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TERRESTRIAL ANALOGS AS A BASIS FOR PLANNING NEW SPACE HABITATS

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ABSTRACT

The relevance of terrestrial analogs in the study and planning of future space habitats was clearly understood by NASA during the Apollo missions and also in planning the Skylab structure.

The possible positive or negative reactions of astronauts to the habitats they had to live in were evident also to technicians whose key problem was to send men into space and maintain them in a fit state to accomplish their mission.

As a result, the U.S. space programme became more and more interested in human responses to critical situations. In the last few years, the great relevance of human factors in the frame of long duration space missions has renewed interest in the problematics of prolonged confinement and isolation.

A first step towards obtaining a comprehensive view of the problem is to analyse as many examples of human isolation on Earth as possible, and compare their peculiar characteristics.

In the frame of an Italian study being performed under the aegis of the Italian Space Agency (ASI), dealing with the habitability of manned systems in space, an overview of several terrestrial conditions of confinement and isolation has been effected.

A wide range of experiences of critical habitability has been considered, including prisons, oil research activities in deserts, different forms of underground human confinement and also monasteries.

This study is aimed at deriving the possible psychological and sociological aspects of such Earth analogs in the light of future human space experiences.

The common aspects of ground confinement and space confinement will therefore constitute the basis for defining a set of habitability requirements to be met in planning new space habitats.

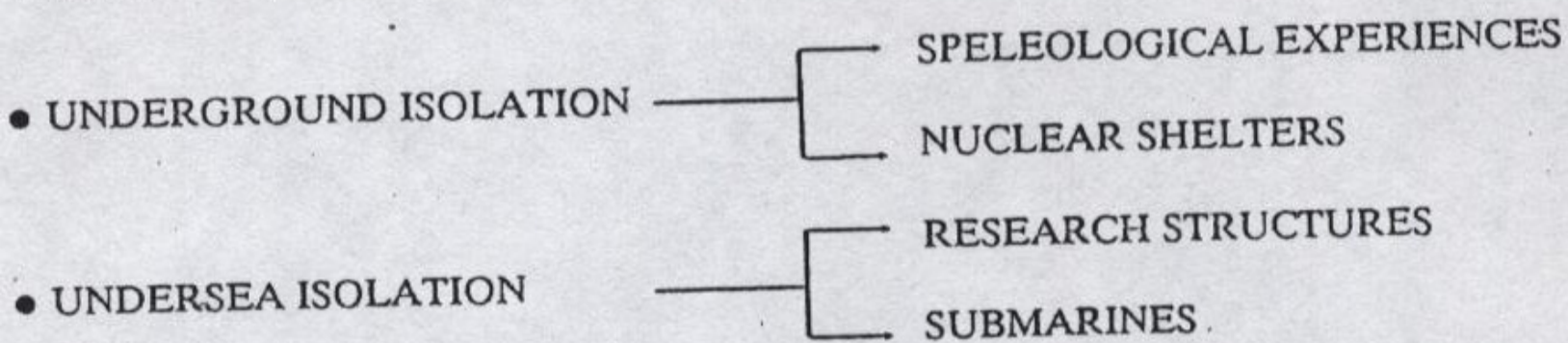
INTRODUCTION

The relevance of terrestrial analogous situations for the study of confinement in space was clearly understood when, in the late 1960's, investigations on living conditions in scientific bases in Antarctica, underwater research units and nuclear submarine fleets pointed out many human factor patterns in common with the situations experienced in space.

Since then, the interest in human problematics embodied in earth conditions of confinement and isolation has increased.

This paper reports an overview of several terrestrial conditions of confinement and isolation carried out in the frame of an Italian study of the habitability of manned space systems; six categories of Earth analogs have been considered:

- FORCED CONFINEMENT : PRISONS
- OIL DRILLING ACTIVITIES IN DESERTS
- POLAR ACTIVITIES
- RELIGIOUS ISOLATION: MONASTERIES



The main relevant characteristics of each analog have been analysed.

Furthermore, in order to allow a comparison of results, standard reference parameters have been adopted; thus, each terrestrial analog has been evaluated with respect to the following aspects, divided into two categories:

A - TECHNICAL, FUNCTIONAL AND ENVIRONMENTAL

- 1 PRIVATE AND PERSONAL SPACE/RELAXATION
- 2 SLEEP
- 3 EXERCISE
- 4 PERSONAL HYGIENE
- 5 FOOD PREPARATION/EATING
- 6 RECREATIONAL OPPORTUNITIES
- 7 WASTE DISPOSAL AND MANAGEMENT
- 8 CLOTHING
- 9 MOVING AND ORIENTATION
- 10 MEDICAL/PSYCHOLOGICAL SUPPORT
- 11 OUTSIDE/INSIDE COMMUNICATIONS
- 12 HABITAT AESTHETICS

B - PSYCHO-SOCIOLOGICAL (HUMAN FACTORS)

- 13 INDIVIDUAL SITUATION
- 14 GROUP SITUATION
- 15 NATURE OF MISSION
- 16 HIERARCHY

Consequently, a comparison of these terrestrial experiences with space experiences of prolonged isolation (SKYLAB, SALYUT, MIR) has been made.

Finally, several common critical aspects of earth and space confinement have been pointed out, and related countermeasures suggested.

TERRESTRIAL ANALOGS

1 - Forced Confinement: Prisons

In a modern prison system, the cells (single or common) generally provide each prisoner with adequate lighting, heating, ventilation and living space.

Every cell is minimally furnished with a wash basin, a toilet and a television set. Often, food can be cooked inside, in addition to that offered by the prison canteen. The cells provide for a minimal degree of comfort and a certain level of privacy for personal hygiene is allowed by a closed-off area.

From a psychological point of view, the prevailing perception is that of coercion, punishment, hostility. The enforced cohabitation is a determining factor in the group dynamics, often leading to internal tensions. Hardships can be alleviated by offering possibilities of work and creative activities, privacy, social intercourse, leisure-time activities.

The hierarchy (external to the group) is normally felt as quite authoritarian and hostile.

PRISONS		
PARAMETER	DESCRIPTION	EVALUATION
1 - PRIVATE AND PERSONAL SPACE/RELAX	private or collective cell	LIMITED/CONTROLLED
2 - SLEEP	single or multiple beds	ADEQUATE
3 - EXERCISE	sport activity	LIMITED
4 - PERSONAL HYGIENE	toilet and shower	STRICTLY ADEQUATE
5 - FOOD PREPARATION/EATING	kitchen with collective mess	FUNCTIONAL/ADEQUATE
6 - RECREATIONAL OPPORTUNITIES	walking, media, library	LIMITED
7 - WASTE DISPOSAL AND MANAGEMENT	housekeeping activity	FUNCTIONAL/ADEQUATE
8 - CLOTHING	uniform	ADEQUATE
9 - MOVING, ORIENTATION	Transfers inside prison	LIMITED/CONTROLLED
10 - MEDICAL/PSYCHOLOGICAL SUPPORT	doctors and sick-room	ADEQUATE
11 - OUTSIDE/INSIDE COMMUNICATIONS	visits, mail, interpersonal contacts	STRICTLY CONTROLLED
12 - HABITAT AESTHETICS	absence of art and decor inside	NON-EXISTENT
13 - INDIVIDUAL SITUATION	personal attitude	HOSTILE
14 - GROUP SITUATION	group attitude	HOSTILE
15 - NATURE OF MISSION	to serve a prison sentence	CONDITIONING
16 - HIERARCHY	external to the group, imposed and felt as hostile	HIGHLY CONDITIONING

2 - Oil Drilling Activities in Deserts

Oil drilling activities in arid, sandy deserts are carried out in very harsh environmental conditions and a mission may last from a few weeks to a few months.

Housing and sanitary facilities are both simple and practical and the habitable space is usually adequate. Living quarters comprise an infirmary and rooms for leisure-time activities. Field kitchens can supply a wide range of meals. The peculiarity of such a confinement is that, in spite of sufficient individual space and a community life, the overall encampment is isolated from other inhabited areas. There are two categories of workers: skilled foreign technicians, from industrialised countries, and local unskilled labourers.

From a psychological point of view, there are clear-cut economic motives for choosing such a life-style. Psychological and sociological problems are related to the cultural differences between ethnic groups. Recreation, sports activities, cinema and television are very helpful for relaxation and cultural/social integration.

OIL DRILLING ACTIVITIES IN DESERTS		
PARAMETER	DESCRIPTION	EVALUATION
1 - PRIVATE AND PERSONAL SPACE/RELAX	barracks	ADEQUATE/NORMAL
2 - SLEEP	single or multiple beds	ADEQUATE
3 - EXERCISE	absence of scheduled exercise	LIMITED/NON-EXISTENT
4 - PERSONAL HYGIENE	toilet and shower	ADEQUATE
5 - FOOD PREPARATION/EATING	kitchen with collective mess	FUNCTIONAL/ADEQUATE
6 - RECREATIONAL OPPORTUNITIES	media, reading, games and music	LIMITED
7 - WASTE DISPOSAL AND MANAGEMENT	housekeeping activity	FUNCTIONAL/ADEQUATE
8 - CLOTHING	overalls and casual wear	FUNCTIONAL
9 - MOVING, ORIENTATION	working and personal activities	LIMITED
10 - MEDICAL/PSYCHOLOGICAL SUPPORT	doctors and sick-room	ADEQUATE
11 - OUTSIDE/INSIDE COMMUNICATIONS	turnover visits, mail, interpersonal contacts, radio	LIMITED/ADEQUATE
12 - HABITAT AESTHETICS	absence of art and decor	NON-EXISTENT
13 - INDIVIDUAL SITUATION	personal attitude	MOTIVATED/NOT MOTIVATED
14 - GROUP SITUATION	group attitude	MOTIVATED/NOT MOTIVATED
15 - NATURE OF MISSION	industrial research	MOTIVATED
16 - HIERARCHY	internal to the group	LIMITED

- Polar Activities

The confinement of human beings in a polar base means a complete immersion in a lifeless and "uninhabitable" site. The harshest conditions can be found in the Antarctic bases, in the frozen wastes of the most hostile and isolated continent of the planet. Among the various installations in the South Pole, of varying sizes, staffing levels and mission duration, the most interesting are those where a number of technicians usually spend a long period, known as "overwintering"; eight months under conditions of complete isolation, inside the confined space of the station or its immediate surroundings.

The only possible links with the outside world are radio, telex, and telephone. The base staff is composed of young people - the average age is 30 - carefully screened and trained to deal with risks and hardships embodied in the mission. Meals mainly consist of frozen food; however, attempts are made to make them interesting by varying the menus. A medical staff is available to ensure the good mental and physical health of the members of the group; inevitably, the physician becomes the confidant and a psychological help to crewmembers.

Although the hierarchy is military-like (in most of the Antarctic scientific bases the technical responsibility rests with military personnel), in general discipline is not strictly necessary and the co-operation between civilian and military personnel is extremely productive.

It is totally impossible to remain aloof from the other crewmembers when "overwintering" because most of the time is spent in community. In some cases, this can provoke tension, frustration and intolerance. Furthermore, the work tendency is to reduce positive and creative tasks into a deadening daily routine. In such a condition, leisure-time activities assume a very important role.

Recreation includes cultural activities, movies, games, handicrafts and hobbies. The possibility of growing plants and flowers or of keeping a pet, whether a dog, a cat, a hamster or a bird, or else taming local wildlife such as penguins, is very helpful.

POLAR ACTIVITIES		
PARAMETER	DESCRIPTION	EVALUATION
1 - PRIVATE AND PERSONAL SPACE/RELAX	barracks and private rooms	ADEQUATE/NORMAL
2 - SLEEP	single or multiple beds	ADEQUATE
3 - EXERCISE	sport activity	LIMITED
4 - PERSONAL HYGIENE	toilet and shower	ADEQUATE
5 - FOOD PREPARATION/EATING	kitchen with collective mess	FUNCTIONAL/ADEQUATE
6 - RECREATIONAL OPPORTUNITIES	media, library, games and music	LIMITED
7 - WASTE DISPOSAL AND MANAGEMENT	housekeeping activity	FUNCTIONAL/ADEQUATE
8 - CLOTHING	ski-suit and casual wear	FUNCTIONAL/ADEQUATE
9 - MOVING, ORIENTATION	working and personal activities	NORMAL
10 - MEDICAL/PSYCHOLOGICAL SUPPORT	doctors, sick-room, emergency operations facility	ADEQUATE
11 - OUTSIDE/INSIDE COMMUNICATIONS	turnover visits, mail, interpersonal contacts, radio, phone	LIMITED/ADEQUATE
12 - HABITAT AESTHETICS	absence of art and decor	ADEQUATE
13 - INDIVIDUAL SITUATION	personal attitude	MOTIVATED/NOT MOTIVATED
14 - GROUP SITUATION	group attitude	MOTIVATED/NOT MOTIVATED
15 - NATURE OF MISSION	scientific research	MOTIVATED
16 - HIERARCHY	internal to the group, definite and accepted	HIGHLY FUNCTIONAL

Religious Isolation: Monasteries

Most all monasteries are very large buildings, and each individual has a relatively large area assigned to them. Cells are sometimes two storeys high and can include a bedroom, a study, an oratory, a store-room. Despite the spartan, the space available, the lighting and the sanitary facilities are sufficient to meet the main physical and spiritual needs of the individual. The refectory, the cloister, the library, etc., are areas for common activities.

Monastic orders are keenly aware of the physical and psychological stress involved in the rigid and prolonged isolation; great care is placed on physical activity, whether working for subsistence or practising handicrafts as a form of "mental relaxation". The hermit's life does not imply complete sensory deprivation; there is the possibility of contact with nature and artistic endeavours.

The daily activities are rigorously organised and alternate private and public moments. The hierarchy is very definite but non-authoritarian.

RELIGIOUS CONFINEMENT IN MONASTERIES		
PARAMETER	DESCRIPTION	EVALUATION
PRIVATE AND PERSONAL SPACE/RELAX	large private cell	HIGHLY ADEQUATE
SLEEP	single bed	ADEQUATE
EXERCISE	physical activity through work	ADEQUATE
PERSONAL HYGIENE	toilet with or without shower	ADEQUATE
FOOD PREPARATION/EATING	kitchen with refectory	FUNCTIONAL/ADEQUATE
RECREATIONAL OPPORTUNITIES	collective moments, choruses, individual activities, contemplation	LIMITED/ADEQUATE
WASTE DISPOSAL AND MANAGEMENT	housekeeping activity	FUNCTIONAL/ADEQUATE
CLOTHING	cowls	ADEQUATE
MOVING, ORIENTATION	working and personal activities	NORMAL
MEDICAL/PSYCHOLOGICAL SUPPORT	sick-room	LIMITED
OUTSIDE/INSIDE COMMUNICATIONS	visits, mail, interpersonal contacts phone	LIMITED/ADEQUATE
HABITAT AESTHETICS	art and decor	HIGHLY ADEQUATE
INDIVIDUAL SITUATION	personal attitude	HIGHLY MOTIVATED
GROUP SITUATION	group attitude	HIGHLY MOTIVATED
NATURE OF MISSION	spiritual enjoyment	HIGHLY MOTIVATED
HIERARCHY	internal to the group, definite and accepted	HIGHLY FUNCTIONAL

Underground Confinement

Underground activities are carried out for economic (mines), military (subterranean military structures) and scientific reasons (speleological experiences), as well as for protection purposes (nuclear shelters). Voluntary underground isolation in particular is aimed at obtaining valuable information about the effects of a prolonged absence of external stimuli on biological rhythms (circadian rhythms).

Speleological Experiences

Between 1987 and 1988, a speleologist, Maurizio Montalbini, carried out an experiment of prolonged human confinement underground, in the grottoes of Frasassi-Genga, near Ancona, Italy.

The experiment lasted seven months; at the end, Montalbini thought he had spent much less time in the cave. His biological cycle had lengthened from 24 hours to 30 hours.

The striking effect of this altered biological cycle was a substantial weight loss. The researcher had followed a diet, carefully balanced and designed for a 24-hour day. Once the circadian rhythm had lengthened, the diet was insufficient.

Another Italian speleologist, Stefania Follini, carried out an experiment of prolonged confinement in a six-metre by four-metre plexiglass booth, ten metres underground in a cave called the "Lost Cave" near Carlsbad, Mexico.

The experiment lasted 131 days, from January 13th, 1989 to May 22nd, 1989. During the experiment, the girl's contact with the outside world was via a video screen.

There was only artificial light and no way of measuring time. The results were in agreement with those obtained by Montalbini. The girl's biological cycles had lengthened up to a 48-hour day. She tended to sleep from 24 hours and to work straight through for up to 30 hours at a stretch.

The main physiological effects were a relevant weight loss, due to eating meals at longer and longer intervals, an interrupted menstrual cycle. During prolonged confinement the woman's internal biological clock showed signs of malfunction.

These tests have also proven that changes in human circadian rhythms caused by prolonged periods of isolation have an impact on the psychology of an individual, influencing parameters such as attention span and mood, and above the physiological impact. More specifically, it would appear that a prolonged period of irregular working shifts, excessive work and scarce rest can alter biological rhythms, which in turn can lead to a drop in efficiency and a serious loss of judgment.

Nuclear Shelters

Shelters built to protect people in case of a nuclear war are designed to be used over long periods and take into account those factors embodied in a prolonged and severe isolation. The volume of shielded areas, fittings and equipment depend on the number of people the shelter is meant to house.

During the isolation period, in which the shelter must be totally self-sufficient, there must be a complete and regular change of air (e.g. by means of hand pumps). Life support elements include a daily supply of 2100 calories per person, (dry goods not requiring cooking), water supplies (about 50 litres per person), sanitary facilities (one toilet per 25 people, supply of toilet paper and garbage bags, wet wipes for personal hygiene to save on water supply), a first aid kit equipment.

Separate quarters for the ill people and for nursing children are foreseen. Careful planning of sleeping arrangements, adequate light/dark periods, sufficient privacy for personal hygiene, silence for sleeping, sufficient and varied food constitute the requirements for the mental well-being of the shelter's inhabitants.

As a general rule, knowledge of dangers and risks that exist outside the shelter helps to accept isolation and hardship. Solidarity within the group and a clear-out chain of command help to cope with hardship and anxiety.

Group leisure-time activities are very important. Possible group tensions are linked to the length of the confinement and to the seriousness of the danger.

UNDERGROUND CONFINEMENT		
PARAMETER	DESCRIPTION	EVALUATION
1 - PRIVATE AND PERSONAL SPACE/RELAX	subterranean cave or shelter without privacy elements	LIMITED /UNADEQUATE
2 - SLEEP	couch	UNADEQUATE
3 - EXERCISE	physical training	LIMITED
4 - PERSONAL HYGIENE	absence of toilet and shower	UNADEQUATE/CRITICAL
5 - FOOD PREPARATION/EATING	canned food	STRICTLY SUFFICIENT
6 - RECREATIONAL OPPORTUNITIES	reading, games, radio and music	LIMITED/UNADEQUATE
7 - WASTE DISPOSAL AND MANAGEMENT	housekeeping activity	UNADEQUATE/CRITICAL
8 - CLOTHING	ski-suit, casual wear	FUNCTIONAL
9 - MOVING, ORIENTATION	activities inside confined volume	LIMITED
10 - MEDICAL/PSYCHOLOGICAL SUPPORT	medical kit	UNADEQUATE
11 - OUTSIDE/INSIDE COMMUNICATIONS	radio, TV, telematic equipments	LIMITED
12 - HABITAT AESTHETICS	none	NON EXISTENT
13 - INDIVIDUAL SITUATION	personal attitude	MOTIVATED
14 - GROUP SITUATION	group attitude	MOTIVATED
15 - NATURE OF MISSION	scientific research/nuclear shielding	MOTIVATED
16 - HIERARCHY	internal to the group, chosen	FUNCTIONAL

5 - Undersea Confinement

Research Structures

A number of studies have been conducted to assess whether or not it might be possible to have humans working for prolonged periods in an underwater environment.

The SEALAB project (1967 and 1968) was a systematic study of the survival of a group of people living and working for long time on the sea bed in a pressurised habitat.

Tests were conducted in the Pacific Ocean about one kilometre from the coastline. Three groups, of around ten people each, took turns living and working for 15 days inside a steel structure at a depth of 70 metres underwater. The habitat consisted of a cylinder about 18 metres long and 4 metres wide. It had 11 round portholes and three entry hatches. The atmosphere inside the habitat was made up of 4% oxygen, 85% helium and 11% nitrogen, pressurised at about 6.8 atmospheres. The cylinder interior housed a "working area", a toilet, a shower, bunks and a galley.

A further experiment - the TEKTITE project (1970/1971) - was aimed at assessing the behaviour and group dynamics of a small crew engaged in prolonged underwater missions. Two cylindrical interconnected structures, (see figure) placed at a depth of 17 metres were used. Each cylinder comprised two levels of living quarters.

The habitat was designed to provide the crew with everything necessary to survive and to work, such as cooking and eating facilities, sleeping, working and study areas. In the structure, crews of 4 and 5 members carried out missions of varying lengths: 60 days for TEKTITE I, 14 and 20 days for TEKTITE II.

Every participant in the SEALAB and TEKTITE experiments was a "professional", i.e., an expert in marine activities, and a volunteer. Consequently, teams were highly trained and highly motivated, physically and physiologically fit. Further, morale and team spirit were very strong and each team member was highly responsible and serious.

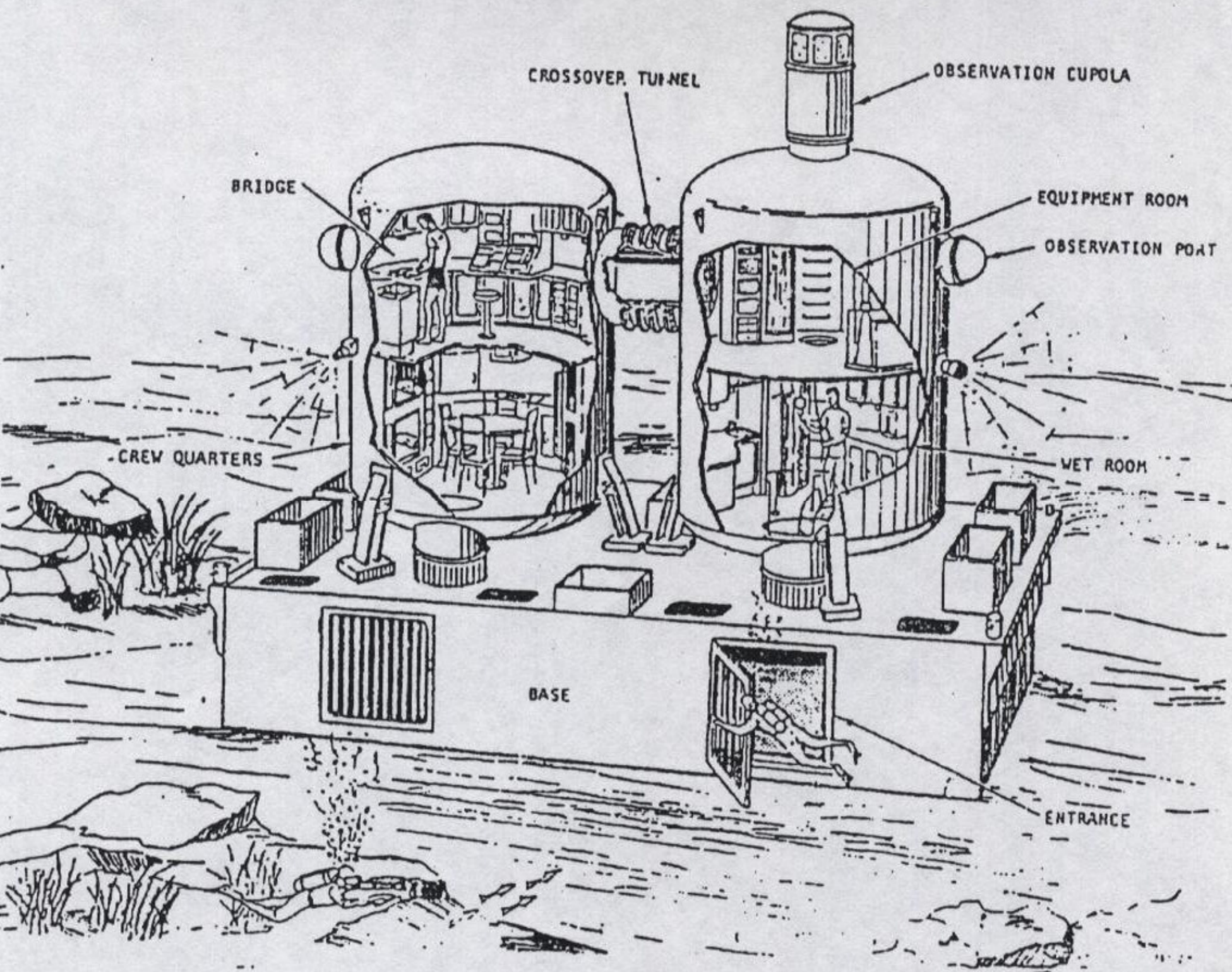
A telephone was the sole link with the outside world. The telephone was hardly ever used, proving that mission members rarely felt claustrophobic. This was probably due to the fact that this was a new experience for every participant and there was no feeling of deadening routine work or business as usual.

Submarines

Submarines were used extensively during the two world wars; as a result they developed rapidly and continuously improved. With the advent of nuclear-powered submarines, the greatest strides forward in terms of capacity and range were achieved. Modern submarines are fitted with special equipment capable of drawing oxygen for use on board from the surrounding sea water; this makes them totally independent underwater systems capable of staying submerged for months on end.

At present, nuclear-powered submarines are used for training missions and as a deterrent to potential adversaries; their missions can last from a few weeks to a few months.

All crew members on board are carefully chosen on the basis of their physical and mental fitness and trained for the mission both physically and psychologically..



TEKTITE II Internal Arrangement

The aim of the training course is to enhance individual productivity whilst promoting good relations amongst the individuals. Great care is taken in assessing behaviour roles and the structure of team work. The number of crew members varies periodically and includes both career (volunteers) and recruited members.

There is a very definite hierarchy which includes commander, officers, petty officers and submariners; everyone has very specific roles and functions.

The quarters are laid out along three different levels or "decks" and include a mess and meeting room for the officers, a mess and a meeting room for the petty officers and the submariners, bunk areas and sanitary facilities.

Living quarters are designed to allow for both vertical and horizontal mobility; a change in level means a total change of environment, both functionally and psychologically. Thus, though the habitat is extremely small, it becomes to a certain extent varied. The officers quarters and facilities are separate from those of the other crew so that they can enjoy a greater degree of privacy.

Sailors' bunks are arranged as bunk beds equipped with light and curtains; they are practical, quite comfortable and allow a certain privacy.

UNDERSEA CONFINEMENT: SUBMARINES AND TEKTITE/SEALAB LIKE STRUCTURES		
PARAMETER	DESCRIPTION	EVALUATION
1 - PRIVATE AND PERSONAL SPACE/RELAX	private or collective cabin	CRITICAL/UNADEQUATE
2 - SLEEP	single or multiple beds (common)	STRICTLY SUFFICIENT
3 - EXERCISE	physical training as far as possible	LIMITED
4 - PERSONAL HYGIENE	toilet and shower	ADEQUATE
5 - FOOD PREPARATION/EATING	galley and wardroom	FUNCTIONAL
6 - RECREATIONAL OPPORTUNITIES	reading, games, media, music,	STRICTLY SUFFICIENT
7 - WASTE DISPOSAL AND MANAGEMENT	housekeeping activity	FUNCTIONAL
8 - CLOTHING	diving-suit, uniform, casual wear	FUNCTIONAL
9 - MOVING, ORIENTATION	EVA and IVA operations	STRICTLY SUFFICIENT
10 - MEDICAL/PSYCHOLOGICAL SUPPORT	doctors and sick-room	ADEQUATE
11 - OUTSIDE/INSIDE COMMUNICATIONS	radio, TV, radar, "familygram"	LIMITED/ADEQUATE
12 - HABITAT AESTHETICS	absence of art and decor	NON EXISTENT
13 - INDIVIDUAL SITUATION	personal attitude	MOTIVATED/NOT MOTIVATED
14 - GROUP SITUATION	group attitude	MOTIVATED/NOT MOTIVATED
15 - NATURE OF MISSION	scientific research, military ops	MOTIVATED
16 - HIERARCHY	internal to the group, rigidly definite	CONDITIONING

COMPARISON

On the basis of the evaluation parameters previously adopted, Earth analogs features were compared with the space experiences onboard Salyut, Skylab, Mir; the qualitative results obtained are reported in the following applicability matrix.

Comparative Matrix of Terrestrial Analogs Evaluations along with Qualitative Applicability Degrees to Space Habitats

	PRISONS	OIL DRILLING STATIONS	POLAR STATIONS	MONASTERIES	UNDER GROUND CONFINEMENT	UNDER SEA CONFINEMENT
PARAMETER						
1 PRIVATE AND PERSONAL SPACE/RELAX	x	x	o	x	x	x
2 SLEEP	o	x	o	x	x	x
3 EXERCISE	x	x	x	x	o	o
4 PERSONAL HYGIENE	x	o	o	o	x	o
5 FOOD PREPARATION/EATING	o	o	o	x	x	o
6 RECREATIONAL OPPORTUNITIES	o	o	o	x	o	o
7 WASTE DISPOSAL AND MANAGEMENT	x	x	x	x	o	o
8 CLOTHING	x	o	o	x	o	o
9 MOVING, ORIENTATION	x	x	o	x	o	o
10 MEDICAL/PSYCHOLOGICAL SUPPORT	x	x	o	x	x	o
11 OUTSIDE/INSIDE COMMUNICATIONS	x	o	o	x	o	oo
12 HABITAT AESTHETICS	x	x	x	x	x	x
13 INDIVIDUAL SITUATION	x	o	o	o	o	o
14 GROUP SITUATION	x	o	o	o	o	o
15 NATURE OF MISSION	x	o	oo	o	o	oo
16 HIERARCHY	x	o	oo	o	x	o

Legenda

- X = scarcely applicable
- O = applicable
- OO = well applicable

CONCLUSIONS

Such a qualitative comparison showed that conditions in polar bases, underwater research structures and submarines offer a good similarity with the actual conditions of confinement in space. It is worth noting, however, that in polar bases the habitable volume is much greater than in space vehicles, whereas submarines and underwater research structures are very similar to space habitats also in this respect.

Experiences of underground isolation in caves, albeit not very similar to the space experiences, have nevertheless demonstrated that a relevant variation of circadian rhythms, often occurring during space confinement, may induce negative physiological and psychological effects.

As a consequent step of this comparative analysis, the common negative factors of each terrestrial analog in comparison with past experiences of long permanence in space have been pointed out in order to focus the possible effects generated by these conditions. The principal troubles experienced during both confinement on earth and prolonged permanence in space are:

- * Prolonged isolation
- * Confinement
- * Scheduled routine activity
- * Lack of privacy
- * Forced commonality
- * Team work
- * Altered circadian rhythms
- * Interpersonal problems
- * Critical situations and events
- * Habitat aesthetic absence or monotony
- * Scarce recreation possibilities
- * Limited resources availability (space, energy etc.)
- * Limited communication possibilities

These critical aspects may lead respectively to:

- * Tension
- * Stress
- * Irritability
- * Aggressiveness
- * Nervous excitement
- * Intolerance
- * Depression
- * Frustration
- * Passivity
- * Lack of self-confidence
- * Group conflicts
- * Interpersonal conflicts/problems
- * Psychopathological behaviour (panic, hysteria)
- * Suppression of leisure interests

In view of future long-duration space missions, all the negative factors previously found must be avoided and their possible effects, if possible, prevented; for this purpose, the common patterns of Earth and space analogs have been used to derive some elements to be applied as countermeasures in future space habitats.

Relevant features to be considered for providing suitable life conditions in critical environments are:

- * Anti-claustrophobic habitability standards
- * Internal environment quality and comfort
- * Maintenance of Earth-like daily rhythms
- * Leisure time
- * Possibility of self-chosen routine activities
- * Privacy
- * Team co-operation
- * Group motivation
- * Group harmony
- * Medical/psychological support
- * Safety standards

These criteria are now being considered, to a certain extent, in the design of the International Space Station, a valuable test-laboratory for investigating the effects of a prolonged permanence in space.

However, the evolution of space activities, which foresees the realisation of an European autonomous space infrastructure, vehicles for interplanetary missions and permanent lunar settlements, requires an increased knowledge of human factors to provide improved habitability conditions; further studies in this field are still necessary.

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