations. For the more likely small leak which is probably isolable, rigid stowage of "missile" objects must be adhered to by the crew members. Rough seas in the North Atlantic teach you that not only personal items become missiles. Large equipment which can generate inertia during movement must be adequately mounted to structural members. Submarine shock mounts for all major equipment guard us against equipment damage and also against personnel hazards caused by excessive movement of equipment.

If the worst case scenario involving depressurization is

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[4]. Ibid

collision with space junk causing a significant hole in the pressurized space, then the polyethylene shielding as described in the Radiation Shielding Section of this research paper should be considered from a safety viewpoint. The addition of this canned poly shield in layers on the outside of the habitation module would act as a shock absorbent shield from meteorites and debris as well as for radiation shielding.

The pressures dealt with in the submarine scenario are much higher than in the space scenario. The submarine submergence pressure is in the range of several hundred pounds per square inch where the space station scenario deals with only 14.7 psi to the vacuum of space. The pressure is in the opposite direction and the submarine scenario involves volumes of water at high pressure which is potentially much more unnerving to the personnel involved in combatting the casualty. Both scenarios do involve the breach of hull integrity and can result in the loss of life if not immediately corrected.

In analyzing the depressurization scenario I will call upon a number casualty procedures utilized by submarines including high pressure air leak, runaway diesel, flooding and toxic gas. This is the basic procedure for the Depressurization casualty as quoted from the Johnson Space Center Scenarios Study:

"CREW RESPONSE TO RATE OF PRESSURE LOSS ALARM

Action Plan Approach:

(1) Safe the crew-get them into a station area that's not

leaking.

(2) Save/Isolate leaking station elements.

Prior to PMC (racetrack not in place) (Permanently manned configuration)

*Close all intermodule ducts

*Isolate elements beginning with that farthest from the orbiter

(1) Push appropriate interface hatch closed (do not latch)

(2) If leak is in isolated element hatch will self-seal via Delta P.

(3) If leak not in isolated element crew retreat to next element toward orbiter.

(4) Repeat step 1

*When cabin pressure drops to 12.5 psia crew dons breathing masks.

*If cabin pressure drops to 10.2 psia crew abandons element isolation procedures and bails out to orbiter.

*If leak isolated to an element begin closing (via dms)(data management system) all known vent sources (relief valves, exp vent lines, etc.)

*Based on current pressure and affected element station CDR would make decision on re-entry to leaking element to close opposite-end hatches.

After PMC (Racetrack established)

*All crewmembers move to lab module, closing hatches 2 and 14 in route.

*If leak in lab module side of half-station, all crewmembers move to hab module side, closing hatches 15 and 28.

*When crew in safe half of station begin closing (via dms) all known vent sources (relief valves, exp vent lines, etc.)

*Based on current pressure station CDR would make decision as to re-entry to nodes 1 & 3 (or 2 & 4) to close all module/node hatches (4) of leaking half-station.

*When cabin pressure drops to 12.5 psia crew dons breathing masks.

*If cabin pressure drops to 10.2 psia crew abandons element isolation procedures and returns to safe half of station."[5]

A basic rule of submarine damage control which is observed throughout our casualty procedures is that the controlling stations immediately don breathing apparatus in any casualty situation involving atmospheric contamination within one minute of the alarm being passed. This provides a survivable element to direct the casualty procedures. A second basic rule is that the watchstanders and the off-going watch section, which forms our casualty assistance team, go immediately to the scene of the casualty. As in the flooding procedure our actions in this "depressurization" casualty procedure would take a different priority of actions than those specified.

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[5]. McLendon, Scenarios, p. 5-6.

Invariably, our first immediate action in every casualty is to pass the word, sound the correct alarm and pass the word again on the ship's general announcing system. Our second action in this case would be for the local watchstander or the personnel closest to the casualty to actively seek and isolate the leak. Except for a catastrophic leak caused by collision or a gross failure of inboard piping, there should be enough air volume in the space station module to perform initial isolation before evacuation. The time allotted for failure of specific components such as station hull fittings can be calculated based on hole size and the volume of the module. Additional watchstanders or crewmembers would rig the spaces for General Emergency which in this case would include isolating the space affected by shutting the intercompartment hatches and all intermodule ventilation paths. With the maximum pressure of only 15 psid in this scenario the man finding the casualty could seal the leak with an adhesive patch and limit the loss of air from the module if he could locate the source. There is definitely a difference between this leak and an inrush of water at 300 psid. This difference might make the leak harder to find. With the extensive racks in the modules a small hole in the external skin of the module might cause a slow leak which could not be located internally. This case probably would not be catastrophic but instead would be a chronic slow leak which would require an EVA inspection and patch.

Casualty procedures for the rapid isolation of sources of leakage should be formulated. Part of submarine qualification is to learn the hull fittings in all spaces of the ship. Damage control supplies are strategically located throughout the ship as well. On submarines we don't give up spaces easily. Shoring material and damage control supplies to patch everything from holes in pipes to hull cracks are available. When you are deep and the water starts coming into the living spaces, men can repair almost anything. The astronauts should be provided the training in repair similar to that given the submarine crews as damage control training at the Naval Submarine School in New London, Connecticut. They should also be given some supplies to repair leaking pipes and hull penetrations and the tools to use them. If we are looking forward to the moon base and the long space voyage, we need to convert the philosophy now to one of "fix the problem" not "wait for someone else to fix it". We cannot live for two years on a Mars mission with a space isolated due to an air leak nor can we live for 6 months on the moon waiting for a supply ship to come and fix the leak that is releasing our air supply.

I agree with the key finding No. two of the JSC Scenarios which states that "a portable breathing apparatus should be supplied with 100% O2 rather than air".[6] With the decreasing ambient pressure the pure oxygen would provide a significantly longer time to combat the casualty. The Navy Oxygen Breathing Apparatus (OBA) (using potassium superoxide canisters) [7] or a

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[6]. McLendon, Scenarios, p. 7.

[7]. Commander, Submarine Force Pacific Fleet, COMSUBPAC Readiness and Training Memorandum (RTM) 23-91; Submarine Fire Fighting Information, (Pearl Harbor: COMSUBPAC, 1991), pp. 23-24.

derivative would provide an easily stored and donned unit for this purpose. For a small leak the activation of the OBA in the confined space would mitigate the pressure decrease due to the exhaled volume from the personnel fighting the casualty.

The only remotely closed hatches on submarines are the mid-compartment door on the SSN 688 class and the escape trunk side hatches. The SSN 688 door weighs almost 1000 lbs and can not be shut at a significant ship's angle by one man so the air assist is provided for closing only. The escape trunk hatch has a hydraulic manual remote closing for subsequent men to be able to enter the escape trunk for buoyant ascent.[8] Making the shutting of all hatches an immediate action for the astronauts would probably suffice for most scenarios .

Pressure loss should not be the only casualty considered here. With the oxygen being rejuvenated by a cryogenic supply an over pressurization condition should also be considered. Other pressurized gases are also stored in the space station. Over pressurization of a compartment is not infrequent in submarines which have significantly larger compartment volumes and can result in hatches being locked due to differential pressure preventing their opening until equalized. A method of venting excessive pressure should be included in the standard operating procedures.

Rapid depressurization on a submarine is a casualty which must be dealt with in the case of the diesel generator. When the 1000HP

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[8]. Knowledge based on personal experience on board those vessels.

diesel is running and the ship loses depth control submerging the snorkel air supply mast, the pressure in the ship drops precipitously. The diesel can change half of the air in the ship in only 40 minutes of operation. A 12" Hg vacuum shutdown is built into the diesel circuitry to protect the crew from the effect of the rapid depressurization. In this case the air is not just escaping through a hole, it is forcibly being pumped out of the ship at a rapid rate. Men still have time to secure the diesel manually and to take other appropriate casualty actions. If the actions of the space station casualty procedure are to be predicated on the remaining pressure in the module, then a controlling station must be designated and communications set up to tell the man fighting the casualty the status of the remaining pressure. Having observed men fighting flooding casualties, they will go to extraordinary lengths to complete damage control efforts and place themselves at risk if they do not have a supervisory element who can stand back and see the overall picture and act on the indications being received.

In my review of the casualty procedures for the space station I have not been able to determine the designation of a single station which could be termed the "controlling station" for casualty control. The exception to this is the orbiter when mated to the space station. In submarines, the Captain goes to the controlling station and other senior men go to the scene of the casualty and execute the casualty procedures. This provides overall coordination of damage control efforts.

## FIRE SCENARIO

Fire is one of the most dreaded and most frequent casualties in the submarine force. The majority of submarine fires are electrical class "C" fires.[9] There are significant differences in the submarine philosophy of fire fighting and the fire scenario of the JSC Study. The assumptions of the JSC fire scenario are:

"Assumptions:

* Baseline fire detection and suppression subsystem in each module and node.

    * Smoke, thermal, and flame detectors which are rack, duct and/or element mounted.

    * Tanks and distribution system that supply the fire suppressant to equipment racks and standoffs.

    * Portable extinguishers for manual fire suppression in nodes and modules.

* Dispersement of CO2 is activated through the DMS(Data Management System) or by a manual switch.

* The crewmembers must pass through the fire, if it is between them and the orbiter or to prevent entrapment.

* Emergency breathing masks in each module and node located near the hatches."[10]

The degree of automation is the greatest difference between

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9. Commander, Submarine Forces Pacific Fleet, COMSUBPAC Readiness and Training Memorandum (RTM) 23-91; Submarine Fire Fighting Information, (Pearl Harbor: COMSUBPAC, 1991), p. 8.

10. Ibid, p. 9.

the technique of fire fighting on the space platform and on the submarine. None of our systems are automatic. Carbon dioxide is never dumped into an occupied space without manual activation. Also most of our major switchboards and controllers are spray tight to prevent moisture introduction.

In the submarine procedure the first action after announcing the casualty and sounding the alarm is deenergizing the piece of equipment. Our systems are built so that electrical equipment can be isolated locally or outside of the compartment if necessary. Usually, the farther from the equipment the isolation takes place, the larger the number of systems affected by the isolation. Rapid electrical isolation has been proven to extinguish most electrical fires in the submarine force.[11] By my best information these design features are incorporated into the present design of the space station electrical system.

The fire scenario for the space station includes the following: "CREW RESPONSE TO A FIRE ALARM

FIRE CONTAINED IN A RACK

*DMS automated response (SDP/MDM)(Standard Data Processor/

* Avionics air valves closed in affected rack

* Rack electrical power turned off

* Fire Suppression valves closed in all unaffected racks

* CO2 dispensed in affected rack (Time Delay)

* Terminate intermodule ventilation (IMV)

* If crewmember in affected element:

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11. COMSUBPAC, Readiness and Training Memorandum 23-91, p. 28.

* Don POS

* Verify automated safing actions complete, backup if required.

* Evacuate fire location closing associated hatches

* If no crewmember in affected element:

* Verify automated safing actions complete

* If required, crewmember don POS, enter module and perform backup

* Close associated hatches

* Verify element atmosphere free of toxins

* Depress element as last resort if necessary

* Initiate emergency shutdown procedure

<u>FIRE CONTAINED IN A MODULE</u>

*DMS automated response (SDP)(Serial Data Processor)

* IMV fans off, IMV ducts closed in affected module

* Cabin air fan off if other sensors confirm

* If crewmember in affected element:

* Don POS

* Discharge portable fire extinguisher

* Verify automated safing actions complete, backup if required.

* Evacuate fire location closing associated hatches

* If no crewmember in affected element:

* Crewmember dons POS, translates to affected element for inspection.

* Crewmember judgement as to element entry for discharge

of portable fire extinguisher

Note: Entrapped crewmember must traverse element towards orbiter if prior to PMC

* Close associated hatches of affected element

* Verify element atmosphere free of toxins

* Depress element if necessary

* Initiate emergency shutdown procedure"[12]

## EMERGENCY BREATHING METHODS:

A significant difference in the capabilities of the space station personnel to survive a fire in comparison to submarine personnel lies in the breathing modes available to each. The astronauts have multiple 10 minute air packs available. The submarines have unlimited time on an air-fed Emergency Air Breathing system. The masks for this system covers both the nose and eyes. The "Toxic Scenario" specifies "don breathing and eye protection" where this scenario does not specify eye protection.[13] By this statement I assume that the breathing system does not include eye protection. Having fought numerous electrical fires submerged in closed spaces, I feel this is a serious deficiency in not providing long-term breathing capability or integral eye protection.

Submarines are equipped with an extensive emergency air breathing system. This system consists of a 150 psi air system fed

[12]. McLendon, Scenarios Study, p. 10-12.

[13]. Ibid, p. 16.

by a low pressure air compressor with a backup of a reducing station tapping off the ship's 4500psi air banks. The system includes special high efficiency filters to clean the air. This system provides multiple connection air manifolds about every 20 feet throughout the ship. Deck markers consisting of red tile inserts with a sandpaper triangle, mark each manifold. These markers are for locating the manifolds during zero visibility heavy smoke conditions.

Emergency breathing masks (EAB) are stored throughout the ship for ready access by crewmembers. These masks cover the eyes, nose and mouth and are provided with an 8 foot hose to permit mobility. Certain watchstanders in the missile compartment are fitted with longer hoses of 25 feet for extra mobility. In a casualty it is an immediate action for a control watchstander to secure the low pressure air compressor and shift the source of air to the main air banks. This provides extended life supporting air capability for all hands in a smoke filled compartment. My personal experience includes numerous casualties which required hours of EAB wearing until the atmospheres were back in specification. In the majority of these cases the ship was able to emergency ventilate the space, reducing the time of out-of-specification atmospheric readings. With no emergency capability to rapidly rejuvenate the space station atmosphere except by depressurization, in my opinion, days could be required to remove contaminants from the modules after a fire. The actual time until the atmospheres are in specification can easily be calculated by using the volume flowrate through the

$CO_2$ removal units and their efficiency given the volume of the module or the station as a whole if the hatches are open. This includes the high concentrations of $CO_2$ from activation of the automatic fire suppression system and manual activation of fire extinguishers from the front panel of the racks into the $CO_2$ nozzle receptacle. Obviously, depressurization of the module can be accomplished, but the limited repressurization air available limits this option to less than two modules. If the hatches were not able to be closed and the entire station were contaminated beyond breathable specifications, such as has been experienced during numerous submarine fires, adequate long term emergency air breathing capability does not now exist.

An option to mitigate the effects of the above scenario in which the entire station becomes contaminated would be to provide the capability for the astronauts to tap into the repressurization air supply using Emergency Breathing Masks (EAB) similar to those used on submarines. This would greatly expand the utility of the air supply and provide time for the onboard air revitalization equipment to clean up the atmosphere.

Presently there is no method to charge the excessive pressure in the station back into the repressurization air banks. Excessive pressure in the station is relieved over board. On long space voyages or on extended stays on the space station this may become a limiting factor. A small leak from one of the repressurization valves would cause the pressure in the station to continually rise. This pressure rise would be automatically relieved over board resulting in eventual depletion of the repressurization air bank.

All modules do not contain air revitalization equipment. Therefore, fires causing out of specification atmospheric readings in those modules would result in one of two options. They could be depressurized or opened to modules having air revitalization equipment. On submarines it is a regular occurence to recirculate the ship after minor electrical fires especially if it is not possible to come to periscope depth to ventilate. This method of revitalization first dilutes the contaminants with the larger volume of the ship and then permits the use of all atmospheric revitalization equipment to clean up the air. This method requires that all personnel have access to emergency air breathing masks for safety until the total atmosphere is within specification.

## FIREFIGHTING TECHNIQUES:

A great philosophical difference exists between the statements of the SSN 637 Class Submarine "Fire Bill" and the "Contingency Operations Scenario Study" of JSC. An excellent example of this difference is demonstrated by this Note to all submarine watchstanders:

> "It is recognized that controlling the fire when it is in the incipient stage is critical. The initial action to control the fire should be accomplished simultaneously with donning air breathing equipment. Those persons involved in the *initial attack* (italics added) without air breathing equipment should be relieved by persons

with breathing equipment as soon as possible."[14]

The point is that submarine personnel are taught to "attack" the fire until it is overcome. These statements come from the Principles of the Fire Procedure,

> "When a fire is discovered, immediate action must be taken to extinguish it, since fires can become uncontrollable in minutes. Smoke from a relatively small fire may completely fill the entire ship in a short time; therefore, ventilation must be secured and the compartment must be isolated. Keep the fire contained."[15]

From the JSC study we find,

> "If crewmember in affected element:
> *Don POS (EAB)
> *Verify automated safing actions complete, backup if required
> *Evacutate fire location closing associated hatches"[16]

The JSC scenario assumes the fire will be immediately extinguished by the automatic system. The submarine scenario assumes that the fire will grow uncontrollably unless immediate action is taken by the watchstander. The astronauts are taught to rely on the automatic system, whereas the submariners are taught to rely only on first-hand observation of the fire being out.

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14. U.S. Navy, Commander Submarine Force, U.S. Atlantic Fleet and Commander, Submarine Force Pacific Fleet, COMSUBLANTINST C5400.14A/COMSUBPACINST C5400.33, SUBMARINE OPERATING PROCEDURES (SSN) (U), "Fire Bill", (Norfolk/Pearl Harbor: 1984), p. 3305-4.

15. Ibid, p. 3305-3.

16 McLendon, Contingency Operations Scenarios Study, p. 10.

## TOXIC GAS CASUALTY:

The casualty procedures used in the JSC study and the submarine force parallel each other very closely. The submarine procedure, however has a number of branches which are not considered in the JSC procedure. These branches are necessary in submarines due to the different procedures required for different toxic gases. The correct procedure for a high carbon monoxide level may be the wrong procedure for a high freon level. For example the CO-H2 burners are started for a high carbon monoxide level but they are secured for the high freon level.

## HIGH FREON CASUALTY:

For high freon refrigerant levels the procedure specifies:

> "If unable to ventilate the ship, remove the carbon from the main carbon filter bed 4 to 5 hours after the spill or at such time as the atmosphere analyzer indicates a definite leveling off of the refrigerant concentration."[17]

This particular step is required due to the action of activated charcoal upon freon. Freon is removed from the atmosphere by the capillary action of the charcoal. However, after a few hours the freon will begin to be released from the charcoal back into the atmosphere again by the same capillary action. If the charcoal is not replaced, chronic high levels of freon will result. An additional step directs securing the CO-H2 burners

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17. Naval Sea Systems Command, Submarine Atmosphere Control Manual S9510-AB-ATM-010, p. 9-4.

which operate at about 609 degrees F. They use a catalyst to convert carbon monoxide and hydrogen to carbon dioxide and water vapor. When freon is processed through this unit, it generates hydroflouric acid, which can etch glass.

The casualty procedure for the space station should include these types of special procedures. If the refrigerant used in the food storage unit (freon 12)[18] will cause damage to the dessicant in the trace contaminant removal units or generate unacceptable byproducts, then the trace contaminant removal units should be secured until the freon can be removed. There should also be some better way to remove these types of contaminants than just by depressurization.

An analysis of the Trace Contaminant Control Subassembly (TCCS) of the space station yielded the following results. The system contains a 50 lb charcoal bed. This action of the bed is specified in the description document:

> "Contaminants are adsorbed on the charcoal as the process air passes through until the bed is saturated, at which time contaminants begin to breakthrough. At this time, the bed no longer has capacity to remove contaminants from the air stream and must be replaced. The design driver contaminant for the charcoal bed is dichloromethane, which requires the largest amount of charcoal to control its level..."[19]

The TCCS also contains a catalytic oxidizer which uses

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[18]. National Aeronautics and Space Administration, <u>Space Station Freedom Work Package I</u>, "WP01 PDR, "Environmental Control & Life Support Nonregenerable Systems" by Hank Kolnsberg, p. 13-30.

[19]. Boeing Defense and Space Group, <u>WP01 Space Station Freedom Program (D683-15003-1) Atmosphere Revitalization Subsystem Description MTC Configuration</u>, (Huntsville: The Boeing Company, October 15, 1991).

Palladium on 1/8 inch alumina pellets to oxidize low molecular weight compounds such as methane, hydrogen and carbon dioxide. It operates at a high temperature of between 750 and 1000 degrees F.[20] The submarine procedure specifies securing of the CO-H2 burners which use a catalyst (Hopcalite) to oxidize CO and H2 at 609 degrees. At this temperature Freon generates significant amounts of Hydroflouric acid when oxidized.

The TCCS also has a sorbent bed of lithium hydroxide. This bed removes undesirable products of catalytic oxidization, such as HCL, CL2, F2, NO2 and SO2. These products are acid gasses.[21]

The document listed dicholoromethane as the design driver contaminant for the charcoal bed.[22] The freon 12 of the Refrigerator/Freezer Assembly is chemically Dichlorodiflouromethane. A significant leak of the freon 12 could probably saturate the charcoal bed. The remaining freon would enter the catalyst unit and generate hydroflouric acid which would probably over drive the sorbent bed of lithium hydroxide. The worst case scenario would result in loss of the food storage unit due to no replacement freon, the contamination of the charcoal bed requiring replacement, poisoning of the oxidizer catalyst, and depletion of the lithium hydroxide.

The submarine procedure would require the securing of these atmosphere control units upon detection of the freon leakage by the

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[20]. Ibid

[21]. Ibid

[22]. Ibid

continuous atmospheric monitoring system on the submarine. The resulting damage would be the loss of the food storage unit but the saving of the atmosphere control system. Submarines could ventilate to lower the freon levels. The only option to the space station would be the depressurization of the module if it had been isolated rapidly. The important factor here is that the atmosphere control equipment would be operational immediately upon repressurization without extensive maintenance.

I have experienced chronic freon leaks at low levels on numerous patrols. These leaks sometimes require dumping the freon to a hermetically sealed catch tank to replace seals in the refrigerant units. On a three year trip to Mars, the loss of a major food storage unit can affect mission capability. Without the maintenance capability to repair the refrigeration units and the ability to remove trace contaminants such as freon the repressurization air can quickly be depleted.

## UNIQUE ALARMS:

One of the Key Findings of the Scenario Study for Depressurization, Fire and for Toxic spill was the capability to alert the crew by a uniquely identifiable alarm. Based on my experience submerged I see the value of the unique alarm. Unique alarms are used in the submarine force for different casualties such as missile emergency, collision, and power plant emergency. However, this will not solve the problem specified in the scenario. No automatic system will replace the first hand reporting of the casualty situation by a member of the crew. Training of crewmembers to make concise and specific reports to alert the rest of the crew to the location and extent of the casualty will always be the best method. The submarine "Toxic Gas Bill" and "Fire Bill" are both consistent on their directions about reports.

> Toxic Gas: "Pass the word to Control by phone, 4MC, or word of mouth giving type of gas (or "Toxic Gas"), amount as Slight or Large Amount, and compartment name."[23]

> Fire Bill: "Person discovering the fire shall:
> (a) Pass the word by phone, MC system, or vocally, giving location and extent of fire. NOTE: Precise terminology as to the extent and location is imperative to ensure proper damage control."[24]

## OTHER SCENARIOS:

Neither the Loss of $H_2O$ nor the Thermal Scenario lend themselves to a parallel analysis to similar submarine scenarios. The Loss of Power scenario does have a parallel comparison to the submarine Rig for Reduced Electrical Power procedure. Whenever there is a casualty which precludes the generation of electrical power by normal turbine generator means, the ship is rigged for Reduced Electrical Power, to conserve battery power. The rigging in all spaces is standardized by marking all non-essential load breakers with yellow paint marks. This permits the excited watch stander to rapidly strip each switchboard of unnecessary loads by just opening all yellow breakers. This order can be simply

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[23]. COMSUBLANT, Standard Operating Procedures, "Toxic Gas Bill", p. 3306-1.

[24]. COMSUBLANT, Standard Operating Procedures, "Fire Bill", p. 3305-4.

executed by announcing "Rig ship for reduced electrical". A similar procedure for the space station would greatly simplify the procedure during a casualty.

# SUPPLEMENTAL PROCEDURES:

Other submarine procedures should be adapted to the operation of the space station due to their extensive testing in the submarine environment.

RIG FOR COLLISION/COLLISION IMMINENT:

This procedure would primarily be directed to improving the station's ability to survive a collision with space debris. Just as in the submarine scenario, all module hatches would be shut and major operations secured. The ventilation system would be isolated to prevent contamination from one module from reaching other compartments. Personnel would go immediately to the safest space. If the polyethylene shield of the habitation module were in place as proposed in the Radiation effects and shielding chapter then they would go to this hardened space for maximum protection.

MANEUVERING WATCH:

This could also be called "docking stations" for the taking alongside of replentishment modules or of the space shuttle. Additional equipment should be broken out to be readily accessible such as damage control equipment and extra personnel would man stations for the evolution. Due to its importance all hands would be assigned a position for this evolution.

RIG FOR GENERAL EMERGENCY:

This is the rigging of compartments for an emergency such as fire or depressurization when the exact location or the extent of the problem is not clear. It heads the personnel in the right direction in terms of making the ship or station more safe. Personnel break out breathing apparatus just in case they are needed. Major evolutions which could interfere with damage control efforts are suspended. This is also used for those casualties which don't have a unique procedure written. An example would be the breaking of the glass of the honey bee biological experiment releasing thousands of honey bees into the lab module. Another example would be the fracture of the mounting assembly attaching the solar panels to the truss assembly. Extra help is needed by the man discovering the problem to prevent further damage.

## CONCLUSIONS:

Submariners have decades of experience in fighting casualties. The factors of atmosphere contamination and isolation from outside assistance make the submerged casualty and the space casualty similar. The adaptation of submarine tested casualty procedures to the space station can take advantage of the experience and knowledge gained from fires and other serious life-threatening events already experienced. These procedures could heighten the learning curve for the astronauts and prevent the loss of life or equipment in the isolation of space.

# CHAPTER VIII

# NUCLEAR POWER

Nuclear fission energy is being fully utilized by the Submarine Forces of the United States to permit operation independent of the surface for extended periods limited only by food supplies. They have the electrical power to operate high power systems for combat and the propulsion capability to traverse entire oceans at maximum speed. The safety of these propulsion plants is unquestioned based on the forty year record of zero accidents.

## NUCLEAR SPACE PROPULSION:

The use of nuclear space propulsion can greatly reduce the time required to complete the Earth to Moon and Earth to Mars voyages. The demonstrated high thrust-to-weight ratios of the engines tested in the sixties and seventies and the improvements possible due to new technologies such as particle bed reactors make the option very favorable for future missions.[1] The demonstrated proficiency of the submarine force in the operatio of reactors safely for forty years should prove the capability of United States to train operators and supervisors in the operation and maintenance of nuclear propulsion systems. It also illustrates the design proficiency and the technological expertise of the Naval Nuclear

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[1]. Thomas Stafford, Lt.Gen.(ret), Chairman, Synthesis Group, America At the Threshold, (Arlington: The Synthesis Group, May 1991), p. 66.

Propulsion Program.

Although the Submarine Force has little knowledge base in the new exotic propulsion systems for space use, they do have extensive expertise concerning shielding and personnel radiation monitoring and possess great experience in the physics of reactor operation. Xenon buildup, fuel depletion, neutron power level detection and reactor control by rod movement are areas of high expertise and experience. Extensive knowledge of casualty procedures and radioactive contamination control is also a strong point of the Naval Nuclear Propulsion Program.

While the use of pressurized water reactors such as those in the submarine fleet has not been considered for propulsion for spacecraft, they should be evaluated for use as electrical power generation systems.

## NUCLEAR ELECTRIC POWER GENERATION:

The reactor physics of using fission reactors to produce safe and reliable electrical power with water as the moderator is a proven technology. The compact size and the high power density of fission reactors is a great advantage when launch weight is a major factor. This factor was recognized by John M. Collins from the Congressional Research Service.

> "Nuclear reactors thus remain the only known long-lived, compact source able to supply military space forces with electric power between about 10 kilowatts (KW) and

multimegawatts (MMW) . . ."[2]

With the dismantlement of many nuclear warheads because of the START agreements, adequate supplies of Plutonium 238 could be made available to supply the space reactor program for many years to come. The technology is proven. The problem with using reactors is political. Though the technology is available to give the space station multimegawatt electric power capability it is not seriously being considered. In present designs the station will be limited to 57.5 kilowatts from the solar arrays. The capabilites of the station and the design of systems for life support and manufacturing will all be affected by the severe shortage of electrical power.

## NUCLEAR POWER: THE SUBMARINE EXAMPLE

One great contribution that can be made by the submarine force is that of providing a successful example of the capability that can be maintained through the safe and intelligent use of nuclear power. Submarines have several means of propulsion. Nuclear power allows high speed capabilty, but backup systems provide the redundancy necessary for safety. The submarine philosophy is never to permit a single system to control the livelihood of the crew. This is based on combat survival. What is the difference between

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[2]. John M. Collins, Military Space Forces-The Next Fifty Years, (Washington, D.C.: Congressional Research Service, 1989), p. CRS-103.

being bombarded by an enemy and being bombarded by space debris? On the receiving end the difference is small. If the electrical power systems fail due to failure of a component and the life support systems are deenergized, the crew cannot survive.

Electrical power generation on submarines is normally by turbine generators powered by steam from the reactor plant. There is also a large diesel generator that can provide emergency electrical supplies. The main ship's storage battery also can provide power for a limited time through DC to AC motor-generator conversion units. Survival in a foreign environment at sea or in space depends on the capability of the ship or station to survive damage and to keep functioning.

Nuclear electrical power generation capability in the megawatt range can transform the space missions and stations into fully functional platforms. It can render them capable of making their oxygen from water supplies by electrolysis. It can provide power to operate defensive systems that can deflect or destroy space debris before a collision occurs as well as furnish large supplies of hydrogen for retrojet usage from the electrolysis process to make oxygen.

The advantages of nuclear electrical power generation and nuclear propulsion systems greatly exceed the dangers faced in the politics of advocating their usage. The safety of these systems is not a political issue, it is a technological and a training issue. The design and operational safety of the Naval Nuclear Propulsion Program should be the shining example used to gain acceptance from the uninformed public for the safe and efficient use of nuclear systems in space.

# CHAPTER IX

# CONCLUSIONS AND RECOMMENDATIONS

The adaptation of submarine experience and technology to the space environment can be very fruitful to the space program of the United States. The space program is in its infancy in dealing with the psychological aspects of isolation, family separation and living in a closed environment. Atmosphere control for long term living which will be necessary for extended space station deployment and for long space voyages is an untried science in the space arena. This same atmosphere control function is the life blood of the submarine force which has logged millions of hours in the submerged environment. Casualty control submerged can mean life or death to the entire crew based upon the performance of any individual. Procedures for fighting casualties have been tested in the environment of smoke filled compartments and during the inrush of tons of sea water.

These recommendations are based on the research completed.

1. Coordination between the Astronaut Corps and the Submarine Service should be established to acquaint the astronauts with the defense mechanisms necessary to cope with long deployments in isolated environments. Consideration should be given to allowing selected astronauts to ride submarines of the Fleet Ballistic Missile Fleet on standard two-month deployments for indoctrination into submarine casualty procedures and to provide extended deployment experience.

2. Submarine counsellors such as the Submarine Group Six Chaplain Corps and Ombudsman Training Academy instructors should be made available for family counselling and indoctrination for astronaut families.

3. The comprehensive medical data gathered in both atmosphere and non-atmosphere related physiologies by the submarine force should be provided to the Closed life support system group at the Johnson Space Center and there should be close coordination with the Naval Submarine Medical Research Laboratory.

4. A shield should be designed for the Habitation Module of Space Station Freedom to provide a "storm shelter" for the astronauts to protect them from the hazards of radiation. A canned polyethylene segmented shield should be considered due to its capability also to provide debris impact protection for the module.

5. Atmosphere limits for the space station and future space flights should take into consideration the extensive data collected by the nuclear submarine force in submerged operations over the last 40 years.

6. The inadequacy of emergency breathing methods on the space station should be corrected. Provision should be made for utilization of the repressurization air system as an emergency breathing source using Emergency Breathing Masks similar to those in use on submarines. The masks should cover the entire face of the astronauts including the eyes. A system using potassium superoxide cannisters should be provided as an emergency pure oxygen supply for astronauts.

7. Submarine experience in fighting casualties submerged should be utilized to revise space station casualty procedures.

8. Nuclear power should be utilized to provide multimegawatt electrical capability to the space station and future space missions.

## TABLE A-1. PROHIBITED CHEMICALS/SUBSTANCES

These chemical substances are prohibited for internal submarine use in pure form or technical grade. Products containing quantities of these chemical items may or may not be prohibited. Each product must be analyzed separately before it can be categorized.

- Acetone
- Acetylaminoazo Benzene
- Alpha Naphthylamine
- Aminodiphenol
- Aniline
- Aromatic Hydrocarbons
- Arsenic and Arsenic Compounds
- Asbestos
- Benzene (benzol)
- Benzene Hexachloride
- Benzidine
- Beryllium and Beryllium Compounds
- Beta Napthylamine
- Beta Propriolactone
- Bromine (Note 1)
- Calcium Hypochlorite (Note 1)
- Carbon Disulfide
- Lead and Lead Compounds
- Lithium Batteries (NAVSEA msg 0217302 Oct 79)
- Mercaptans
- Mercury and Mercury Compounds (except as authorized by NAVSHIPINST 5100.3)
- Methyl Ethyl Ketone (butanone)
- Methoxychlor (DMDT)
- Methyl Alcohol (methanol)
- Methyl Bromide
- Methylenebis (2 chloroaniline)
- Mineral Spirits
- Nitrobiphenyl
- Nitrous Dimethylamine
- Ortho-chloroaniline
- Paradichlorobenzene
- Phenols and phenolic compounds
- Pyridine
- Selenium and Selenium Compounds



1. NAVSEA, ATMOSPHERE CONTROL MANUAL, PP A3-4 APPENDIX I

TABLE A-1. PROHIBITED CHEMICALS/SUBSTANCES (Continued)

- Carbon Tetrachloride
- Carboxide (fumigant, Union Carbide Corp.)
- Chlorine
- Chloroform
- Cyanide Salts
- Dichlorobenzidene
- Dimethylaminoazo Benzene
- Dried Bacteria Cultures
- Ethylene Dichloride
- Formaldehyde and Formalin
- Ethyleneimine (aziridine)
- Halogenated Hydrocarbons (unless specifically categorized)
- Hydrogen Cyanide Gas
- Sodium Arsenite
- Sodium Chromate (powder)
- Steel Wool (Note 2)
- Sulfamic Acid
- Tetrachloroethane
- Tetrachloroethylene
- Tetraethyl Pyrophosphates
- Toluene (toluol)
- Trichloro Isocyanuric Acid
- Trichloroethylene
- Trichlorotrifluoroethane (Freon 113) and other solvents such as Freon TF, Freon PCA, and Genesolve which contain trichlorotrifluoroethane.
- Vinyl Chloride
- Xylene (xylol)

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**NOTE 1:** Calcium Hypochlorite and Bromine are prohibited except for those quantities required for potable water disinfection and by Medical Department.

**NOTE 2:** Steel wool may be used during upkeep/overhaul. It is prohibited, not for atmosphere contaminant reasons, but for material safety reasons.

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APPENDIX I

TABLE A-2 2.
CHEMICALS/SUBSTANCES

| Permitted | Limited | Restricted |
|---|---|---|
| (1) Disodium Phosphate | (1) Ethyl Alcohol (Ethanol) | (1) Ammonia |
| (2) P-Methyl Amino Phenol Sulfate | (2) Sodium Sulfite | (2) Dichloromethane (methylene chloride) |
| (3) Refrigerants R-11 R-12, R-114 | (3) Dye Penetrants | (3) Isocyanates |
| (4) Sodium Bicarbonate | (4) Isopropyl Alcohol (Isopropanol) | (4) Methyl Chloroform (Trichloroethane) |
| (5) Sodium Borate and Sodium Tetraborate | | |
| (6) Sodium Carbonate | | |
| (7) Sodium Chromate (liquid) | | |
| (8) Sodium Perborate | | |
| (9) Sodium Thiosulfate | | |



2. IBID, P. A-5

APPENDIX II

Table 3-5. 3 Limits and Measuring Methods for Atmospheric Constituents in Nuclear Submarines
(Limits are in ppm by volume unless otherwise noted.)

| Compound | 90-Day Limit | 24-Hour Limit | 1-Hour Emergency Limit | Measuring Method |
|---|---|---|---|---|
| Acetone | 200 | 1000 | 6000 (1) | T, TGA |
| Ammonia | 25 | 50 | 400 | T |
| Benzene | 1.0<br>3mg/m$^3$ | 2.0<br>6mg/m$^3$ | 50<br>150mg/m$^3$ | TGA, T |
| Carbon Dioxide (2) (3) | 0.5%<br>3.8 Torr | 4%<br>30 Torr | 4%<br>30 Torr | C |
| Carbon Monoxide | 15<br>11.5<br>Millitorr | 50<br>38.2<br>Millitorr | 200<br>152.6<br>Millitorr | C, T |
| Chlorine | 0.1 | 0.5 | 3.0 | T |
| Hydrocarbons | | | | TGA |
| (a) Total Aromatics (Less Benzene) | 10 mg/m$^3$ | * | * | |
| (b) Total Aliphatics (Less Methane) | 60 mg/m$^3$ | * | * | |
| Hydrogen (4) | 10,000<br>1%<br>7.6 Torr | 10,000<br>1%<br>7.6 Torr | 10,000<br>1%<br>7.6 Torr | C |
| Hydrogen Chloride (Hydrochloric Acid) | 0.5 | 20 | 20 | T |
| Methane (5) | 5,000 | 5,000 | 13,000 | NONE |
| Methyl Chloroform (1,1,1 Trichloro-ethane) (6) | 2.5 | 10 | 25 | T |



3. IBID, PP. 3-10 - 3-12

APPENDIX III

Table 3-5. Limits and Measuring Methods for Atmospheric Constituents in Nuclear Submarines (Continued)
(Limits are in ppm by volume unless otherwise noted.)

| Compound | 90-Day Limit | 24-Hour Limit | 1-Hour Emergency Limit | Measuring Method |
|---|---|---|---|---|
| Monoethanolamine (MEA) | 0.5 | 3.0 | 50 | T |
| Nitrogen Dioxide | 0.5 | 1.0 | 1.0 | T14. |
| Oxygen (7) | 130-160 mm Hg not exceeding 21% by volume 130-160 Torr | 130-160 mm Hg not exceeding 21% by volume 130-160 Torr | 130-220 mm Hg not exceeding 30% by volume 130-220 Torr | C, P |
| Ozone | 0.02 | 0.1 | 1.0 | T |
| Refrigerant R-11 (Trichloromonofluoromethane) (6) | 5<br>3.8 Millitorr | 20<br>15.2 Millitorr | 50<br>38 Millitorr | C |
| Refrigerant R-12 (Dichlorodifluoromethane) (6) | 100<br>76 Millitorr | 1000<br>760 Millitorr | 2000<br>1520 Millitorr | C |
| Refrigerant R-114 (Dichlorotetrafluoromethane) (6) | 100<br>76 Millitorr | 1000<br>760 Millitorr | 2000<br>1520 Millitorr | C |
| Sulfur Dioxide | 1.0 | 5.0 | 10 | T |
| Toluene | 20 | 100 | 200 | T |
| Vinylidene Chloride | .15 | 10 | 25 | TGA |

* Limit has not been established



APPENDIX III

**Table 3-5. Limits and Measuring Methods for Atmospheric Constituents in Nuclear Submarines (Continued)**
**(Limits are in ppm by volume unless otherwise noted.)**

KEY: TGA - Trace Gas Analyzer (See 6.3)

C - Central Atmosphere Monitoring System (See 6.2)

T - Detector Tubes (See 6.5.2)

P - Portable Analytical Equipment (See 6.5)

NOTES:

(1) Value is set at approximately 1/4 of the explosive limit of 2.55%.

(2) The 90-day limit for carbon dioxide is an average reading. Levels are not to exceed a maximum of 4 percent, tactical situation permitting. A 72-hour limit of 4% (30 Torr) has been established.

(3) The 90-day limit for submarines with MK II, MK IIA, and MK III scrubbers is relaxed to 0.8% to compensate for reduced removal capacity. The 0.5% average applies to MK IIIA, MK IIIB, and MK IV scrubbers.

(4) During battery charges, the hydrogen limit at the battery well monitor may exceed values listed. Refer to NAVSEA Technical Manual 0901-LP-223-0000 for limits at the battery well detectors. Hydrogen limits set at 1/4 of the explosive limit of 4%.

(5) Values are set at approximately 1/4 of the explosive limit of 5.3%.

(6) Values are based on decomposition or reaction in $CO\text{-}H_2$ burner.

(7) Physiological lower limit. Fire safety upper limit.

3.3.2 LIMITS FOR ATMOSPHERE CONTAMINANTS.

Criteria have been developed for establishing safe limits for contaminants. The limits in Tables 3-5 and 3-6 represent the safest value based on these concentrations:

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DATE 30 Oct 1991

From: CDR STEPHEN M. JARRETT USN CNW
(Rank) (Name) (Service) (CNW or CNC&S)

To: President, Naval War College
Via: (1) Director, Advanced Research Program
(2) Advanced Research Council
(3) Deputy to the President

Subj: REQUEST TO PERFORM ADVANCED RESEARCH PROJECT IN LIEU OF CORE CURRICULUM DURING WINTER TRIMESTER
(Fall, Winter, Spring)

Ref: (a) NAVWARCOLINST 3920.1B

Encl: (1) Application for Designation as Advanced Research Associate

1. In accordance with reference (a), I request permission to conduct an Advanced Research Project during the WINTER trimester in lieu of participating in the core curriculum during that period. Enclosure (1) describes my proposed project and outlines my qualifications to accomplish such an undertaking.

2. If this request is approved, I understand that I will be designated an Advanced Research Associate and be administratively assigned to the Advanced Research Program while engaged in my project. Despite the full-time nature of this one-trimester withdrawal from the core curriculum to pursue a rigorous research commitment, I understand that I am still required to take an elective and meet all JPME requirements. During the period of my research, I will participate in special Naval War College events to the same extent as other students remaining in the core curriculum.

3. If selected for the student Advanced Research Associate Program, I recognize that I will be expected to complete a substantial project report or research contribution of professional quality, in final smooth form, in the time allotted.

Stephen M Jarrett
(Signature of Applicant)

# CENTER FOR NAVAL WARFARE STUDIES
# ADVANCED RESEARCH PROGRAMS

## ADVANCED RESEARCH ASSOCIATE APPLICATION

31 Oct 1991
(Date of Application)

92-05 W
ARP Control No. (Leave Blank)

**NOTE FOR STUDENT APPLICANT: Please complete this application by typing (or neat printing), attach the formatted forwarding letter and return to ARP.**

A. NAME JARRETT STEPHEN M CDR USN CNW
(Last) (First) (Middle Init) (Rank) (Svc) (Coll)

1120 [redacted] TOP SECRET /
(Desig/MOS) (SSN) (Security Clearance/Date Granted)

B. ADDRESS [redacted]
(Number and Street) (City and State) (Zip)

C. TELEPHONE [redacted] CUBE 2077
(Student Station #)

D. TITLE/TOPIC OF PROPOSED PROJECT THE MISSION OF THE U.S. SUBMARINE FORCE IN THE NEXT CENTURY
(Attach to this form a 2-3 page descriptive summary of your planned research undertaking to include clear, concise statements of subject, purpose, scope, methodology, anticipated data sources, nature of product, audience for whom writing, possible applications of your work, and expected security classification)

E. CHARACTER/STYLE OF PROPOSED RESEARCH
Research to be performed during Fall, (Winter,) Spring trimester (circle one) and will be (individual)/Group (circle one) project.
(If group project, all members of proposed group shall submit individual applications as a package).

F. FINANCIAL SUPPORT (Please estimate costs):
Travel $ 300.00 Per Diem $ 320.00 Total $ 620.00

Trips to (No. of days) NEW LONDON (2), OP02 WASH. DC (2), NORFOLK CSL (2), ______ ( ) ______

G. EDUCATION (List all military/civilian undergraduate and graduate schools attended, major courses of study, and degrees awarded, in reverse chronological order):

| DATES | INSTITUTION | MAJOR | DEGREE |
|---|---|---|---|
| 1991 | SALVE REGINA COLLEGE | BACHELOR OF SCIENCE IN MANAGEMENT | NONE |
| 1988-1991 | CCE NWC | MARITIME OPS | COMPLETED (A) |
| 1986-1988 | CCE NWC | STRATEGY & POLICY | COMPLETED (A) |
| 1968-1972 | U.S. NAVAL ACADEMY | ELECTRICAL ENGINEERING | BACHELOR OF SCIENCE IN ELECTRICAL ENGINEERING |

**H. EXPERIENCE/BACKGROUND** (List all significant duty assignments for past six years in reverse chronological order):



| DATES | ORGANIZATION | LOCATION | NATURE OF DUTIES |
|---|---|---|---|
| FEB88-JAN91 | USS DANIEL BOONE SSBN 629 BLUE | CHARLESTON, SC | COMMANDING OFFICER |
| JUL87-JAN88 | PCO TRAINING | WASHINGTON, DC NLON, CT | STUDENT |
| APR87-JUL87 | NAVSEA PMS402 | ADCAP MK48 CHARLESTON SC | MK48 ADCAP TORPEDO DEVELOPMENT FIELD REP |
| DEC 83 - FEB 87 | USS VON STEUBEN SSBN632 | GOLD CHARLESTON, SC | EXECUTIVE OFFICER |

**I. ACADEMIC/SCIENTIFIC HONORS AND PROFESSIONAL SOCIETY MEMBERSHIPS:**

U.S. NAVAL ACADEMY ALUMNI ASSOCIATION / US NAVAL INSTITUTE
US NAVAL INSTITUTE / US NAVY SUBMARINE LEAGUE

**3. RECORD OF AUTHORSHIP/PUBLISHING**

| DATE | TITLE/DESCRIPTION | INSTITUTION/PUBLISHER |
|---|---|---|
| 1981 | AUTHORED RECOMMENDATION FOR NWP CHANGE TO MK48 TORPEDO WEAPON SETTINGS | APPROVED AND ENTERED BY COMSUBLANT. |
| 1987 | AUTHORED RECOMMENDED CHANGES TO MK48 ADCAP TORPEDO PROGRAM BASED ON AT SEA OBSERVATIONS. | NAVSEA PMS. 402. |
| 1988 | AUTHORED SHIP'S POLICY AND ETHICS STATEMENT | USS DANIEL BOONE (SSBN 629 BLUE) |
| 1989 | AUTHORED ARTICLE "TRIDENT IS NUCLEAR DETERRENCE" | JACKSONVILLE NEWSPAPER. |

**K. PRELIMINARY LIAISON** (It is recommended that you consult with others prior to submitting this research application-if you have done so describe the extend of liaison beyond internal NWC discussion.)

DISCUSSED THE SUBJECT AND SOURCES OF DATA WITH CAPTAIN MENDENHALL + PROFESSOR SOMES + CAPTAIN HARTMAN

**L. FACULTY ADVISOR(S)** (All Advanced Research Associates must have one or more faculty advisors for their projects. Advisors may be chosen from the teaching departments and/or the Center for Naval Warfare Studies. Since part of the faculty advisor's responsibility is assisting in defining the terms of reference and scope of the project, it is necessary to acquire at least one faculty advisor prior to submitting this application. In addition, by signing on as a faculty advisor, the faculty advisor agrees to offer guidance, review your work, and provide written comments and a recommended grade for inclusion in ARP's overall appraisal of your final research project.):

| FACULTY ADVISOR'S NAME | DEPT. | SIGNATURE OF ADVISOR |
|---|---|---|
| CAPT. DICK HARTMAN | OPS | [signature] |
| CAPT GUY MENDENHALL | OPS | C G Mendenhall III |

CDR Stephen M. Jarrett, USN
Advanced Research Associates Project
31 October 1991

# THE POSSIBLE MISSIONS OF THE U.S. SUBMARINE FORCE IN THE NEXT CENTURY

## SPECIFICATION OF TOPIC:

This project will develop the possible missions of the U.S. submarine force during the 21st century in light of the force reductions, changing threats and the improved capabilities of new construction and proposed submarines. Missions for both fast attack and ballistic missile submarines will be included. The changing threat posed by the instability of the Soviet Union and by third world powers armed with weapons of advanced technology will be analyzed to determine the missions of the U.S. submarine force. These missions must ensure that the capability of the United States armed forces is protected and that they can defend our national interests. Historical strategies will be considered as well as proposed scenarios and global strategies for future conflicts.

## GOALS OF RESEARCH:

The goal of the research is to use documented historical conflicts, contemporary writings and interviews with senior submarine officers both active duty and retired to draw conclusions about the capabilities of our force structure during the next century. Then based on an assumption of these capabilities a formulation of basic missions will be completed. These missions will first look at the fast attack submarine including the Seawolf and the Los Angeles classes and then the SSNX follow-on class. The strategic area will look at the Ohio class with Trident II (D-5) missiles and at a proposed SSBN(X) follow-on.

In conclusion, the potential missions will be evaluated in relation to the National Security and the National Military Strategy. This evaluation will conclude whether the submarine force will be a major contributor in meeting the needs of the nation and how the submarine force should be structured in the future.

## METHOD OF APPROACH:

Senior submarine officers at the Naval War College including Captain Dick Hartman and Captain Guy Mendenhall have agreed to sponsor my research efforts in this project. Information will be obtained from the OP-02 submarine branch at the Pentagon through contacts provided by Capt. Hartman. Both Classified (up to Secret) and Unclassified documents and writings from the NWC library will be utilized for historical documentation and for gathering of ideas. Interviews with senior active duty and retired submarine officers will be performed as available.

The research will be approached in steps based primarily on previous mission categories such as strategic deterrence, surveillance, anti-submarine warfare, sea line of communication protection and anti-surface ship warfare. Potential new missions will be examined as they develop based on the proposed capabilities of new construction submarine classes.

The steps of the research will be outlined and the ideas formulated into basic strategies supporting future missions as the data is accumulated. The first draft will be reviewed and further research will be accomplished to more fully explore areas of interest based upon sponsor inputs.

## UTILIZATION OF THE RESEARCH:

The research conclusions should provide a new view of the submarine force of the future for critique by future Naval War College students. It should give new ideas for utilization of the submarine force in the forecasted "New World Order" and should provide a viewpoint from which to discuss future force planning. It should use all available resources to determine the most realistic statement of the mission of our future submarine forces in the 21st century.

3 February 1992

From: CDR Stephen M. Jarrett, USN
To: ARP Director

Subj: Trip Report for Washington, D.C. Trip 31 Jan 1992

1. The US Air flight schedule, departure at 0630, permitted me to arrive in Washington in adequate time for my first appointment at 1000 at the National Space Council. My lunch meeting with Dr. Tom Ward at DOE was effective and I still had plenty of time to make my 1300 appointment at Reston. The 2100 evening flight permitted me to complete three meetings including the last in Reston, Va. at NASA Freedom headquarters and saved the extra expense of an overnight accommodation.

2. Thrifty Rent-a-Car provided excellent service. They advised me to take the Metro to my morning meetings due to the problem of parking and they met me at the metro terminal at Crystal City with my car after my lunch appointment. This service enabled me to make the last appointment on time.

3. The meeting with Dr. George Abbey at National Space Council was a very cordial one on one discussion concerning my research project. After the meeting he advised me to pursue discussions with Dr. Rollins, the Deputy Director of Space and Life Sciences at Johnson Space Center Houston, who I have previously contacted. He advised a trip to Houston to present data in the life science area to the team there and told me to call him after making arrangements with Houston and he would give me a list of people to talk to there.

4. Major Beason, USAF of the Office of Science and Technology Policy was called into an unscheduled meeting and I was unable to talk to him during the trip.

5. Dr. Tom Ward and I had a discussion over lunch in the DOE cafeteria. Data on the Nuclear Thermal Rocket is close held and classified and hard to obtain. Open literature does give me the basic facts which can be entered into my research for discussion purposes. I was able to obtain from him an extensive study on "Galactic Cosmic Radiation: Constraints on Space Exploration", done by the Naval Research Laboratory. This study and subsequent discussions with the engineers at Reston indicated that submarine shielding expertise is drastically needed to solve a issue of astronaut safety in the space station. I have drawn up several potential shielding schemes for the habitation module to protect the personnel during maximum solar flare activity. The protection of personnel during the Mars mission is the major contention point argued in the Naval Research Laboratory study. It however indicated no expertise in shielding theoretical knowledge by the author.

6. The discussions at Reston were extremely well received.

I was introduced to several additional engineers and distributed a quantity of data which I had brought for that purpose. The life science engineer, who was a former navy flight surgeon, was extremely surprised by the extent of the data from the Naval Submarine Medical Research Laboratory (NSMRL). Several decisions on issues under present controversy, including the Carbon Dioxide Limits on the space station, may be affected by the data which I provided in the NSMRL studies.

7. I had dinner on the way back to Crystal City from Reston at a restaurant named "New York, New York" on the second floor of the USA Today building at Rosalyn. The food was excellent and the price very reasonable. Most menu items average about $12.00.

8. The worst part of the trip was the exorbitant $20.50 parking fee for parking my vehicle at the TF Green airport parking lot while I was in Washington for the day.

9. The trip was very fruitful and gave me several good leads concerning areas of concentrated effort. The Public Affairs group at Reston is mailing me a two hour video on the space station including the procedure for in space construction.

Very respectfully,

Stephen M. Jarrett
CDR, USN

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TITLE: THE APPLICATION OFF SUBMARINE EXPERIENCE AND TECHNOLOGY TO THE SPACE PROGRAM

NWC NO.__________ ARP NO. __________

AUTHOR: CDR. STEPHEN M. JARRETT, USN

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3. MR. GEORGE ABBEY NATIONAL SPACE COUNCIL, EXECUTIVE OFFICE BLDG OF THE PRESIDENT, WASHINGTON, DC 20500
4. VADM KENNETH M. CARR, USN (RET) 2322 FORT SCOTT DRIVE ARLINGTON, VA. 22202
5. MR. DAVID FINNEY CODE CA3, FLT CREW OPS DIR, JOHNSON SPACE CTR, HOUSTON, TX 77058.
6. DR JUDY ROBINSON, SPACE STATION PROJECT OFFICE, CODE KB2, NASA, JOHNSON SPACE CTR, HOUSTON, TX 77058

ENCLOSURE (1)

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7. DR. THOMAS WARD U.S. DEPARTMENT OF ENERGY, GA-155-SC1, WASHINGTON, DC 20585
8. CAPT MIKE McCULLEY, USN, 1100 LOCKEED WAY, TITUSVILLE, FLA 32780, MAIL CODE LSO-383.
9. DEPARTMENT OF THE NAVY NAVSEA CODE 56Y14 (JOE THILL) WASHINGTON, DC 20362-5101

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The submarine force of the United States has operated in the closed environment of submerged operations for almost 80 years. For the Last 40 years, the only limitation to the duration of submerged operations was food supply. Submarine patrols more closely simulate space travel than any other type of operation. Upon submerging, submarines manufacture their own air supply, distill their own water supply and provide their own power. They do not expect resupply of food or spare parts for months. They see neither day nor night. If casualties occur such as fire or flooding, the ship must fight the casualty with the available men and equipment. This paper will explain how the utilization of submarine knowledge of personnel adaptation, atmospheric rejuvenation, casualty control, and nuclear technology and experience can greatly aid the space program in its advance into the frontiers of space.

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