NASA/TM- 81 207546

Sounds of Silence:
A Design Process for the Acoustical System of An Enclosed Space Colony

A Thesis

Submitted to

The Faculty of the

Cybernetic Systems Program

San Jose State University

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

By

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December 1981

Abstract: Sounds of Silence. Using a general systems approach, factors and components of the acoustical design process for an isolated, confined space community in a torus space enclosure are considered. These components include the following: organizational structure and its effect on alternatives; problem definition and limits; criteria and priorities; methods of data gathering; modelling and measurement of the whole system and its components; decision methods; and design scenario of the acoustics of the complex, socio-technical space community system with emphasis on the human factors.

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Dedicated to Veronica,
Theresa, and Monisa

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PREFACE

Designing an acoustical system for a future space colony may seem a trifle premature. In this thesis, however, the problem serves as a device to consider the broader, more basic problems in the development of man/machine systems. The exaggerated dependence of a space community on its mechanical, artificial cocoon suggests the importance of the need to plan the entire system with humanistic values and criteria. This involves a great deal of care about the humans using the system and high standards for the manufactured products that bring about high quality of human living. The essential concern of this thesis may be summed up in the question: "How can a technical system be designed for human users with care, quality, and human criteria as well as technical know-how?"

Hundreds of people aided and encouraged the development of this thesis, both directly and behind the scenes. I wish to acknowledge and thank those whose contributions added to the completed paper, while admitting that any flaws or mistakes are entirely my own.

First, my thanks are given to those researchers who spawned my interest in the space colony project very early in my tenure in the Cybernetic System Program: Roger Arno, Mary Conners, William Gilbreath, and Jeff Cuzzi of NASA Ames.

Numerous colleagues and experts took the time to answer my technical questions and give their advice on all aspects of space and acoustical systems. I extend my thanks in a special way to the following people for their technical advice and assistance: Earl Knechtel, Robert Morris, Bud Greenlee, Richard Johnson, Jules Dods, and David Nagel of NASA, Ames; David Saunders of Informatics; Herb Taylor of Disney Productions; Karl Pearson of Beranek, Bolt and Newman; Jack Freytag of Bechtel; Ronald Hawke of Lawrence Livermore Laboratories; and Sherman Moore of the General Accounting Office.

I am indebted to my thesis advisor and committee chairman, Preston Probasco, for his availability and expert advice on organization and form throughout the entire project; and to committee member, William Reckmeyer, for helping clear away so many of the logistics of completing the degree.

A great many friends and acquaintances were there to discuss the problems of the topic, and to agonize and ecstasize over the progress; in particular, I would like to express warm gratitude to my dear friend, Annette Moore for her supportive friendship and constant encouragement. Sherman Moore, Ronald and Nancy Hawke, and their family were also a continuous source of encouragement during the highs and lows of putting this thesis together. My appreciation extends to those who gave their time, energy, and thought to answering the sound awareness questionnaire.

Another source of supportive encouragement was my family: my father, Robert Archibald, and his wife, Nora; my sisters, Jancie and Joyce, and my brother, Andrew, who not only gave moral support but frequently listened, advised, and gave a willing hand helping with the many details encountered.

For the final steps of drafting, editing and typing, my heartfelt thanks are given to Cecilia Wong, who spent many hours creating a convenient editing file on the PDP 11/70 computer and editors, Alice Barlow, Oso Barlett, and Nina Zottoli. I wish to give very special thanks to Janice Penix and Joyce Amick for the hours of professional editing, typing, and re-editing in preparation of the rough and final copies.

Finally, I must mention with deep love and appreciation the constant support, love, and understanding I received throughout the endeavor from my daughters, Veronica, Theresa, and Monisa.

I. INTRODUCTION

The Space Colony Concept

Historical Development

Since time immemorial, human beings have looked into outer space and wondered about man's connection with the vast unknown stretches beyond the Earth. We now live in what is called the "advent of the space age." The human race has recently participated, at least as observers, in man's giant leap beyond his earthly home to the first small steps on the moon.

While the initial, popular excitment of this first monumental event has subsided, space exploration has begun and quiet plans for its continuation go on. Outer space probes and planetary probes have been sent to Jupiter, Saturn, Mars, and Venus, and more are planned. Some of these are still returning data on conditions in other parts of our planetary system. Most recently, the Space Shuttle, whose purposes are those of exploring and researching in space, our planet, and the solar system from space orbit, was successfully tested the beginning of 1981 (NASA Activities and NASA Astrogram).*

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*Space shuttle flight was accomplished with the maiden voyage of The Columbia in April 1981.

The technology to probe space with unmanned craft, as well as to send a contingent of humans to develop space industries, is available right now (Van Putten p.1). How much actual support the space effort receives is a political factor that depends on the expediency of current events and conditional priorites. When space development becomes economically feasible, catastrophically or strategically necessary, civilization will again begin pioneering into space in earnest. Otherwise, such gargantuan endeavors will be considered by those with the economical power to proceed as not much more than idle curiosities of a handful of dreamers.

This situation does not mean space expansion is hopeless. Many other historically-reshaping explorations have had just such a background. The problem of the space exploration process is not a new one. Space will be--or rather is--the only other physical frontier besides ocean exploration available to provide for the ever growing needs of mankind and Earth. Whether the process is set in motion by the pressure of events in the near future or awaits those of a distant generation, man will either forge outward into space or perish as his total conquest devastates limited earthly resources. The critical time will arrive.

Colonization Now

Even now, numerous groups are studying the possibilities of preparing for the grand opening of the space frontier to the whole human race (Johnson). Space colonies of pioneer communities have already been envisioned and discussed in great detail. Their very vocal proponent, Dr. Gerald O'Neil of Princeton, is pushing the economic and political feasiblity into the government, the public, and the commercial arena (O'Neill).

The appeal of a space colony from these angles is hard hitting as well as glamorous and romantic. These angles include the mining of the moon and asteroid minerals; possible unlimited solar energy conversion; the superior quality of metals produced in a vacuum; and a host of other miscellaneous production and research projects, as well as technological gains from meeting the demanding constrictions of space survival. These very real benefits lend professional credence to the peopling of space as a truly economic endeavor (Van Putten).

A major question to be answered concerns who will be the sponsors of this economical endeavor. There are numerous possible combinations: an exclusive United States' undertaking, with subcontracting only to US companies; a US-USSR competition to claim space/moon territory with a division of world nations which would be the fastest conceivable developmental process; a US alliance or even a possible world alliance with all nations subdividing the economics, labor, and gains of space expansion--probably the hardest to obtain in actual agreement; and private corporations attempting to gain proprietary rights to space goods and production--a very probable alternative, considering the number of companies already involved in aerospace exploration and development (Van Putten). Who organizes the project--and how it is organized--will have a major impact on the priorities and decisions of the space colony.

Whoever sponsors the endeavor, the process leading to completion and implementation of a full-fledged space community will be complex, lengthy, and involve state-of-the-art comprehensiveness. To succeed, more than single variable measurements per discipline involved will be necessary. In other words, only a total systems approach will be likely to succeed. Because of the lack of this very necessary, complex, coherent organization, only piecemeal studies and prototype development are now being carried on by the government, private agencies, corporations, and devoted individuals (Smith, 1976; Johnson; Van Putten).

All concerned parties are seriously involved in the attempt to gain interest and backing for a space community thrust. This is the position of this author/student of systems of the future.

Acoustics

History

Acoustics is the study of energy as vibrational pressure waves travelling through a medium. Pressure waves, like water waves, can only be produced in a carrier and cease to exist in a vacuum. There is total silence in the realm of space. The enclosed colony, however, will have an atmosphere in which sound can be generated and therefore studied.

The interest in acoustics began in the Middle East over 8,000 years ago, with the study of vibrational tones of musical instruments. The earliest Greek scholars theorized about the harmonic relation of different length strings, sound propagation in air, and the acoustical properties of the Greek amphitheaters. Although Pythagoras did some physical measurement for harmonic chords, most of the ancients were content to philosophize intuitively (White, p. 9). Seventeenth-century scientists began systematic measurements of sound waves and were able to determine relational equations for sound travelling in media. At this time it was demonstrated with certainty that sound waves could not travel in a vacuum.

The mathematical equations that have been developed from these first and successive sound wave experiments describe the functional relations of sound waves and the surrounding media they travel in. These equations describe the relation of the frequencies, wavelengths, and velocities of sound; the velocities in relation to the properties of heat, density, and the elasticity constant (characteristic sound impediment factor of a material) for a variety of media; and the intensity of power (wattage) and pressure (barometic pressure in dynes) of the energy wave compressing and rarefying the media as it passes through them.

At the turn of the century, Wallace Clement Sabine of Harvard developed the first scientific study of interior acoustics while redesigning the Harvard's Fogg Art Museum. He continued to develop acoustical science by designing numerous other halls and theaters used for live presentations (Sabine). Since then, long-distance communication--the practical application of theoretical knowledge of sound waves and electronics--was developed by Bell, Edison, Morse, and Marconi in the last century.*

There was worldwide interest in the marvels of long distance communications via wires, radio, and recordings. These deliberate productions of sound along with the noises of industry and transportation made the world a noisier place than it had ever been before, especially in the growing urban centers. Noise pollution had begun, but it was not until as recently as this century that a growing concern for the health and well-being of urban and now even rural citizens has redirected acoustical research to include noise control.

Physics

While the mathematical basis of sound is of general interest, those concerned with noise control are primarily interested in the decibel (dB) measurements for intensity and

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*The logarithmic sound level unit of measurement, the decibel (dB), is named after Alexander Bell.

sound pressure at the sound sources; sound wave frequencies in Hertz (Hz, cycles per second); and the dissipation, reflection, absorption, and transmission of the waves into their surroundings.

Intensity--the power measured in watts--ranges from .3 x 10^{-12} watts at the threshold of hearing up to 3,000,000 watts for a Saturn rocket. The equation,

$$SPL = 10 \log W/W_0$$

where SPL is the sound power level (in dB), W is the watts of the sound of interest, and W_0 is the reference wattage (generally accepted as 10^{-12} dB), describes intensity. Thus, the dB scales measure the logarithm of any two powers. This would be 5 dB for the threshold of hearing up to 200 dB for the Saturn rocket.

Decibels can also be used for the sound pressure scale where 1 dyne = 1 microbar of atmospheric pressure (neutons per meter squared N/m^2). The equation,

$$SPL = 10 \log P^2{}_{rms}/P^2$$

where SPL (in dB) is the sound pressure level, $P^2{}_{rms}$ is the root mean square of the sound wave of interest over the square of the reference wave pressure, P (generally about .00002 dynes at the threshold of hearing or 0.0 dB on the pressure scale), describes the average pressure of a travelling sound wave.

A Saturn rocket would equal 20,000 dynes (about 1 atmosphere) or 194 dB. One dyne is equivalent to about 74 dB of sound pressure. The threshold of pain in sound pressure is given as anywhere from 120 dB to 140 dB because experiments for pain thresholds have not been done on human beings to determine the exact pain threshold (White, pp. 9-75).

Although all frequencies travel at a constant velocity in a homogeneous medium (about 1,052 feet per second in air at 72 degrees F), the velocity changes depending on the elasticity of the molecules in the different media of gasses, liquids, and solids. While a given frequency remains at a constant velocity for each homogeneous material, the intensities and pressures can be attenuated or heightened. When a structure of a material resonates with a certain frequency, the entire material vibrates at that frequency or its harmonic and increases the power of the sound emitted. Sound boxes of instruments are an example of this sound augmentation. If the construction impedes the acoustical waves of the frequencies, the power is greatly dissipated as frictional energy and the sound is dampened--as in insulation.

Like water waves, sound waves can go around barriers in their path and continue slightly abated, refracted, or changed in frequency on the other side. Sounds of particular frequencies are transmitted through barriers, especially those that reverberate in tune with the frequency. Sound waves are reflected and refracted at interfaces of two media and can be focused (similarly to light waves) by concave surfaces and dispersed by convex surfaces. The size of the impinging structure and the molecular construction of the material determine in part how the wave will behave when it reaches the boundary (White, pp. 43-50).

Psychoacoustics

For noise control to be effective it is necessary to know not only how to reduce noise and produce sound, but also what is considered to be noise and what constitutes desired sound signals. Psychoacoustics is the science of human perception of acoustical waves and deals with the desirability of sounds.

The frequency range of hearing, in Hertz, is from 20 Hz to about 20,000 Hz. Infrasound below 20 Hz can be felt as body vibrations. Dogs can hear over 20,000 Hz, and some people claim to feel a painful nervous tension in the presence of ultrasound.

Single, pure-frequency tones are seldom heard; rather, combinations of frequencies make up most of the sounds we hear. There are harmonic frequency sets which are multiples of a prime frequency; discordant sounds, where the frequency beats are not multiples of the prime frequency; and random noise in which there are no frequency beats but merely broad-band collections of frequencies.

The most recent study in acoustics examines the positive effects of sound stimulation as well as the particulars of what makes noise annoying. The study has parallelled psychoacoustics, psychology and interest in human perception. More has been done on discovering what makes sound/noise annoying than on what qualities make it pleasant and stimulating and therefore desirable, except in the field of musical acoustics (White).

The Acoustical System in a Space Colony

There are a number of ways in which the space colony's community sound systems will be analogous to those of communities on Earth, but there are a number of important difference. For example, the walls surrounding the space community will affect sound levels within the torus and its hub. The area will be small enough that, without careful planning, problems of noise transmission will be created throughout the entire colony. On Earth, annoying noise from machinery and heavy equipment can either be isolated or dissipated into open air and only temporarily present. In the colony, however, the heavy systems that recycle and condition the atmosphere and water, and rotate the torus, will be continuously running and generally will be located directly below the living areas. Extreme care in designing for these processes and their potential noise is of utmost importance. One of the plus features is that there will be no airplane noises, sonic booms, or noises from internal combustion engines to contend with in a colony surrounded outside by the vacuum of space. The community's citizens, totally isolated from the Earth will need to determine what sounds of nature can be successfully designed into the community.

Among other considerations, possibly different atmospheric composition and pressure other than normal on Earth will affect the intensity and possibly change the frequency of propagating sound waves. Additionally, sound stimulation of all types will need to be coordinated, taking into account the enclosure size, shape, construction, and isolation of the community (Van Putten, pp. 983-995).

Similarities in the community activities and industrial construction on Earth will permit using terrestrial case studies as examples in zoning allocation, noise control ordinances and acoustical measurements in the torus community.

The acoustical system as defined by this study, then, consists of sound being generated into the surroundings by a source and then being perceived and controlled by humans. Only effects as might be found in an enclosed space colony are dealt with.

II. GENERAL SYSTEMS APPROACH

The Acoustical Design as a General Systems Problem

General Systems Methodolgy

The general systems approach is a global method for working with the global problems of any set of internally related functions that can be defined as a system. The approach involves treating the system as a whole functioning over time and space, rather than from only a few functional aspects. Although the elementary subsets can be studied in a variety of ways to any degree of depth during the work process, it is continuously necessary to relate them back to the functioning of the overall system as defined. This often requires the viewpoint of both a telescope and a microscope on the part of investigators, in order to bring the defined system into macro-focus at the level of the user and his goals for the system.

Boulding describes nine levels or categories of systems progressing from the simplest static framework to the all-encompassing transcendental system of the universe. Following are the nine levels of complexity of systems, paraphrased:

1. Structural framework
2. Pre-determined, stablized, functional clockwork

3. Feedback or cybernetic system of the thermostat
4. Open self-maintaining growth systems of the cell
5. Specialization of functions--differentiating subsystems--the plant
6. Mobility, self-awareness, and sensory input systems--the animal
7. Systems with complex, symbolic synthesis and awareness beyond their own selves--the human
8. Societal systems and organizations of humans
9. The system of systems; the universal system of all existence--transcendental system (Boulding, pp. 3-10)

Rather than see these as exclusive categories of systems, I have chosen to see them as Kenneth Boulding, in his Essay on General Systems Theory, has described them--levels of the systems approach in studying a very complex system that in truth involves all of these levels. The levels are seen as analogous models for each step of this system design study.

In pursuit of knowledge about a given system, the general systems approach has a progression of orderly steps to aid in studying the system at hand. These are not hard and fast dictums; nor do they necessarily follow a strictly sequential pattern in actual usage. Rather, they define the various stages of progress in use of the systems approach. Methods of investigation that lend themselves to the particular state are given as examples of how that step is handled in working towards a final solution to a systems problem.

The first step is to define the limits of the system under study and how it is separated from and fits into its environment. This system definition phase would be like a 'still picture' of the system under study and analogous to the static framework of Boulding's ladder. To telescope the vague, universal system into more compact form, brainstorming, analogous studies, experimental data, historical analogies, flowcharting, verbal and written descriptions are used (Cybernetic Systems Teams of 230).

The goals, objectives, purposes, and ideals of the system need to be studied in the next phases and relevant criteria formulated. Venn diagrams, blueprints, and function diagram methods are used to show what moves and activates the system in respect to formulated goals. The second phase of Boulding's ladder--functional clockwork--is reached. The system becomes a dynamic model.

Continuing with the process at the third level, the problem definition or statement worked out. Why is this system being examined? What is expected to be found or learned from the investigation? Is the system directed towards or directed from the stated goals? What is being done to change the system? System tools similar to those used in the first stages that help organize the knowledge already gained and knowledge that will be gained, as to what and how it will be applied, are the most useful in these stages of the analysis. Such techniques as diagramming, flowcharting, and verbal modelling can be used to define the problem, as well as the system. The problem statement presents the system in respect to its goals and realigns the two. This is the cybernetic feedback loops of Boulding's system.

The next six steps of complexity are directly applicable to organisms. Examples of life forms best demonstrate the processes described at each of these steps. However, the steps are also frequently applied to analogous sytems that are not living as well. Boulding's order can be successfully compared to the phases of this systems design development, but within the context of verbal modelling.

A project grows or dies at the fourth step. Interest, need, and resources would expedite the ongoing growth of an initial space colony and the subsequent progression of a space settlement. Conversely, the lack of this support from the society would result in the project remaining as fragmented, in the stage of localized studies and research, with no immediate goal of implementation. This is the current state of affairs. Yet, more publicity of the benefits of space exploration and settlement could renew the interest in space worldwide.

At the fifth level, the variety of specialized parts amalgamate into a coherent whole, with a common goal and lines of communication among all nodes and levels. The coherence towards a goal distinguishes a system from loosely organized local groups of common interest. The importance of the common goal to the participants, and the quality and quantity of communication correlates with the systems operating cohesion.

The integrated system, performing within the larger environment, receiving information from outside itself, and in turn affecting the environment it is in, reflects the sixth level of sensory awareness. Data gathering, experimentation, polls, questionnaires, and the like, are a few of the methods to receive information on the status of the system in its environment as well as on the topic under study--in this case--space settlements.

The seventh level, characterized as the intelligent human being with an awareness beyond the immediate self, is also indicative of institutes of one mind and body intently directed towards goals higher than the mere preservation of the system. Churches and religious groups put themselves in this category. Groups in the sciences, arts, and humanities dedicated to the enrichment of mankind, such as the Apollo Moon Landing Team, also fit this metaphor. Dedication of the system and all the integrated subsystems to the higher goals of humanity is required to function at this level of coherence. This degree of wide-spread dedication to the ideals of space colonization is still an eidolon for the future.

The eighth and last step to be demonstrated here is not merely a metaphor, but the real description of an operating system of the future, the acoustical design team. It is a part of society--an organization of a multitude of human individuals contributing their share to the defined goal of humanity in a space development. This active, inter-relating organization of teams is what makes the developmental phase of the colony a system in its own right. It is an entity separated from, but involved in, the development of an acoustical system in the space colony system.

Many of the analytical tools that can be used in these phases are to be found in a handbook, "If I Had a Hammer", from San Jose State University's Cybernetic Systems Teams of 230 in 1976 and 1977.

The last level of complexity, the transcendental or state of the all encompassing universe, will be related to the space colony system after the section on design scenario.

Although some less complex systems can be tested in a concrete way over a finite period of time (i.e., manufactured products), the more complex the system, the more difficult it is to test in a given length of time. This is because once the system is produced, like the birth of a creature, it begins its own life beyond the planning of any designers and continuously grows and changes from its original design. The final criterion of any complex system design is how well it survives and grows in conjunction with the overall ecological system into which it was spawned; that may take generations of growth.

The case for the systems approach lies in the care given the initial system so that it has better than half a chance to be a productive, useful system. Shortsightedness rarely gives a system the longevity of organization needed to progress beyond the immediacy of now into the continued promise of tomorrow.

Systems Approach as Applied to the Thesis Subject

Numerous definitions and applications of the term system and cybernetic system can be found in one book of essays by a variety of authors from a range of disciplines. Modern System Research for the Behavioral Scientist attempts to deal with a wide scope and the multiple levels of system in the abstract, occasionally using a concrete example of a process to demonstrate a single point of the process in examining systems and system problems (Buckley).

Still, actual operating systems--even future operating systems--do not exist in an abstract vacuum; nor are they isolated entities that can easily be separated from their environment, except by definition. Systems must be defined as systems by those observing or using them. Therefore, a system can be any set of related parts whose boundaries must be defined by a user, observer, or designer who should be aware of the effect that these very observations have upon the nature of the system.

The problem of this thesis is to show how the tools of general systems research can be used to conceive, assess, consider, balance, and control the factors of a defined integral system in the future of human space expansion. In turn, this synopsis of a system design will be a first-cut model useful in further studies of the complex, involved problems of space colony acoustical systems.

The very definable physical parameters of the torus enclosure and its isolated, self-sufficient society aids in encompassing the study of the acoustical aspect of the problem. What is learned in the very contained and futuristic nature of the acoustical design serves as an analogous systems model that can be used to find solutions to our sound environment here on Earth.

In abstract terms, a system is defined as an assemblage of related elements that have a common basis, goal, or linking process. This assemblage is set apart from its environment by defined boundaries. The whole assemblage operates in such a way as to be unable to predict the outcome from a mere examination of the parts and subsystems separately.

In concrete terms, it would be hard to predict what the acoustical system of the space colony would be like by knowing only some of its parts without reference to the total system. How loud some of the sound sources are is not enough to know what it will sound like in the entire colony or even if it matters how loud some sources are. For example, it would not matter if sound sources were located where they could not be heard, such as rockets in the space vacuum.

The functioning of the system may or may not have a goal or feedback loops or even internal consistency. It may have a series of goals and purposes and only a generally predictable process with a great deal of probable and random outcomes. An example of this variable functioning would be the Earth's weather system, which has only the goal humans have defined for it: that of seeking a state of equilibrium which it never seems to reach. The weather is constantly repatterning itself in ever changing, yet familiar variety. Such would also be the sound system of any place never reaching a steady state but continuously changing. By modifying, controlling, and reducing acoustical waves, humans would be the feedback element defining the parameters and functions within the acoustical system as a cybernetic system. Human use of sound might be considered the feedback loop regulating sounds to meet specific goals of particular situations of the human elements involved.

While the description, inclusion, and exclusion of elements and processes of this sound system may become very complex, what the system is and does can be summed up in the answer to the very simple question: "How will the interior of the space colony sound and what will be heard there?"

Organizational Factors

Space Exploration Organization

To achieve a complex system design, teams from various disciplines would need to collaborate on the primary system as a whole design and carefully incorporate the many and varied secondary subsystems. Researchers would conceivably be members of a number of related teams making different decisions. A system this complex would be represented by an overlapping network structure with many nodes and lines of communications, rather than a simple hierarchical ladder.

With such a complex organizational structure, only a systems approach, integrating the participation of the hard and soft sciences, arts, and humanities, with their technology and expertise can achieve the design of an outer space community. However it is formed, the organizational structure will define the budget and priorities given to the community environment.

Acoustical Design Organization

The acoustical design will emerge from the efforts of researchers considering problems fitting into, but defined separately from, the overall design. The acoustical system design would be part of a complex network of groups and subgroups interfacing with still other groups all interested in the interior design of the colony and human livability. Even if acoustics were to be considered a subsystem, the design is complex requiring systems insights rather than techniques used in isolation from other colony design problems.

Elements of the acoustical system and its design team would be: (1) the organizers, researchers, and technicians;

(2) the community's needs, wants, and desires; (3) the acoustical machinery and equipment located within the colony; (4) the acoustical characteristics of the community; (5) the acoustical attributes of the torus shape and the construction materials; and (6) the acoustical features of the community living quarters.

The list suggests that both the hard and soft sciences are needed to determine the criteria, design process, choice of alternative models, and final design plan to handle the acoustics within the colony.

If these processes and plans were actually progressing today, the teams involved would have the manpower, money, and expertise to effectively use the holistic methods of the systems approach. This paper, as an investigation by one author within a limited budget and time schedule; can only sample the total possibilities presented by the systems approach to the acoustical problem. The intent of this sample is to present an overview of the multiplicity of disciplines and approaches needed to solve a problem of this magnitude.

Assumptions

Basic Assumptions

The space colony configuration used as the constraining environment for the acoustical system design of this study is the Stanford Torus settlement, which will be orbiting the L5 point between the earth and moon. The balanced gravitational field at this location would produce a saddle orbit around the L5 point (Figures 1 and 2; Johnson, p. 9 and p. 2).

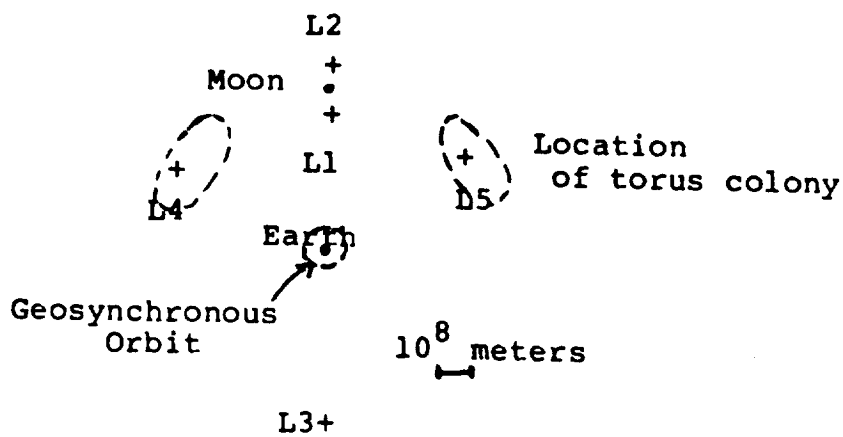


FIG. 1. Lagrangian libration point "L5" among the earth-moon libration points--points of equalized gravitational attraction between the moon and earth.

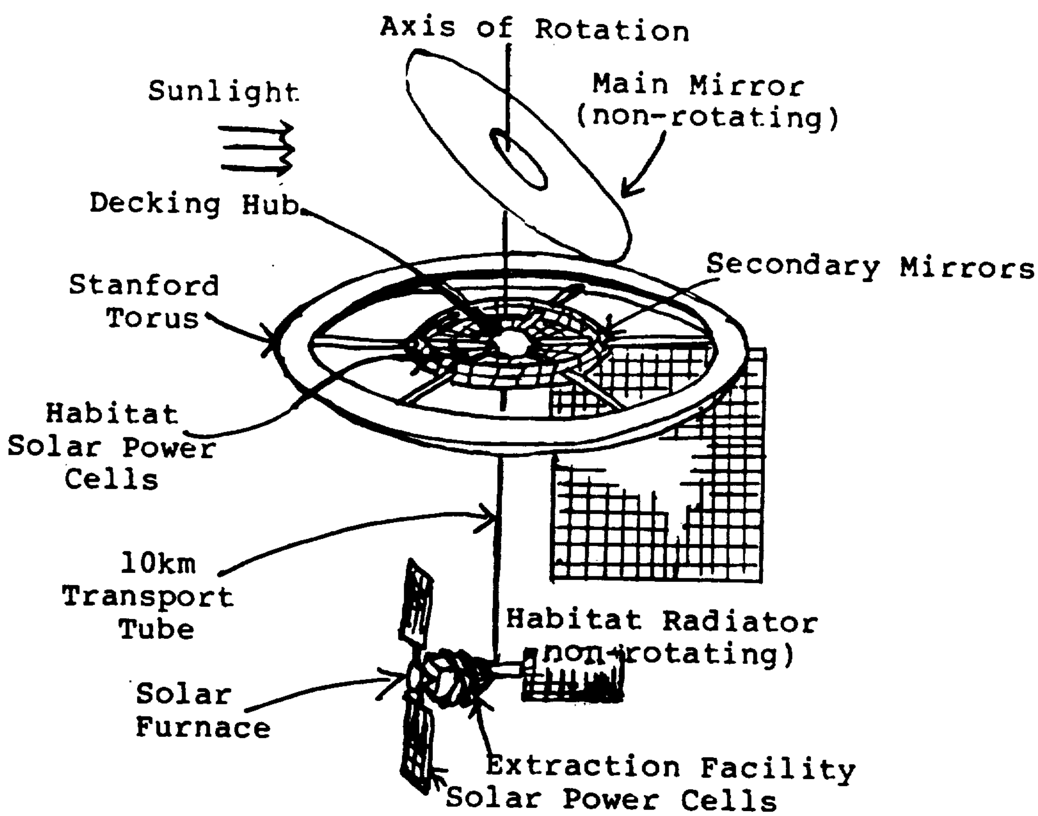


FIG. 2. Stanford torus configuration with attended exterior life support systems.

The entire torus diameter will be approximately a mile. The outer section will have a 500 foot diameter, leaving over 4,000 feet as the inner diameter. The gigantic shell structure will enclose an entire, self-sustained community of about 10,000 citizens and all its multitude of requirements. At the same time the lives of these 10,000 people will be precariously dependent on the torus cocoon and communication ties with the Earth. At least the early communities in space will be this dependent.

A serious design development of a space community enclosure will occur in the next century. By then, the budget will have been determined by the sponsoring organization, hopefully with a sufficient amount of funds for the study of environmental effects on a space community. Although the acoustical parameters could be viewed as a subsystem of the ecological system of the enclosure, the acoustics can usefully be considered as a system constrained by the habitat environment. On the other hand, the acoustical system is part of the surroundings of the citizens in the enclosed space community.

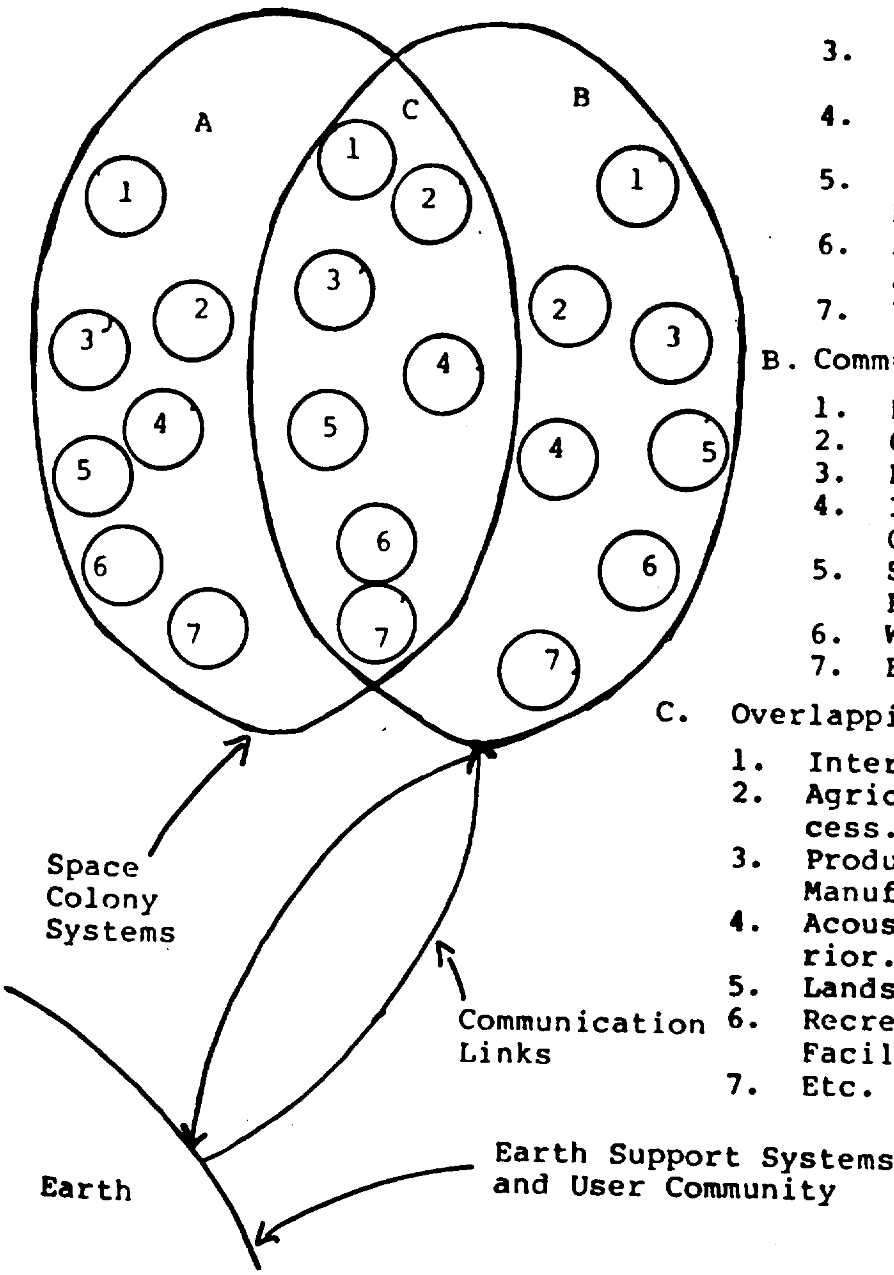
A team of psycho-ecological engineers and researchers will be involved in the colony design process and study the effects of an encapsulated environment on its users, the space colony citizens. The various experts of the space community will have to integrate their disciplines into subsystems of the overall space colony ecology system. No system will be designed in isolation from other subsystem studies (Figure 3).

This study will be pragmatically limited in coverage to only the acoustical system aspects of the environment. Educated assumptions about other system designs impinging on the acoustical system will be made when necessary to curtail lengthy discussions on the details of choice involving more than the acoustical system.

Environmental Constraints

Space colonization will be unique in the pioneering efforts of history. Never before has a group of pioneers had to be so totally dependent on an artificial environment created completely by man. The settlers of previous ages conquered, modified, and controlled parts of the natural world for their own uses. While nature was hostile and resistant to these intrusions, with coaxing, force, and experience the pioneers carved their niche and used some of the natural resources to protect themselves in new and ingenious ways from other ravages of the natural environment. In general, the more successful groups learned to live in harmony with their natural environment. After all, humans have evolved within the Earth's abundance.

Beyond the Earth's environmental elements exists precious little that is hospitable to man. There are great



A. Physical Support Systems

1. Torus Structure.
2. Gravitational System.
3. Shield structure.
4. Air Conditioners.
5. Recycling Mechanisms.
6. Architectural Structures.
7. Etc.

B. Community Systems

1. Family
2. Government.
3. Education.
4. Informal Social Groups.
5. Schedules and Routines.
6. Work Groups.
7. Etc.

C. Overlapping Systems

1. Interior Designs.
2. Agricultural Process.
3. Production and Manufacturing.
4. Acoustical Interior.
5. Landscaping.
6. Recreational Facilities.
7. Etc.

FIG. 3. Venn diagram of the Space Colony Systems with Earth Support Environment.

dangers even though he encapsulates his space habitats. Therefore, although humans must enclose themselves in totally man-made surroundings, these surroundings should resemble, at least in the first stages, man's natural setting on Earth. Will this environment be completely artificial and controlled or could the space pioneers allow nature to take over within the huge enclosure, if only in a semi-controlled manner? In other words, how much nature and how much man/machine control will be necessary to maintain man's safe and healthy survival in the sever, silent nothingness away from earth? A great many more ecological and psychological studies of human's well-being under conditions resembling space isolation are needed.

Studies of man in enclosed and/or isolated communities here on Earth similar to space confinement have begun already for a variety of reasons. The results of these studies suggest that a colony interior must be conservatively designed to match Earth's nature as much as possible (Aiken; Serxner 1968, pp. 25-30; Zuckerman et al. 1968, pp. 183-194).

Many futurists envision a space community becoming a possible idyllic utopia, with only the finest of Earth's nature designed into the colony. This is a tempting possibility that may be used as a model for subsequent community planning on Earth. If the degree of cooperation and care needed for the colonization of space is also invested in the design of the interior community, space colonies could well become an ideal existence even when compared to their earthly counterparts. With such an attractive alternative, space migration could become common.

Although mass migration to space colonies could create some problems and conflicts, many others may well be solved. Obviously, space colonization would mean the growth of humanity beyond terrestrial constraints (Figure 4).

Standards and Criteria

Although it is difficult to set absolute standards in a non-definitive study, the following cases will serve as guidelines for the areas of acoustical concern.

Upper Limits of Noise Levels

The upper limit of dB permitted would be well below the thresholds of ear damage and pain. This criteria would not be a single value, but a series of values based on place, duration of exposures, and frequency (Figure 5).

A sound level exposure profile studied in the design process will minimize both noise exposure and later design alterations necessary for quieting noisy areas already in use. Remedial quieting is far more difficult to administer than simply to design quieter machines in the first place. Therefore, standards for quietness should be included in the design specifications of the equipment needed in the colony.

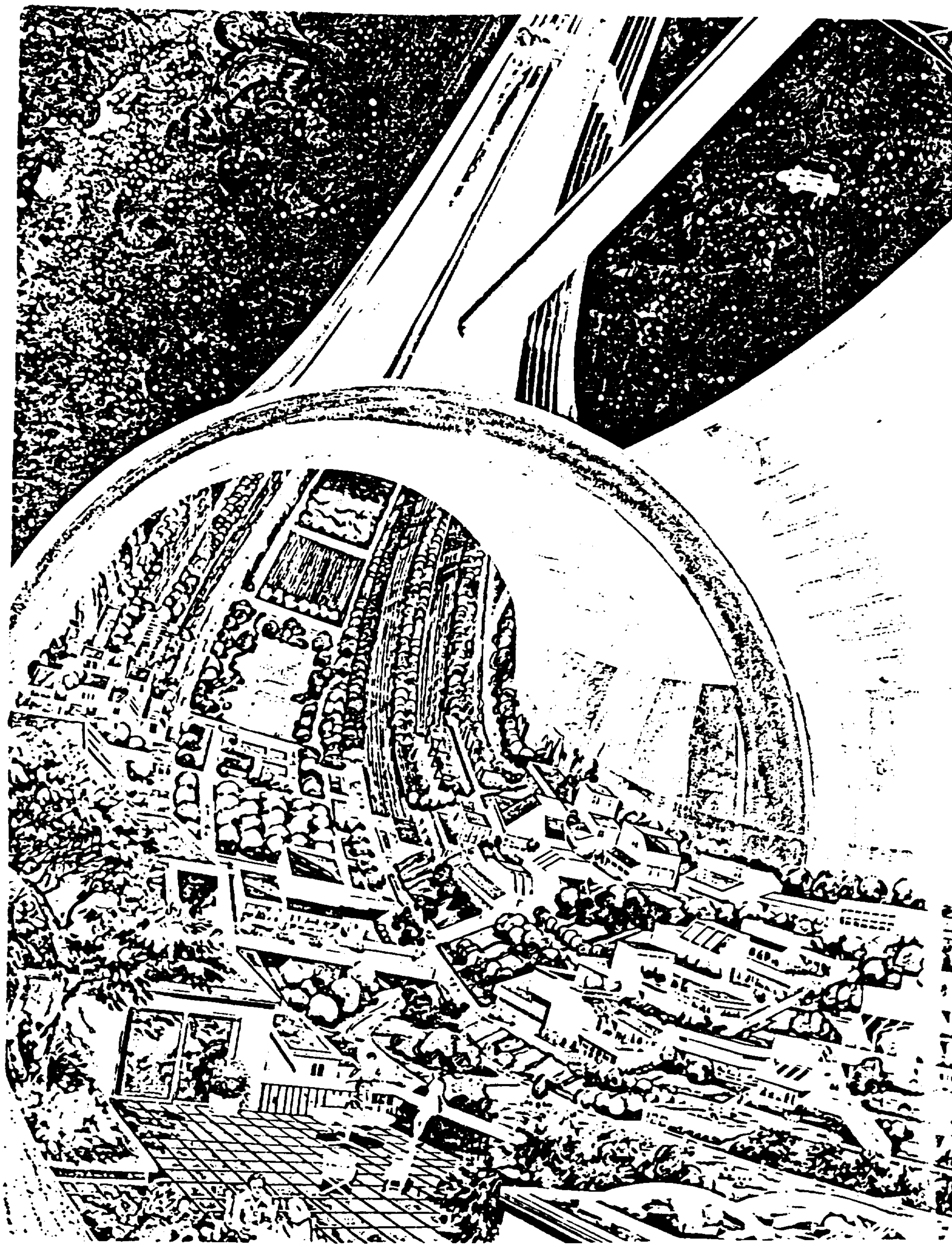


FIG. 4. The interior of a space colony within a mile wide torus (Johnson, p. 86).

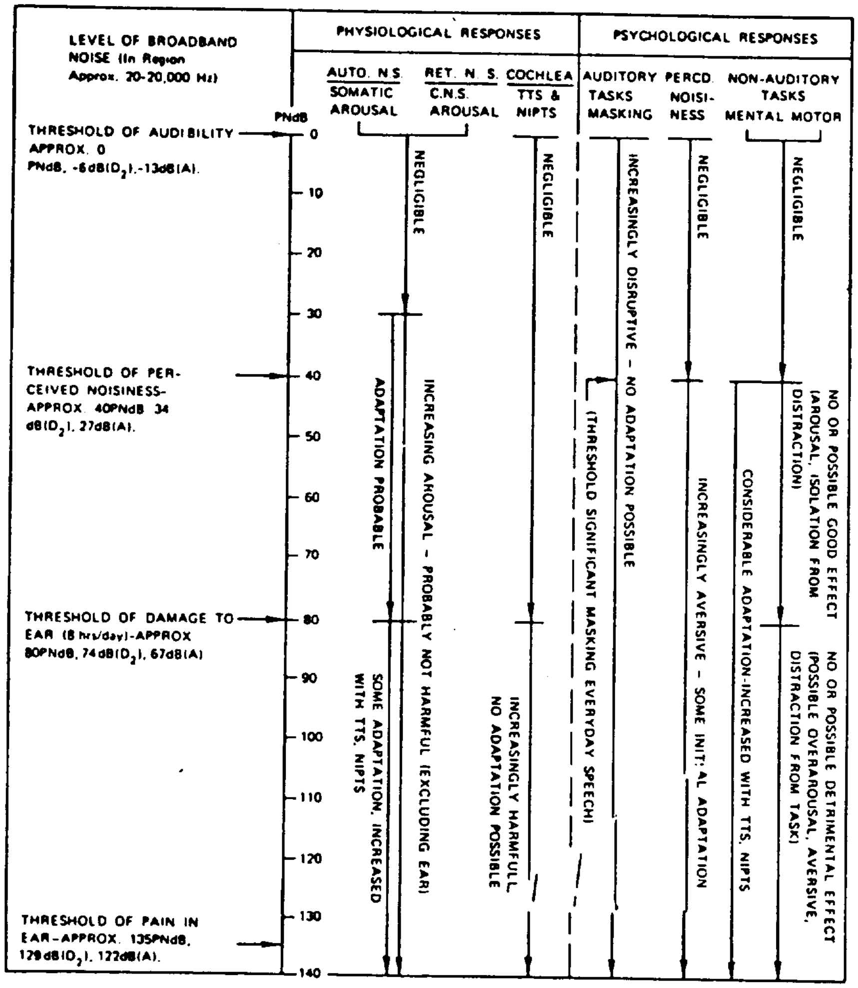


FIG. 5. Basic physiological and psychological responses of man to habitual environmental noise. Auto. N.S., Ret. N.S., and C.N.S. stand for autonomic, reticular, and central nervous systems, respectively. (From Kryter's The Effects of Noise on Man, p. 588).

Even today, quiet standards are becoming more prevalent in machine and equipment specifications as people become more aware of the need for quiet and better quality (Petterson, p. 61; Krishnappa, pp. 82-90; Britton, pp. 43-51).

Day/Night Levels

In the living areas, day/night sound levels in usage zones can be charted for the acceptable ambient ranges and sound limits of the community. Standard tables can be derived from different sources of noise regulations and actual normalized measurements of different zones. Figure 6 depicts such a chart (White 1971). While this chart is based on transient noises more common to Earth communities, it can be modified to reflect lower ambient noise levels, especially in the quiet zones of a space community without internal-combustion engine noises.

Subjective Sound Criteria

The final criterion of subjective sound is the least defined, yet needs to be the most carefully studied and considered in the design. An utterly quiet community similar to an anechoic chamber is not a practical goal of acoustical designs. Studies of human environments with too few sounds have shown that utter quiet can be deadly and unnerving, resulting in severe sensory abnormality. Your own breathing and body movements would sound loud in total stillness.

	Zone 1 Industrial and Heavy Commercial	Zone 2 Light Commercial and City Residential	Zone 3 Quiet Residential and Quiet Zones
Day dB level Average Range Peaks	75 70 —— 80 85 59 90	65 60 —— 70 73	40 35 —— 45 47
Night dB level Average Range Peaks	73 70 —— 75 80	50 50 —— 60 65	38 30 —— 40 43

FIG. 6. Table of Day/Night Noise Levels. Averages, ranges, and peaks for three zones of a model community. Adjusted down to reflect the overall lower dB of the space community.

Therefore, no ambient sound at all would be as much of a problem as too much noise (Aiken; Zuckerman, pp. 183-194).

Some acoustical designers favor a uniform spectrum of white noise or selective bands of pink noise, within community enclosures to mask all unwanted sounds and fill the silence. This simplistic idea is not a sufficient solution, for many reasons that will be discussed further along in the paper.

General Guides

Some general guides can be used as a basis for predicting annoying noises in specific cases. These guides would include the following relative disturbances:

1. Vocal communication interference called speech interference level (SIL)
2. Noise interference with sleep relaxation, concentration, and sound signals
3. Uncontrollable and uninvolved intrusions of sound
4. Extreme frequencies below 100 Hz and over 10,000 Hz
5. Loud, sharp, intermittent and random noises
6. Subliminal sounds, either at the lower threshold or continuous background, and broadband white noise (Kerrick)

Signal Clarity

Signal clarity involves developing those sound signals that are desired and needed. These sounds, designated to give information, will require some quieting of the surroundings and sharpening of the signal. For example, using appropriate parameters, such as those that create the reflecting, amplifying, absorbing, and diffusing ambience designed for theaters to highlight sounds on stage, is necessary. Designing appropriate interior parameters to augment defined sound signals is the concern of building acoustics, a highly technical art/science dealt with here only in a general way. Electronic and emergency signals are also included in the total acoustics of a community. Both of these types of signals will be considered as black box factors of the design, without any further analysis.

Positive Sound

The criteria for the intentional inclusion of positive sound stimuli is far more subjective than criteria for sound annoyance. Reducing annoying sounds from the mechanical structure and interior community is necessary in planning, but not sufficient to produce a stimulating environment. Very little information about what sounds and conditions generate positive stimulation was found in a literature review. Further study in this area would be warranted before an actual acoustical interior of the torus is designed.

Two small studies, one by Dr. David Nagel of NASA Ames and a poll by the author, however, did suggest some pertinent information. In Dr. Nagel's study of sound identification and quality of response, identity association was an important variable in classifying the sounds as more or less positive. For example, a nondescript wide-band swish was found very unacceptable when identified as even a rather 'quiet jet', while those considering the noise as a 'loud, noisy wind' still found it acceptable (Kerrick).

In the poll study, an open ended pilot questionnaire was given to twenty-five friends and acquaintances of the author to identify typical daily sounds of which they were aware, and their reactions to them. While the questionnaire was not very definitive and would need several iterations to gather enough data for a rigorous analysis, some interesting trends were noted. While the recording of positive sounds was emphasized in the instructions, all sounds and responses were elicited. The annoying sounds recorded generally fell into one of the six categories of annoyance listed earlier.

Responses to the positive sounds had an extensive range and were generally too unique to find specific commonalties. Some were mentioned often enough, however, for a few common categories to be initially summarized.

1. Natural sounds were found pleasant (not that all unnatural sounds were unpleasant)
2. Sounds made by one's own work were enjoyed
3. Music controlled by the hearer was found very enjoyable
4. Sounds indicating well-being received pleasant responses
5. Finally, the sound of running water, both at home and in natural environments, was mentioned by every single subject to be pleasant

While this data could not be used to substantiate cause and effect correlations or be used as a representative sample of the population, further studies of this nature would be very necessary in any acoustical design considerations for a humanized space community. Therefore, preparation and research for a space torus community should include many more subjective studies to ascertain the general desirability of various sound settings.

An Overall Criterion

A final overall criterion needed to fully evaluate the acoustical environment of the colony is the desirability of living there and the level of productiveness and satisfaction of the colonist. While the composite interplay of the entire colony environment would affect the quality of life implicit in such a criterion, that quality of life could not be achieved in a stressful acoustical environment.

The sound surroundings are very necessary to meet any quality of life criteria designated. Continuous, annoying, and stressful sounds will be less escapable than comparable terrestrial urban area noises noted for being stressful. Without the normal, natural, and pleasant sounds of earth that we take for granted, such as running water, insects, birds, animals, wind and waves, the acoustical surroundings would be dismal indeed.

III. DESIGN PROCESS

Defining the Problem

Metaphysical Limits

What are the parameters that constrain the system and the limits of the problem? The problem of this thesis is a metaphysical one outlining the methodology of an acoustical design. As such, the problem definition itself becomes a verbal model and tool for limiting and shaping the acoustical system design. The problem defining schema might look like the chart in Figure 7 (Dickerson, p. 24).

Physical Limits

Blueprint models of a torus space colony can be found in two NASA Summer Study Reports (Johnson; Billingham). From these two studies, other detailed studies such as MIT's "A Systems Design for a Prototype Space Colony", and educated assumptions, placement of acoustical sources and sound dispersion patterns can be generally deducted (Smith, 1976). This graphic model would produce a "still picture" of the physical parameters of the problem (Figure 8). This would be similar to Boulding's static, structural framework level of the system design.

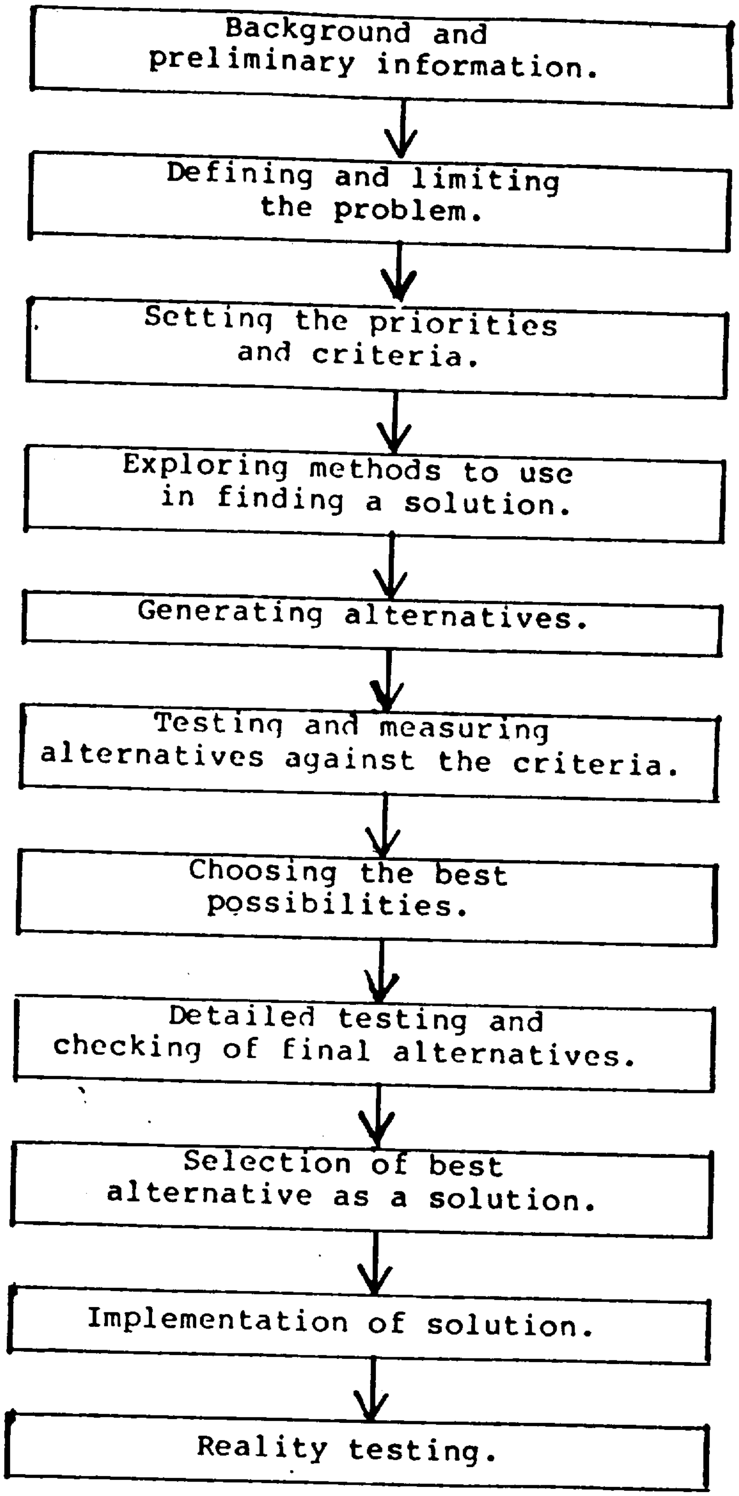


FIG. 7. Flow chart of the steps in the problem-solving process.

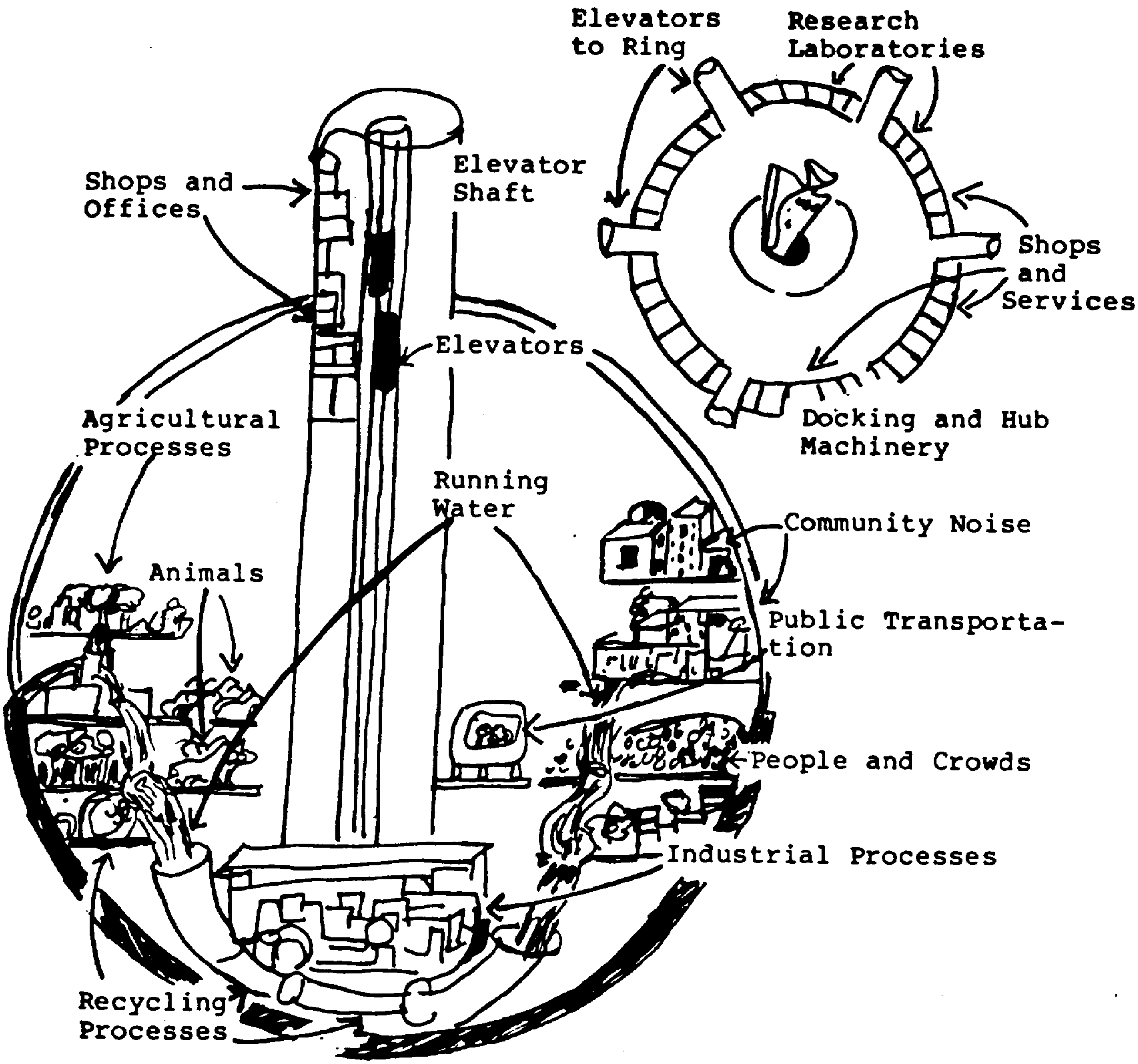


FIG. 8. Graphic model of noise source locations and sound centers within the torus and hub.

Functional Limits

A system can be identified by its functions. The system can be further detailed by relating component functions using a functional-level diagram of the successive levels of detailed subsystems.

Each level can be thoroughly detailed by functions or left with a general, operational description. This mapping immediately shows the inter-relations within the system, and suggests parameters at the system interfaces (Figure 9, Dickerson, pp. 158-160).

This predetermined functional model of the system design process compares to Boulding's second level of deterministic clockwork.

Relational Factors

Knowing the elements and functions are necessary but not sufficient for the study of a system. It is also important to learn the relational dynamics of the elements and their functions in the supra-system over time and space. What are the system's overall patterns of behavior, deviations, oscillations, inconsistencies, and cycles? What are the growth and decline feedback loops?

Other questions to be asked at this stage would include: (1) What will be the range of ages, educational levels, interests, professions, and acoustical sensitivities of the people inhabiting the colony? (2) What are the estimated transportation costs from Earth of supplies not produced or available in space, e.g. nitrogen, plastic, organic goods? (3) How will the stages of development progress? (4) How much research will go into the interior design, including the acoustics? (5) What areas can be and need to be determined

FIG. 9. Function Chart. The general overall function is a safe and sane acoustical environment. This function can be broken into more detailed functions in the following manner:

Level One Functions:

1.	2.
Provides safe sound levels.	Permits and promotes positive sound.

Level Two Functions:	Level Three Functions:
2.1 Provides a variety of sound levels.	2.3.1 Studies characteristics of positive sound.
2.2 Enhances clear signals.	2.3.2 Finds the ranges of population sound awareness.
2.3 Contributes positive background sounds.	2.3.3 Designs natural sounds in natural settings.
2.4 Allows a wide variety of personally selected sounds.	2.3.4 Develops new sound arts.

FIG. 9. Continued

Level Four Functions:

2.3.3.1

Discovers what sounds are appropriate to what settings.

2.3.3.2

Studies the effects sounds and settings have on humans.

2.3.3.3

Correlates wide varieties of settings and sounds for use in space enclosure.

2.3.3.4

Develops, designs, and plans for aesthetically pleasing surroundings with sound.

in the planning stage and what can be left for the space community itself to decide? (6) How will the acoustical system be controlled and regulated?

Brainstorming by the systems research team would undoubtedly turn up hundreds of other questions to be answered concerning the dynamics of the colony and its systems, including, in this particular case, the system of sound. Brainstorming techniques also aid in clarifying the core design and questions that need to be asked to gain knowledge of the operating acoustical system as well as the surrounding environmental constraints.

Modelling at this very complex, dynamic stage would require monumental inputs from numerous areas and studies of any analogous cases. Many alternative models, from stochastic computer programs to dynamic physical models, would define and determine the progress in these phases of the design process. From these determinations, the next stages of the systems problem will be brought to the next six categories of Boulding's hierarchy of complexity.

The time spent defining the problem and setting the limits of the system will pay off after investigating the alternatives and gaining satisfactory results by solving the right problem. Giving more time and thought to the first stage of planning produces a solution that is more likely to be flexible, yet optimal.

Methods

Mechanical Factors

Noise measurements, indicating intensities in octave band, third octave band, or single tone frequency, if warranted, can be made of the emitting equipment components before they are utilized in the space habitat. In many cases, manufacturers can do this by complying with sound specifications already existing. Otherwise, the design engineers can measure the sound intensities in anechoic chambers. With the knowledge of sound level requirements, machine and equipment manufacturers can emphasize such acoustical considerations as insulated housings, tighter machine tolerances, tougher materials, and more aerodynamic lines in their structural machine designs and quality control. Such carefully maintained machines will also perform better, achieving a lower probability for failure (Britton, pp. 43-51).

Knowing the sound intensities of the separate machines (including electronic and computer components) even under working loads is not enough. A blueprint of machine locations within the torus would aid in determining the dB levels of the area and the need for insulation and barriers (Figure 10). These measurements and calculations can be accomplished using linear programming and computer modelling (Greenwood)

A number of computer programs have already been developed to measure, calculate, and correlate the fluctuating power intensities of acoustical waves at specified frequency bands for various situations. NASA Ames has developed programs that determine the patterns of acoustical frequencies in wind tunnels. Other such programs exist for indoor and outdoor sound areas.

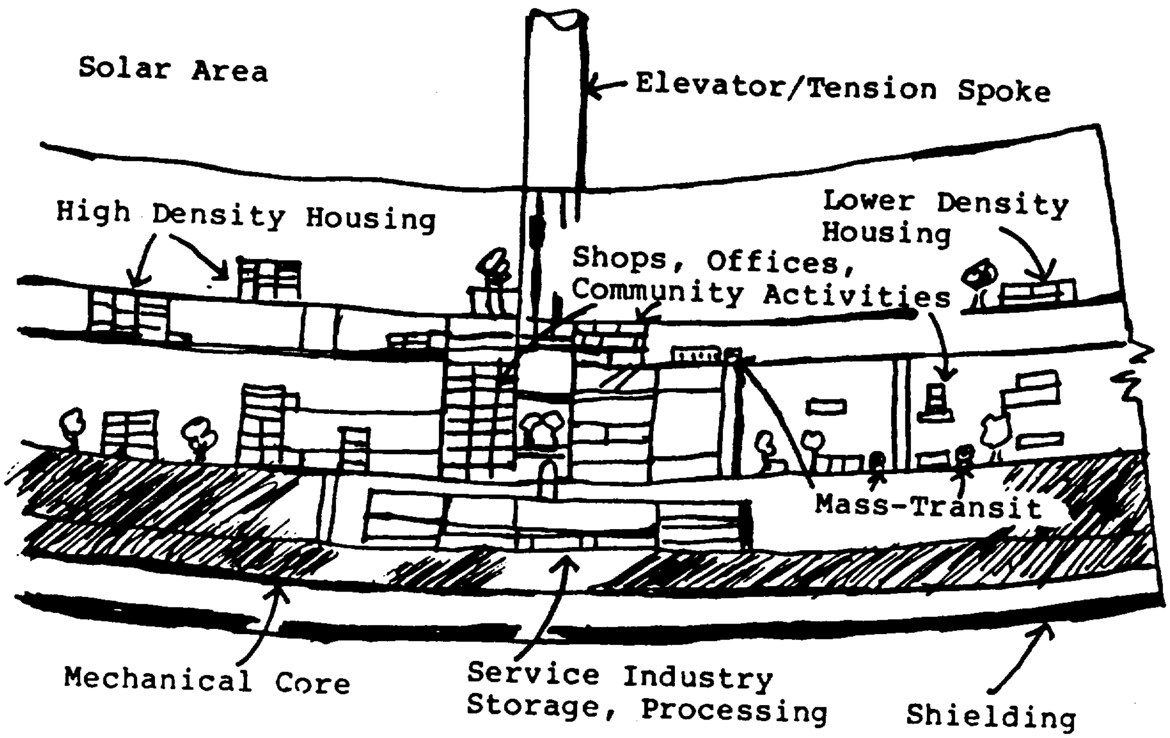


FIG. 10. Longitudinal cross-section of torus profile showing location of the various zones and areas of the torus.

For the purpose of this study, the beginning of a sound program was developed to show contours of sound levels at the cross-plane on the area of interest. A flow chart was also created to indicate sophisticated additions that will assist in the determinations of the patterns of sound waves frozen at a point in time. The program uses absorption and reflection factors, measured dB, frequencies from the sound sources, and the values of parameters from the surroundings as the input. The results are a series of plots of sound planes that simulate a three-dimensional space. This sample program, its input data, and output plots, is found in Appendix A.

The absorption characteristics materials needed to insulate walls can be found in manufacturing catalogues, from the United States Government, and from research firms specializing in sound research and noise control, such as General Radio Corporation and Bolt, Beranek and Neuman. These values representing reasonable ranges of source dB at various frequencies can be used as the input to the computer program to determine what balance of machine standards, placements, and acoustical control is necessary to keep the ambient noise locally contained and well below predetermined annoyance and injury levels (NIOSH; USEPA 1979).

Community/Social Noise

Again, the methods for the abatement of mechanical noise are the most concrete, direct, and easiest to use. Ambient noises from the social community will also need to be measured and treated. It is not as easy to measure the ambivalent sound sources of a community or to determine what they should and/or will be before the community exists. Searches for analogous studies and measurements of similar communities are possible, but allowances must be made for some differences.

While the community enclosed in the torus will have the ubiquitous mechanical noises of operating equipment, it will not have to contend with jets or internal combustion engines (there will be no petroleum products). Nor will it have strong, unpredictable winds blowing and refracting sounds out of the normal ranges.

Using a "B and K" sound meter, a number of places in a local community with noises similar to those that might be heard in a space colony were measured for ambient levels using the octive band frequencies. However, these analog measurements can only be used as rough gauges for locating sound zones and determining approximate levels per zone (Appendix A).

Determining what community activities would exist in a colony and where to locate these activities would require a number of systems methods before designers could begin modelling the torus interior: analogous fantasies, hypothical situations, verbal modelling, surveys, polls, questionnaires, studies of life styles, and value analysis. Research of existing community populaces as well as of people destined to become part of the colony population would also aid in defining community sound needs and acoustical problems in view of preliminary designs.

This thesis has primarily used analogous cases, fantasies, and verbal modelling to simulate the needs of a community and the sounds of its activities. Here, as in mechanical areas, acoustical characteristics of insulating barriers can be determined from charts. Community noise ordinances, such as the "Model Noise Control Ordinance" (USEPA), can also serve as analogous modelling controlling factors in zoning for sound isolation yet allowing wide ranges of sound levels.

Statistical analyses of experimental communities in simulated space colony situations will provide important numerical results for weighing the attributes of alternative acoustical living conditions.

The following is a breakdown of the steps leading to the modelling of community noise configurations:

1. Determine the sound needs and problems in a variety of communities and activities
2. Calculate and/or measure the ambient noise levels for such areas and any possible localized sources
3. Set up tables of coefficient values for the absorbing and reflection of sound by a variety of barriers and structures
4. Use these various numerical values as input to a computer program, to model the components dynamically for ways to balance, and optimize them in alternatives that can then be measured against the standards and priorities

Subjective Individual Factors

Because the subjective factors are impossible to evaluate in a rigorous scientific manner, why bother including them in the design at all? Probably because thoughtful consideration for the range of individual preferences makes the difference between a minimum stress human environment and a over-stimulated and stressful mechanical environment. Certainly the colonist will have enough challenges without such surroundings.

Yet, lowering noise levels is only preparing the stage for the real values of sound stimulation. Just because this problem is extremely vague and subjective does not mean that it cannot be evaluated by the designers. Such things as questionnaires, polls, and psychological experiments can be used to obtain information from either analogous population samples or the actual preferences of the colonists themselves regarding sound reactions. Patterns that occur will limit ranges and give the design problem a more defined, realistic scope, including individual subjectivity to form human scales. Even in so vague and subjective a survey as used for this thesis, patterns began to emerge that can be further refined if necessary.

Fantasy analogies of colonial life styles in a space torus will present some ideas of the scope of possible settings. These will be aided by predictions of what the personal characteristics of the future settlers are likely to be. Along with these predictions, actual studies of astronauts and persons interested in the space adventure will give a certain amount of factual information about the people willing to inhabit space colonies (NASA Activities 1977-1980). The sounds and conditions that annoy and please a wide selection of pioneering people, would be helpful in designing an acoustically aesthetic torus interior that would be desirable and increasingly more stable.

Statistical analysis of the results of these studies will yield common ranges, variances, overlapping patterns, and trends of positive sound stimulations to include in design considerations. Statistical studies of this nature will also help separate those features that really need to be planned into the hardware design, those that can be left to chance, and others that can be controlled by the changing whimsy of the colonists (Cybernetic Systems Teams of 230 1975-1976).

Evaluating Components

How will designers be able to measure such diverse components as community needs, dB measurements, and individual preferences? One way is to reduce priorities, ratings, needs, and attributes to numbers. The numbers are then compared in combinations representing the effectiveness of the component attributes with priorities for the performance of the system.

Although the assumption has been made that the budget sufficiently covers the research design and actual implementation, a comparative cost study will aid in selecting alternatives of equal merit on other grounds. Thus cost becomes one of the numerical factors that is conveniently used in the numerical analysis of system alternatives. In order not to overuse this simplistic reduction to costs, leaving the cost comparison until the end or giving it very low priority at first allows more concern with the humanistic elements of the design.

Statistical data gathered from previous studies of people confined in isolated communities, such as submarine crews and outposts in the Arctic and Antarctic, would give some early indications of perceptual responses and needs under these conditions. This data may even lead to the development of experimental groups in simulated enclosed colonies that could explore these conditions in controlled ways. In fact, a systems engineering class at MIT has gone so far as to design a prototype colony for one thousand people on a lower-budget, shorter-duration basis than the Stanford Torus Community (Smith).

The preliminary stages and the more measurable and easier to use numerical phases, will clearly show wide ranges of diverse acoustical components in perceptive. The abstract subjective input used in weighing models for selection of alternatives needs to be made concrete and measurable through these stages of the design process.

Attribute Priority and Ratings

A weighing configuration follows, using possible alternative isulators measured against a set of acoustical considerations and expected attributes of the design (Figure 11).

What are the attributes that can be relevantly measured other than mere dollar costs? These would include such factors as the following list of conditions and qualities necessary for an effective acoustical system design:

MATERIAL SELECTION

Criteria	Fiberglass	Petroleum Acoustical Foam	Laminated Glass Panels	Air Space Glass Panels	Treated Honeycomb Aluminum	Silicon Ceramic	Landscaping Earth Burns, Trees, etc.	Water
Cost .05	9 / .45	2 / .1	5 / .25	5 / .25	8 / .4	5 / .25	9 / .45	8 / .45
Sound Absorption .45	8 / 3.6	8 / 3.6	6 / 2.7	6 / 2.7	5 / 2.25	3 / 1.35	7 / 3.15	6 / 2.7
Attrac-tiveness .1	7 / .7	7 / .7	7 / .7	7 / .7	5 / .5	6 / .6	10 / 1.0	10 / 1.0
Versa-tility .1	8 / .8	6 / .6	4 / .4	3 / .3	7 / .7	4 / .4	5 / .5	8 / .8
Avail-ability .15	9 / 1.35	0 / .0	9 / 1.35	9 / 1.35	9 / 1.35	9 / 1.35	3 / .45	5 / .75
Strength .15	3 / .45	1 / .15	7 / 1.05	6 / .9	9 / 1.35	9 / 1.35	3 / .45	2 / .3
= 1.00 Material Scores =	7.35	5.15	6.45	6.2	6.55	5.3	6.0	5.95

FIG. 11. Ratings of attributes of goodness on a scale from 0 to 10 against a list of priority criteria that sum to 1.00, for a selection of acoustical treatments.

1. Attenuation of noises (Reduction of noise level)
2. Availability (transporting verses producing)
3. Aesthetic and social appeal
4. Ease of handling and controlling
5. Strength and durability of treatment
6. Levels of personal freedom desired by the colony citizens.

By giving each of these functional factors a weighted priority value between zero and one so that the entire attribute list totals one, the factors to be quantified can be based on a variety of attributes that could not otherwise be measured in relation to the whole or to each other. A careful comparison of attributes gathered from the data of the tangible factors, as well as data from the more intangible factors of human concerns and the community needs regarding noise, becomes part of the final decision process as well as part of the various modelling phases of the design process (Lapin).

Decision Process

Just as each alternative material or model plan can be assigned a value and rated on how well it corresponds to the attributes of interest, so can values for whole system models be generated and measured against the system goals and priorites.

This information comes from the consolidation of all previous numerical data derived from tables and questionnaires. Some of the measurements will be concrete values, such as absorption/reflection coefficients, while others may be statistical probability or weighted preference values.

By clearly establishing the relative importance of sets of system attributes and guaging how much each alternative could contribute to those factors, comparisons of otherwise unwieldy system alternatives can become convincing. This process also allows for trial and error priorities that will show how each model configuration would affect the resultant system and its development before the final implementation.

What needs to be clearly stressed about this process of weighted evaluations is that any hidden agenda priorities need to be dealt with explicitly and honestly to make the best use of this systems tool. The evaluation process quantifies a great many factors for the decisions throughout the development stages, and in the final decisions as well. It allows the orderly, objective evaluation of a great many factors in alternative models to convincingly justify decision actions (Greenwood).

IV. MODELLING MECHANICAL NOISE AREAS

Consideration of the Sound Elements

Finding and Using the Source Decibels

Machinery

All dynamic equipment emits some level of sound vibration that can be easily measured with sound meters. Basically, an area cannot be made quieter than the sum of the free field generated by the machinery that are the sources of the sounds. It is of prime importance to assess the basic intensities and pressures of sound vibrations at these sources. Even now, many firms are willing to supply this information, in varying frequency bands, for the equipment they manufacture. Making this a stipulation when contracting such equipment for the colony would accentuate the importance of quieter mechanical products.

Anechoic chambers and measuring devices are used to determine the precise noise source pressures. Calibrated pressure microphones, analog recorders, multiband frequency meters, and simple dB pressure meters exactly locate and measure the points of pressure or the cycles of vibrating air. Intensities can then be calculated from the pressure levels and used to correct or redesign the machinery before it even leaves the test stage at the factory (Peterson).

Ambient Noise Levels of Industrial Zones

Location

Life-support systems, industry, and production will be located in two general areas of the torus. Mechanisms to rotate the torus and equipment involved in Zero G industrial processes will be located in the hub center. Other facilities will also be in the hub. It is therefore important to keep the noise contained within its own zone.

The second area will house recycling, atmospheric conditioning, manufacturing, water pumping, central computing, and other supporting mechanical systems, and could become a problematic ear-sore to the entire community if not designed for quiet efficiency and securely enclosed. The projected location of this industrial zone is on the outer perimeter of the torus, under the upper living areas. Noises emanating from below could produce either a continuing stress condition or a comforting level of soft humming that signals all is in order.

Sound Dynamics Program

Because physical models of the colony will be generally static, a way is needed to show noise levels of possible combinations of elements and configurations with regard to sound levels. Knowing the acoustical values of individual elements is not enough to predict the sound dynamics of an area. Linear programming seems to present a model that is simple and direct enough to test many possible configurations with the least amount of time and cost.

A simple program has been designed that, by inputting the size, location, and dB intensity for each sound source, shows the sound levels for an area. While this rather basic core program will produce free-field calculations, it would need elaborations and many test model iterations to show the full dynamics for a three-dimensional zone. Including sound absorption and reflection factors, many planes of sources, a three-dimensional zone, and a wide range of frequency bands would increase the general usefulness of such a program in predicting noise levels (Appendix A).

The program would handle the many iterations in juggling the factors of the dB levels of the machine sources, and of acoustical insulation placement, thus helping to determine the optimal balance to quiet the noisy elements (Figure 12).

Another consideration is the effect of vibration from these machines on the torus shell and its rotational rhythm. It would be necessary to know the characteristics of the structural components and their masses, as well as the vibrational characteristics of the moving elements that might set up reverberations in the structure.

Again, the measuring of the components separately is necessary but not sufficient to predict overall vibrational

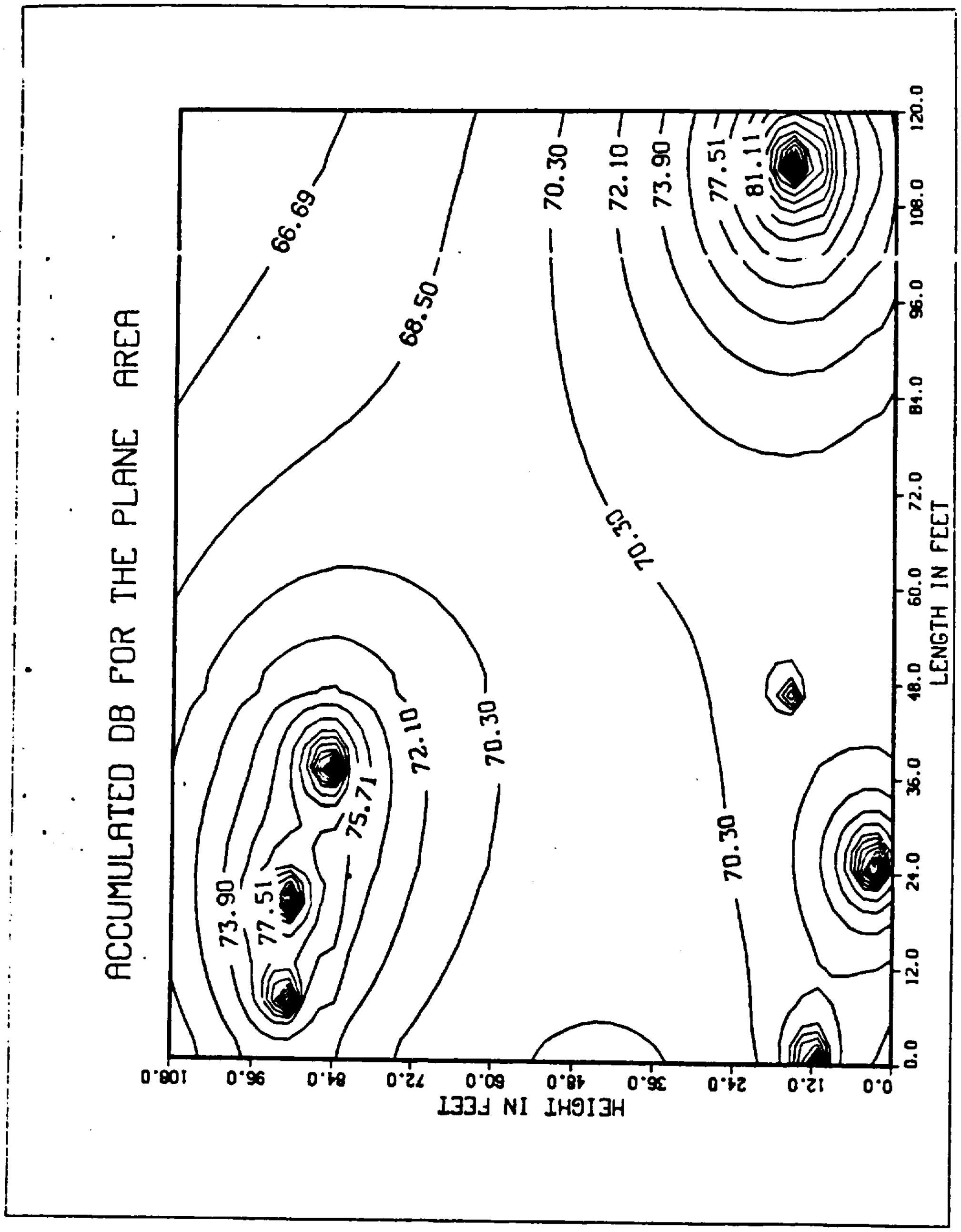


FIG. 12. Sound pressure contours for seven sources in a plane area.

effects. A program designed to handle solid vibrations of the structure would give general values needed to determine a final structure design as well as the necessary interfaces between the shell and machines.

Isolating Noisy Industrial Areas

No matter how well-designed machinery is, it still makes noise. It would be necessary to enclose the noisier equipment, such as presses, in small, tight acoustical compartments to prevent the noise from spreading to other areas. The enclosures of some machines would need to be transparent and would thus require special insulating glass. Currently, there are windows of high acoustical insulation that allow a totally quiet room to be placed right next to an extremely noisy one.

For some of the space colony conditions, it may be feasible and beneficial to choose alternative processes to extremely noisy ones. Printing could be replaced by quieter photo reproducers and so on. While it is impossible to reduce all noise to a very low level in mechanical equipment it is possible to get it well below 90 dB--to as low as between 70 and 80 dB which is a reasonable ambient level in the vicinities of the machine bays (Peterson).

As the final resort in a totally noisy atmosphere where a place to concentrate is necessary, an enclosed acoustical operating room may be required as an office or control room.

Knowledge of the source dBs and the computer calculations of the total area dB will aid in the planning of insulation around this noisier area to contain all machine noise within allotted spaces and away from occupants in and around the industrial zone.

Operators.

While most uninvolved bystanders would object greatly to even a reduced but continuous machine noise level of 75 to 80 dB, there are a few who have found it contributes to their sense of well-being.* Perhaps they associate it with productiveness and/or security; whatever the underlying association, their positive perception of machine noise makes them ideal operators. Because of their ease of adjustment to noisy machines, they would be less distracted and disturbed by these surroundings, and would be better able to concentrate on their work. Nonetheless, it is still imperative to reduce ambient noise intensities below the physical and psychological damage levels indicated on the dB chart of Figure 5.

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*Out of several dozen people queried, two regarded high-level mechanical noises with positive attitudes. One enjoyed the sounds of the machines in his tool and die shop. The other needed mechanical hums to sleep by, having been conditioned by the constant submarine noises in the navy.

V. MODELLING COMMUNITY NOISE

Community Noise Levels

Measuring Ambient Noise

Although industrial noise sources can be tracked fairly precisely to stationary or at least predictable dynamic points, it is a little more difficult to measure the continuously moving noise sources of a community. Also in the case of the space community habitat, there are a great many more unknown variables affecting community noise than there are in the more controllable industrial region. The free movements and actions of people, as well as more numerous small untrackable sources, make the difference. However, it is possible to measure ambient sound levels as well as the waning and waxing of sound during twenty-four-hour cycles.

There may or may not be air currents that produce yet other patterns of sound. As in the mechanical case, however, measurements of analogous situations and various use conditions can aid in determining levels and ranges for preparation of an appropriate design that will enhance or reduce sound as required.

A first set of approximate values can be derived from measurements taken in various areas of a community on Earth. Appendix A contains worksheets of dBs in eight frequency bands as measured for a number of normal living situations in the office, home, and a commercial shopping mall. Actual measurements of this type can be used as control standards against which quieting treatments can be measured by using dynamic computer models. The noise and quiet levels of general sound areas can be noted and used as wide spread source values to input into the sound dynamics program discussed previously. The calculations thus plotted would indicate necessary insulation placement and other quieting techniques. Discovering rough noise levels indicates where design can improve these levels and create more isolation of sound zones.

Insulating Against Noisiness

Acoustical Properties of Materials

To effectively dampen, reflect, attenuate, divide, and dissipate sounds within the torus, the construction materials need to be considered for their acoustical qualities in addition to other necessary qualities. Sound is reflected back into an area by surfaces that are molecularly hard and smooth, or that have a large change in the sound index at interfacing surfaces. A perfect sound reflector would be rated with a reflection coefficient of 1.0 and an absorption factor of 0.0. High reflection indexes indicate materials opaque to sound. Barriers for low frequency would also need to be larger than the energy wave impinging on them, or the wave will merely be deflected around them. This is a very important low-frequency factor.

Absorption and transmission by a material is also frequency-dependent. Materials can be excellent attentuators of one range of frequencies, while simultaneously allowing transmission or even enhancing other frequencies passing through. It is therefore important to know the acoustical characteristic coefficients for insulating as well as the frequency emissions of the sources to be insulated.

Insulators

NIOSH of the U.S. Government, Owens Corning, and other manufacturers of insulating materials provide tables of acoustical insulators from which it is possible to roughly categorize the various acoustical properties of building materials. The more promising categories could then be studied in greater detail.

Insulation in Space

The availability of materials with which to insulate will be a unique problem in a space enclosure. It is very doubtful that any petroleum-based products will be used because of the unavailability of that raw material in lunar and asteroid compositions and because of the excessive transportation cost from Earth. Silicon-based material, of which there is an ample supply, would be an appropriate substitute. In fact, because of the high silicon content of both lunar and asteroid sources, silicon-based material could be used for numerous structural elements. The fiberglass process is discussed at length by Ho and Sabon in the 1977 NASA Summer Study (Billingham). The acoustical coefficients of fiberglass building components can be found in Owens/Cornings, sound insulator catalog.

Sound Zoning

Once the range and acoustical properties of insulation and materials have been established to create sound zones, the question arises of how much space should be allocated to the varying levels of sound corresponding to the ranges of human activity in daily living. Three factors need to be considered here:

1. What is the appropriate sound level for various activities?
2. Are there any analogous zone designs here on Earth to aid in setting precedents?
3. What appropriation of space will be allocated to the variety of necessary functions in the pioneer community?

A detailed breakdown of community functions and their allocated space is given in the prototype colony of MIT (Smith, pp. 6.127, 6.132). The following range of sound-level zones in the space community have been approximated. They are based on the proto-colony allocations multiplied by a factor of ten for a larger torus structure and community; on approximate sound-level usage of an Earth community (USEPA

1972) and on the ratios of allocated living space, considering the lower industrial space separately (Johnson, p. 93). Ten to fifteen percent of allocated living space would be adequate for a very quiet zone; twenty percent for the extremely noisy zone; and sixty-five to seventy percent in the mid-range of variable noisiness.

Section Summary

All of the measurements mentioned above are primarily concerned with noise (sound levels and noise reduction), which is the minimal function of a sound system. The following sections deal with response to sound stimulus, annoyances, and positive aspects from a human point of view.

Other Factors of Community/Social Noise

Subjective Perception of Noise versus Sound

Guides of Noisiness

While sound-source levels, ambient levels, and the acoustical characteristics of surroundings can easily be measured with sound equipment, other factors of sound stimulation are harder to define and measure. Sound perception has been widely studied in comparative analyses of frequency bands and sound pressure levels, and scales of equal pitch and loudness (subjective perception measures) have been deducted from these. The statistics gathered indicate lower frequency bands must be of higher pressures to be perceived as equal in loudness to the higher frequency tones. Does this mean that higher dB low frequencies are tolerable or not as annoying as higher frequencies? Do verbal descriptions of a sound such as "loudness," "pitch," and "tone," or definition of a sound as "harmonic" or "discordant" correspond directly and constantly to sound annoyance or pleasantness? Not necessarily! It appears from random field studies and certain perceptual experiments that a great many subjective and situational factors are involved; an absolute verbal scale of annoyance is impossible to formulate.

A perceptual experiment by Kerrick, Nagel, and Bennett indicated that sound is perceived as being more or less pleasant, depending on association of the sounds with experience (as previously discussed in the section on methods).

Relative guidelines of annoyance have been derived from these experiments and broader field studies (See Methods, page 43). Some of the guides, such as speech interference level have ranges of measurable characteristics such as frequency and intensity (SIL). Broadband noises between about 250 Hz to 5,000 and Hz over 40 dB are considered speech interference noise, in that it becomes more difficult to communicate in a normal voice as the dB level goes up. This range can be used as a guide to determine a general sound level throughout the majority of the living zones.

Individual Ranges of Differences

In Kryter's Effects of Noise on Man (p. 588), a scale of auditory adaptation and responses to sound stimulus indicates the threshold of noisiness at about 40 dB, with continued arousal as the dB level rises. Glass and Singer and Kryter have shown that experimental groups of subjects as well as field groups of a wide range of people can adapt fairly easily to an environment with ambient noise levels of up to 70 to 80 dB and can tolerate such noise levels for varying lengths of time without ill effects. This is only a general rule under certain conditions (i.e., the people are involved in noisy work and/or have some control over the noise level and are not already under stress).

A number of authors have suggested (but not definitely stated) that the normal person can be exposed to an average of 70 dB over a 24-hour period without any long or short-term physiological or psychological damage. In actuality, however, most people would find a continual 70 dB noise stressful and, in becoming fatiqued, would make more errors (Glass and Singer, p. 156). For a person with exposure to high levels of sound during the day, very quiet periods at other times will ease and balance too much sound stimulus. Those who must work in a very low level of sound (e.g., librarians) may desire a jazzier atmosphere when away from work to prevent them from going stir-crazy.

This is for the range of the normative population; there are exceptions in both directions. High-noise tolerant people do not seem to mind overexposure to loud noise levels as much as do those who are low or even normal-noise tolerant. In fact, people who have a high tolerance to noise not only adapt readily, but even derive pleasure from noise stimulation. At the opposite end are those highly sensitive to even low-dB noise and ambient sound levels. These people prefer a greater degree of quiet over sound stimulation.

In large downtown areas of cities, where ambient noise levels are continuously high and where there are not any or very loose noise ordinances, citizens are constantly exposed to noxious noise levels beyond their control. It has been demonstrated that these people frequently suffer from such side effects as frustration, stress, a lowered ability to cope and concentrate, nervousness, and a general feeling of helplessness. These people may feel like they are at the mercy of their environment; passing annoyance may become permanent neurosis (Glass and Singer, pp. 162-163).

These subjective differences and functional needs for varying levels of sound are the reasons for sound zoning in any community. It is difficult to set precise sound standards for each situation, but determining a reasonable range is quite possible and necessary.

Functional Sound Differences

Besides the differences in individual ranges of sound stimulus, there are sounds associated with a variety of situations, with appropriateness determined according to the nature of the situation. People come to expect certain sounds or noises in a particular situation: quiet in libraries, hospitals, and churches; noisier during the day than at night; mechanical noises of industry; and noises of crowds at parties, carnivals, and spectator games. In a theater, audiences expect to hear a performance not the crowd, but do not object to the noise of crowds while shopping. There is continuous annoyance and disturbance in reaction to unnatural noises in the wilderness, and a delight at the sounds of spring. Everyone enjoys listening to music of his own choice, although the intrusion of someone else's music is an annoyance.

Zoning Design

Why Zoning?

Zoning provides for these wide ranges and fluctuations in the small space community, while minimizing excessive intrusions into the freedom of self-expression. The partitioning into zones will not preclude the need to insulate areas of exception within a zone, such as a noisy cafeteria in a hospital, or the quiet office in an industrial zone. Effective interfacing buffers will be needed to isolate both extremely noisy and very quiet areas. There could be a natural increase or decrease in sound levels through the middle regions between quiet and loud, or it could be a series of physical barriers. The zones can be functionally designated very much like similar zones in terrestrial communities.

Quiet Zones

Hospitals, libraries, classrooms for quiet subjects, churches, a mortician, a quiet wandering park, perhaps a shop or two, and a small, intimate restaurant would appropriately be placed in a quiet zone. There will be noisy times and places relative to the quiet. Emergency injuries, a lively cafeteria, noise of sanitation and maintenance functions, and lively discussions will disturb the relatively peaceful ambiance. Berms of earth and areas of thick foliage could be used to block incoming noise, and setting up low-noise areas to either side will permit a gradual transition. Quiet apartments, offices, retail shops, galleries, theaters, restaurants, and hotels would benefit from the quiet of the surroundings.

Noisier Zones

Progressing around the torus, the ambient noise levels would rise gradually to the far side of noisy activity. Stadiums, sports clubs, gyms, discos, night clubs, playgrounds, shopping malls, noisy places of business, amusement parks, and the like, would give this side a city-like atmosphere. Light industry, such as tailors and print shops, would also be found in this area. The agricultural areas would be divided evenly throughout the torus, and the noisier operations of food production would also be included in this area. The quieter aspects of farming and gardening would serve as green belts in the residential and urban areas.

Apartments for those whose preference runs toward city scenes could perhaps be built at the perimeters. Again, some type of absorbing barriers, such as walls and trees, would keep the height of the noise contained within a relatively limited area, and would also prevent an overwhelming buildup of noise within the area from reflective parameters such as large walls and glass. During both day and night, noise levels would be higher here than elsewhere in the community, because of the nature of the activities. Pockets of quiet within these areas would need dense insulation to isolate them from the surrounding noise.

Intermediate Zones

The intermediate areas would be characterized by a variety of levels and wider fluctuations of noise levels from day to night. Elementary schools could be located nearby but not adjacent to the noisier end because of the noisiness of playing kids. An alternative would be to locate the classrooms closer to the quiet end, while placing the noiser play areas closer to the noiser end. All areas would be relatively close in any given quadrant of the torus. City and administrative offices, communication centers, most small shops, (e.g., beauty, barber, clothes, dry goods, and specialty shops) restaurants, quieter recreation clubs, and most residential areas would be in these two largest zones to either side of the noisy and quiet zones. Further categories of zone subdivisions would hardly be useful in such a contained community.

Ordinances and Regulations

Besides the physical layout of zoning, how will sound and unwanted noise be kept within their acceptable limits?

The Need

In order to maintain fairly stable areas, it might be necessary to initiate community ordinances to regulate nonnormative noises. While it would be nice to think everyone easily and voluntarily would make only appropriate sounds in appropriate places at appropriate times, this seems unrealistic. Besides protecting the majority from noise harassment and annoyance, regulatory norms would also provide statutory limits to prevent peevish cranks from constantly complaining about sound/noise normal to an area. Additionally, regulations would help to define the zoning areas in concrete terms.

This process of providing sound ordinances would probably be left up to the discretion of the internal affairs government of the space community. How they are decided and used is a problem for the community citizens themselves to control and solve.

Analogous Community Action

The community may well use a guide such as "Model Noise Control Ordinance," put out by the EPA or create its own unique way for regulating sound offenders (USEPA 1972). A great deal of the ordinance aspect will be dependent on how free yet responsible the community feels its individual citizens to be. In such cases, how often court action will be necessary is dependent on far more variables than the mere sound disturbance itself.

An analogous Earth community situation may give a clue to how much noise control will be exhibited in the space community. While sound ordinances are seen as necessary and are used in large high-quality communities, they are seldom found or enforced regularly in very small grass-root communities or in the down-towns of urban centers. So how the colonists feel about the organization of their community would determine to what extent such regulations would even be wanted. These regulations may form gradually, with each individual precedented case as is done in Earth proceedings, or they might nicely be decided in advance, to slowly fall into disuse like so many obsolete laws and regulations here.

Although designing sound zones seems a necessary initial step, how to maintain and regulate them seems more of an ongoing community process.

Special Acoustical Considerations

Division of Public and Private Areas

To achieve full self-potential people need a balanced combination of community, intimacy, and solitude. Each of these has a varied menu of sounds that are associated with public and private activities (Mehrabian). These vaguely-defined spaces overlap a great deal with changes in function. While a public restroom may be public on the outside, it is best in our culture if it is very private on the inside. At yet other times, it becomes an informal meeting hall for the "group." A bustling public square at mid-day may be the intimate meeting place of a couple at midnight. Are commercial buildings public or private, or does a building contain a little of both?

Since there will be less fluctuation in the atmospheric conditions of space enclosures, at least for quite some time, it is reasonable to expect far more open places and perhaps portable enclosures for special events. In these situations, drifting sound could be quite a problem. There will still be the need for many permanent structures, mostly because of the highly-specialized nature of our culture.

Public space can be defined as any space which can be trespassed without special permission; semiprivate, as areas of selective permission to enter; and private, as those where exclusive invitation is needed from a particular owner. Retail shops, parks, public libraries, squares, public transportations, roads, and the like, are public. Semiprivate areas include theaters and stadiums where a ticket is required for entrance, churches, and some clubs and apartment complexes. The last category of private comprises homes, apartments, offices, yards, and other areas of private ownership.

These certainly are not mutually exclusive, but how they are treated and what conduct and noise is expected is very different in each case. In common areas certain levels of sound are expected and are generally beyond the control of an individual. There may be regulations in public areas, but these are enforceable by the administration and not the citizens using the area. In other words, acceptance of the noise level is intrinsic to being there. In the semiprivate category, selective decorum is expected as a function of the activity and if it is not kept by the individual attendee, he will hear about it from others using the facility. Private space noise levels, on the other hand, are very much regulated by the command of the owner or owners who can initiate action to remove offending parties. The first two categories of sound problems, public and semiprivate, are dealt with in the section on public community noise, while the last, private spaces, is covered later in its own section.

Design Problems of Common Areas

Common Unspoken Expectations

Because of the nature of the sound sources (namely, people and crowds of people), intensities seldom rise above the level of 65 to 75 db, which is quite tolerable for most common areas. Three problems would be: (1) peaks of noise by disruptive individuals, (2) mechanical noises in the vicinity that are loud enough to interfere with speech, and (3) containment of the noise within its allocated area.

The first and second problems need to be taken care of by the decorum of the activity and general ordinances regulating disruptive behavior. Mechanical noises are either an acccident or incidentally necessary to the maintenance of the area, and are generally understood by those subjected to it as being only a temporary annoyance. This is not true if the decorum is supposed to be generally quiet and there is loud unnecessary mechanical work going on in spite of a planned activity of the nature of a funeral or concert.

Decorum

Stomping, yelling, and shouting at a football game would not be considered disruptive behavior, and would in fact be expected. The same conduct might be viewed with disdain in a quiet park, and would be considered totally out of place in a library or at a funeral. If the conduct is loud and bizarre enough, a peace officer would consider it justifiable to remove the person from the premises. It is an interesting observation that, generally, merely quiet bizarre behavior is more tolerated by bystanders than is loud, bizarre behavior. This auditory aspect seems to be a triggering mechanism that signals the limit between tolerance and intolerance of public behavior in places where there is quiet decorum. In places that are customarily noisy (i.e., stadiums, busy streets, and carnivals), no one seems to care about loud and/or bizarre behavior unless personally violated by the offender.

Containment

The third problem of containment is a design problem concerning the use of sufficient acoustical barriers to keep sound within its boundaries and from emanating into quieter adjacent areas. One way to stop the noise at the boundary is to use enclosures that have internally reflective surfaces. The interior reverberations reach an extremely high crescendo, however, which may or may not be desirable. An audience absorbs some of the sound within an enclosure. Movable drapes surrounding the walls will also dampen some unwanted reflections, while pulling back the drapes will allow reflection of noise if desired. Outdoor areas with high levels of noise need to be surrounded by dense brush and trees; perhaps being sheltered in a slightly depressed area would attenuate some of the sound outward but not upward. Lining the inner shell over the noiser areas with a highly absorbent material would prevent the sound from bouncing back into the quiet area. Semi-enclosure could be used as a last resort.

Communication and Signals in Loud Public Places

It is known that only a very loud speaker can be heard over the din of a football crowd, and it is frequently the loudspeaker announcements that are the most annoying to those involved in adjacent activities. The unnecessarily loud broadcasting could probably be solved by directional speakers, rather than the broadcasting of omnidirectional speakers. Bullhorns would probably be unwelcome at rowdy activities unless everyone is participating, or unless the nonparticipating half is on the other side of the torus. Highly noise-absorbing boundaries around stadiums would completely solve the problem.

Semipublic Areas

Theaters, lobbies, churches, and other quiet buildings would need heavy outer insulation to keep noise out while allowing very small sounds to be heard within. Architectural acoustics is a discipline involving the use of a combination of absorption and reflection areas to create a very delicate balance of reverberation of sound waves in the interior design of halls, theaters, and the like. Different uses of a hall require different acoustics. Lecture halls require that the speaker be perceived as a point source; therefore, amplification is planned to be directional, with very dispersed reverberation that does not echo from single points other than the speaker. Plays, orchestras, operas, and filmed productions all have different acoustical needs.

Since around the turn of the century, a great deal has been done in quantifying large-hall acoustics, with the studies of Sabine, an acoustical professor at Harvard; additionally, a great deal has been learned about the physical dynamics of enclosed sound waves. Designing a theater with proper acoustics, however, is still considered an art with many unknowns. Physical modelling and computer programming aid in such designs today. As with other engineering structures, much trial and error is needed before an optimal design can be reached.

Because many of the halls in the space community will be required to do double duty and fulfill multiple purposes, designing temporary, portable acoustical settings will challenge the best of acoustical engineers and architects. It may be better to have the interior finished by the colonists, regardless of how imperfect the results may be. This would give them a very real and functional control of the development of their environment. Interesting views on both sides of this issue were discussed at length in the proceedings of the 1977 AIAA conference in San Francisco.

Home and Private Area Acoutics

The design process discussion of special public acoustical considerations completes the section on community factors of the design process. Private space factors are considered next.

Insulation of Walls and Interiors

The home will be one of the places requiring the use of extensive acoustical panelling to keep the outer noises from infiltrating the house and the inner noises private. Totally dead rooms are not anymore desirable than totally live rooms. Generally, cushions, drapes, carpeting, and furniture disperse the sound throughout the room well enough to eliminate the necessity for further interior wall insulation. Windows present a significant sound transmission problem as do open windows and doors. Carefully considered window placement may be helpful if the surroundings are completely developed first. It is also possible to have acoustically insulated windows where the noise level inside or outside warrants (Owens/Corning). An example of this technique in use is at NASA Ames' computer facility, where a very quiet-almost dead-room shares a wall with a very noisy computer and machine room, separated by only a window and an insulated door.

Because of the abundance in space bodies of aluminum and silicon raw material, windows and aluminum panels with fiberglass cores would be used extensively in the interior construction (Billingham and Gilbreath 1979). These would be excellent sound barriers, but must be properly treated to be transparent to sound on the surface (attenuating as well as opaquely reflecting sound).

Care should be taken so that the reflected sound from the walls and the vibrational coefficient of the panels will not create the tinny sound of a quonset hut. This could be very disturbing by association to the temporariness and cheapness of tin huts, as well as unnerving from the uncontrollable intrusion into daily life. The outer surfaces of the panels would need to be treated with pliable or thick material on the interior and some sort of conditioning to the outer wall surface, such as texturing or basrelief, with rigid welded construction in a cushioned foundation to prevent the effect of tinny vibrations.

Appliances

Currently, the acoustical aspects of home appliance designs leave much to be desired. Appliances are some of the loudest sources of everyday encounter. Generally, a person using an appliance for a short while is not in any way adversely affected by the noise. However, problems arise for people pursuing other activities in the vicinity in which the noise intrudes. The high-pitched whines of small motors such as hair dryers and model engines are especially disturbing. If the use is prolonged, the closeness of the noise may either physically damage the ears or produce nervousness and headaches for no apparent reason. The worst case of noise is when numerous appliances are used simultaneously for long periods of the day. Housecleaning and meal preparation are some activities in which the noise factor can become pronounced, producing a din that is difficult to communicate in. It could be physically damaging, and certainly is stressful and irritating. Even those working at the tasks may be unaware of the sources of their stress.

This may seem like a very innocuous area of noise to be concerned with. Yet most citizens of suburbia are exposed to a great deal of small-motor noises daily, either their own or a neighbor's motors. The priority for solving this problem seems rather low because of its seeming insignificance. The only way that appliance noise can be reduced is at the source, through a better-designed product; however, few manufacturers seem interested in producing quieter designs in products that are relatively small, short-lived, and that emit noise of no apparent consequence to the user.

Even in comparison of home appliances on the market today, it would appear that those of higher quality and designed to last longer usually are also quieter; so it can be done if necessary. Perhaps the cost of producing better-designed home machines that have longer lives and operate more quietly would be offset by the prohibitive cost of replacement in the space colony. This factor, combined with apparent noisiness in quieter ambient surroundings, might motivate production of quieter, longer-lasting, heavy-duty appliances for use in the space enclosure. Perhaps quieter production might result if care for the human occupants is of some importance to the project success.

Other Home Noises

Noise from appliances and tools is not the only type of home noise that can be solved by design. Noisy conduits for water and gas need to be insulated and isolated from vibratory structural bodies to prevent roaring, popping, and creaking. Faucet washers that prevent dripping, and muffler silencers on water pipes would prevent disturbances from these seemingly inconsequential sources that can become obnoxious on a quiet night when a person is trying to sleep. The ring of the telephone or doorbell could be designed to have a more pleasant pitch, such as a bell or chime rather than a rude "brrrring."

Carpeting exposed metallic surfaces would prevent the noisy clanging of walking on metal floors and stairs. Properly balanced electronic components can eliminate the annoying undercurrent of static interuptions during music and broadcasts. Eliminating or substantially reducing all mechanical noise will make the home more of a haven from noisier areas and will allow choices, at least in the home, of positive sound stimulation, rather than merely masking the nuisance of undesirable mechanical noises.

Correct insulation will prevent loud music, voices, and noise from parties from spilling out into neighboring areas. Dense shrubbery contain most of the noise from an outdoor party except loud music. In this situation the party-giver could either show discretion by keeping the music within tolerable limits, or by inviting surrounding neighbors, or at least informing them of the party so that they have the option of leaving the area. Such manners and consideration of citizens about intruding noises quite frequently eliminate the real bite of noise--its uncontrollable aspect.

Barking dogs are another extremely annoying source of noise. It would seem that an owner should take the responsibility to train his dog not to bark unnecessarily. One suggested method is to squirt the offending dog on the nose with water and give a sharp command every time he barks needlessly; this will take from two to three days to be effective (USEPA 1972).

While the home can be noisy or quiet by choice of the occupants, it does not have to be noisy from uncontrollable sources or impinge on the acoustical space of others in the vicinity. With a little planning and consideration, everyone within the residential areas can enjoy his own noise levels without upsetting others. After all, is not a home the place where one can best control his environment to his own desires. This kind of control will be extremely important to the confined colonist (Zuckerman).

Positive Aspects of Sound

Auditory Balance

The Natural Sounds of Silence

No one would be able to stand living in loud, constantly noisy surroundings. Nor could most humans long remain in absolute silence, as has been shown by experiments in sensory deprivation. A place devoid of sound would exaggerate the sounds of breathing and bodily movements. A person would begin to hallucinate after too long in such silence. Even the quietest spots in nature have a multiplicity of sounds, even if low in intensity--like the hum of an insect, rustling leaves, and the gentle lapping of water. A balance of auditory fields is needed for both sanity and perceptual stimulation. How can this dynamic play of sound and silence be achieved within such a diversity of preferences and tolerance levels, and in such a tiny enclosed space?

Stress from Noise

A great many more studies are needed to discern what sounds people are aware of and what they like and dislike. Most studies have been concerned with the physical and psychological damage from overexposure to noise.

Glass and Singer's extremely thorough and extensive studies of urban stress, which used noise as the stressing stimulus, have shown that although people can adapt to loud, harsh unpleasant sounds in their daily environment, it is not without a price. Long-term effects of stress have not yet been comprehensively determined.

Studies of noise annoyance have turned up even less definitive data. Yet there are common points of annoying noise that have permitted a set of guidelines to be drawn up. While these guides are primarily subjective and situational, noise annoyance can be controlled to a great degree with a well-designed plan for dividing, isolating, and dampening sound fields unwanted in adjacent areas. Once the noisy elements are eliminated, what sounds would be heard in the community of space?

Guidelines to Positive Sound

Signals are designated as the sounds we want to hear from our environment. And what sounds would these be? What would their characteristics be? Just as there is a list of guides for what constitutes noise, a set of the attributes of desirable sounds has been drawn up as a preliminary tool to be used in designing the acoustical interior. As mentioned earlier many more studies of people's sound preferences are necessary before actual conclusions can be drawn about what people hear and experience as good sound. The literature is thin in this area of how and what people want to hear.

Sound Awareness Poll

In an attempt to investigate positive-sound awareness rather quickly, a preliminary poll was given to twenty-five friends of the author to ascertain common features in sound awareness and perception. Many more questionnaires would have to be accumulated from a broader sample to more accurately determine a distribution of the common attributes of positive sounds. Guides of positive sound perception were compiled from personal experience and assumptions; interviews and discussions with sound producer Herb Taylor of Disney Productions, who uses sound to appeal to the populace, (Interview, August 1979) and Dr. David Nagel of NASA Life Sciences, who has experimented with sound associations (Interview, 1979); and the questionnaire study mentioned above (Appendix B). These are the guides for positive sound.

1. Sounds with pleasant associations are found enjoyable
2. Involved participants in producing a sound while working or playing not only do not mind it, but usually find it enjoyable and helpful to their activity
3. The human voice presents the widest scale of acceptability, ranging from intolerable (when coming from undesirable people; when it is harsh; when the situation or what is being said is disagreeable or unpleasant, as with fear, criticism, pain, etc.), to indifference (when surrounded by noisy, impersonal crowds), to the most desirable of sounds (e.g., intimate conversation, entertainment, and so on)

4. Music one chooses to make or to listen to is high on most people's list of desirable sound; conversely, someone else's intrusive music is frequently very unacceptable
5. Natural sounds of birds, trees, breeze, rain, ocean waves, streams, lakes, and waterfalls were usually found very pleasant by everyone polled. (Notice that the last five are water sounds. In the awareness poll, everyone at least once mentioned the sound of moving water, in one form or another, as being pleasant).

Designing Desirable Sound

The preceding five points have two features in common: sound is desirable when it is part of a pleasant situation or experience, and when it is of free choice and controllable. How can these points be used in developing space environments? Below are suggestions of ways to consider auditory stimuli in an acoustical design.

1. Plan wide ranges of sound zones to give people choices of being in a noisy or quiet place, with many levels in between
2. Isolate the zones and private spaces to prevent intrusion of one persons's sound into another's activities
3. Make the entire interior setting as perceptually pleasant as possible to produce a sense of well-being. The

simulated outside living areas should include natural sounds in natural settings to alleviate some of the artificial feeling of the interior

4. Allow the colonists to decide how to finish the details of the interior to give them control over their own environment and the cycles of the system, including day and night

5. The interplay of points three and four allows a dynamic balance between manmade environmental control and the spontaneous cycles of natural settings

What are some concrete examples of qualities of pleasant sounds that will distinguish them from annoying sounds? Desirable sound falls into one of two broad categories: (1) background sound; and (2) the focus signal.

Use of Sound

Sounds Set Moods

Whether background or signal, sounds in drama and music, as well as in reality, set particular moods for both participant and observer. The overall character of a sound space seems to elicit particular feelings and emotions from those within the space.

This effect is brought about directly through the sound qualities of the sounds themselves as they fall on the ear, and indirectly through previous associations. People can know approximately what is happening in a situation from nothing but its sounds. Considering sounds within their settings produces a total picture--a perceptual gestalt.

Soothing Background Sound

A sound that blends into a pleasant background "noise" has quite different characteristics than those sounds we hear as signals. Pleasant acoustical backgrounds can be described as low, undemanding, and unobtrusive. Low-pitched, randomly rhythmic, or soft broadband noises of rather low intensity could be used successfully in background situations. Distant drones--mechanical such as airplanes, natural such as insects, and human such as crowds--have been found pleasant and soothing if they are far enough away to fade in and out randomly, and are not threatening in character. Chimes and softly tinkling church bells are other examples of general randomness in sounds. The natural sounds of birds, rustling leaves, rain, and other water sounds are not only acoustically pleasant but combine in creating visually and tactilely pleasant scenes.

On some occasions soft music masks other less desirable noises as a perfume masks odors. The use of soft music to mask noise needs to be considered carefully, however, for if overused in areas where people are trying to focus on other activities, the same music may become as disturbing and fatiguing as too much quiet or noise.

Although the Muzak Company has done numerous studies that support the unilateral benefits of background music in numerous activity areas--including classrooms, factories, shops, and even hospitals--continuous humdrum music has also been named by some sensitive people as a cause of extreme nervousness and a desire to be elsewhere (Muzak). Soft human voices singing or even conversing gently a short distance away is a mellow sound, with associations to lullabies. Finally, as soothing background times of chosen quiet can be very refreshing. A person who is deep in concentrated thought usually finds quiet the most appropriate background.

Stimulating Auditory Background

Soothing backgrounds alone are not sufficient for a full range of stimulation. Because of the constant presence and extreme range of associations, sound has the ability not only to relax and sooth overstimulated persons, but also the power to stimulate and activate lethargic people. Therefore, stimulating backgrounds intended to arouse and excite are also necessary. To be stimulating, background noise need not be excessively loud, harsh, or piercing; in fact, many stimulating background noises are not. In the home, kitchen noises of meal preparation frequently are enough to arouse a sleepy person into activity. A purposeful bustling in the work vicinity has been cited as a way to raise production.

High-keyed music can turn an apathetic, boring job such as housework into a more acceptable activity. Many a low-load task can be alleviated with music--preferably self-chosen, such as personal tapes rather than music that is centrally controlled like that emanating from public address speakers (Mehrabian, p. 49).

Holiday crowds at sports events, rallies, shopping malls, downtown areas, circuses, and the like not only provide a means of drowning one's own thoughts and escape for awhile but also serve as a communal outlet for excited, pent-up energy. Unless there is an underlying spirit of fun and merriness, milling crowds have been known to degenerate into belligerent mobs. The difference here is usually one of intent--general discontent verses pleasure seeking. A place for noisy crowds would definitely need to be part of the plan, even in this small community, to allow for harmless release of such excitement and energy.

Natural and Recorded Sounds

Monumental natural sounds--oceans, thunder, enormous waterfalls that inspire awe and wonder--have a place in human life, yet such enormous noises within the limited space enclosure would be overpowering, to say nothing of their frequent association with frightening rather than assuring experience. The recording of these sounds may suffice for some but may only bother and upset others. To have the real sounds in their natural settings, however, will have to wait for greater expanses into space beyond small, isolated island colonies.

Recordings of these sounds in movies might be a possible substitute for the unobtainable natural noises. This experience would smack of make-believe at worst and be only a short artistic encounter at best, but could alleviate (or activate) the yearning to be in nature.

Using recordings of natural sounds or other pleasant, unobtainable sounds may or may not fill the gap of being in totally artificial surroundings. Some experts claim that the repetition of recorded sounds does not have the subtle randomness of natural occurrences and, if used as daily background, can easily produce boredom, annoyance, and fatigue. It is not likely that this type of background would be suitable for very many areas where people had to be all day long. It may, however, find a place in specialtiy areas of the nature of a Disney tableau, where people come and go for entertainment.

Herb Taylor of Disney Production has even suggested that this type of recorded sound could be combined and arranged in the manner of a musical piece to produce a new art form to entertain and amuse the community in any number of ways, including movies, concerts, and celebrations. He indicated that the entire Disney library of recorded sounds and soundtracks--compiled over 50 years of movie making--could be made available for this kind of application (Interview, Herb

Taylor, August 1979). An art of sound arranging would certainly add to the variety of sound and the charm within the interior limits of a space enclosure.

Sound Signals

What one chooses to hear is a sound signal--the focal stimulus and most elusive to define in concrete terms. This is because what one chooses to hear is a multivariable decision. One can go to a lecture and not hear it at all; conversely, a person can be surrounded by a crowd of voices and pick out a particular voice with great ease. Choice and, in some instances, forced attention are probably the prime factors in tuning in to a particular sound as a signal from surrounding auditory stimuli. Clarity of the chosen signal would enhance its communication properties. A person has to listen intently to a faint, ambiguous, or barely audible signal, and he is not likely to remain "tuned in" to it without a significant interior motive.

Signals, alarms, and warnings, unlike background sounds we choose to hear, are not always of the pleasant variety. Often they are warnings or symbols of hidden fears that leap out at a person and demand his attention. There is a purpose for this type of signal, but a steady diet of warnings and frightening sounds would produce emotional strain and unbalance.

Sirens, loud whistles, harsh grating, moans and groans, and the like, indicate something is wrong and needs attention or is to be avoided. When these types of warning signals become continuous background noise by being left unattended, as with faulty mechanical equipment or the pitful cries of unattended human suffering, they can become the sources of stress and/or irritation to those subjected to them. While some may claim to be unaware of distress signals in their surroundings, they still frequently have to pay the price of fatigue or worse. The best way to eliminate unnecessary, stressful warning and alarm noise is by taking the action to eliminate the cause of the sound through maintenance and care of the problem signalled.

Generally, when people become tired and bored with too much "background sound" and no signal to tune in on, they seek out a signal to alleviate their loneliness. Some of the time, radio, records, or TV help to fill an emptiness, but what most people yearn for is the human voice, then a phone call, visit, or other vocal contact would bring a person into touch with another's world. In extreme cases of sensory deprivation, a mind produces hallucinations to fill its emptiness (Corso, pp. 574-583). Sound as a perception keep us in touch with the outer world. Sound is a necessity for a healthy person, and sound in the colony consequently needs to be thought out very carefully. (Pirsig 1972).

Pleasure to Pain

This brings the paper to the last point of what makes a pleasant sound into an unpleasant sound. Any unvarying and unalleviated sound would become more than merely annoying; over a long period, with no other sound stimuli in the area, it would become torturous. Any type of artificial noise that is constantly present and unvarying would produce an overly stressful condition in an already stressful situation. This would eventually drive out the most tenacious of pioneering colonists, or make them too stressed to perform their tasks with verve and accuracy. It is better to take care to produce a rich, stimulating sound environment by considering and planning for it in the beginning than to have the entire project aborted because of a shortsighted economy that does not take into account the human element of the environment.

VI. DESIGN SCENARIO

The Sounds of a Space Colony

The Trip and Arrival

If is far beyond the scope of this paper to complete a design study and implement it in the grand space colony of the future. But you are left wondering what will be heard in a space colony? How will it sound? This imaginary trip is meant to answer that question.

Suppose you have been sent by a major acoustical research firm to get a story on how the sixty-year-old colony in space has handled its acoustical problems and auditory stimulation. You are hoping to learn how such a small community deals with its noise problems and to learn something to help solve problems of noise in communities on Earth.

The trip begins as you board the shuttle vehicle that will lift its passengers out of Earth's gravitational field and into orbit, where it will dock with a ship that was constructed entirely in space. There will be exchange of the entire passenger compartment between the two ships. Cargo and supplies have been jettisoned up from their space sources to the space shuttle station by railgun (Hawke 1980). Now your journey proceeds.

Space Shuttle

The shuttle vehicle lifts off with a mighty force, but you as a passenger hear only a faint rumbling from outside, accompanied by high gravitational forces and severe vibrations. Once beyond the inner atmosphere and well on your way, you turn your attention to the cabin and other passengers.

There are highly absorbent walls, furnishings, and sound insulation between structural and inside surfaces. Thus, the cabin is now exceptionally quiet, and only a slight steady vibration is felt. Yet a person speaking nearby can be heard clearly. Voices in conversation around you give a feeling of security and well-being. A chime announces dinner, and the light clinking of tableware is soon to be heard. Because of the high absorption of the surroundings, the low-intensity direct sound is perceived as distant and localized yet clear and distinct, as opposed to dispersed sound throughout the compartment. This allows easy conversation without interference from other sounds and a comfortable awareness of other human beings.

Outer-Space Transfer

The transfer is made without incident, and you watch the jettisoned cargo being brought into the hold of the outer space ship. There is only minimal vibration and no engine noise at all as the ship lifts off for the final leg of the journey. Space has silenced all outside sound. Weightlessness is now quite noticeable, and you are glad for the preflight orientation.

Docking Terminal and Crowd Noises

Once docked and welcomed to the colony within the confines of the torus hub, you notice a pleasant gentle bustling--like people scurrying about at work, but without the oppressive, harsh qualities usually found in a transportation terminal. Then you notice the carpeted surroundings that give the impression of a high-class hotel. You wonder if all the habitat is this muted in its sound surroundings.

A courteous young guide shows you to a room in a nearby building that has been set aside for visitors. She explains that the docking area is within the hub and to take care because of the area's low gravity. You reply that you have been prepared for the low-gravitational field, but were not expecting the subdued nature of the colony.

Your room is also very quiet, but muffled sounds of people moving about and talking can be heard from outside. You sigh; not all sound has been blocked out. The window of the hotel room looks out over a huge open area. You hear the chirp of a bird; surprised, you peek out. You are astounded! You had expected only the throbbing of life-support equipment to be audible in this manmade enclosure, and you hear quiet voices and a bird!

The huge, airy aviary is filled with diffused and filtered sunlight from its window hundreds of feet above. The setting is a jungle of lush tropical growth and even water-fountains which are now audible as you focus on them. You open the window so there is only a screen between you and this wonderfully Earth-like arena. You marvel as you listen to the birds and water, and the gentle rustle of leaves as a breeze blows through them--this is indeed different than the noise of a factory or downtown apartment that you somehow had expected. You think this is wonderful, but are there no other sounds? Are they all so muffled?

You meet with your host and hostess in a quiet, intimate dining/bar that is similar to the type you would find in any good Earth hotel. Your friends describe this zone as relatively quiet--subdued and stately--and mention that the aviary is only one of many. This aviary is a multipurpose arrangement to study the effect of low gravity on birds and their flight; other plants and animals and their living habits are also investigated here. It is also homey and decorative. Many public buildings open onto the area and share the tropical atmosphere. There is even an open theater and restaurant strategically placed for enjoyment of the breeze, low gravity, and lush tropical setting. You ask if the entire space colony is this quiet and hushed. Their laughter sounds good, ringing gently in the hushed surroundings.

"No," is the answer. "We come here to meet guests who need a quiet place to recover from the rather jarring experience of being hurled through space in a container! We also come here for the pleasant feeling of stately elegance found in metropolitan hotels. Tomorrow we will show you all the areas of the outer torus and you will hear many, many varieties of sounds; surely you will find sounds most appropriate and satisfying."

They return to their home while you rest and become acquainted with this entirely new place. At last you feel that it is time to turn in. The falling of evening, as the night curtains are pulled over the sun windows, adds to the charm of this little community. You feel rather like you are at a sophisticated rustic inn or in a quiet city, as you hear the chirp of crickets outside your window; it certainly does not feel like you are within a structure in space that you ever thought of!

Into the Torus

A Mall

In the morning, you awaken to the songs of birds and, after having breakfast in a cheery coffee shop, you take a silent elevator to the outer ring. The elevator opens onto a busy shopping mall, where your friends have agreed to meet you. The mall immediately reminds you of the mall in your city. Milling crowds cavort about the mall, creating the dispersed cluttered, droning noise that melts pleasantly in and out of awareness.

"This is indeed pleasant," you mention to your friends. A splashing fountain adds a tinkle and swish, offsetting the drone of the crowd. Loud rock and roll blares from one shop, and you back away.

"You still have rock-and-rollers!" you exclaim.

"Oh yes."--But we are not subjected to such noise unless we choose to be. Here the noise is being used as an advertisement and come-on. We do not all approve, but there are enough people who enjoy it that we cannot object too strenuously, especially since it is very localized and directional. You'll notice it cannot be heard on either side of the shop, only directly in front. It adds a little spice, as long as we are not subjected to it for long. It does jounce pedestrians into awareness!

"There is such good insulation against this kind of noise that a person could be right next door and not hear it. To insure privacy even the insulation of our homes is practically soundproof. The acoustical characteristics of the modular construction materials--namely, fiberglass and aluminum from the abundant silicon and aluminum found in asteroids--were considered and used to the fullest. We can play our stereo as loudly as we care to and no one will hear it outside our walls, unless we open the door or windows."

"There is a great sense of community and consideration for one's neighbor--there has to be in these close quarters!

But that does not mean we have to be in a dead, silent environment. Our variety here is the spice of our life, and there is lots of variety, especially in auditory stimulus, being created as we live our lives here."

Your host's long explanation ends as you enter an area that is flashy and very loud.

"Our carnival and stadium zone!" your companion shouts above the din. "We do not have to stay here if you would prefer not to," he adds thoughtfully.

The happy noise is welcome after the quiet, and you feel rejuvenated enough to want to join in. Soon the three of you are playing penny-ante games and watching a sideshow. An hour is enough of the din, and you again ask to be shown to a quieter area.

Residential Areas

Rounding the torus into a relatively quieter residential area, you relax from your excited state. Here there are activities of gardening, children playing, a small ensemble practicing a melody and a few small shops.

The three of you have lunch at a little cafe, which has a bright, snappy atmosphere enhanced by a low level of conversation. The atmosphere is somewhere between the subdued dining room of last night and the bouncy coffee shop of this morning. There is no attempt to hide the inconsequential sounds from the kitchen, the waiters, and other diners.

Although the ambient sound is not very loud, it is distinctly there. You applaud the forethought of the structure and community designers in the wide variety they have planned into such a small enclosure.

Inside a Country Home

You will be spending tonight with your host and hostess and will experience the rest of the community tomorrow. They are anxious to show you their home with their personal treasures and collections. You relax and visit while a tape of preselected mellow music plays in the background. Later in the evening there is a TV concert performance live from the Kennedy Center for the Performing Arts.

After a light dinner, you are shown to a very quiet bedroom--pin-drop quiet and almost eerie. It resembles a country bedroom, with a green hillside and small fruit trees outside your window. A small stream, whose gurgle and babble can barely be heard through the window, winds its way down the gentle slope. You throw open the window for a better view and listen. The slowly closing nightshades on the sun windows above give the illusion of dusk falling over the scene. The country sound is enhanced by the clear sound of the stream, and now you can hear the distant hum of bees settling for the night, along with the sound of animal calls.

Your hostess stops by to see if everything is all right with you, and you ask her if you have really heard bees or just a hum that sounds like bees.

"Honey bees," she tells you. "Very useful as well as aesthetic. We use primarily use honey for sweetener and the bees keep our plants naturally pollinated. They seem to have adjusted quite well. Actually they are especially bred to not have stingers, which are really not needed here--the honey bees have no predators except us, and we are careful to leave as much honey as we take. We share with the bees and they share with us. They truly add a great deal to make this place Earth-like."

In the morning, you awaken to rousing march music that you preselected. Already there are the noises of a family on the go. A hum you recognize as an electric shaver can be heard from the next room. The shaver is quieter and has a slightly different, lower tone than the shavers you are accustomed to.

"Where would I get one of those on Earth?" you ask.

Your host shrugs. "They cost more than most people on Earth are willing to pay, but they last longer. They are a necessity here. All of our appliances are quieter and lower-pitched by design. They last forever, and the acoustics are a by-product. We cannot afford to buy another model from Earth every two or three years, and we would not be permitted to transport more than one set of anything like this, anyway. That is the crux of the demand for the new, quiet, everlasting designs you find in all our home appliances. Our dishwasher, stove, garbage grinder, mixmaster, refrigerator, hair dryers, and even toasters--all of these have to be permanent. Also some appliances such as mowers, garden tools, washers, and dryers are shared in common and therefore get lots of use.

By using tighter tolerances and better quality materials--many of which we mine and send back to Earth in processed form--better equipment can be produced. Because we produce the high-quality industrial materials, we can demand better designs in return. Better design and consideration for permanence just naturally produce quieter moving parts. When your economy decides that it is better to build for permanence instead of obsolescence, Earth civilizations will also get better electrical aids, and the price will probably go down if quality can be mass produced. It is mostly economics, but it can be done."

He finishes his lecture, and you take a deep breath. "Wow, that is a lesson for us to learn!" The whole family laughs.

Good sounds--you have heard nothing but good sounds since you have been here.

A Peaceful Place

After breakfast, a short stroll brings you to the quiet zone with its spacious grounds and almost classical buildings. You feel very peaceful and at ease today. Here are the hospital, library, college classrooms, a few research laboratories, and an expansive ground interwoven among the terraced structures. Again a very placid stream of water quietly glides through the grounds, headed out through a small stand of trees that effectively separates the quiet area from other zones. Here stand a few giant redwoods; or at least the babies of giant redwoods on their way up. They somehow seem out of place yet ideally suited to this strange space island.

"Ah, even the appreciation of the silence of nature in these cramped quarters!" you observe.

A Farm

After a picnic lunch, your group wanders through the agricultural areas, where animal calls make it sound a bit barn-yardish. Even here the ubiquitous water forms a neat gushing channel, as it provides water for the food plants and animals and hosts several kinds of fish for the table. It is rather noisy in the farm area, with the sounds of high-pressured water being recycled and channeled, the animals, and agricultural machines. Even though the sounds are less pronounced than on farms you have visited on Earth, they are nonetheless very noisy by reason of their functions of harvesting, cutting, and processing.

"Is this the noisiest area?" you yell over the work.

"No! The carnival we were at yesterday was actually noiser in decibels. You just notice this more because you are not part of the noisy scene," your friend returns.

"There are a whole range of noise tolerances in this community." He continues, "We are tested for that before we came. I would never make it in here but not only do these workers not seem to mind if, they thrive on it. The decibels are well below the pain and damage level. The workers are rotated frequently and have ear protection if needed for special situations."

Industry

Better Machinery

"There is one last area we would like to show you for noise impact--the machine and equipment bay where all the life-support systems, manufacturing, and production is carried out."

"Where is that?" you inquire, expecting some remote area far outside the torus.

"There are two basic industrial areas in this torus: a small one, located in the hub below the docking area, that services the space vehicles and turns the structure once a minute, and the main one, which is right below us in certain sections of the outer hull of the torus ring itself."

"Below us? There is no hum or vibration, or anything indicating a noisy factory!" you retort in surprise.

"Again, our machines have to be the epitome of good design. We cannot afford even a single breakdown and thereby jeopardize the entire colony. Because they are better designed they have a lower level of sound and vibration to begin with."

The two of you descend a flight of metal stairs that do not clang or ring because of their cushioned surfaces.

"There is also a balanced design of acoustical insulation that breaks and dampens any noise before it gets too far."

Preplanning

"Careful preplanning helped to eliminate matching of materials of the same critical frequency and so reduced--no, eliminated--vibrations. A wobble or fast vibration could upset the spin rhythm of the hull. It had to be well-planned in advance. We have had very little trouble with these machines; remarkable for man-made mechanical things, but it can be done when necessary. They are also constantly maintained and backups are available in case of an emergency failure."

You think the noise deafening now and you are handed ear-protection muffs. Once these are in place, you are surprised that you can still hear voices so well.

"These block out high frequencies and dampen lower frequencies so that actually we hear nearby sounds better. Muffs make it easier to communicate in this area, as well as protect hearing. It is rather low for an industrial area--only 75 to 85 decibels at various places in here. For short periods of exposure, this is considered to be quite good."

A Silent Control Room

A short distance away a number of people are grouped in a glass room, which you and your host now move toward. Except for the operators talking, there is total silence once through the double glass doors. Of course quiet rooms are nothing new and have been around long before the space colony had even been thought of. This group and its discussion of the work is so much like on Earth you could almost forget where you are.

"We have not found a way to completely eliminate the noise of machines in an atmosphere, so we still need quiet rooms. Everyone tries to make all our areas as humanly habitable as possible."

You note that the various pieces of equipment are very colorful as well as quiet, and when the group finishes their business, music can be heard from the intercom.

"We have our own tapes and play what we all agree on when we work up here. That way no one becomes upset at the choice of music or bored by too much quiet when alone," your companion explains to you over a cup of coffee.

"We go into the shop only when absolutely necessary and with ear protection."

The two of you leave the industrial area through an exit elevator in the control room and are soon strolling toward your host's home up a walkway that seems quiet, compared to the machines you have left.

Back in the Living Areas

An Active Park

Kids play about freely in this area, and parents lounge, work, or join in group games. Two youngsters, whom you recognize as your host's children, rush up as you approach. Talking and sightseeing, the four of you continue happily along. A small group of bicyclists pass you on their way around the torus for exercise. There are also joggers and swimmers, and a few boats on a small, placid lake.

You stop at a set of shops that house a bakery, butcher, and green grocery. The produce and meat, while somewhat limited, are very little different from what you are used to eating on Earth. To the rear is a larger supermarket, and the noise of shopping falls pleasantly on you ears. Your friends shop for dinner before continuing on.

Dinner on the patio arrives with the soft sounds of evening, as the sunshades once again fall over the sun-windows high above. A few birds flock and fly free over the space scape.

An Evening of Entertainment

That evening you are invited to a theater piece by a famous composer you have enjoyed before. You learn that this is actually part of a celebration of the colony's sixtieth anniversary and begins a week of community celebration.

Those who miss the special composition tonight will have two other performances to choose from, in addition to a TV production which also will be seen on Earth.

The entertainment is superb and beautifully clear in a theater that befits the performance. Afterward your host and hostess mention that this is one of two theaters. Many portable sections can be jockeyed into position as needed for an individual performance and its particular acoustical needs. By converting the sports arena an open-air amphitheater can also be created. There is some event, activity, or performance happening almost any hour of the day or night.

At a small cocktail party at a neighbor's house, you are introduced as a researcher from Earth. The small group gathering sets a happy holiday mood. As you talk with various people at the party, you appreciate the noise of laughter and human voices again. You decide that the human voice is, after all, the most important sound to us. This community is really involved in playing, acting, sports, and music as well as hard work.

"Part of the multiversatility!" you laugh. Your friends nod in agreement.

"We have been here about fifteen years, since shortly after we got married and decided that this was where we wanted to raise our family. We have not regretted our decision yet. And I think you will find our family not merely well-adjusted but also lots of fun, with a true spirit of work, play, and enjoyment in this small island of a community. We hope that Earth can learn from our lifestyle--we can live in peace without boredom!"

And so ends your last evening in this lovely little space island.

"Not a bad place to live at all," you muse as you prepare to leave. "Well worth all the expense and cost it took to launch sixty years ago."

As you board the return flight after a night of peaceful sleep in a very quiet setting, you vow to return again to check the colony's progress, and to promote more of the colonist's ideas and ways on Earth. You feel you have learned a lot from your short stay, particularly about how it sounds in a tiny, enclosed but well-planned community in the void of outer space.

This community represents a tiny pebble of humanity in an effort to connect with the greater transcendental system the universe, as it has been defined by the 9th level of Boulding's systems ladder.

VII. SUMMARY AND RECOMMENDATIONS

Conclusions

The Problem

The acoustical design is begun by defining the system: its physical properties and parameters; its functions and processes. The physical limits can be simply described as what is heard within the space enclosure.

The functioning requires a more detailed definition of the acoustical system and the design plan. The following primary categories can be broken into levels by the secondary functions of the system. A well-designed acoustical system:

1. Provides an overall safe level of ambient sound
2. Provides a variety of levels of pleasant background sound
3. Allows a clear signal/noise separation

Process

The definition of the process includes and limits the means to bring about the implementation of the functional design. The process includes developing the criteria and priorities; measuring the sound levels of the sources (separately where possible and in combinations for given areas) and measuring the ambient levels when sources are difficult to define and locate; analogous study of existing systems and measures; studies of user preferences; Examples of possible scenarios incorporating the sampled preferences, sound source placement plans, and noise controlling techniques, measure these attributes in alternative models against the criteria formed during the earlier stages.

In the actual implementation of the acoustical system design within a space colony, this careful holistic planning and forethought to the needs of the community citizens as opposed to piecemeal plans and fragmented construction will bring about as optimal of a balance of controlled and natural, sound fields in the colony environment as is humanly possible.

Care in the Solution Design

The key here is care--care about the human population of the colony in terms of their humanity, rather than concern about merely short-termed efficiency and economy factors. A few hours or dollars saved immediately, could possibly destroy a generation of progress. It is wiser to find the needs of a human society in terms of their entire environment, generate alternatives along the lines of those needs, and <u>then</u> measure the dollar costs of the best alternatives. This paper has emphasized the human factors and the various ways to measure them in consideration of an optimal acoustical design, maintaining that the human factors criteria need to be met before making a cost comparison of viable alternatives. In the case of the space community, what may seem to us like luxurious frills may well be the necessities of existence in such a confined isolation. It would be a sad hind-sight and a waste of money to build a colony no one could long live in productively. Adaptation of the human to adverse conditions may be possible, but at the higher price of destroyed sanity. Such adaptation to adversity is not desirable for either the individual or society (Glass and Singer).

Human Criteria for Human Systems

It is impossible to design a system used by human beings without using criteria based on needs of humans from real subjective data of the users. Measuring against abstract objective standards alone results in a flat, inflexible, often inhuman system and reduces the full spectrum of use that the system was developed for. How noisy, quiet, boring, stressful, varied, and changing a human environment should be, can never be fully discovered by ascribing to one person's ideal nor standards decided by experts nor by singular narrow experiments under limited conditions. The human individual and his community as a dynamic system in both scope and time can only be discovered--and optimal standards derived--from actual field studies that examine the direct experiences of the many aware persons within the system, using the system, and experiencing the system in their own lives.

Methods are needed that enable people to become more aware of their various perceptions and of their reactions and responses to these perceptions. Compiling data from studies of real people over time will yield a far truer reflection of human preferences than merely statistical studies or experiments that are limited by time. Some needs and wants will continuously repeat themselves, creating overall patterns throughout humanity; others will be unique, isolated to individuals or small groups, yet be quite as necessary to their existence as the overall needs. It is at the junction of broad and narrow needs that a system such as the acoustics of a community should allow for flexibility and consider as much variety as necessary and possible in the original plan, including dynamic as well as structural variety.

With human considerations, systems designed for human use become more humanly usable, fulfilling, and productive. Without human criteria, no amount of standards met (based on other "objective measurement criteria," such as measurement of size, monetary costs, or the mean average of a whole population distribution) will produce a truly human environmental system that incorporates the necessarily wide dynamic range of perceptual variety needed by healthy individuals.

Organizing the Process

In order to conceive and complete a design for a space colony project of this immensity and complexity, it would take many teams involved in an intricate organizational system with a multiplicity of disciplines using the entire gamut of system methods and tools. The physical and natural sciences as well as the soft sciences and the arts and humanities would be called into play to make this design happen successfully.

The entire interior environment of a space colony would be dependent on this manmade design to bring about the desirable level of human-livable and secure surroundings in the hostile void of outer space. As a subset system of the space settlement, the acoustical design problem demonstrates the intricate relationship of the functional factors of a truly complex cybernetic system.

The ultimate criterion of how well this system has been designed is the contribution of the interior acoustics of the settlement to the success of the human space expansion endeavor. If the sounds are more than just humanly tolerable and are truly part of an enticing and enriching interior, then, indeed, whole communities of people may be quite willing to spend the rest of their natural days in the development of space and space products. On the other hand, a carelessly-designed sound system that sustains high levels of stress and annoyance in the face of continuous danger and possible hardship of the confined, isolated community spells the difference between success and total disaster of the community. A catastrophe initiated by the mistakes of overstressed personnel, or even a mass exodus of the community unwilling to tolerate the noise pollution would be the end of space exploration for a long time.

Even merely tolerable noise levels that isolated and confined citizens perceive as disturbing and uncontrollable would cause an unnecessary return of the inhabitants, possibly some of the most sensitive and creative of the pioneering group.

Recommendations

Studies of human response to ranges of sound stimuli and knowledge of the desirable sounds are much needed to plan the most advantageous sound environment for an enclosed community. If the possibility of an unusual atmosphere with less nitrogen or with a helium substitution are considered alternatives to our normal atmosphere, differences in auditory perception and their effect on people would need to be studied. Finally, because of the complexity of the design considerations of an acoustical system, it would be justified in using teams from many disciplines to do those studies that have not yet been done and to carry on the integration of the various design aspects. It certainly is too great a task for one person, or even a single team; it is even too great a task to be completed in one generation. Every such monumental effort is built upon the efforts, trials, and errors of previous generations.

All in all, while the scope of such a project appears monumental, it is a quite feasible enterprise as man inches his way into the broader reaches of the universe. It is well for the designers to keep in mind that it would be impossible to design an environment for huge populations that would completely satisfy everyone in the population. It may not even be beneficial to the advancement of humanity to try and design such a perfect utopia of no discontent. This is because it is usually discontent that pushes humans onward to find what is beyond us now and to bring it into our knowledge and awareness, if not under our control. Planners, designers, and users of any such dynamic system need to be aware that undetermined as well as programmed changes happen, and only fast-witted ingenuity rather than slow ponderous thought can handle such situations in reality.

Nonetheless, designing a livable and kind environment in the hostilities of space, where there will be enough duress and stress for all, seems to be an important, admirable, and very necessary goal to insure the success of our push into space.

APPENDIX A

1. Basic computer program to calculate collective source dB for a given area
2. Flowchart of expanded program enhancements
3. Sample contour plots of sound pressures of an area
4. Tables of sample field measurements of sound pressure dB's for real areas and sources to be used as program input data

```
NASA/AMES CF 7600. SCOPE 2.1.3 205-25( 06/04/80 ) 10/29/80      80303

 SYS. DEVICES 817/4P/   844/SAC/1;1/   FLS=0200K FLL=1750K MXS=0160K MXL=1200K MXB=1267B

HH.MM.SS CPU SECOND ORIGIN
          12.07.24.:::. ::      AMES  SCOPE 3.4.4  414-9  - 03/04/79
12.06.46 00000.011 ARC.     -JOANNE.T20.PN.
12.06.46 00000.011 JOB.     -ACCOUNT.FARDAS.T3253Y.
12.06.49 00000.081 JOB.     -COMMENT.   CALCUALTES THE DB PRESSURE OVER AGIVEN PLANE.
12.06.49 00000.082 JOB.     -DISPOSE.TAPE15.ST=ARSIRM.*PR=CSB.
12.06.49 00000.082 JOB.     -DISPOSE.OUTPUT.ST=ARSIRM.*PR.
12.06.49 00000.083 LOD.     -FTN.R=1.OPT=1.PL=6000.
12.08.54 00000.468 USR.           .379 CP SECONDS COMPILATION TIME
12.08.54 00000.468 JOB.     -EXIT U.
12.08.54 00000.469 LOD.     -COPYSP.INPUT.OUTPUT.
12.08.55 00000.478 USR.        UT300 - COPYSP COMPLETE
12.08.55 00000.479 LOD.     -REWIND.INPUT.
12.08.55 00000.482 LOD.     -SKIPF.INPUT.1.
12.08.55 00000.518 USR.        UT160 - SKIP COMPLETE
12.08.56 00000.523 JOB.     -ATTACH.DISSPLA.ID=AMESLIB.
12.08.56 00000.523 ARC.        PF053 - LFN  IS   DISSPLA
12.08.56 00000.527 ARC.        PF254 - CYCLE   82 ATTACHED FROM SN=SYSTEM
12.08.56 00000.527 JOB.     -ATTACH.ZETA.VERSAZETALIB.ID=FAPLIB.
12.08.56 00000.531 ARC.        PF234 - CYCLE    3 ATTACHED FROM SN=SYSTEM
12.08.56 00000.531 JOB.     -LIBRARY.DISSPLA.ZETA.*.
12.08.56 00000.532 LOD.     -LGO.
12.09.06 00004.675 ARC.        LD610 - FLS REQUIRED TO LOAD - 0023006 OU.COC
12.09.45 00004.678 ARC.        LD603 - EXECUTION INITIATED OS.EXP
12.09.45 00004.678 USR.       FORTRAN LIBRARY 460-3          05/01/79
12.09.45 00004.681 USR.      $$$  PLOT ON FILE = TAPE15
12.11.24 00010.716 USR.           STOP
12.11.24 00010.716 USR.            6.037 CP SECONDS EXECUTION TIME
12.11.24 00010.723 ARC.        RM770 - MAXIMUM ACTIVE FILES                      4
12.11.24 00010.724 ARC.        RM771 - OPEN/CLOSE CALLS                         42
12.11.24 00010.724 ARC.        RM772 - DATA TRANSFER CALLS                   4,037
12.11.24 00010.724 ARC.        RM773 - CONTROL/POSITIONING CALLS                27
12.11.24 00010.724 ARC.        RM774 - BM DATA TRANSFER CALLS                2,893
12.11.24 00010.724 ARC.        RM775 - BM CONTROL/POSITIONING CALLS            139
12.11.24 00010.724 ARC.        RM776 - QUEUE MANAGER CALLS                     573
12.11.24 00010.724 ARC.        RM777 - RECALL CALLS                            544
12.11.24 00010.725 ARC.        SCM                  280.230  KWS
12.11.24 00010.725 ARC.        I/O                    0.639  MW
12.11.24 00010.725 ARC.        RMS                    0.740  MWS
12.11.24 00010.725 ARC.        USER                   5.651  SEC
12.11.24 00010.726 ARC.        JOB                   10.728  SEC
12.11.24 00010.726 ARC.        DIO                1 392.479  KW
12.11.24 00010.726 ARC.        MAXS=0113K MAXL=0000K MAXE=0163B
12.11.24 00010.726 ARC.             .24 PRIORITY N ACCOUNTING UNITS =      $3.48
12.11.24 00010.726 ARC.        SC050 - 000530 SC/LC SWAPS
```

```
C-----------------------------------------------------------------------
C
      PROGRAM SOUND(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,
     +        TAPE15,QQLBSC)
C
C
C-----------------------------------------------------------------------
C     PURPOSE
C      THE SOUND PROGRAM CALCULATES THE DB CONTOURS FOR A PLANE AREA
C      INPUTTING THE SOURCE LOCATIONS IN FEET AND PRESSURES IN DB.
C
C      IT PLOTS THESE CONTOURS IN DB OVER THE AREA IN FEET SQ.
C      USING THE CDC 7600 DISSPLA PACKAGE.
C
C-----------------------------------------------------------------------
C     ENVIRONMENT: CDC 7600
C
C     PARAMERTERS
C     VARIABLE       TYPE       I/O/S      DIM       DESCRIPTION
C
C      ADSO           R          S                  INTERMEDIATE RAW PRESSURE
C      ASPL           R          O         50,50    ACCUMULATED SOUND P. LEVEL
C      DX             R          S                   X INTERVAL
C      DY             R          S                   Y INTERVAL
C      FOURPI         R          S                  10 * LOG(4*PI)
C      IT             C          I         20        DATA TITLE
C      NPTS           I          S                   NPS - 1
C      NPS            I          I                   # OF POINTS PER VECTOR
C      NSO            I          I                   # OF SOUND SOURCES
C      R              R          S         50,50     RADIAL DISTANCES FROM SOURCES
C      RP             R          S         20        RAW PRESSURES
C      RS             R                              RADIAL SQUARED
C      SP             R          I         20        DB VALUE SOUND SOURCES
C      SPL            R          S                   INTERMEDIATE SOUND PRESSURE
C      SS             R          O         50,50     SOUND PRESSURE PER SOURCE
C      SX             R          I         20        SOUND SOURCE X COORDINATE
C      SY             R          I         20         "      "    Y    "
C      X              R          I         20         X POINTS LOCATION
C      Y              R          I         20         Y POINTS LOCATION
C      XLEN           R          I                    X   LENGTH
C      YHI            R          I                    Y   HEIGHTH
C
C
C     COMMONS:
C        /          /  INTERFACES WITH DISPLA LIBRARY--BLANK WORK ARRAY
C
C     EXTERNAL REFERENCES:   KONPLOT USING DISPLA
C
C     AUTHOR:    JOANNE HAWKE          INFORMATICS INC.
C
C
C-----------------------------------------------------------------------
      COMMON /     / WORK(5000)
      DIMENSION X(50),Y(50),ASPL(50,50),SX(20),SY(20),SP(20),
     1 PLOTIT(40),IT(20),R(50,50),SS(50,50),RP(20),LASTIT(4)
```

```
C
      DATA PLOTIT/'SOUND SOUR','CE  ONE   ','SOUND SOUR','CE  TWO   ',
     1  'SOUND SOUR','CE THREE  ','SOUND SOUR','CE  FOUR  ',
     2 'SOUND SOUR','CE  FIVE  ','SOUND SOUR','CE  SIX   ',
     3  'SOUND SOUR','CE SEVEN  ',26*'0000000'/
       DATA LASTIT/'ACCUMULATE','D DB FOR T','HE PLANE  ','AREA      '/
C
     NAMELIST/IN/XLEN,YHI,NSO
     NAMELIST/SOURCE/SX,SY,SP
C
C.......INITIALIZE PLOTTING DEVICE
C
      CALL ZETA(15)
C
C.......INITIALIZE SOUND ARRAYS
C
C
     DO 10 I = 1,50
     DO 10 J = 1,50
      ASPL(J,I) = 0.0
10   CONTINUE
     DO 20 I = 1,20
        SX(I) = 0.0
        SY(I) = 0.0
        SP(I) = 0.0
20   CONTINUE
        FOURPI = 10 * (ALOG10(3.14 * 4))
        NPS = 50
        NPTS = NPS -1
        NCILAR = -20
        KOUNT = 1
C
C.....READ INPUT PARAMETES, SOUND SOURCES, X,Y LOCATIONS
C..... AND PRESSURES IN DECIBELS  AND PRINT FLAGS
C
C.........DATA TITLE......
            READ (5,450)(IT(I),I=1,10)
           READ (5,IN)
           READ (5,SOURCE)
C
C........SET UP GRID
C
     DX  = XLEN /  NPS
     DY  = YHI / NPS
     X(1) = DX
     Y(1) = DY
     DO  30  IXY = 2,NPS
         X(IXY) = X(IXY-1) +DX
         Y(IXY) = Y(IXY-1) +DY
30   CONTINUE
C
C........BEGIN FILLING AREA GRID WITH ACCUMULATING DB
C
     DO 40  J = 1, NSO
C
C.......INITIALIZE THE SINGLE SOURCE ARRAY OF VALUES
C
```

```
PROGRAM SOUND        76/76  OPT=1                      FTN 4.6+460-3       10/29/80  12.06.50
                     DO 35 J0 = 1,NPS
                        DO 32 K0 = 1,NPS
                           SS(K0,J0) = 0.0
         32           CONTINUE
         35       CONTINUE
                      DO 50  K = 1,MPTS
                         IF ((SX(J).GT.X(K)).AND.(SX(J).LE.X(K+1))) GO TO 55
         50          CONTINUE
         55      DO 60 L = 1, MPTS
                         IF ((SY(J).GT.Y(L)).AND.(SY(J).LE.Y(L+1))) GO TO 65
         60      CONTINUE
         65      X(K) = SX(J)
                 Y(L) = SY(J)
                 RP(J) = (2E-5) * (10**(SP(J)/20))
                  SS(L,K) = RP(J)
                    WRITE(6,200)J,SP(J),RP(J),L,K,X(K),Y(L)
        200       FORMAT(//10X,'SOUND SOURCE  SOUND PRESSURE IN DB       RAW',
               1    ' PRESSURE IN  DYNES     X - Y COORDINATES  ',
               2    /14X,I2,13X,F5.1,16X,F10.6,13X,2(2X,I2),2(1X,F5.1)//)
                 DO 70  MX = 1,NPS
                 DO 80 NY = 1,NPS
                    IF((NY.EQ.L).AND.(MX.EQ.K))ASPL(L,K)=ASPL(L,K)+RP(J)
                    RS = ((X(K)-X(MX))**2)+((Y(L)-Y(NY))**2)
                    IF (RS.LT.1.0) RS = 1.0
                    R(NY,MX)=SQRT(RS)
                    IF((NY.EQ.L).AND.(MX.EQ.K))GO TO 210
                SPL = SP(J)-FOURPI-(10*ALOG10(RS))
                ADSO = (2E-5) * (10 **(SPL/20))
                IF(ADSO.LT.0.0) ADSO = 0.0
        C....       IF ((J.EQ.1).AND.(NY.LT.10))WRITE(6,590)NY,MX,ADSO,R(NY,MX)
        590       FORMAT(10X,'AT COORDINATES    ',I3,4X,I3,
               *  '  THE RAW PRESSURE IS',F10.5,'  DISTANCE FROM SOURCE  = ',F12.3)
                ASPL(NY,MX) = ASPL(NY,MX) + ADSO
                SS(NY,MX) = ADSO
        210      CONTINUE
        C....       IF ((NY.EQ.L).AND.(MX.EQ.K))WRITE(6,590)NY,MX,ASPL(L,K),R(NY,MX)
        80      CONTINUE
        70      CONTINUE
                  IF(.TRUE.) GO TO 75
                IF((J.GT.1.0).AND.(J.LT.NSO))GO TO 40
                  WRITE(6,535) J
                 WRITE(6,550)((ASPL(N,M),N=1,50),M=1,50)
                   WRITE(6,540)J
        C...       WRITE(6,550)((R(N,M),N=1,50),M=1,50)
        75        CONTINUE
                        DO 140 M =1,NPS
                           DO 130 N = 1,NPS
                     SS(N,M)   = 20 * (ALOG10(SS(N,M)/2E-5))
        130                CONTINUE
        140          CONTINUE
        C....     WRITE(6,530) J
                     CALL KONPLOT(PLOTIT(KOUNT),NCHAR,SS,50,25)
                     KOUNT = KOUNT + 2
        40      CONTINUE
                        DO 150 M =1,NPS
                           DO 160 N = 1,NPS
                           IF(ASPL(N,M).LT.0.0) ASPL(N,M)= 2E-5
```

```
PROGRAM SOUND       76/76   OPT=1                         FTN 4.6+460-3      10/29/80  12.06.50

                              ASPL(N,M) = 20 * (ALOG10(ASPL(N,M)/ 2E-5))
            160           CONTINUE
            150        CONTINUE
                       WRITE(6,600) DX,XLEN,YHI,NSO
                       WRITE(6,625) (SP(I),I=1,NSO)
            C...        WRITE (6,550) (((ASPL(N,M),N=1,50),M=1,50))
                      CALL KONPLOT(LASTIT,-40,ASPL,50,25)
            C
            C
                     CALL DONEPL
            C
            C
            C.......FORMATS......
            C
            450         FORMAT(10A8)
            530     FORMAT(///10X,'AREA DB WITH ADDITION OF SOUND SOURCE ',I2//)
            535     FORMAT(///10X,'RAW PRESSURE VALUES AT SOUND SOURCE ',I2//)
            540       FORMAT(///10X,'FROM SOUND SOURCE  ',I4,'  DISTANCES  IN FEET')
            550      FORMAT(/(1X,10F12.5))
            600     FORMAT(///  '   TOTAL DECIBEL LEVEL AT ',F10.5,' INTERVALS,  ',
                   1' FOR A PLANE,', F10.5,' BY ',F10.5,'FOR',I3,1X,'SOURCES OF  '/)
            625       FORMAT (/(1X,10(F6.1,'DB ')))
                    STOP
                    END
```

SYMBOLIC REFERENCE MAP (R=1)

```
ENTRY POINTS
  110  SOUND

VARIABLES     SN  TYPE          RELOCATION
   713  ADSO      REAL                          1062  ASPL     REAL      ARRAY
   700  DX        REAL                           701  DY       REAL
   673  FOURPI    REAL                           671  I        INTEGER
  6132  IT        INTEGER   ARRAY                702  IXY      INTEGER
   672  J         INTEGER                        703  J0       INTEGER
   705  K         INTEGER                        677  KOUNT    INTEGER
   704  K0        INTEGER                        706  L        INTEGER
 20012  LASTIT    INTEGER   ARRAY                715  M        INTEGER
   675  MPTS      INTEGER                        707  MX       INTEGER
   714  N         INTEGER                        676  NCHAR    INTEGER
   674  NPS       INTEGER                        670  NSO      INTEGER
   710  NY        INTEGER                       6062  PLOTIT   REAL      ARRAY
  6156  R         REAL      ARRAY              17766  RP       REAL      ARRAY
   711  RS        REAL                          6036  SP       REAL      ARRAY
   712  SPL       REAL                         13062  SS       REAL      ARRAY
  5766  SX        REAL      ARRAY               6012  SY       REAL      ARRAY
     0  WORK      REAL      ARRAY     //         716  X        REAL      ARRAY
   666  XLEN      REAL                          1000  Y        REAL      ARRAY
   667  YHI       REAL
```

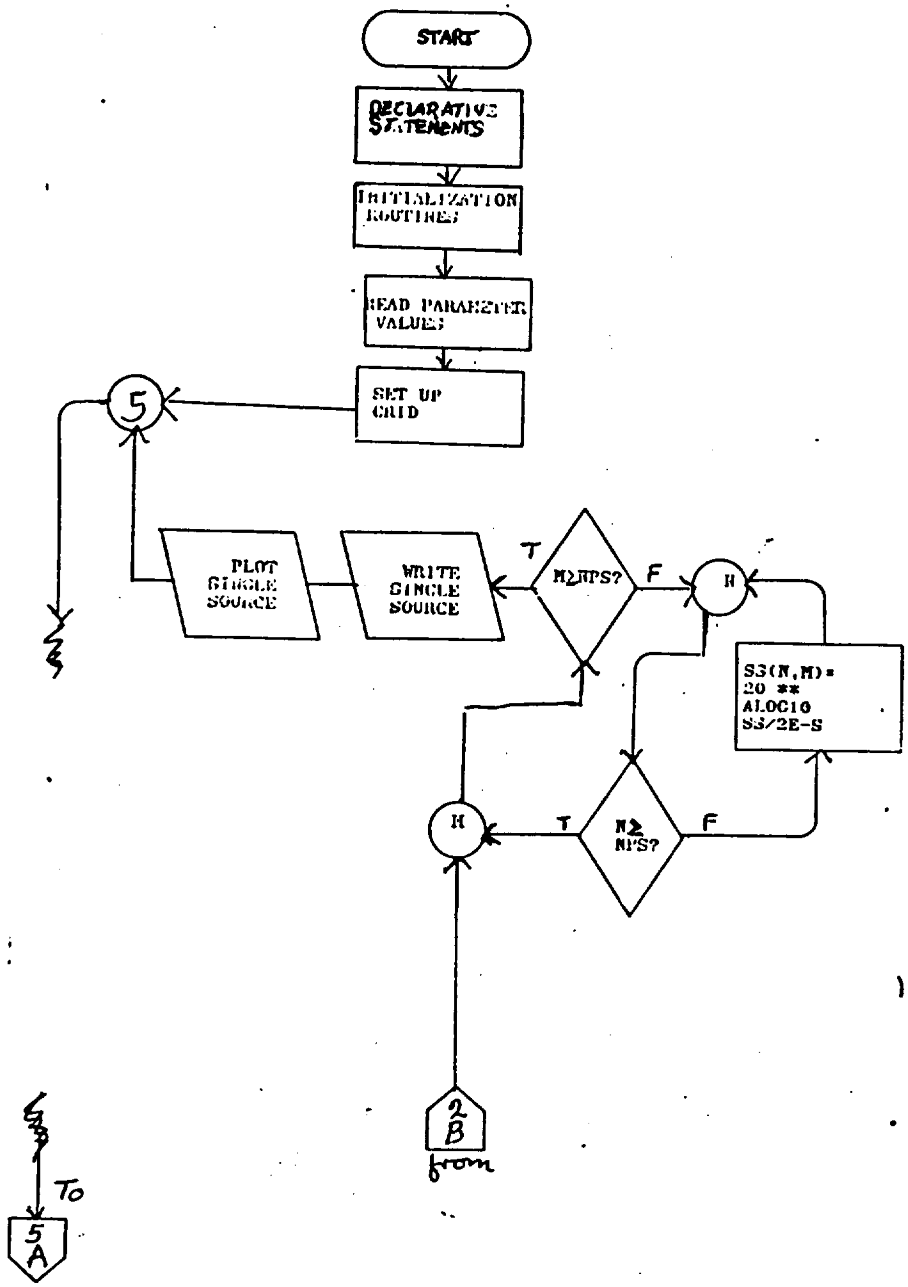
```
SUBROUTINE KONPLOT    76/76   OPT=1                         FTN 4.6+460-3      10/29/80  12.06.50

      *DECK KONPLOT
            SUBROUTINE KONPLOT (PLTITLE,ICAR, PLTVAL,  NP,  NLEVS )
      C
      C  PURPOSE: PLOT PRESSURE CONTOURS FOR EACH FIELD...
      C
      C  ENVIRONMENT:  CDC 7600
      C
      C  PARAMETERS
      C    ARG  TYPE  I/O/S    DIM         DESCRIPTION
      C  PLTVAL  R      I     NP*NP        FUNCTION FOR CONTOURING
      C    NP    I      I       -          DIMENSION OF GRID AND FUNCTION
      C   NLEVS  I      I       -          NUMBER OF CONTOUR LEVELS DESIRED
      C
      C  COMMONS USED
      C      /   /      DISSPLA INTERFACES CONTOUR LINES THROUGH
      C                  THE WORK ARRAY IN BLANK COMMON
      C
      C  FILES USED:  NONE
      C
      C  LOCAL VARIABLES:
      C    VAR  TYPE          DIM          DESCRIPTION
      C   ZINCR   R            -           INCREMENT IN FUNCTION FOR CONTOURING
      C
      C  EXTERNAL REFERENCES:
      C       *NAME*, *DESCRIPTION AND SOURCE*
      C       TITLE         DISSPLA      TITLES PLOT
      C       GRAF          DISSPLA      ESTABLISHES AXES
      C       FRAME         DISSPLA      FRAMES PLOT
      C       BCOMON        DISSPLA      ESTABLISHES LINK WITH WORK ARRAY
      C       CONMAK        DISSPLA      GENERATES CONTOUR LINES
      C       CONLIN        DISSPLA      DRAWS CONTOUR LINES
      C
      C
      C
      C-----------------------------------------------------------------
      C
              COMMON /    / WORK(5000)
            DIMENSION  PLTVAL(NP,1), PLTITLE(5)
      C
            PMIN = PLTVAL(1,1)
            PMAX = PMIN
      C
            DO 250 J=1,NP
               DO 300 I=1,NP
                  IF ( PLTVAL(I,J).LT.PMIN ) PMIN = PLTVAL(I,J)
                  IF ( PLTVAL(I,J).GT.PMAX ) PMAX = PLTVAL(I,J)
       300     CONTINUE
       250  CONTINUE
      C
            ZINCR = ( PMAX - PMIN ) / NLEVS
      C
            CALL BGNPL(-1)
              CALL TITLE(PLTITLE,ICAR,
           1    'LENGTH IN FEET',14,'HEIGHT IN FEET',14,8.6,6.5)
                CALL GRAF (0.,12.,120.,0.,12.,108.)
            CALL FRAME
            CALL BCOMON ( 5000 )
```

```
SUBROUTINE KONPLOT     76/76    OPT=1                          FTN 4.6+460-3        10/29/80  12.06.50

                       CALL CONMAK ( PLTVAL,NP,NP,ZINCR )
                       CALL CONLIN ( 0,5HSOLID,6HLABELS,1,1 )
                       CALL CONANG( 270 )
                       CALL CONTUR ( 1,6HLABELS,4HDRAW )
                       CALL ENDPL(0)
                C
                       RETURN
                       END


      SYMBOLIC REFERENCE MAP (R=1)

 ENTRY POINTS
    3  KONPLOT

 VARIABLES      SN  TYPE            RELOCATION
   157  I           INTEGER                             0  ICAR       INTEGER                   F.P.
   156  J           INTEGER                             0  NLEVS      INTEGER                   F.P.
     0  NP          INTEGER                 F.P.        0  PLTITLE    REAL         ARRAY        F.P.
     0  PLTVAL      REAL         ARRAY      F.P.      155  PMAX       REAL
   154  PMIN        REAL                                0  WORK       REAL         ARRAY        //
   160  ZINCR       REAL

 EXTERNALS          TYPE    ARGS
        BCOMON               1                             BCNPL                1
        CONANG               1                             CONLIN               5
        CONMAK               4                             CONTUR               3
        ENDPL                1                             FRAME                0
        GRAF                 6                             TITLE                0

 STATEMENT LABELS
    0  250                                    0  300

 LOOPS  LABEL    INDEX     FROM-TO    LENGTH    PROPERTIES
   13   250    * J          43 48       21B                 NOT INNER
   21   300      I          44 47        7B       INSTACK

 COMMON BLOCKS   LENGTH
      //          5000

 STATISTICS
   PROGRAM LENGTH                203B      131
   SCM BLANK COMMON LENGTH     11610B     5000
```

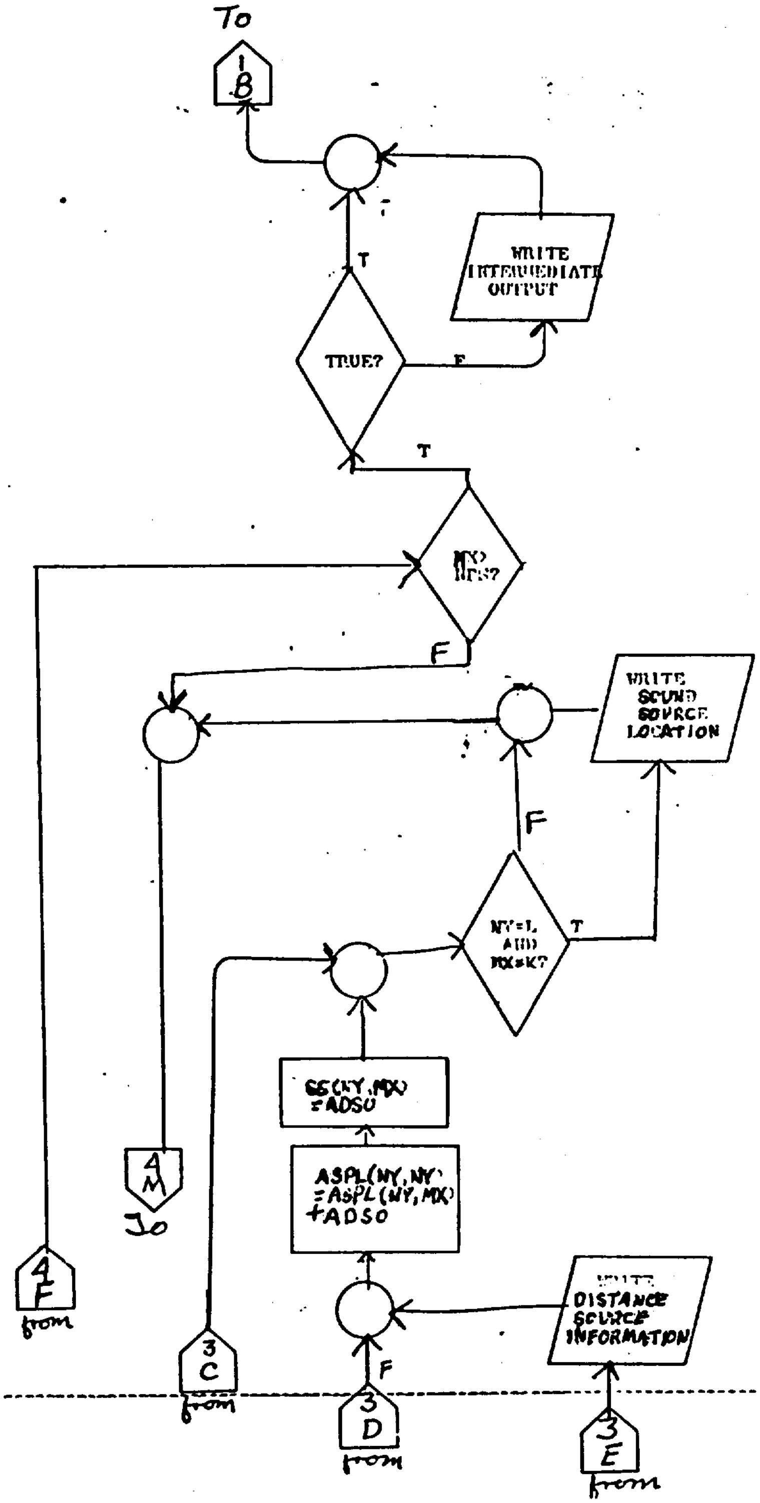
DATA OF THE VALUES FOR THE PARAMETERS OF A MACHINE HOLD IN THE TORUS

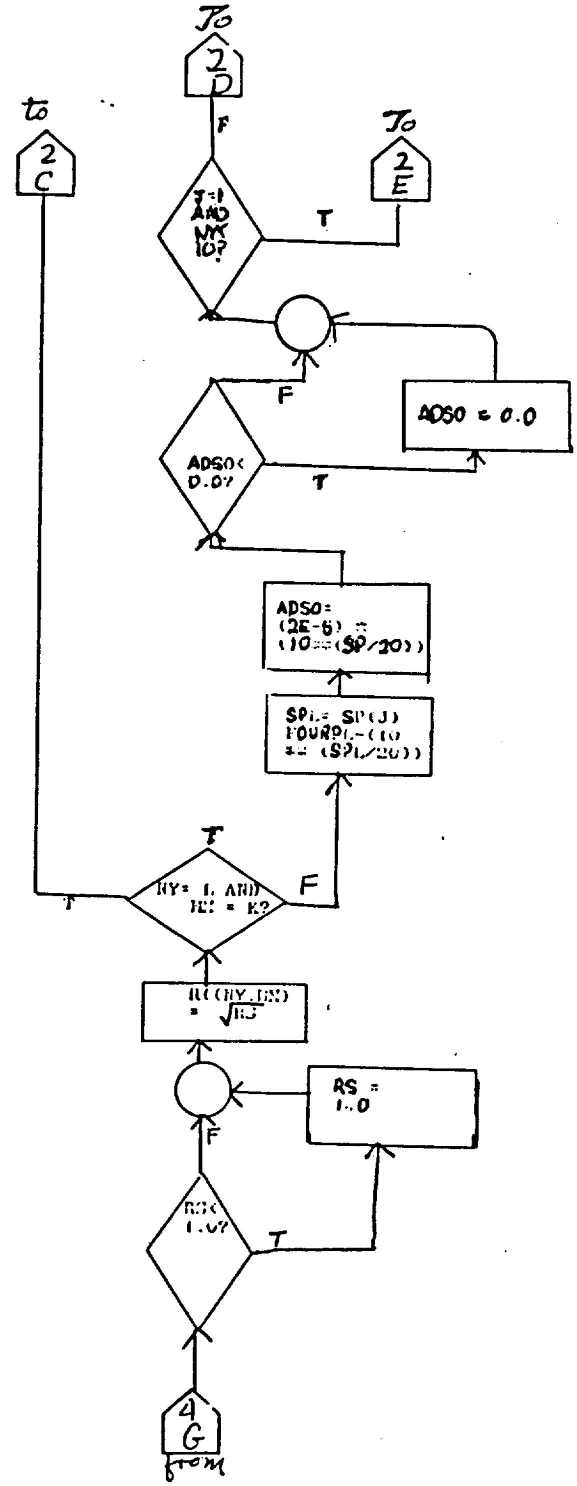
```
$IN    XLEN=120.0, YHI = 108.0, NSO = 7  $END
$SOURCE    SX = 5.9,15.8,19.4,20.6,95.3,101.5,102.6,13*0.0,
           SY = 24.8,3.5,102.3,44.6,34.9,20.1,9.6,13*0.0,
           SP = 98.0,88.0,110.0,75.0,99.0,98.0,90.0,13 * 0.0  $END
```

one

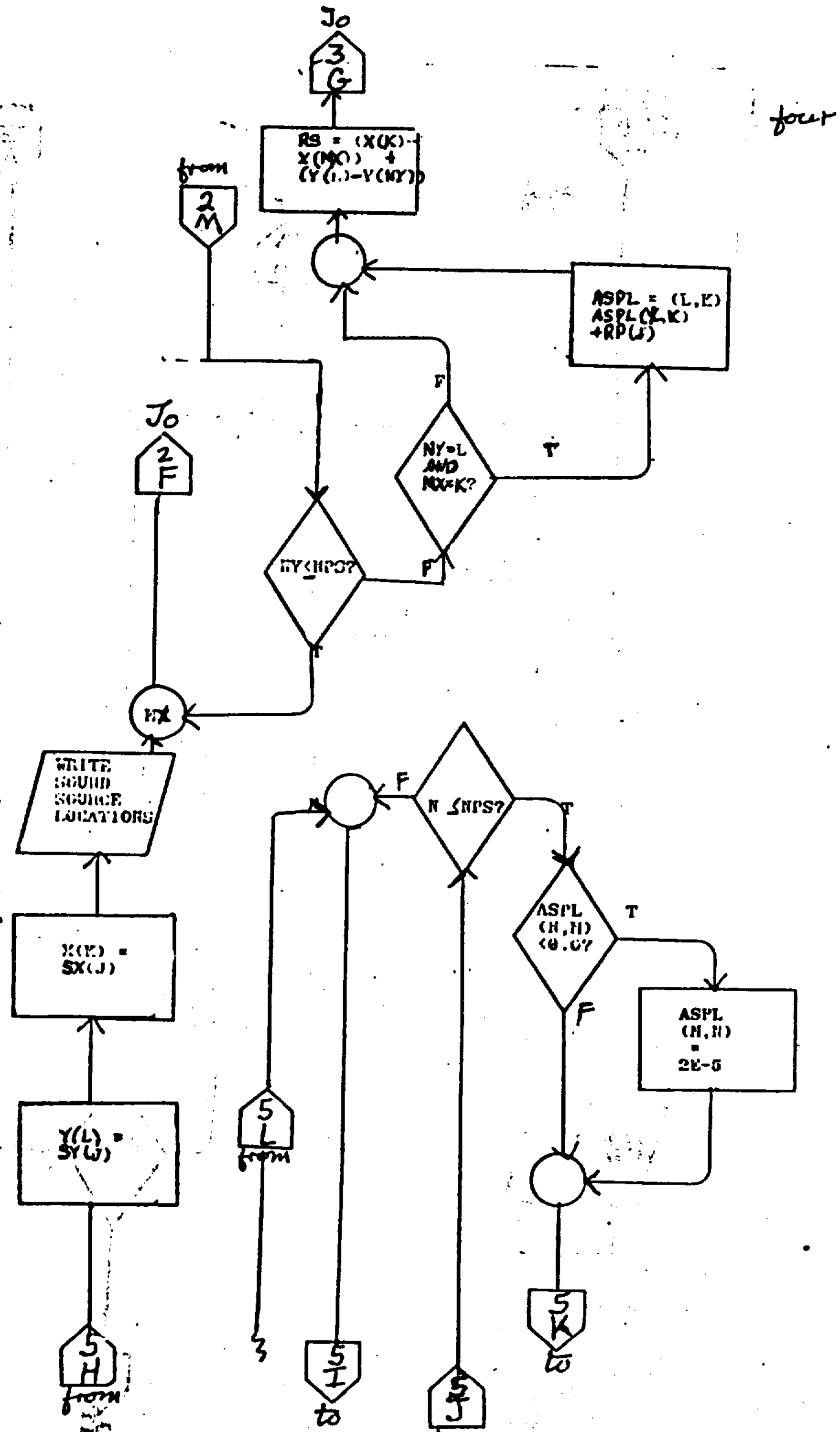

START
DECLARATIVE STATEMENTS
INITIALIZATION ROUTINES
READ PARAMETER VALUES
SET UP GRID
5
PLOT SINGLE SOURCE
WRITE SINGLE SOURCE
T
M≥NPS?
F
N
S3(N,M)=
20 **
ALOG10
S3/2E-S
N≥
NPS?
T
F
M
2
B
from
To
5
A

two

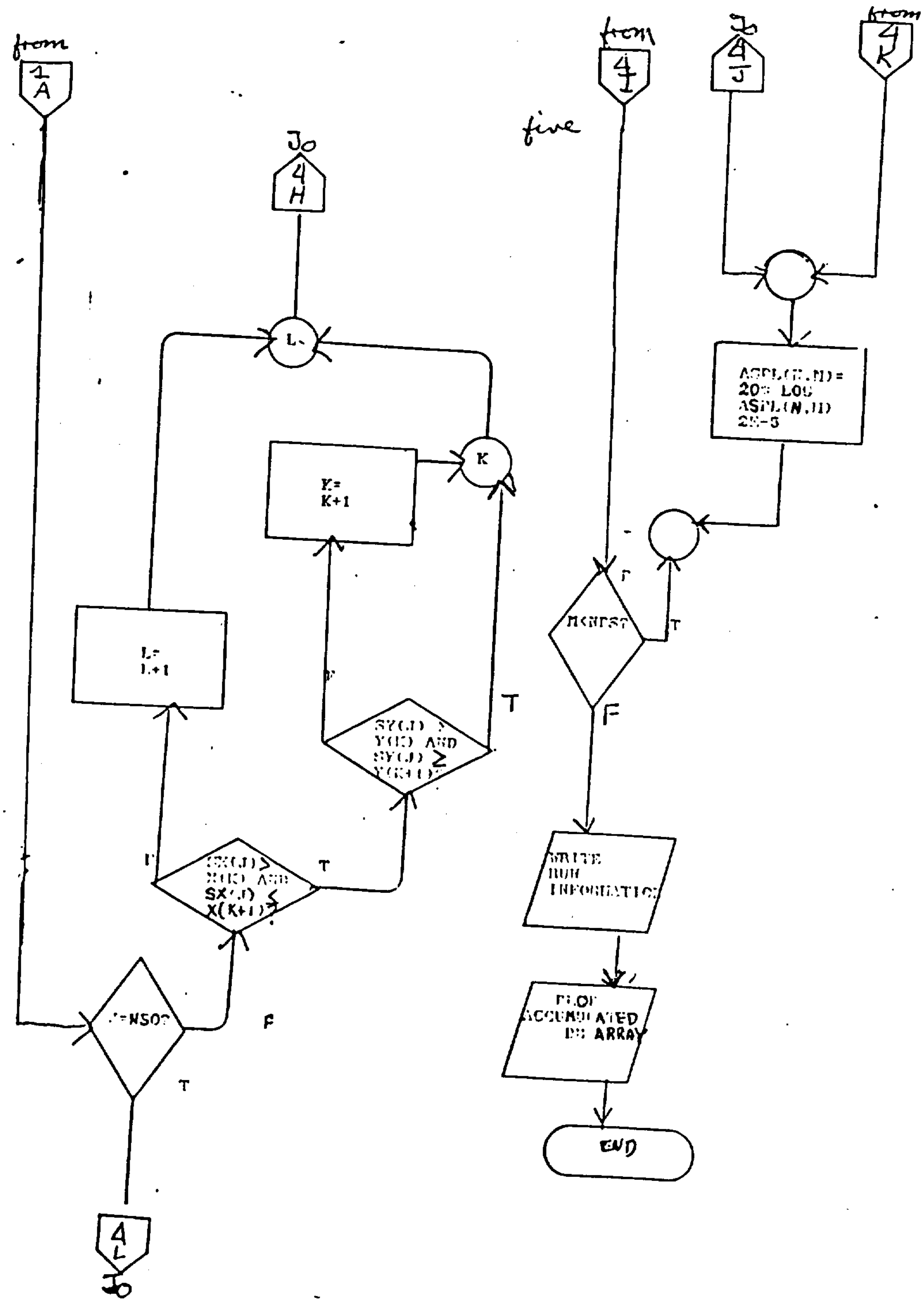

To
1
B
WRITE INTERMEDIATE OUTPUT
T
TRUE?
F
T
F
WRITE SOUND SOURCE LOCATION
F
NY=L AND MX=K?
T
SS(NY,MX) =ADSO
ASPL(NY,NY) =ASPL(NY,MX) +ADSO
4
M
To
4
F
from
3
C
from
F
3
D
from
DISTANCE SOURCE INFORMATION
3
E
from



three



To
3
G
four
RS = (X(K)-X(NX)) + (Y(L)-Y(NY))
from
2
M
ASPL = (L,K)
ASPL(L,K)
+RP(J)
F
NY=L
AND
NX=K?
T
To
2
F
NY≤NPS?
F
NX
WRITE
SOUND
SOURCE
LOCATIONS
N
F
N ≤NPS?
T
ASPL
(N,N)
<0.0?
T
F
ASPL
(N,N)
=
2E-5
X(K) =
SX(J)
Y(L) =
SY(J)
5
L
from
5
H
from
5
I
to
5
J
from
5
K
to



from
1 A
To
4 H
L
K
K= K+1
L= L+1
T
F
T
T
F
T
To
4 L
from
4 I
five
To
4 J
from
4 K
F
T
F
END

ADDITIONS TO THE BASIC PROGRAM TO ENHANCE USE AS A DATA TOOL

FREQUENCY BANDS LOOP # OF FREQUENCY BANDS

RANGE, CENTER FREQUENCY AND NUMBER OF SOUND SOURCES

INPUT MEASURED DB FOR BAND LEVELS OF EACH SOUND SOURCE

CALCULATE ACCUMULATED DB'S FOR EACH OF SOURCES

CONVERT EACH ARRAY OF FREQUENCY BAND DB TO SOUND

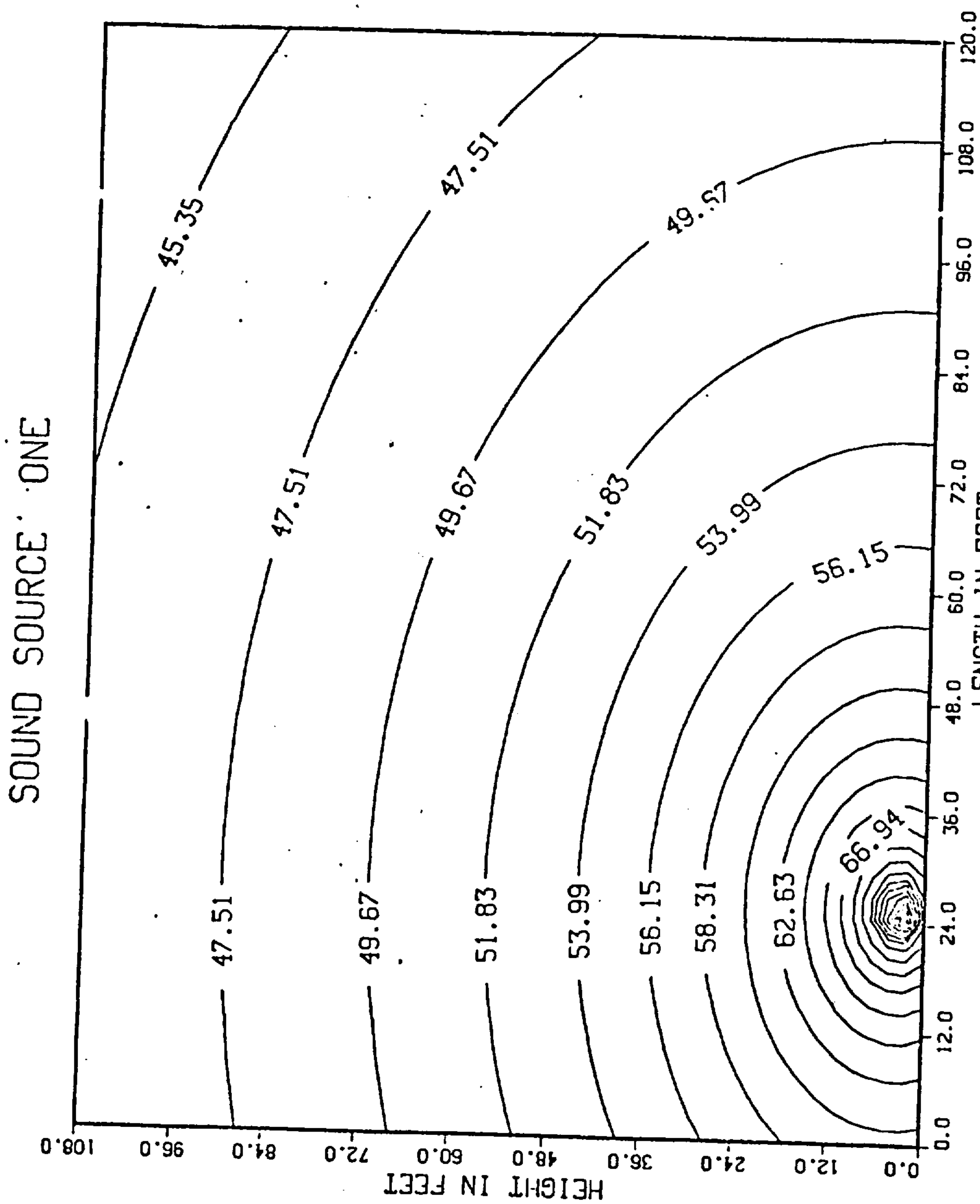
PRESSURE OR INTENSITY FOR EACH BAND OF FREQUENCIES

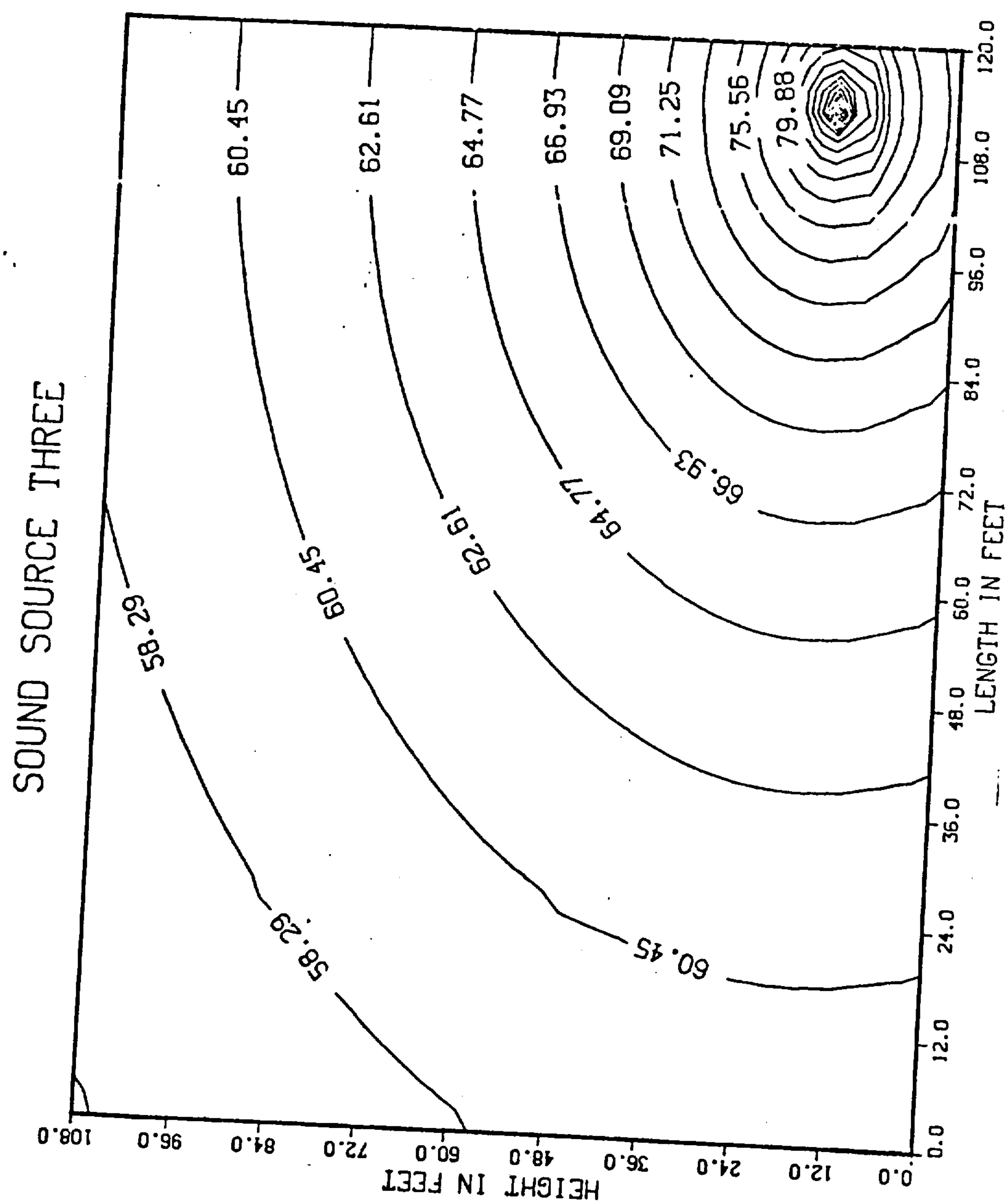
ACCUMULATE ALL DB FOR ALL FREQUENCY BANDS AND ALL SOURCES

USE LOOPS TO MODIFY THE FREE FIELD DB WITH WALL CHARACTERISTICS

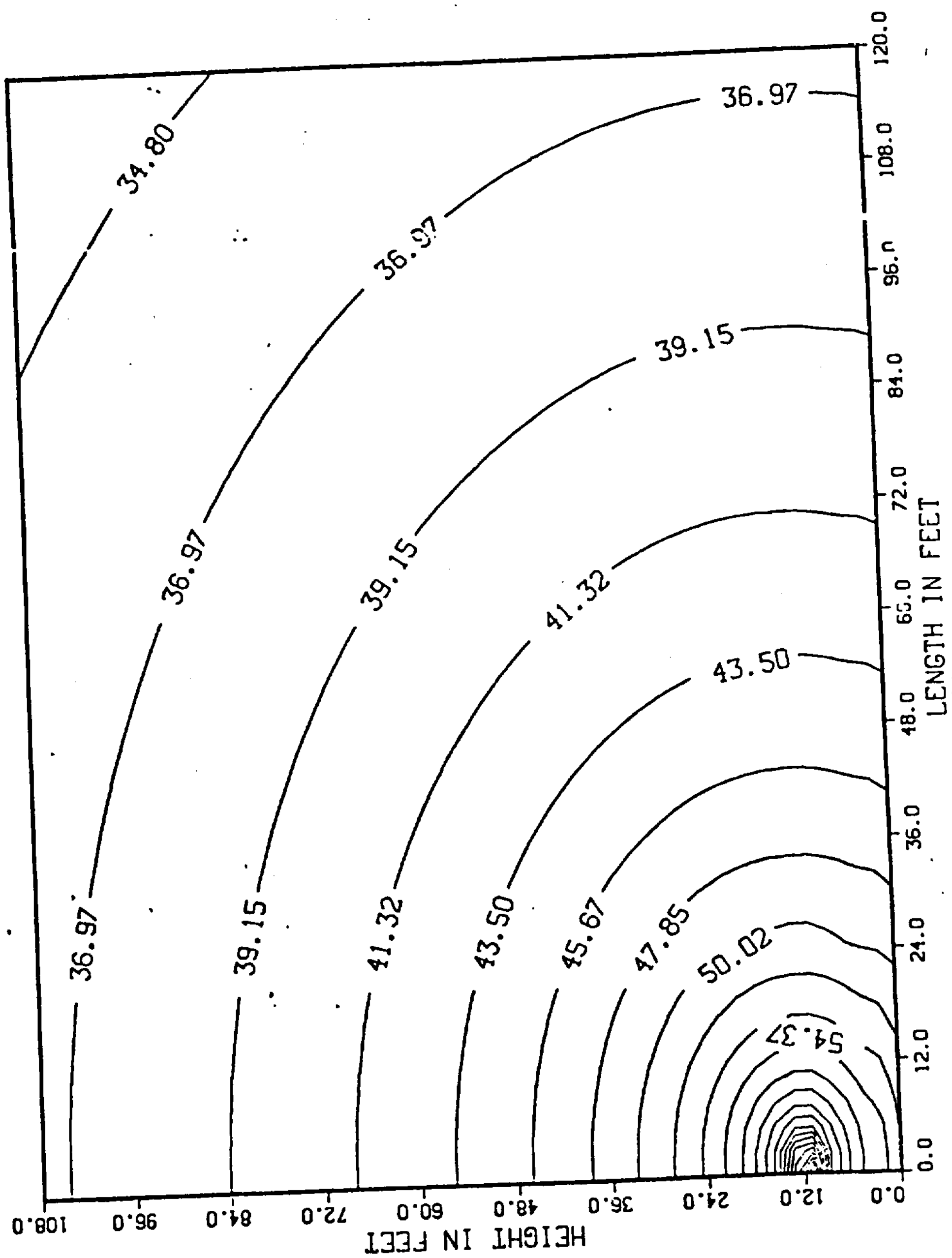
USE REFLECTION ABSORPTION COEFFIECENTS AND WALL COORDINATES AS

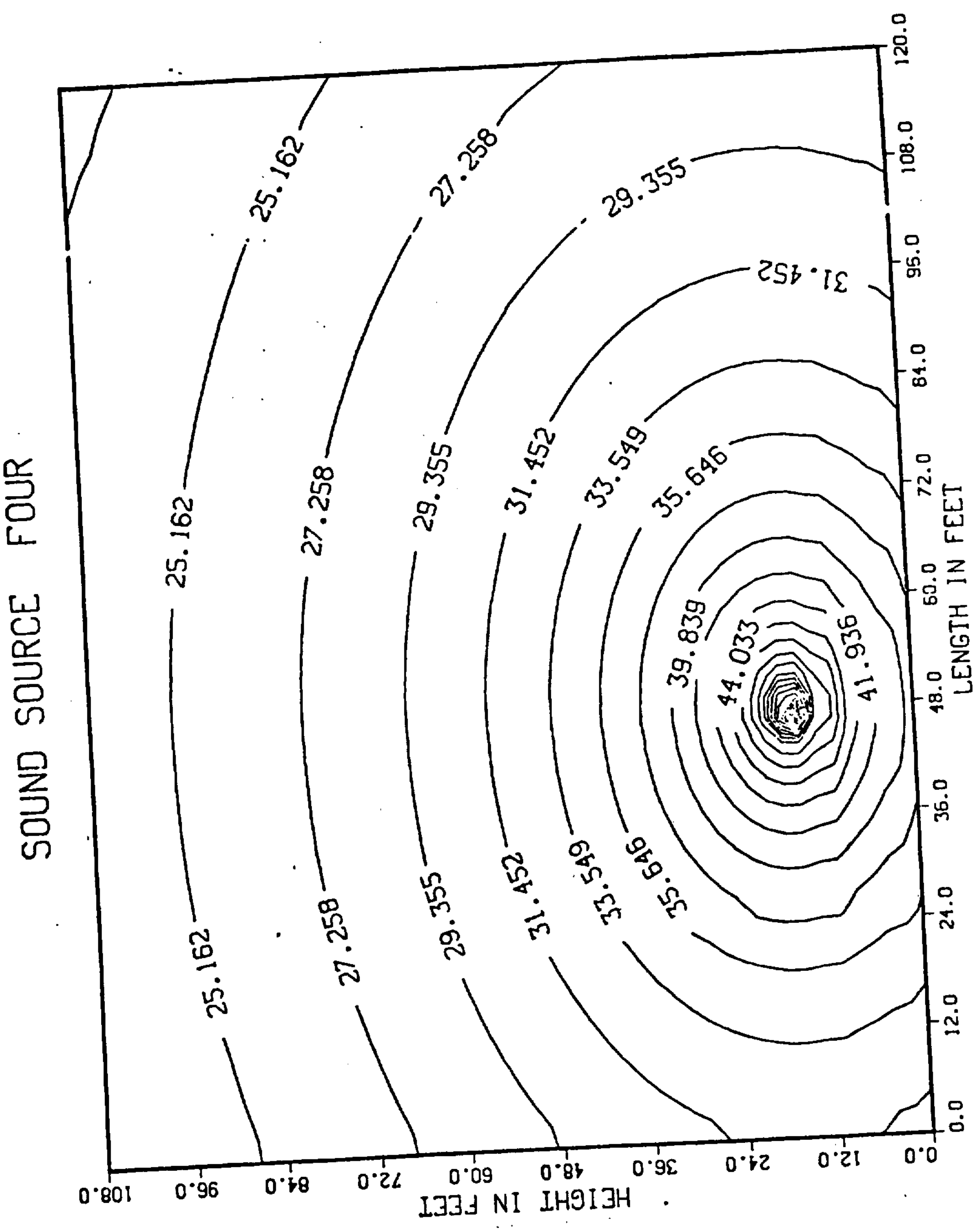
INPUT TO THE PROGRAM.

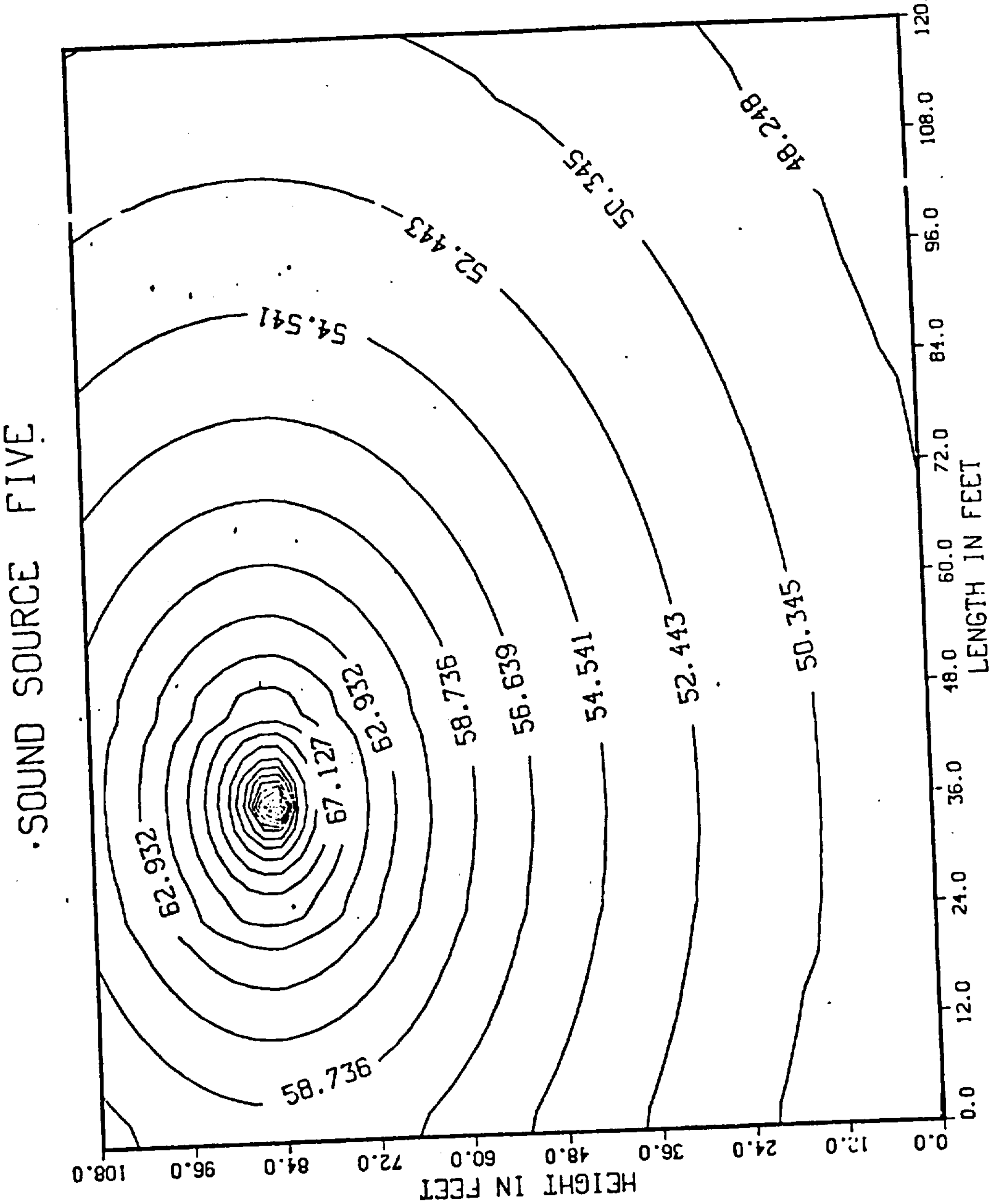

SOUND SOURCE ONE
LENGTH IN FEET
HEIGHT IN FEET
0.0
12.0
24.0
36.0
48.0
60.0
72.0
84.0
96.0
108.0
120.0
45.35
47.51
49.67
51.83
53.99
56.15
58.31
62.63
66.94

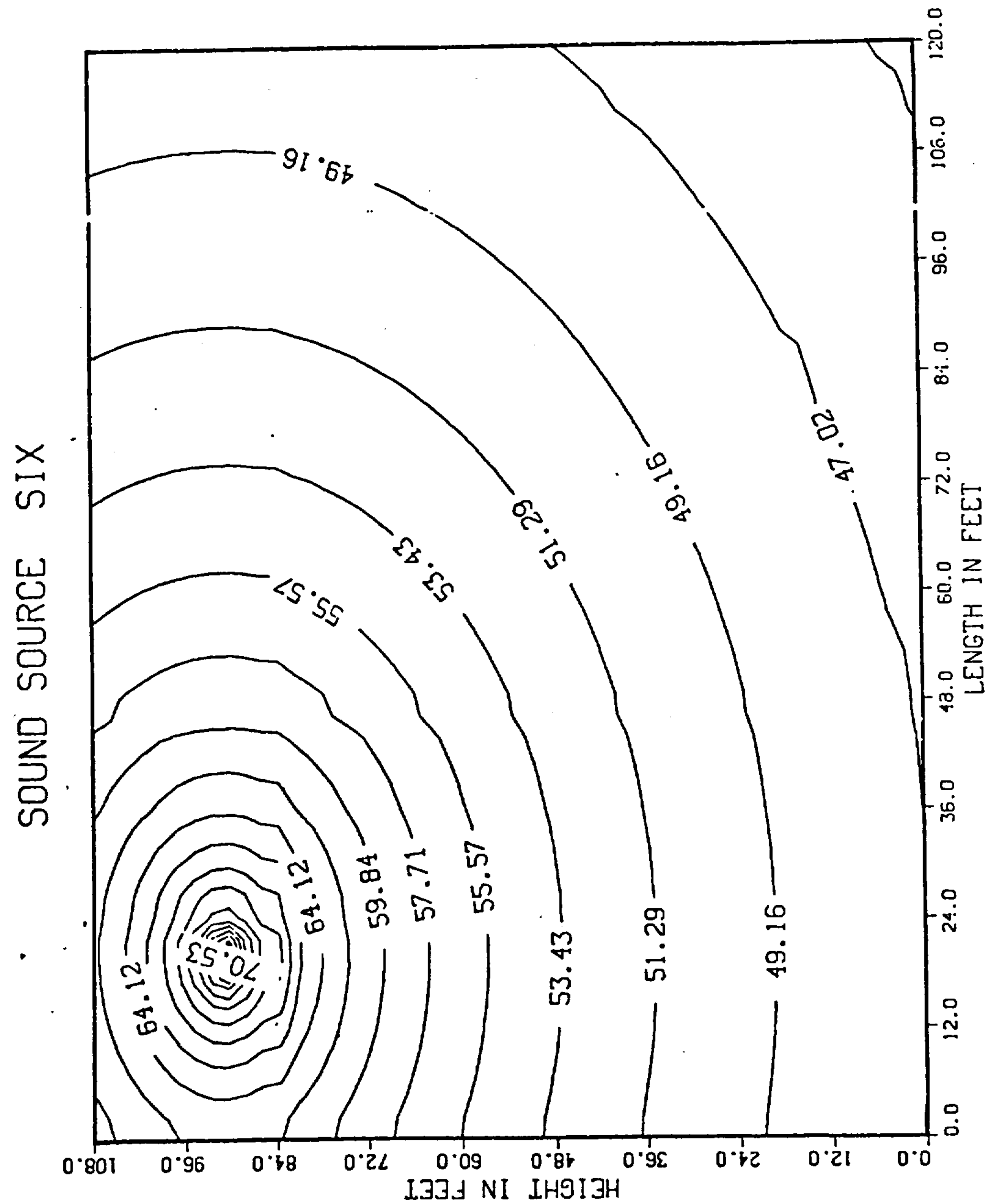

SOUND SOURCE THREE
60.45
62.61
64.77
66.93
69.09
71.25
75.56
79.88
58.29
LENGTH IN FEET
HEIGHT IN FEET
0.0
12.0
24.0
36.0
48.0
60.0
72.0
84.0
96.0
108.0
120.0

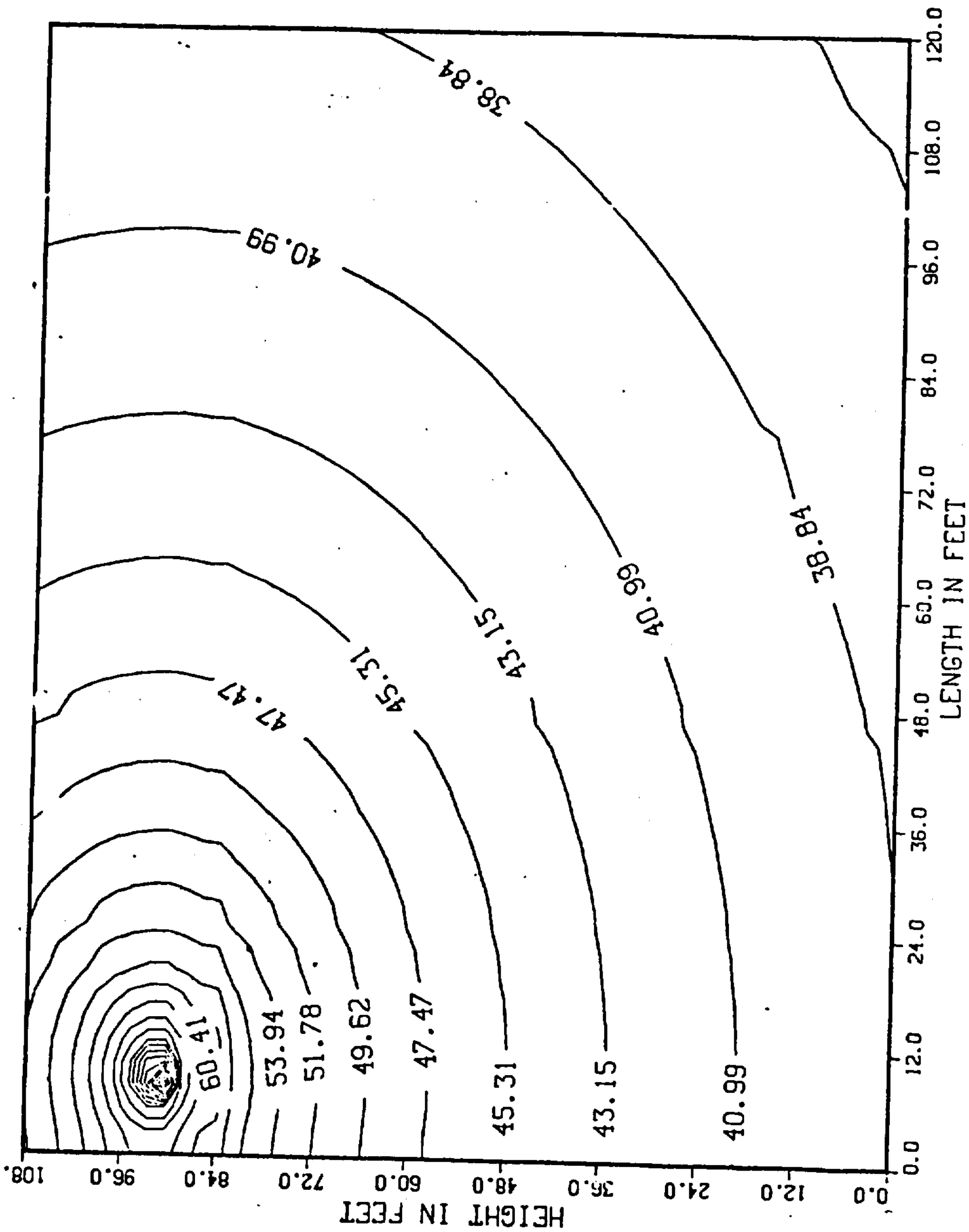
SOUND SOURCE TWO




SOUND SOURCE FOUR
LENGTH IN FEET
HEIGHT IN FEET
0.0
12.0
24.0
36.0
48.0
60.0
72.0
84.0
95.0
108.0
120.0
0.0
12.0
24.0
36.0
48.0
60.0
72.0
84.0
96.0
108.0
25.162
27.258
29.355
31.452
33.549
35.646
39.839
41.936
44.033


SOUND SOURCE FIVE
LENGTH IN FEET
HEIGHT IN FEET
0.0
12.0
24.0
36.0
48.0
60.0
72.0
84.0
96.0
108.0
120.0
48.248
50.345
52.443
54.541
56.639
58.736
62.932
67.127


SOUND SOURCE SIX
LENGTH IN FEET
HEIGHT IN FEET
0.0
12.0
24.0
36.0
48.0
60.0
72.0
84.0
96.0
108.0
120.0
70.53
64.12
59.84
57.71
55.57
53.43
51.29
49.16
47.02



SOUND SOURCE SEVEN

all band width | octave band center +10 dB

	SOURCE DESC & DISTANCE	A	B	C	31.5	63	125	250	500	1000	2000	4000	8000	16000	31500
64 to 65	spinning ring machines	55	59	64	58 to 59	57 58	55	54 to 55	54	53	48	41	35	32	27
78	door slam	72													
68	dryer peaks w/ slinking of clothes	54	62	67	62 63	61 63 peak 65	66	59	53	42 43	38 39	39	29 30	25 to 32	26½
44	quiet apartment just mo-	42 peaks 45	31	[illegible] 30	41	36 to 40	28 to 30	25	21	19	18	18	20	23	26
	generator only ≈50 ft.	54	54	57 56	48 min 45	max 48 ≈50									
	generator pump & fan	57	59	61	56½ ±½	56	56 ±1dB	56	55½	60 68	63 12	63 65	62 63	63 65½	64 65
wind 80%	mild wind end of	43	48 52	53 59	66	55	52	46	38 to 40	37 → 38	34.6 ≈ 36	32	27 29	25	[illegible]
84	BTO recording 10 ft	61 60	70 74	74 76	75	67 → 76	62 67	59 60	50	48.6 54	45	40 44	38 36	24	26
80 70	" fast	75 70	60 70 76	57 60	70 75	65 70 74	65 70 78	55 62	40 45 50	45 50 60	45 46 50	36 40 46	38 40	32	35

Total	SOURCE DESC & DISTANCE	A (all band width)	B	C	31.5 (octave band center +10)	63	125	250	500	1000	2000	4000	8000	16000	31500
87-90	9x7 wind tunnel just outside wall ≈20 ft	70 72 74	76	85	65 72	65 70	64	65	72 70 75	62 to 64	57 60	47	37	30	34
54 56	ambient office noise ≈ 4:30	34	43 46	54	54	48 50	44	35 44	44 peaks 35-40	25 40	peaks 40 34	20 → 30	Carol talking 20 25	35	25
55 56 58	[illegible] outdoor court [illegible]	45 46	50 52 peak 56	55 57	49 52	54 58	52 50 56 peaks	44 [illegible] 50 peaks	41 42 46	39 48 peaks 50	47 peak 50	36 40	32 36	25 42	35
70	music practice room [illegible] piano	60 65 72	65 68 72	65 70 75	46 47	55	59 60 68 peaks	peaks 65 70	65 70 74	62 68 peaks	56 58	46 52 56	35 40 42	32 36	31
75 76 peak	6 ft violin piano live rm.	65 72	60 72 78	70 76	54 55 56	48 50 peaks 60	60 70	60 72	60 68 70	66 70	55 66	50 56	35 10	30 [illegible]	35
75 76 84 peaks	4 piece German band ≈10 ft live room	low 72	75 82 peaks	75 [illegible]				70	76	68	55 69	50	42	55	54
60	cello 6 ft	65	65 74 peak	70 74	45 50	40 playing low	45 50 60 peaks	64 66	55 64 70	65	57 58 peak	40 54 peaks	36 50 peaks	34	35
	clapping 65			74											
76	3 ft deodorant foam	70 75	60 75	74	60 72	60 70 76	65 73 78 peaks	65	65 78	65	65 74	65 70 [illegible] peak	70 75 80 peaks	78 80	65 70 peaks

	all band width			octave band center							+10 in			
SOURCE DESC & DISTANCE	A	B	C	31.5	63	125	250	500	1000	2000	4000	8000	16000	31500
5:00 pm ambient office noises Carol talking	40	50	46 to 50	Carol phone off 48	49 50	quiet office 48-50	47-50	46→50 peak	48 51	48 50	50	50	49 A	50
Hand clap 10 ft											48	56		
desk punch 10 ft											50	56		
low conditioner overhead				49→52	48 low 50 A									
wind tunnel couple 100 ft behind a cement wall	31 peak 38	46 42	53 50	54→ 54	54→ peak 56	54 peak 58	54→ 58	54→58 peak 60	52 to 58	54→ peak 60	→		54 up toward 60	51 peaks 60
idling engine from inside compartment	48	63	72 build up	74	74'	74	74	76	74	74	76	76	77	78
car running revving	72 74	79 80	84 90	80 85 40	75 83	72 78	67 71	62 63	54 58	45 48 50	44 45	38 42	30 35 42	30 35
my radio 10 ft	32 43	45 46 49	48 49 50	48 51	49 50	49	49 50	46 51	46 50	50	49 51 45	46 50 55	46 50	49 50
heater 4 ft gas off				46	45	45/48	44 47	46 to 47	45 46 48	46½ 47	48	45	45	46 48

SOURCE DESCR & DISTANCE	A	B	C	31.5	63	125	250	500	1000	2000	4000	8000	16000	31500
	all band width			octave band center										
76 68 violin dead room 5 ft	60 76	66 70	64	68 70	60 69 70	64	64 68	69 76	65 72	70	67	68 69	60	55 62
above violin same room 1 foot	76											25 49 peak		
Smaller violin 1 foot same	68 70	76 peak	60 78	30 40	35 45	40	55 66 peaks	40 54 peaks	~~50~~ 60	30 50	30 45 peak	30	30	34

APPENDIX B

1. Sample set of awareness poll questionnaire, instructions and recording sheet
2. Samples of actual answers
3. Count of responses of sounds participants were aware of
4. Sample of questions on pleasantness of sounds derived from answers to awareness poll

SOUND AWARENESS STUDY

INSTRUCTIONS:

This study is being conducted to aid in indentifing sounds that people are aware of during their normal day and what effects the various daily sounds have on people. The outcome will be used in designing further studies on the subjective, phycological impact of sounds on individuals. Both these studies will be used as examples of how broad, complex patterns of human response can be incorporated into a design for an entire acoustical system of a projected space colony, the topic of a master's thesis.

Please first fill out the biographical information sheet. Then keep close tabs on all the sounds that you are hearing during your day (and if warranted, night) for about two days, 48 hours. These days do not have to be contiguous. One work day and one non-work day would be best for the purpose of this study. Fill in the "Time" and "Sound" as immediately close to the hearing as possible. Elaborate on the sound at your convenience. Be clear and specific. However, there's no need to linger over grammatical details. Give brief phrase and one word descriptions as to the details of a sound. Nothing lengthy is required. Include all varieties of sound in your day: routine, usual, unexpected, sudden, non-sound (levels of quiet as noticed), complex, simple, unpleasant, pleasant, especially those sounds that you enjoy and give you a good feeling.

Describe the "Sound" in one or two identifing words that distinquishes its character, such as office noise, swishing, bong, symphony music, female voices, mixed voices, whish, or however the sound is heard by you.

"Sound source" is what is producing the sound, like a radio, jet, people in conversation, a crowd, water pipes, babbling brook, etc..

For "Time", "Duration", and "Your location in respect to sound", approximate quanties are sufficient in terms of hours for time (11:00, early morning) and duration, (1 sec., all day, 2 min. every 20 min.); in distance and refereniece points for location. (I'm inside. The sound is 50 ft. down on the street., 20 ft. in the next room, surrrounding me in a room, 1 ft. in front of me, etc.)

"Place" need only be brief, one or two word references and can be abbreviated if repeated. Terms such as my yard, busy street, in car, my office at NASA, are examples. The last can be abbreviated to "my office" in subsequent answers.

Activity information is what you're engaged in when you hear the sound. For example, working at my desk, writing, driving, partying, exercising, work or non-work conversation and so on.

"Qualities of sound" are words and phrases used to describe the characteristics of the sound itself...harsh, gentle, high pitched, background, throbbing, low, however you perceive the sound. In a complex sound such as party noise, describe each of the elements as you become aware of it in the composite sound. (garbled voices, music from the stero, soft, swishing clothes, encompassing, etc.)..

"Effects" of sound are the inner feelings, your responses (or the response, you'de like to make) and reactions to the sound you're hearing: makes me angry, soothing, fills a vacuum, pleasant, puts me to sleep, happy, etc.; only enough of a phrase or phrases to indicate clearly what the sound does to you. Do include your paradoxical responses to a sound.

There may be times answers seem to overlap. Write in duplicate answers, making distinctions whenever possible. For example, for "Sound", the sound may be "running water" twice, but once for "Sound source" the source may be "the kitchen tap" and a "babbling brook" another time. Or, "heater noise" may be used for "Sound" and "Sound source" with appropriate descriptions used..."low, intermittent, crackling, with an overall continous swishing etc." with "an hour" or "all night" whatever for "Duration".

If there are any doubts about the instructions, questionnair or your reactions, your own best assumptions and guesses are sufficient. If completely perplexed by anything, ask me to clarify the point.

In partcipating in this study it is hoped that it not only provides information to the design but also aids you in becoming aware of the numerous daily sounds that effect you and your activities. Thank you for you time and cooperation in participating.

BIOGRAPHICAL INFORMATION

AGE ____________ MALE ☐ FEMALE ☐ OCCUPATION ____________

HEARING LEVEL HARD OF HEARING ☐ NORMAL ☐ ACUTELY SENSITIVE ☐

CIRCLE ONE NUMBER FROM ONE FOR VERY QUIET TO FIVE FOR VERY NOISY FOR THE FOLLOWING FOUR QUESTIONS.

	very quiet		→		very noisy
IS YOUR IMMEDIATE WORK ENVIRONMENT.......	1	2	3	4	5
IS YOUR WORK LOCALITY............	1	2	3	4	5
IS YOUR INNER HOME ENVIRONMENT.........	1	2	3	4	5
IS YOUR HOME NEIBORHOOD............	1	2	3	4	5

WHAT HOURS OF WHAT DAYS ARE YOU NORMALLY HOME? ____________

WHAT ARE YOUR NORMAL WORKDAYS AND HOURS? ____________

WHAT HOURS DO YOUR NORMALLY SLEEP? ____________

WHAT ARE YOUR COMMUTE HOURS? ____________

BY CAR ☐ BY CARPOOL ☐ BY TRAIN ☐ BY BUS ☐ OTHER ☐ ____________

DESCRIBE YOUR FAVORITE SOUNDS AND THEIR SETTINGS.

SOUND	SETTING

DESCRIBE SOUNDS THAT ARE ANNOYING AND INTOLARABLE TO YOU AND WHEN THEY ARE SO.

SOUND	SETTING

SOUND ____________ TIME ________ ____________

SOUND SOURCE ____________ DURATION ________

YOUR ACTIVITY ____________

YOUR LOCATION IN RESPECT TO SOUND ____________

QUALITIES OF SOUND ____________

EFFECTS OF SOUND ON YOU ____________

SOUND ____________ TIME ________ PLACE ________

SOUND SOURCE ____________ DURATION ________

YOUR ACTIVITY ____________

YOUR ACTIVITY ____________

YOUR LOCATION IN RESPECT TO SOUND ____________

QUALITIES OF SOUND ____________

EFFECTS OF SOUND ON YOU ____________

SOUND ____________ TIME ________ PLACE ________

SOUND SOURCE ____________ DURATION ________

YOUR ACTIVITY ____________

YOUR LOCATION IN RESPECT TO SOUND ____________

QUALITIES OF SOUND ____________

EFFECTS OF SOUND ON YOU ____________

SOUND ____________ TIME ________ PLACE ________

SOUND SOURCE ____________ DURATION ________

YOUR ACTIVITY ____________

YOUR LOCATION IN RESPECT TO SOUND ____________

QUALITIES OF SOUND ____________

EFFECTS OF SOUND ON YOU ____________

SOUND ____________ TIME ________ PLACE ________

SOUND SOURCE ____________ DURATION ________

YOUR ACTIVITY ____________

YOUR LOCATION IN RESPECT TO SOUND ____________

QUALITIES OF SOUND ____________

EFFECT OF SOUND ON YOU ____________

BIOGRAPHICAL INFORMATION

AGE 24 MALE ☒ FEMALE ☐ OCCUPATION COMPUTER PROGRAMMER

HEARING LEVEL HARD OF HEARING ☐ NORMAL ☒ ACUTELY SENSITIVE ☐

CIRCLE ONE NUMBER FROM ONE FOR VERY QUIET TO FIVE FOR VERY NOISY FOR THE FOLLOWING FOUR QUESTIONS.

	very quiet				very noisy
IS YOUR IMMEDIATE WORK ENVIRONMENT	1	2	3	4	5
IS YOUR WORK LOCALITY	1	2	3	4	5
IS YOUR INNER HOME ENVIRONMENT	1	2	3	4	5
IS YOUR HOME NEIBORHOOD	1	2	3	4	5

WHAT HOURS OF WHAT DAYS ARE YOU NORMALLY HOME? M 8PM-9AM, Tu 10PM-9AM, W 7PM-9AM, Th 10PM-9AM
F - See Attached

WHAT ARE YOUR NORMAL WORKDAYS AND HOURS? MTWThF 9:30 - 6:00

WHAT HOURS DO YOUR NORMALLY SLEEP? 11:00 - 6:00 AVERAGE.

WHAT ARE YOUR COMMUTE HOURS? 9:30 ← 6:00

BY CAR ☒ BY CARPOOL ☐ BY TRAIN ☐ BY BUS ☐ OTHER ☒ BICYCLE

DESCRIBE YOUR FAVORITE SOUNDS AND THEIR SETTINGS.

SOUND	SETTING
SOUND OF WATER RUSHING (IN A STREAM)	THE HIGH SIERRAS IN A WOODED GROVE AT OR ABOVE TIMBERLINE (I CAN FEEL THE WETNESS)
THE SILENT CRUNCHING OF NEW SNOW BEING SKIED ON	A BRISK DAY IN THE SIERRAS SKIING
THE SOUND OF WAVES BREAKING	THE FOGGY COAST OF CALIF CARMEL.

DESCRIBE SOUNDS THAT ARE ANNOYING AND INTOLERABLE TO YOU AND WHEN THEY ARE SO.

SOUND	SETTING
SOUND OF A V-ENGINE SCREWING UP	DRIVING CAR FAR FROM HOME

SOUND Hum & low roar TIME 1:30 PM PLACE work
SOUND SOURCE Machinery & trucks DURATION all day
YOUR ACTIVITY Working machine & paper work
YOUR LOCATION IN RESPECT TO SOUND 20 ft to 100 ft
QUALITIES OF SOUND various mixed sounds
EFFECTS OF SOUND ON YOU Familiar – soothing

SOUND Dog Barking TIME Night PLACE neighborhood
SOUND SOURCE Dogs DURATION intermittent
YOUR ACTIVITY Sleep
YOUR ACTIVITY
YOUR LOCATION IN RESPECT TO SOUND 100 to several hundred feet
QUALITIES OF SOUND
EFFECTS OF SOUND ON YOU Distant-soothing Close-annoying

SOUND Birds chirping & calling TIME Daytime PLACE neighborhood
SOUND SOURCE Various Birds DURATION intermittent
YOUR ACTIVITY normal everyday activity
YOUR LOCATION IN RESPECT TO SOUND 5 ft to 500 ft
QUALITIES OF SOUND some musical some harsh (crows)
EFFECTS OF SOUND ON YOU Pleasant

SOUND Rumble TIME 12:30 PM PLACE
SOUND SOURCE Train distant DURATION 2 or 3 minutes
YOUR ACTIVITY Sleep
YOUR LOCATION IN RESPECT TO SOUND about 2 miles
QUALITIES OF SOUND Low
EFFECTS OF SOUND ON YOU Nostalgic

SOUND TIME PLACE
SOUND SOURCE DURATION
YOUR ACTIVITY
YOUR LOCATION IN RESPECT TO SOUND
QUALITIES OF SOUND
EFFECT OF SOUND ON YOU

BIOGRAPHICAL INFORMATION

AGE 68 MALE ☐ FEMALE ☐ OCCUPATION Machine Shop

HEARING LEVEL HARD OF HEARING ☐ NORMAL ☒ ACUTELY SENSITIVE ☐

CIRCLE ONE NUMBER FROM ONE FOR VERY QUIET TO FIVE FOR VERY NOISY FOR THE FOLLOWING FOUR QUESTIONS. very quiet → very noisy

IS YOUR IMMEDIATE WORK ENVIRONMENT	1	2	3	4	5
IS YOUR WORK LOCALITY	1	2	3	4	5
IS YOUR INNER HOME ENVIRONMENT	1	2	3	4	5
IS YOUR HOME NEIBORHOOD	1	2	3	4	5

WHAT HOURS OF WHAT DAYS ARE YOU NORMALLY HOME? 5pm to 8am

WHAT ARE YOUR NORMAL WORKDAYS AND HOURS? irregular

WHAT HOURS DO YOUR NORMALLY SLEEP? 8 to 9

WHAT ARE YOUR COMMUTE HOURS? 8am 5pm

BY CAR ☒ BY CARPOOL ☐ BY TRAIN ☐ BY BUS ☐ OTHER ☐

DESCRIBE YOUR FAVORITE SOUNDS AND THEIR SETTINGS.

SOUND	SETTING
Waves - Ocean or Large lake	
Wind in trees - neighborhood or Forest	
Music - pleasant and Soothing not wild or overpowering	

DESCRIBE SOUNDS THAT ARE ANNOYING AND INTOLARABLE TO YOU AND WHEN THEY ARE SO.

SOUND	SETTING
Auto horns and squealing tires - especially when close	
Polititians and other speakers	Telling their lies very loudly and positively over Var(Radio

SOUND Truck in distance TIME 7:00AM PLACE 4 1/2 miles
SOUND SOURCE Truck on Dirt Road DURATION 5-10 min
YOUR ACTIVITY Walking outside
YOUR LOCATION IN RESPECT TO SOUND FARAWAY
QUALITIES OF SOUND Muffled exhaust occasional Rattles Backfire
EFFECTS OF SOUND ON YOU Familiar pleasant

SOUND Stream babbling TIME 7:30 PLACE Stream
SOUND SOURCE Stream running over rocks DURATION Steady
YOUR ACTIVITY Getting Pump ready to start
YOUR ACTIVITY
YOUR LOCATION IN RESPECT TO SOUND Close 2-3 feet
QUALITIES OF SOUND Rocky, mapily babbling
EFFECTS OF SOUND ON YOU Very relaxing - messmemizing

SOUND Small engine TIME 7:35 PLACE Stream
SOUND SOURCE Exhaust from enging DURATION Steady
YOUR ACTIVITY Taking break
YOUR LOCATION IN RESPECT TO SOUND Close 2 to 3 feet
QUALITIES OF SOUND Sootering moving on to smooth quiet Low Rour
EFFECTS OF SOUND ON YOU Reassuring - Familiar

SOUND Hammer noise TIME 8:30 PLACE 1/4 mile away
SOUND SOURCE People building DURATION intermittent
YOUR ACTIVITY Walking
YOUR LOCATION IN RESPECT TO SOUND Above
QUALITIES OF SOUND - Rythmic thud
EFFECTS OF SOUND ON YOU Familiar soothing

SOUND Fire roar TIME 9.00 PLACE House
SOUND SOURCE Stove DURATION Steady
YOUR ACTIVITY Standing by Stove
YOUR LOCATION IN RESPECT TO SOUND Close
QUALITIES OF SOUND Warm mellow muffled roar
EFFECT OF SOUND ON YOU Very pleasing + warming to area

BIOGRAPHICAL INFORMATION

AGE 34 MALE ☐ FEMALE ☒ OCCUPATION mother/farmer/gardener/cook/cleaning lady, etc.

HEARING LEVEL HARD OF HEARING ☐ NORMAL ☒ ACUTELY SENSITIVE ☐

CIRCLE ONE NUMBER FROM ONE FOR VERY QUIET TO FIVE FOR VERY NOISY FOR THE FOLLOWING FOUR QUESTIONS.

	very quiet				very noisy
IS YOUR IMMEDIATE WORK ENVIRONMENT	1	2	3	4	5
IS YOUR WORK LOCALITY	1	2	3	4	5
IS YOUR INNER HOME ENVIRONMENT	1	2	3	4	5
IS YOUR HOME NEIBORHOOD	1	2	3	4	5

WHAT HOURS OF WHAT DAYS ARE YOU NORMALLY HOME? Day & Evening

WHAT ARE YOUR NORMAL WORKDAYS AND HOURS? All day

WHAT HOURS DO YOUR NORMALLY SLEEP? 9pm - 6am

WHAT ARE YOUR COMMUTE HOURS?

BY CAR ☒ BY CARPOOL ☐ BY TRAIN ☐ BY BUS ☐ OTHER ☐

DESCRIBE YOUR FAVORITE SOUNDS AND THEIR SETTINGS.

SOUND	SETTING
6am. Rooster crowing	rural home.
8am. Distant auto movement - signifying to days beginning.	" "
	" "
Distant voices, dogs barking, cows being vocal.	" "
Fire burning	home
Water boiling	home
Hammering etc. (construction)	rural distant

DESCRIBE SOUNDS THAT ARE ANNOYING AND INTOLARABLE TO YOU AND WHEN THEY ARE SO.

SOUND	SETTING
5:45 alarm	home
close dogs barking	"
Sonic Booms	"
Poorly recorded music	"
Distant gun shots	"
Poor running auto OR	" distant

BIOGRAPHICAL INFORMATION

AGE 39 MALE ☐ FEMALE ☑ OCCUPATION minister - musician

HEARING LEVEL HARD OF HEARING ☐ NORMAL ☑ ACUTELY SENSITIVE ☐

CIRCLE ONE NUMBER FROM ONE FOR VERY QUIET TO FIVE FOR VERY NOISY FOR THE FOLLOWING FOUR QUESTIONS.

	very quiet				very noisy
IS YOUR IMMEDIATE WORK ENVIRONMENT	1	2	3	4	5
IS YOUR WORK LOCALITY	1	2	3	4	5
IS YOUR INNER HOME ENVIRONMENT	1	2	3	4	5
IS YOUR HOME NEIBORHOOD	1	2	3	4	5

WHAT HOURS OF WHAT DAYS ARE YOU NORMALLY HOME? 4 1/2 mos in summer - other on road

WHAT ARE YOUR NORMAL WORKDAYS AND HOURS? no constant

WHAT HOURS DO YOUR NORMALLY SLEEP? 10 PM - 6 AM

WHAT ARE YOUR COMMUTE HOURS? any day or night

BY CAR ☑ BY CARPOOL ☐ BY TRAIN ☐ BY BUS ☐ OTHER ☐

DESCRIBE YOUR FAVORITE SOUNDS AND THEIR SETTINGS.

SOUND	SETTING
breeze through trees	anywhere
concerts / worship music	halls or churches
gurgling streams	mountains
waves on shore	ocean
birds	outside
farm animals	where they belong...
radio music	in car especially - not in home or stores, etc.

DESCRIBE SOUNDS THAT ARE ANNOYING AND INTOLARABLE TO YOU AND WHEN THEY ARE SO

SOUND	SETTING
1 - heavy traffic	outside apartment or home
2 - nails on blackboard - fork on plate.	anytime
3 - dentists' drills + cleaners	anytime
4 - jack hammer	anytime
5 - horns honking	in traffic
6 - Muzak	offices, elevators, restaurants, etc

YOUR LOCATION IN RESPECT TO SOUND

QUALITIES OF SOUND

EFFECT OF SOUND ON YOU

SOUND SWISHING BUBBLING TIME 6:AM PLACE ON LAKE MERRIT
SOUND SOURCE WATER RUSHING PAST HULL OF BOAT DURATION 5 MIN
YOUR ACTIVITY ROWING
YOUR LOCATION IN RESPECT TO SOUND JUST ON TOP OF WATER CLOSE BELOW AND BEHIND
QUALITIES OF SOUND SOFT FAST SHARP LOUD BUT QUIET IF NOT CONCENTRATING
EFFECTS OF SOUND ON YOU PLEASENT MAKES ME HAPPY EXCITED A GOOD SOUND.

SOUND "WHISH" TIME 6:15 AM PLACE ON LAKE MERRIT
SOUND SOURCE WATER BEING THROWN UP BY OARS ... FEATHERED TOO SOON DURATION 20 MIN
YOUR ACTIVITY ROWING
YOUR ACTIVITY
YOUR LOCATION IN RESPECT TO SOUND BETWEEN THE SOUND 7 FT AWAY ON EACH SIDE
QUALITIES OF SOUND BACKGROUND QUIET
EFFECTS OF SOUND ON YOU INTELLECTUALLY: FRUSTRATING (MEANS SOMEONE IS ROWING WRONG)
EMOTIONALLY: NEUTRAL.

SOUND RATTLING TIME 4:15 PLACE IN CAR
SOUND SOURCE VW ENGIN DURATION 1 MIN
YOUR ACTIVITY DRIVING CAR
YOUR LOCATION IN RESPECT TO SOUND BEHIND ME FROM CAR ENGIN
QUALITIES OF SOUND LOUD RATTLING
EFFECTS OF SOUND ON YOU ANNOYING AND WORRING

SOUND TIME PLACE
SOUND SOURCE DURATION
YOUR ACTIVITY
YOUR LOCATION IN RESPECT TO SOUND
QUALITIES OF SOUND
EFFECTS OF SOUND ON YOU

SOUND TIME PLACE
SOUND SOURCE DURATION
YOUR ACTIVITY
YOUR LOCATION IN RESPECT TO SOUND
QUALITIES OF SOUND
EFFECT OF SOUND ON YOU

1.

SOUND Talking & music TIME 7 Am PLACE Home

SOUND SOURCE RADIO - AGD DURATION 1 Hour

YOUR ACTIVITY getting it together for another day @ work

YOUR LOCATION IN RESPECT TO SOUND

QUALITIES OF SOUND TALKING AS WELL AS MUSIC - Background noise

EFFECTS OF SOUND ON YOU WAKES my mind up

SOUND hammering TIME 7:30 PLACE home

SOUND SOURCE Neighbors DURATION minutes

~~YOUR ACTIVITY~~

YOUR ACTIVITY Breakfast

YOUR LOCATION IN RESPECT TO SOUND Kitchen

QUALITIES OF SOUND harsh

EFFECTS OF SOUND ON YOU annoying

SOUND running water - hiss TIME 6:30 Am PLACE home

SOUND SOURCE Shower DURATION ½ h

YOUR ACTIVITY Showering

YOUR LOCATION IN RESPECT TO SOUND surrounded by it

QUALITIES OF SOUND pleasant

EFFECTS OF SOUND ON YOU nice feeling

SOUND Office noise TIME 9 - 5 PLACE work

SOUND SOURCE Coworkers talking - background music DURATION all day

YOUR ACTIVITY working

YOUR LOCATION IN RESPECT TO SOUND surrounded by noise

QUALITIES OF SOUND neither + or -

EFFECTS OF SOUND ON YOU NONE

SOUND roar TIME 10 PM PLACE home

SOUND SOURCE airplane DURATION 1 minute

YOUR ACTIVITY reading

YOUR LOCATION IN RESPECT TO SOUND plane out there somewhere - not sure how but within 1 mile probably

QUALITIES OF SOUND ~~[illegible]~~ loud long noise

EFFECT OF SOUND ON YOU

BIOGRAPHICAL INFORMATION

AGE 3[illegible] MALE ☐ FEMALE ☒ OCCUPATION patent [illegible]

HEARING LEVEL HARD OF HEARING ☐ NORMAL ☒ ACUTELY SENSITIVE ☐

CIRCLE ONE NUMBER FROM ONE FOR VERY QUIET TO FIVE FOR VERY NOISY FOR THE FOLLOWING FOUR QUESTIONS.

	very quiet →				very noisy
IS YOUR IMMEDIATE WORK ENVIRONMENT	1	2	3	4	5
IS YOUR WORK LOCALITY	1	2	3	4	5
IS YOUR INNER HOME ENVIRONMENT	1	2	3	4	5
IS YOUR HOME NEIBORHOOD	1	2	3	4	5

WHAT HOURS OF WHAT DAYS ARE YOU NORMALLY HOME? 6PM - 8AM M-F S, [illegible]

WHAT ARE YOUR NORMAL WORKDAYS AND HOURS? 8:30 - 5:15

WHAT HOURS DO YOUR NORMALLY SLEEP? 10PM - 7:30 AM

WHAT ARE YOUR COMMUTE HOURS? 8-8:30 AM 5:15 - [illegible] PM

BY CAR ☒ BY CARPOOL ☐ BY TRAIN ☐ BY BUS ☐ OTHER ☐ ______

DESCRIBE YOUR FAVORITE SOUNDS AND THEIR SETTINGS.

SOUND	SETTING
1. child's laughter	1. anywhere
2. soft music	2. especially enjoy home alone sitting in the dark.
3. wind thru trees	3. in the mountains when everything else is still.
4. complete silence	4. anywhere especially [illegible] side when I can breathe in the natural surroundings

DESCRIBE SOUNDS THAT ARE ANNOYING AND INTOLERABLE TO YOU AND WHEN THEY ARE SO.

SOUND	SETTING
1. loud voices, music	1. during the night
2. noises that are constant such as traffic sounds	2. all the time but especially when I crave a silent time.
3.	

BIOGRAPHICAL INFORMATION

AGE 13 MALE ☐ FEMALE ☒ OCCUPATION student

HEARING LEVEL HARD OF HEARING ☐ NORMAL ☒ ACUTELY SENSITIVE ☐

CIRCLE ONE NUMBER FROM ONE FOR VERY QUIET TO FIVE FOR VERY NOISY FOR THE FOLLOWING FOUR QUESTIONS.

	very quiet				very noisy
IS YOUR IMMEDIATE WORK ENVIRONMENT	1	2	3	4	5
IS YOUR WORK LOCALITY	1	2	3	4	5
IS YOUR INNER HOME ENVIRONMENT	1	2	3	4	5
IS YOUR HOME NEIBORHOOD	1	2	3	4	5

WHAT HOURS OF WHAT DAYS ARE YOU NORMALLY HOME? Babysitting don't have the fi

WHAT ARE YOUR NORMAL WORKDAYS AND HOURS? Babysittin don't have one

WHAT HOURS DO YOUR NORMALLY SLEEP? 9:30

WHAT ARE YOUR COMMUTE HOURS? 8:00, 2:30

BY CAR ☐ BY CARPOOL ☐ BY TRAIN ☐ BY BUS ☐ OTHER ☐ Bycycle

DESCRIBE YOUR FAVORITE SOUNDS AND THEIR SETTINGS.

SOUND	SETTING
Music-band music	school, home.
records	any time except when I study
flute	when I'm playing
rivers	in the woods
birds	forest around house

DESCRIBE SOUNDS THAT ARE ANNOYING AND INTOLARABLE TO YOU AND WHEN THEY ARE SO.

SOUND	SETTING
mother talking too much	everywhere
scratchs on black board	

SOUND music TIME 7:30 PLACE my bedroom
SOUND SOURCE my flute DURATION 20 min
YOUR ACTIVITY playing flute
YOUR LOCATION IN RESPECT TO SOUND right by it
QUALITIES OF SOUND pretty
EFFECTS OF SOUND ON YOU makes me feel good

SOUND train TIME 8:00 PLACE family room
SOUND SOURCE TV DURATION few seconds
YOUR ACTIVITY watching TV
YOUR ACTIVITY
YOUR LOCATION IN RESPECT TO SOUND ≈ 8 ft in front
QUALITIES OF SOUND toot-oo
EFFECTS OF SOUND ON YOU good

SOUND water TIME 8:00 pm PLACE same
SOUND SOURCE TV DURATION few seconds
YOUR ACTIVITY TV
YOUR LOCATION IN RESPECT TO SOUND 8 ft in front
QUALITIES OF SOUND very pretty
EFFECTS OF SOUND ON YOU nice

SOUND singing TIME 8:00 PLACE same
SOUND SOURCE TV DURATION few seconds
YOUR ACTIVITY TV
YOUR LOCATION IN RESPECT TO SOUND 5 ft in front
QUALITIES OF SOUND pretty
EFFECTS OF SOUND ON YOU great

SOUND TIME PLACE
SOUND SOURCE DURATION
YOUR ACTIVITY
YOUR LOCATION IN RESPECT TO SOUND
QUALITIES OF SOUND
EFFECT OF SOUND ON YOU

BIOGRAPHICAL INFORMATION

AGE 14 MALE ☐ FEMALE ☒ OCCUPATION student

HEARING LEVEL HARD OF HEARING ☐ NORMAL ☒ ACUTELY SENSITIVE ☐

CIRCLE ONE NUMBER FROM ONE FOR VERY QUIET TO FIVE FOR VERY NOISY FOR THE FOLLOWING FOUR QUESTIONS.

	very quiet				very noisy
IS YOUR IMMEDIATE WORK ENVIRONMENT	1	2	3	4	5
IS YOUR WORK LOCALITY	1	2	3	4	5
IS YOUR INNER HOME ENVIRONMENT	1	2	3	4	5
IS YOUR HOME NEIBORHOOD	1	2	3	4	5

WHAT HOURS OF WHAT DAYS ARE YOU NORMALLY HOME? 7:00 pm - 7:00 am

WHAT ARE YOUR NORMAL WORKDAYS AND HOURS? 7:45 to 7:00 pm

WHAT HOURS DO YOUR NORMALLY SLEEP? 0:30 - 5:00

WHAT ARE YOUR COMMUTE HOURS? 7:00-7:30 2:45-3:15 pm

BY CAR ☐ BY CARPOOL ☐ BY TRAIN ☐ BY BUS ☐ OTHER ☒ bike

DESCRIBE YOUR FAVORITE SOUNDS AND THEIR SETTINGS.

SOUND	SETTING
1. Rain	1. whenever I like it
2. Nicky's collar	2. whenever

DESCRIBE SOUNDS THAT ARE ANNOYING AND INTOLERABLE TO YOU AND WHEN THEY ARE SO.

SOUND	SETTING
1. Nails scraching on blackboard	classroom
2. Rumbling of an earthquake	2. Anywhere
3. Bells ringing close by	3. school

... Music TIME 9:00 PLACE Bedroom
SOUND SOURCE Radio DURATION 5 min.
YOUR ACTIVITY sleeping
YOUR LOCATION IN RESPECT TO SOUND across the room
QUALITIES OF SOUND good
EFFECTS OF SOUND ON YOU it woke me up

2 SOUND air blowing from vent TIME about every once in PLACE one vent in wall
SOUND SOURCE heater vent DURATION all day
YOUR ACTIVITY miscelaneus
YOUR ACTIVITY "
YOUR LOCATION IN RESPECT TO SOUND I somewhere in a room
QUALITIES OF SOUND its a quiet noise but now know its there
EFFECTS OF SOUND ON YOU when it goes off when you're in bed you notice it wasn't completely quiet before morning

3 SOUND Bed squeeking TIME ... PLACE Bedroom
SOUND SOURCE Bed DURATION between 5 and 15 min
YOUR ACTIVITY getting up or going to sleep
YOUR LOCATION IN RESPECT TO SOUND in bed
QUALITIES OF SOUND when you hear it you think the upper bunk will break.
EFFECTS OF SOUND ON YOU " " " "

4 SOUND Phone ringing TIME whenever it feels like it PLACE family room
SOUND SOURCE Phone DURATION 3-6 rings
YOUR ACTIVITY miscolanious
YOUR LOCATION IN RESPECT TO SOUND somewhere in the house
QUALITIES OF SOUND loud
EFFECTS OF SOUND ON YOU I like it because it might be for me

5 SOUND vacuum cleaner TIME 10:00 am PLACE family room
SOUND SOURCE " DURATION
YOUR ACTIVITY writing
YOUR LOCATION IN RESPECT TO SOUND right next to it
QUALITIES OF SOUND whirring machine sound
EFFECT OF SOUND ON YOU I can't hear the Radio!!

BIOGRAPHICAL INFORMATION

AGE 10 MALE ☐ FEMALE ☐ OCCUPATION student

HEARING LEVEL HARD OF HEARING ☐ NORMAL ☑ ACUTELY SENSITIVE ☐

CIRCLE ONE NUMBER FROM ONE FOR VERY QUIET TO FIVE FOR VERY NOISY FOR THE FOLLOWING FOUR QUESTIONS.

	very quiet				very noisy
IS YOUR IMMEDIATE WORK ENVIRONMENT	1	2	3	4	5
IS YOUR WORK LOCALITY	1	2	3	4	5
IS YOUR INNER HOME ENVIRONMENT	1	2	3	4	5
IS YOUR HOME NEIBORHOOD	1	2	3	4	5

WHAT HOURS OF WHAT DAYS ARE YOU NORMALLY HOME? weekdays 3:00 weekend all day

WHAT ARE YOUR NORMAL WORKDAYS AND HOURS? weekdays 2:00

WHAT HOURS DO YOUR NORMALLY SLEEP? 8:30

WHAT ARE YOUR COMMUTE HOURS? 8:00 - 2:30

BY CAR ☐ BY CARPOOL ☐ BY TRAIN ☐ BY BUS ☐ OTHER ☑ My bike

DESCRIBE YOUR FAVORITE SOUNDS AND THEIR SETTINGS.

SOUND	SETTING
Orchestra Music	Music room, theater.
Quiet	home, Neibohood
bells	ringing for dinner
birds	campground
wind	blowing through trees
waves crashing	ocean
waterfalls - lakes	woods camping

DESCRIBE SOUNDS THAT ARE ANNOYING AND INTOLARABLE TO YOU, AND WHEN THEY ARE SO.

SOUND	SETTING
Errm errrm snow mobil	when I'm skiing
clink clink clink	ice cubes dropping into bin at home
truck roar	on freeway
high pitched whine	any time
finger scratching on a Blackboard	at school

SOUND Squealing TIME 7:15AM PLACE bedroom
SOUND SOURCE ~~[illegible]~~ bed DURATION 2sec
YOUR ACTIVITY making my bed
YOUR LOCATION IN RESPECT TO SOUND in the room
QUALITIES OF SOUND high pitched
EFFECTS OF SOUND ON YOU ~~[illegible]~~ long bother annoys

SOUND swishing low hum TIME 1 feet PLACE family room
SOUND SOURCE Microwave DURATION 30 sec
YOUR ACTIVITY eating
YOUR ACTIVITY
YOUR LOCATION IN RESPECT TO SOUND in the room next to me
QUALITIES OF SOUND low hoom hoom hoom
EFFECTS OF SOUND ON YOU reminds me a meal's coming

SOUND enorm clunk TIME 5:20 PLACE in bedroom
SOUND SOURCE kitchen facett water DURATION 1 min
YOUR ACTIVITY sitting on bedroom floor
YOUR LOCATION IN RESPECT TO SOUND 6 ft in other room
QUALITIES OF SOUND short - liven clunk
EFFECTS OF SOUND ON YOU like it getting ready for dinner

SOUND [illegible] TIME 5:00 PLACE in bedroom
SOUND SOURCE foot DURATION 1 sec
YOUR ACTIVITY talking
YOUR LOCATION IN RESPECT TO SOUND 2½ ft
QUALITIES OF SOUND funny
EFFECTS OF SOUND ON YOU laugh

SOUND ding ding TIME dinnertime PLACE in house
SOUND SOURCE dinnerbell DURATION 5sec.
YOUR ACTIVITY washing my hands
YOUR LOCATION IN RESPECT TO SOUND 20 ft 2 rooms away
QUALITIES OF SOUND sharp happy
EFFECT OF SOUND ON YOU Good happy

BIOGRAPHICAL INFORMATION

AGE 32 MALE ☑ FEMALE ☐ OCCUPATION Farmer

HEARING LEVEL HARD OF HEARING ☐ NORMAL ☑ ACUTELY SENSITIVE ☐

CIRCLE ONE NUMBER FROM ONE FOR VERY QUIET TO FIVE FOR VERY NOISY FOR THE FOLLOWING FOUR QUESTIONS.

	very quiet				very noisy
IS YOUR IMMEDIATE WORK ENVIRONMENT	1	2	3	4	5
IS YOUR WORK LOCALITY	1	2	3	4	5
IS YOUR INNER HOME ENVIRONMENT	1	2	3	4	5
IS YOUR HOME NEIBORHOOD	1	2	3	4	5

WHAT HOURS OF WHAT DAYS ARE YOU NORMALLY HOME? All day except for trips to to[illegible]

WHAT ARE YOUR NORMAL WORKDAYS AND HOURS? Sunrise to Sunset when I work

WHAT HOURS DO YOUR NORMALLY SLEEP? 1 or 2 hours after sunset to sunrise

WHAT ARE YOUR COMMUTE HOURS? Approx 45 min to town

BY CAR ☑ BY CARPOOL ☐ BY TRAIN ☐ BY BUS ☐ OTHER ☐

DESCRIBE YOUR FAVORITE SOUNDS AND THEIR SETTINGS.

SOUND	SETTING
1- Light breeze blowing thru the trees.	1- Sitting out in forest in contemplative mood.
2- Babbling Stream	+ Same as above
3- Rooster crowing at the crack of dawn.	- In bed anticipating a new day,
4- Sound of fire in wood Stove	Cold night
5- Listening to good jazz or music	- Church music - Type Jazz - cloudy day with fluffy white clouds - [illegible] - [illegible] wind - Summer [illegible]
6-	

DESCRIBE SOUNDS THAT ARE ANNOYING AND INTOLARABLE TO YOU AND WHEN THEY ARE SO

SOUND	SETTING
1- Sonic booms	Anytime, esp least expected.
2- Sound of gunshots	Also Anytime.

TABULATION OF UNPLEASANT SOUNDS

These are sounds that causes irritation or other unpleasant feelings when heard by the subjects.

NEARBY TRAFFIC 卌 卌 卌	LOUD ROCK MUSIC 卌 ||	SIRENS ||
SLAMMING DOOR 卌 |	SCREECHING TIRES //	ALARMS //
|| CLOSE AIRPLANES 卌 ||	CAR BACKFIRING //	CROWDS //
PHONE RINGING 卌	LOUD BELLS, BUZZERS ////	SNORING //
REFRIGERATOR HUM ||	NEARBY YELPING, BARKING DOGS 卌 卌 ||	
LOUD TALKING 卌 卌	CONVERSATION IN A QUIET LIBRARY //	
SONIC BOOMS 卌 |	NAILS ON BACKBOARD 卌 |	JACK HAMMER |
RADIO, TV STATIC 卌 |	MACHINERY NOISES |||	MOTORCYCLE ///
CAT FIGHTS |	CRYING BABIES /	THUDS /
DISC DING MUSIC /	SOMEONE ELSE'S MUSIC /	GUNSHOT //
AUTO HORNS ///	CAR NOISES MEANING THERE'S SOMETHING WRONG 卌 卌	
VACUUM CLEANERS ///	DRIPPY FAUCET ///	HEATER NOISES ////
TV AND RADIO TALK SHOWS 卌|||	CLOCK TICKING /	BOWLING ALLEY /
WATER PUMPS ///	HAIR DRYERS //	SKATEBOARDS /
CHEWING ON ICE /	SOMEONE ELSE'S LOUD TV OR RADIO 卌 |	
LAWN MOWERS AND POWER TOOLS 卌	SQUAWKING BIRDS /	TEETH SCRAPING /
KEYPUNCH AND PRINTER CHATTER ///	THUMPING BASS ///	
LOUD COUNTINUEOUS NOISES ||	GARBAGE TRUCKS //	COUGHING /
DENTIST DRILL /	DOG SCRATCHING HIMSELF /	CITY NOISES /
RUMBLE OF EARTHQUAKE /	HIGH WIND /	CREAKING TREES /
STORM BY SEA /	SNOW MOBILES IN QUIET /	HAMMERING /
BREAKING GLASS /	HISSING CB /	EXPLOSIVES /
UPPER BUNK SQUEAKING /	HIGH PITCHED WHINES /	
MOTHER TALKING TOO MUCH /	MICROWAVE ALARMS /	TRAIN ROAR /
OFICE SOUNDS /	CHAIN SAW BUZZ /	CONSTRUCTION CLANK /
CONSTRUCTION ROAR /	SQUEAKY CHAIRS IN QUIET /	CHICKENS /
HIGH SQUEALS OF KIDS /	LOUD CLICK IN EMPTY HALL /	TEAM MATE ROWING WRONG /

(FROM THE PEOPLE EMPLOYED AT NASA AMES CENTER)

LOW FREQUENCY RUMBLE /	WIND TUNNELS ///	HIGH PITCHED WHISTLE ////
RUMBLING ///	HISSING //	

TABULATION OF INDIFFERENT SOUNDS

These sounds were tuned out or not noticable in the opinion of the 25 subjects.

RADIO MUSIC //
OFFICE NOISE //
OWN TYPING //
HEATER BLOWER ///
CLOCK HUMMING /
DOG WALKING ON FLOOR /
SOME ELSE'S SHOWER //// DISHWASHER / CLOCK CLICKING /
IRON SWISH / GAS PUMP / CLOCK HUMMING /
DISTANT CONVERSATION //// MECHANICAL CHATTER /// CROWD // slipping
TRAIN WHISTLE / HOOT OWLS / DRIVING A TRUCK /
TRAFFIC ////
ROAR OF AIRPLANE PERSON IS TRAVELING ON /
RAKING OUTSIDE / PLANE WHINE / RINGING PHONE /
RUSHING AIR FROM OUTSIDE PLANE / ANIMAL NOISES /
REFRIGRATOR HUM // RATTLE OF WORK / DISTANT DRONE /
PUMPING LIQUID FROM TRUCK / AIR CONDITIONING /
CARS ON WET PAVEMENT // DOOR CLOSING CLICK /
SON IMATATING ANIMAL NOISES / RUSTLING OF PAPER /

TABULATION OF PLEASANT SOUNDS

Sounds heard by twenty-five subjects over approximately two day periods, which were pleasant and produced "good feelings".

SOFT MUSIC 𝍸 𝍸 𝍸 |
BIRD SONGS 𝍸 𝍸 ||
OCEAN WAVES 𝍸 𝍸 ||
RAIN(DRIPPING SNOW) 𝍸 𝍸
STREAMS; WATERFALLS 𝍸 𝍸 |||
LAPPING LAKES ||||
SHOWER 𝍸 |||
BREEZE IN THE TREES 𝍸 𝍸 𝍸
MECHANICAL NOISES AND HEATER 𝍸 ||
CRICKETS ||
ROCK MUSIC 𝍸 |
DUCKS AND ROOSTER ||||
SUMMER NOISES ||
DISTANCE TRAIN WHISTLE |||
LIVE MUSIC ||
COOKING FOOD ||||
DISTANT PLANE DRONE ||
DISTANT CARS AND TRUCKS ||||

PEOPLE IN CONVERSATION ||||
PINK, MODULTED NOISE ||
SKIING ON SNOW |
GURGLING COFFEE POT |||
CUCKOO CLOCK |
ANIMAL SOUNDS 𝍸
SILENCE 𝍸
LAUGHTER OF CHILDREN 𝍸
TV AND RADIO PROGRAMS OF OWN CHOICE ||||
TINKLING ICE CUBES |
FIRE IN FIREPLACE ||||
DISTANCE HAMMERING ||
WOOD CHOPPING |
DISTANT CHAIN SAW |
BELLS 𝍸
FROGS ||
JET TAKE-OFF |

USING THE AWARENESS QUESTIONNAIRE AS A BASES FOR A QUANTITATIVE STUDY

Based on the sounds that the subjects have indicated they were aware of in their daily lives from the sound awareness poll, the following study would attempt to quantify and arrange the list of sounds on a scale of pleasantness to unpleasantress.

A number of sounds found common to daily living and work situations would be recorded on a high fidelity tape. The ubjects would listen in a quiet room either in a group or by temselves or a combination of the two situations. They would then answer a set of questions on each sound. This would allow the subject to identify the sound and make a judgement as to its properties from his own associative perception while allowing for him to rate it on a scale that could be used statistically.

Following is a possible paradignm of questions.

What is the sound?
Where would you normally hear it?

	1	2	3	4	5	6	7
Is it loud?	very loud			moderate			very soft
Is it pleasant?	intolarable	very annoying	slightly annoying	indifferent	acceptable	pleasant	very enjoyable

Some of the sounds that might be included and used for the scaling.

Music; quiet, loud, various types, singing, practicing, Voices; soft, loud, childrens, laughter, distant, singing, arguments, crying, commericals, talk shows, discussions, crowds, various moods etc., Animals; barnyard, dogs, birds of various kinds, insects, wild, Water; ocean waves, streams, faucets, drippy faucets, shower, waterfall, rain,lake lapping, etc., white noise in various ranges; Machinery noises, loud, distant, one, many, different frequencies, home appliances, auto noises, heaters, aircondioners, etc., Work sounds; hammering, sawing, dishes, cooking, etc., Natural; wind, leaves, indect humming,thunder, water, etc., Alarms, Sirens, Non descript; scraping, scratching, footfall, whines, creaks, squeals, etc.,

BIBLIOGRAPHY

Prime sources are annotated.

"Acoustical Foam Improves Machinery Enclosure Performance." Sound and Vibration 12 (September 1978): 7.

Akins, Faren R. "Isolation and Confinement: Consideration for Colonization." Reprinted at NASA Ames CA, n.d.

Allen, D.C. "Noise Categories and Aspects of Teaching." Ph.D. dissertation, University of Arizona, 1972.

Allen, William H. ed. Dictionary of Technical Terms for Aerospace Use. Washington D.C.: NASA, 1965.

Alberts, Vernon M. The World of Sound. South Brunswick, New York: A.S. Barnes and Co., 1970.

Ament, Robert. "Comparison of Delphi Forecasting Studies," Futures 2 (1970): 35-44.

Anthrop, Donald F. Noise Pollution. Lexington, Mass.: Lexington Books, 1973.

Bell, David E.; Keeney, Ralph L.; and Raiffa, Howard. Conflicting Objectives in Decision. New York: John Wiley and Sons, Inc., 1977.

Beranek, Leo Leroy, Acoustic Measurements. New York: John Wiley, Inc., 1940.

Beranek, of the firm, Bolt, Beranek and Neuman, is considered the leading authority on acoustical control.

———. Noise Reduction. New York: McGraw-Hill Book Co., 1960.

———. Music, Acoustics and Architecture. New York: John Wiley and Sons, Inc., 1962.

———. Noise and Vibration Control. New York: McGraw-Hill Book Co., 1971.

Beranek, Leo Leroy, and Peterson, Arnold P. Handbook of Noise Measurement. Cambridge, Mass: General Radio, 1954.

Bergoust, Erik. Space Colonization. New York: G. P. Putman's Sons, 1978.

Berglund, B.; Berglund, U.; and Lindwall, T. "Scaling Loudness, Noisiness and Annoyance of Community Noises." Journal of the Acoustical Society of America. (November 1976): 1119-1125.

Berlund, Theodore. The Fight for Quiet. Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1970.

Billingham, John. "Physiological Parameters in Space Settlement Design." Proceedings of the Third Princeton/ AIAA Conference on Space Manufacturing Facilities, 1977. (Princeton, N.J.), Washington D.C.: NASA, 1979.

Billingham, John; Gilbreath, William; and O'Leary, Brian, ed. Space Resources and Space Settlements, Technical papers derived from 1977 Summer Study at NASA Ames Research Center, Moffett Field, California. Washington D.C.: NASA, 1979.

Bluth, B.J. "Alternative Social Structures in a Vacuum," The Industrialization of Space, 961-981. San Diego: Univelt, 1978.

Bock, Edward; Lambrou, Fred, Jr.; and Simon, Michael. "The Effect of Environmental Parameters on Habitat Structural Weight and Cost." n.p.; n.d. (circa 1976).

Bock, Edward; Lambrou, Fred, Jr.; and Simon, Michael. Habitat Design--An Update." The Industrialization of Space, 575-590. San Diego: Univelt 1978.

Boulding, Kenneth E. "General Systems Theorv-The Skeleton of Science," In Modern Systems Research for the Behavioral Scientist, 3-10. Edited by Walter Buckley. Chicago: Aldine Pub. Co., 1971.

Bragdon, Clifford R., and Miller, Richard K. "Regulation and Control of Animal Noises in the Community." Sound and Vibration 12 (December 1978): 8-11.

Breeuwer, R., and Trucker, J.C. "Resilient Mounting Systems in Buildings." Applied Acoustics 9 (April 1976): 77-101.

Britton, Peter. "How Science Makes War Against Noise." Poplular Science (February 1980): 43.

Broadbent, D.E. Decision and Stress. New York: n.p., 1971.

Brody, J. "Noise Can Make You Ill: on the Job, at Home, Even While Asleep." San Jose Mercury, 10 April 1979.

Buckley, Walter, ed. Modern Systems Research for the Behavioral Scientist. Chicago: Aldine Pub. Co., 1971.
Definitions and models of systems as used by the social and psychological sciences.

Cain, William S., and Mark, Lawrence E. Stimulus and Sensations. Boston: Little, Brown and Co., Inc., 1971.

Canter, David; Stringer, Peter; Griffiths, Ian; Boyce, Peter; Walters, David; Cheryl, Kenny. Environmental Interaction--Psychological Approach to Our Physical Surroundings. New York: International University Press, Inc., 1975.

Carroll, M.M., and Miles, R.N. "Steady-State Sound in an Enclosure with Diffusely Reflecting Boundary." Journal of the Acoustical Society of America 64 (November 1978): 1424-1428.

Chadwick, Jones et. al. Urban Environment and Social Psychology. Baltimore: University Park Press, 1979.

Cheston, Stephen. "Low Profile Approach to Social Science Study of Space Industrialization, Space Manufacturing Facilities and Space Settlements." n.p., n.d.

Corso, John F. The Experimental Psychology of Sensory Behavior. New York: Holt, Rinehart, and Winston, Inc., 1967.

"County Considers Noise Bill." San Jose Mercury, 2 June 1980.

Croome, D.J. "Predicting the Sound Emission from Air Conditioning and Ventilating System." Applied Acoustics 9 (October 1976): 303-315.

Crosby, Andrew. Creativity and Performance in Industrial Organizations. New York: Tavistock Publications, 1968.

Cybernetic Systems Teams of 230--Spring 1975 and Spring 1976. "If I Had a Hammer and Other Tools--A Systems Tools Handbook." San Jose State University, January 1977.
A complete coverage of the use of a wide variety of methods of cybernetic modelling.

Dauw, Dean C., and Frederick, Alan J. Creativity and Innovation in Organizations--Application and Exercises, 2nd ed. Dubuque, Iowa: Kendall/Hunt Pub. Co., 1974.

Davis, H. "Effects of High-Intensity Noise on Navel Personnel." U.S. Armed Forces Medical Journal 9 (1958): 1027-1048.

Dickerson, Steven L., and Robertshaw, John E. Planning and Design--The Systems Approach. Lexington, Mass.: Lexington Books, 1975.

Dubos, Rene'. Torch of Life--Continuity in Living Experiences. New York: Trident Press Book, Simon and Schuster, 1962.

Duerden, C. Noise Abatement. London: Butterworth, 1970.

Farbstein, Jay, and Kantrowitz, Min. People in Places--Experiencing, Using and Changing the Built Environment. Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1978.

Farrenkopf, Toni. "The High Frontier for Psycho-Social Engineering." Paper presented at Symposium on Extraterrestrial Anthropology, California State University, Los Angeles, April 1978.

Furrer, Willi. Room and Building Acoustics and Noise Abatement. London: Butterworth, 1964.

Glaeser, Ludwig. "Architectural Studies for a Space Habitat." Proceedings of Space Manufacturing Facilities--Space Colonies. NASA Conference, May 7-9, 1975, New York: AIAA Inc., 1977.

Glass, David C., and Singer, Jerome. Urban Stress--Experiments on Noise and Social Stressors. New York: Academic Press, Inc., 1972.
A directed study of noise pollution on psychological and social behavior of city dwellers.

Glorig, Aram, M.D. "Industrial Noise." Accident Prevention Manual for Industrial Operations. 5th edition, Washington D.C.: National Safety Council, n.d.

Gordon, William. J.J. Synetics, The Development of Creative Capacity. New York: Harper and Brothers, 1961.

Greenwood, William T. Decision Theory and Information Systems. Cincinnati, Ohio: South-Western Pub. Co., 1969.

Grey, Jerry, ed. Space Manufacturing Facilities--Space Colonies. Proceedings of Princeton/AIAA/NASA Conference, May 1975. New York: AIAA Inc., 1977.

Gunsfield, Joseph R. Community--A Critical Response. New York: Harper and Row Publishers, Inc., 1975.

Hawke, Joanne. "Pirsig's Journey, Quality, Philosophy, and Our Technological Society." Term paper for Cybernetics 200, San Jose State University, Fall 1978.

Hawke, R.S.; Brooke, A.L.; Fowler, C.M.; and Peterson, D.R. "Electromagnetic Railgun Launchers; Space Propulsion and Applications." Preprint of 1981 International Electric Propulsion Conference presentation. Livermore, CA: Lawrence Livermore Laboratories, 1980.

Heppenheimer, T.A. Colonies in Space. Harrisburg, PA.: Stockpole Books, 1977.

Innovation Staff, ed. Decision Making in a Changing World--Book of Essays from "Innovation." New York: Academic Press, Inc., 1970.

Johnson, Richard, and Holbrow, Charles, ed. Space Settlements; A Design Study. Washington D.C.; NASA, 1977.

Authored by participants of 1975 Summer faculty fellowship program in engineering systems design--NASA; American Society for Engineering Education; Ames Research Center and Stanford University. A collection of detailed studies and imaginative models of various space colony factors: mechanical, social, economical, and psychological.

Jones, Christopher J. Design Methods--Seeds of Human Futures. New York: Wiley Interscience, 1970.

Jones, Rober. "How to Design Walls for Desired STC Ratings." Sound and Vibration 12 (August 1978): 14-17.

________. "How to Accurately Predict the Sound Insulation of Partitions." Sound and Vibration 10 (June 1976): 14-25.

Kerrick, Jean S.; Nagel, David C.; and Bennett, Ricarda L. "Multiple Rating of Sound Stimuli." Journal of the Acoustical Society of America 45: 1014-1017.

Kerry, Mark Joels. "Space Industrialization Education." The Industrialization of Space.

Krishnappa, G. "Some Experimental Studies on Centrifugal Blower Noise." Noise Control Engineering 12 (March/April 1979): 82-90.

Kryter, K.D. The Effects of Noise on Man. New York: Academic Press, Inc., 1970.

Laird, D.A., and Caye, K. "Psychological Measurements of Annoyance as Related to Pitch and Loudness." Journal of the Acoustical Society of America 1 (1929): 15-21.

Lamb, Horace, Sir. The Dynamic Theory of Sound. London: Edward Arnold, 1931.

Lapin, Lawrence L. Statistics for Modern Business Decision. New York: Harcourt Brace Jovanovich, Inc., 1973.

Lawrence, Anita. Architectural Acoustics. New York: Elsevier Pub. Co., 1970.

Lundin, Kjell, "Noise Control in a Newspaper Pressroom." Noise Control Engineering 12 (March/April, 1979): 53-59.

MacCrimmon; Kenneth R., and Wehrung, Donald A. "Trade-off Analysis--The Indifference and Preferred Proportions Approaches." In Conflicting Objectives in Decisions. New York: John Wiley and Sons, Inc., 1977: 253-265.

McGraw, Michael G. "Working Smarter Not Harder--Goal of Method Study." Electrical World 91 (1 January 1979): 49.

Mack, Roger, Dr., and Culliman, Terrence. "Space Community Planning. In a Down to Earth Context." Industrialization of Space, 983-995. San Diego: Univelt, 1978.

Martino, Joseph, ed. Technology Forecasting for Decision Making. New York: Gordon and Breach Science Pub., 1972.

Maruyama, Magoroh. "Design Principles and Culture," The Industrialization of Space, 949-959. San Diego: Univelt, 1978.

Mehrabian, Albert. Public Places and Private Spaces. Psychology of Work, Play and Living Environments. New York: Basic Books, 1976.
In-depth studies and a personal statement on the public and private needs of humans.

Mischke, Charles R. An Introduction to Computer-Aided Design. Englewood Cliff, N.J.: Prentice-Hall, Inc., 1968.

Mitroff, Ian I., and Turoff, Murray. "The Whys Behind the Hows." IEEE Spectrum (March 1973): 62-71.
Philosophical backgrounds to the basic divergent assumptions and beliefs of researchers and scientists.

Morse, Philip M. Vibration and Sound. New York: McGraw-Hill Book Co., Inc., 1948.

Muzak, Research Reports on Functional Music. New York: Muzak Corporation, n.d. (circa 1969 or 1970).

NASA Activities. (January 1977-July 1980).
News stories of current space research of the National Aeronautics and Space Administration throughout the United States.

NASA Astrogram. (January 1977-July 1980), Ames Research Center Newsletter, Moffett Field, CA.
Prime source of immediately current space research progress.

Navarra, John Gabriel. Our Noisy World. Garden City, New York: Doubleday and Co., Inc. 1969.

NIOSH (National Institute for Occupational Safety and Health of the US Health, Education and Welfare Dept. Compendium of Materials for Noise Control. directed by Ernest Purcell.) Washington D.C.: HEW, 1975.
A pragmatic documentation of noise indexes, figures, and tables, as well as basic equations, for acoustical construction materials.

O'Keefe, Edmund. "Physical and Acoustical Properties of Urethan Foam." Sound and Vibration 12 (July 1978): 16.

O'Neill, Gerard K. The High Frontier. New York: William Morrow and Co., Inc., 1977.
A popular account of scientific advances into space pioneering.

Osgood, Charles E. The Measurement of Meaning. Urbana, Ill.: University of Illinois, 1957.

Owens/Corning Fiberglass. Owens-Corning Commercial Interior Products. Toledo, Ohio: Owens-Corning Fiberglass Corp., 1979.

Peterson, Arnold P.G., and Gross, Ervin E., Jr. Handbook of Noise Measurement. 5th ed. West Concord, Mass.: General Radio Co., 1963.

Complete coverage of techniques and details of sound measurements for the professional and layperson.

Pirsig, Robert. Zen and the Art of Motorcycle Maintenance. New York: Bantam Books, 1974.

Prinie, George M. The Practice of Creativity. New York: Harper and Row Pub., Inc., 1970.

Proshansky, Harold M.; Ittelson, William H.; and Revlin, Leanne, eds. Environmental Psychology. People and Their Physical Setting, 2nd ed. New York: Holt, Rinehart and Winston, 1976.

Good sampling of studies of the psychological responses of people to a wide variety of environments.

Purcell, W.E. "Materials for Noise and Vibration Control." Sound and Vibration (July 1976): 6-33.

Rapoport, Anatol. Conflict in Man-Made Environment. Baltimore, Maryland: Penguin Books, 1974.

Reed, V.F. "The Sounds All Around Us." San Jose Mercury News, 10 April 1979.

Rosen, Stanley, Capt. USAF. "Part I. How NASA and Advisers to Astronauts See Psychological Change." Newsletter of the National Space Institute. (December 1976).

Ross, Helen E. Behavior and Perception in Strange Environments. London: George Allen and Unwin Ltd., 1974.

Rudoff, Alvin. "Space Sociology, A Terrestrial Perspective: Public Perceptions of the Space Program." n.p., n.d. (circa late 1977).

Ruzic, Neil P. Where the Winds Sleep. Garden City, New York: Doubleday and Co., Inc., 1970.

Sabine, Wallace Clement. Collected Papers in Acoustics. New York: Dover Pub. 1964.

Salkeld, Robert. "Towards Men Permanently in Space." Astronautics and Aeronautics (October, 1979): 60-67.

Scharf, Bertram, and Reynolds, George S., eds. Experimental Sensory Psychology. Glenview, Ill.: Scott, Foresmen Co., 1975.

Scheshter, Howard R. "Economical Solutions to Community Noise Problems." Sound and Vibration 12 (September 1978): 20-22.

Selye, Hans, M.D. The Stress of Life, revised ed. New York: McGraw-Hill Book Co., 1976.

Serxner, Jonathan L. "An Experience in Submarine Psychiatry." American Journal of Psychiatry 125 (July 1968): 25-30.

Sharp, Ben H. "A Study of Techniques to Increase the Sound Insulation of Building Elements." Hud Contract H-1095. Springfield, VA: Clearinghouse for Federal Science and Technical Information., n.d.

Sheffield, Charles. Keynote address given at the Industrialization of Space Conference at the San Francisco Airport Hilton/AAS, 7 October 1977. (Also preface of The Industrialization of Space Conference Proceedings, x).

Shelly, Stanton H. "Developing a Successful Municipal Noise Control Program." Sound and Vibration 12 (December 1978): 12-14.

Smith, B.J. Environmental Physics: Acoustics. New York: American Elservier Pub. Co., 1970.

Smith, David, ed., and Mc Carthy, John F., Jr., Professor. "A Systems Design for a Prototype Space Colony." (Student Project in Systems Engineering, Spring 1976. Oscar Orringer, Lecturer). MIT Mass., n.d.
An excellent example of a systems approach to the design of a prototype space enclosure.

Steward, George Walter, PhD., and Lindsay, Robert Bruce, PhD. Acoustics. New York: D. Van Nostrand Co., Inc., 1930.

Swets, John A., ed. Signal Detection and Recognition by Human Observers. New York: John Wiley and Sons, Inc., 1964.

Tripp, Ralph H., and Stotz, John K., Jr. ed. Space Technology Transfer to Community and Industry. Proceedings of AAS 18th Annual Meeting and 10th Goddard Memorial Symposium, (March 13-14, 1972, Washington D.C.). Tarzana, CA: AAS Pub. Office, 1972.

Ursin, Holger; Eivind, Baade; and Levine, Seymore, ed. Psychobiology of Stress. A Study of Coping Men. New York: Academic Press, Inc., 1978.

USEPA Office of Noise Abatement. Noise Control Program, Progress to Date. Washington D.C.: USEPA, 1979.

USEPA Office of Noise Abatement. Model Noise Control Ordinance. Washington D.C.: USEPA, 1972.

US Gypsum. Sound Control in Design. n.p., 1959.

Van Putten, Richard A.; Siegler, Paul; and Stearns, E.V.B. The Industrialization of Space Parts I and II. Proceedings of the American Astronautical Society 23rd Annual Meeting. San Francisco, CA., October 18-20, 1977. San Diego: Univelt, Inc., 1978.

A comprehensive collection of conference presentations of the Society of American Astronautical and Aeronautical Engineers, covering a broad segment of disciplines and interests involved in space expansion in the hard and soft sciences. The collection covers such subjects as the transport vehicles; space structures; life-support systems; industrial, economical, and commercial developments; community-social structures and activities; the psychological effects of space pioneering; and philosophy and aesthetics.

The conference presented space pioneering as an exciting humanistic pioneering development that has already begun and is thrusting into a brighter, expansive future, just over the horizon.

Vernon, Jack A. "The Other Noise Damage: Tinnitus." Sound and Vibration 12 (May 1978): 26.

Von Braun, Mernker, Dr. Space Frontier. New York: Holt, Rinehart and Winston, 1967.

Watson, F.R. Acoustics of Buildings. New York: Wiley and Sons, Inc., 1930.

Welch, Bruce L., and Welch, Annamarie S. Physiological Effects of Noise. New York: Plenuim Press, 1970.

West, M. "The Effects of Furniture and Boundary Conditions on the Sound Attenuation in a Landscaped Office--Part One." Applied Acoustics 8 (January 1975): 43-66.

White, Frederick. Our Acoustical Environment. New York: John Wiley and Sons, Inc., 1975.

A prime source of basic acoustical information from all aspects.

The basic physics, measurements, areas of general concern, legalities, and psychoacoustics are all treated scientifically in everyday language comprehensable to the layman.

Wilson, Jon. "Noise Suppressing and Prevention in Piezo-electric Transducer Systems." Sound and Vibration 13 (April 1979): 22-25.

Wilson, Richard H.; Steckler, Jane F.; and Jones, Howard C. "Adoptation of the Acoustical Reflex," Journal of the Acoustical Society of America 64 (September 1978): 782-787.

Wood, Alexander. Acoustics. New York: Dover, 1966.

Zaltman, Gerald; Duncan, Robert; and Holbrek, Jonny. Innovation and Organization. New York: Wiley, 1973.

Ziegler, Warren. "A Preliminary Investigation of Space Habitat Atmospheres." The Industrialization of Space, 983-995. San Diego: Univelt, 1978.

Zuckerman, M.; Persky, H.; Link, K.E.; and Basu, G.K. "Experimental and Subjective Factors Determining Responses to Sensory Deprivation, Social Isolation and Confinement." Journal of Abnormal Psychology 73 (1968): 183-194.

Interviews

Arno, Roger. Aeronautical/Economics Engineer, NASA Ames Research Center. On the "Economics of a Space Structure." Moffett Field, CA. Fall 1979.

Connors, Mary. Psychologist and Space Engineer, NASA Ames Research Center. On the "Trends of the Space Thrust." Moffett Field, CA. Fall 1977.

Dods, Jules. Aeronautical Engineer, NASA Ames Research Center. On the "Acoustics of Aerodynamic Structures." Moffett Field, CA. Fall 1979.

Freytag, Jack. Acoustical Researcher & Designer, Bechtel. On the "Acoustics of Manmade Designs, Structural and Mechanical." San Francisco, CA. November 1979.

Gilbreath, William. Astronautical Engineer, NASA Ames. On the "Space Program Research Being Done at Ames and elsewhere." Moffett Field, CA. Spring 1980.

Geer, Ed. Acoustical Ceiling Installer. On the "Properties and Make-Up of Acoustical Ceilings." Cupertino, CA. May 1980.

Hawke, Ronald. Electronic Engineer, Livermore Lawrence Labortories. On "Electronic Acoustics." November 1979-Spring 1980.

Johnson, Richard. Director Astro-life Sciences, NASA Ames. On the "Possible Scenarios of a Space Colony." Moffett Field, CA. Summer 1979.

Knecktel, Earl. Aeronautical Engineer, NASA Ames. On the "Steady State Equation of a Noisy Enclosure." Winter 1980.

Moore, Sherman. Auditor/Investigator, General Accounting Offices. On the "Use of Subjective Information from Questionnaires as Data." November 1979.

Morris, Robert. High-Altitude Flight Engineer, NASA Ames. On the "Qualities of Sound at High Altitudes." Moffett Field, CA. December 1979.

Pearson, Karl. Acoustical Engineer, Bolt, Berenak and Newman. On the "Sources of Acoustical Data and Measurements." Canoga Park, CA. August 1979.

Probasco, Preston. Professor and Director in Cybernetic Systems and Business, San Jose State University. On the "Organization of a Space Colony Project." San Jose. Many times from 1978-1980.

Rogers, William. Architectural/Acoustics Engineer, NASA Ames. On the "Acoustical Properties of Interiors." Moffett Field, CA. October 1979.

Taylor, Herb. Sound Director, Disney Productions. On the "Propagation and Psychological Effects of Sounds." Burbank, CA. August 1979.

Woodgran, Ross. Acoustics of Owens/Corning. On the "Acoustical Properties of Fiberglass and the Probabilities of Its Being Produced in Space." San Francisco, CA. Spring 1980.