U. S. NAVAL SCHOOL OF AVIATION MEDICINE
U. S. NAVAL AVIATION MEDICAL CENTER-54
PENSACOLA, FLORIDA

IN REPLY REFER TO
341/sfh
23 October 1964

Dr. Sherman P. Vinograd
Chief, Medical Science & Technology
Space Medicine
Office of Manned Space Flight
National Aeronautics and Space Administration
Washington, D. C. 20546

Dear Sherm:

Thank you very much for arranging an invitation to the NASA C.N.S. and C.V. Data Symposium. It was very nice of you to go to so much trouble for me. I have discussed this with Dr. Graybiel and while he feels that it would be very nice for me to attend, he feels it would be wrong for me to miss the opportunity of recording zero gravity ECG's this week at Wright-Pat. This is especially true since there may be difficulty on the first two days and the only days I can count on are the 29th and 30th.

Thank you again. I really appreciate it and as you know I would love to hear the latest on computer analysis of cardiovascular data. Please drop me a line when you get a chance to come down.

Sincerely yours,

NEWTON W. ALLEBACH
CAPT, MC, USN

Copy to:
Dr. F. B. Voris, NASA
Dr. W. Jones, NASA
Dr. L. D. Proctor, General Chairman

P.S. I was lucky and got a ride back Navy. Should I drive C.W.U. or can you take care of it? Thanks
M.

SIMULATION

AN ADDRESS BY

DR. E. J. MCLAUGHLIN, PH.D.
28 October 1964

at

GEORGE WASHINGTON UNIVERSITY

Frasier ( ) states, "The art of simulation is neither new nor is it confirmed to the design and use of complex electromagnetic devices intended for training and research purposes. In fact, in its broadest sense it has existed since man drew his first picture in the sand, or made his first model out of clay, and it has developed through the skills of the artist, the actor, the set-designer, the illusionist, and more recently the information theorist, the psychologist, the mathematician, and the engineer."

In a search for a working definition, we can begin with the most general and simple expression taken from Webster of Webster Dictionary: "Simulate: To assume the appearance of without the reality"

Focusing on the particular application of simulation to Man-Machine

elements of a space system, we find three definitions, each pertinent and each with a different focus of attention. (Slide #1) Redgrave ( ) presents a broad definition of simulation as a representation, or technique, which transforms, either iconically (as a representation or symbol) or by abstraction, selected aspects of the real world out of their resident framework into a form more convenient for the purpose of the analyst. A second and somewhat more specific definition is offered by Ruby et al ( ) as the representation of the characterists of a system for the purpose of evaluating the performance of that system under various conditions.

A third definition, presented by Westbrook ( ) states that simulators are facilities which allow an analog representation of a particular control element, combination of control elements, or a complete flight-control-airframe- pilot system. Fraser's consolidation of these ideas into the following definition appears reasonable, " Simulation is the art and science of representing the essential elements of a system out of their normal setting in such a manner that the representation is a valid analog of the system under study." Representation is the element which is herein stressed;

however, the purposes and uses of simulation are not limited by the description. So when we talk about simulation, we speak of something which represents the real situation. (Slide #2) Here is a statement which expresses the purpose of simulation.

Theory involved in Man-Machine Simulation:

In man-machine simulation we are concerned with the integration of the man with the machine and an evaluation of some sort regarding that integration. I use "integration" here in an extremely broad sense. The simulation model, the representation of the real world elements, chosen for such an appraisal may be abstract, as a mathematical representation of the human response to impact, acceleration, etc., or it may be concrete, as it would be in the mock-up of a cabin design. The model may be static, as in the case of a display panel or a food compartment mock-up, or it may be dynamic, as would be seen for example with the human centrifuge or six-degree-of-freedom integrated motion simulator.

Obviously, it is not difficult to conduct a static-type study as would be the case in presenting a mock-up of a display panel to determine the

optimum positioning of specific displays. The problems become increasingly complex as more and more dynamic characteristics are included in the simulation model. A series of fairly elaborate mathematical equations are generally adequate to express the dynamic responses characteristic of the machine. (Slide #3) (Slide #4) This slide demonstrates the flow of movement of a complext, integrated piloted flight simulator: A task is presented to the pilot. The pilot executes a control action and this action is then reflected, by means of computers, in the dynamics of the control system , the vehicle dynamics and the flight instruments. The resultant vehicle response may modify the pilot environment, eg in the case of acceleration, and further imparts both motion cues and external visual field information. The data from all of these sources are available to the pilot, thus providing him with feedback information on the effects of his response. Depending upon the criteria established, and his knowledge of them, he can then judge the adequacy of his response in relation to the task presented to him. To reflect desired degrees of information to the operator (pilot) requires that the simulator be equipped to display and reproduce data of varying degrees, such as operative displays and controls, a realistic physical environment,

and even degrees of motion. It is critical to realize therefore, that, as stated, by McNally ( ) that an operation can be simulated only to the extent that it can be defined in a manner suitable for programing, and also that the simulation equipment has its own characteristics which are further imposed upon those of the operations simulated. Both of these points are critical. If the first cannot be met, this type of simulation cannot be done. In regard to the second element, if the characteristics of the equipment used are not representative of the actual equipment, the simulation loses some of its value. SIMULATE ONLY WHEN PERTINENT.

Classes of Simulations:

(Slide #5) This chart displays various types of simulators which may be utilized to study the variety of the problems with which we are faced. We shall not attempt to discuss all of them, but rather focus on some of them to illustrate their use in the space program. All of these uses can be categorized into one or more of the following: Development of Operational Procedures, Systems Checkout, Training, Human Response to Altered Environmental Conditions, and Prediction of Human Response to the Space Environment.

Simulators may be modified flight vehicles or they may be ground-located facilities. The modified flight vehicles consist of aircraft whose aerodynamic characteriests, controls or instrumentation may be varied to represent the situation found in the vehicle under investigation, or whose operational techniques are controlled to produce a desired effect such as zero g with the Keplerian trajectory.

The groundbased facilities may be considered primarily as having fixed-base or moving-base characteristics. Among the fixed-base simulators are computers, such as can be and are used in design studies (thermal cooling in suit), and procedures trainers as were used in Project Mercury and are being used in Project Gemini (Slide #6). (Slide #7) I stated that I used the term "man-machine integration" in the broadest sense. I did this primarily because of this item - environmental simulators. The degree of man's control function with this type of simulator can vary significantly, beginning at a level of zero g - or none at all- and extend to a considerable degree. This type of facility can be used for evaluation of materials and their response to environmental conditions and such an instance man may not - or need not

be a part of the simulation. This type of simulator can and is used extensively in psychophysiological research. Some of you are familiar with the program which was designed to validate the physiological acceptability of the 100% oxygen, 5 psi atmosphere for Gemini and Apollo. A series of 14 day studies were completed with the Air Force, Navy and industry using human subjects. Man did not contribute to any control function of simulator or chamber itself; however, his ability to conduct flight type functions such as tracking, monitoring, etc., was evaluated. In addition, a rather extensive series of physiological measurements were made on the subjects to evaluate their ability to tolerate this environment. During one phase of the total program, accelerative forces, comparable with those of G and A profiles were applied to each of the subjects. This was added to evaluate a parameter additional to those available through the use of the environmental chamber alone.

An illustration here is one study which was conducted jointly by NASA/MSC and the Air Force with Ames Research Center involved a combination of sustained acceleration, imparted by a centrifuge, and vibration to the Gondola, effected

by a piston arrangement to evaluate the pilot's capacity to perform dial reading and certain control functions in the face of this combined stress. I'm certain last Monday you heard discussions by Dr. Von Gierke, Col. Stapp and Mr. Pesman on the use of translation simulators in our impact program.

The Multi-Axis Trainer (Slide #8) has been used for both evaluation and for training in respect to roll pitch and yaw. This is capable of all three. The Centrifuge at ACEL-Johnsville has been used extensively for astronaut familiarization, training and evaluation in respect to the Mercury, Gemini and Apollo launch and reentry profiles.

These mission simulators listed here under moving base seem to include some which could be categorized under fixed base as well. Either they do not move or the movement is minimal to a point which, once imparted to the subject it is held for a majority of the simulation time. Some rendezvous and docking simulators have both a fixed based and moving base component. NASA is also working on a lunar landing simulator which I suppose could more properly be identified as a flight simulator rather than one under the "Moving Base" grouping.

These part-task and whole mission simulators are generally extremely complete mechanisms. The Gemini Simulator is capable of "flying" any or all aspects of the Gemini program. It is complet activation, when a switch is thrown or a thruster activated, or a control stick movement made, the resultant effect is displayed to the operator on the control panel. I assume that Dr. Grodsky mentioned the full Apollo mission simulation which he conducted for NASA at the Baltimore plant. Briefly, the lunar landing mission was simulated in its entirety, with three types of exceptions:

Certain environmental forces such as acceleration, vibration and weightlessness, the atmosphere and radiation were absent; secondly, the mission sequence was altered slightly to give each crew member a trial at an activity which would normally be conducted only once and by only one crewman, e.g., LEM transposition and lunar landing; and thirdly, where certain mission elements are automatized in Apollo, some were made manual operations to gain a greater sampling of pilot performance. The main point of mentioning this study here is to point up the tremendous complexity of the equipment to make this simulation representative of the lunar mission. A computer complex was necessary to display control panel information to the crewmen. A star field apparatus with a viewing

mechanism was necessary for the mid-course correction maneuver and an out the window display of a star field and CM - with a shift to a representation of the CM for final docking - was necessary to conduct the LEM Rendezvous and Docking maneuver following Lunar ascent of the LEM. Obviously, the cost in terms of manpower, energy and money is just about relative to the complexity, (and completeness of the simulation.).

I'd like to mention the "pseudo-weightlessness" area listed here. Anyone who can devise a method to really simulate weightlessness or zero g can retire immediately. To date, we have utilized water immersion as one "analog" of weightlessness and the very unsophisticated practice of bed rest as another to attempt to gain baseline or control information on physiological effects of zero g. Some of these practices and "simulators" could reasonablely be placed under the fixed base category.

There is little, if any, argument of the value of simulation for use in the following areas:

1. Development of Operational Procedures

2. Systems Checkout - Including Man

3. Training - (Dr. Schwichtenberg will mention use in Selection)

4. Human Response to Altered Environments

5. Design tool - (Industry)

There is, however, a considerable amount of discussion regarding the use of simulation for prediction of man's response to the space flight situation. To a large degree, this discussion appears based on two main factors--the difference in the gravity situation (1 g on earth as opposed to the zero g of space, and secondly, the difference between the emotional aspects of simulation's or lack of them) and those of space. Here, I include such significant variables as danger and its meaning and effect. No matter how realistic the simulation, the crewmen always realize that in such a situation they are surrounded by support personnel and they can get out of the simulation by going throwgh a door--and the consequences, whatever they might be, probably will be less than a catastrophe in space. Also included here is the factor of motivation. Extremists, without attempting to define the term, state that motivation is completely lacking or, in the other end of the scale, it is equivalent to that involved in an actual flight mission. I don't accept either position; however, information from full 7 day mission simulations suggests that it may be

greater than we previously judged. This introduces the question which I understand you discussed somewhat last Wednesday, namely, how long should a simulation persist to make predictions regarding a long duration flight? Frasier suggests that we attack this question by examining some aspects of the stress response. (Slide) He states, "When the body is exposed to a mild stimulus, it reacts to that stimulus by modifying its physiological and psychological outputs. Where the intensity or the duration of the stimulus is such as to exceed the body's capacity to modify its outputs at that level of function, energy consuming compensatory changes occur in the body. These compensatory changes are manifested as measurable alterations in physiological function and may be regarded as evidence of strain from which the existence of a causative stress may be inferred." With further increase in intensity or duration, still further compensatory changes take place until there are no reserves left, at which point psychological and/or physiological failure will occur. It is to be noted that where a stressful stimulus is maintained at the same level or for a prolonged period, a highly motivated operator will maintain a high level of performance despite the occurence of progressive

compensatory changes, until just prior to his physiological failure.

(Duration of simulation) (Slide). Discuss - Offer - Sim - In-Flight

Meas = PRED.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546

IN REPLY REFER TO: MMD

21 June 1965

TO: Participants in George Washington University Course, October 19-30, 1964

FROM: S. P. Vinograd, M.D., Director, Medical Science & Technology

SUBJECT: Forwarding of Data Book

Enclosed for your information is a copy of the Bioastronautics Data Book. I hope you will find it useful.

S. P. Vinograd, M.D.

S. P. Vinograd, M.D.

Enclosure
a/s

FILE

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON 25, D.C.

IN REPLY REFER TO:

7 July 1964

Dear

This letter is to affirm your participation as a lecturer in the postgraduate course "Engineering Aspects of Space Medicine" to be given October 19 through the 30th, 1964, at George Washington University in Washington, D.C. The purpose of the course is to promote and advance mutual understanding between life scientists and engineers in order to permit these two formerly rather separate disciplines to join forces more firmly and effectively in the accomplishment of the highly technical task requirements of space medicine and biology. To date. comments by reviewers have been enthusiastic. I hope that after reading the enclosed material your impressions will be similar.

The printing of the brochures, one of which is enclosed for your inspection, has just been completed. They are currently being given wide distribution throughout the country. I believe you will find the list of your fellow participants and the course outline of particular interest. Also enclosed is a course schedule which indicates the date and approximate time of each lecture. Present plans call for lecturers to remain for the entire morning or afternoon of their lecture to allow for a half hour period of questions and answers at the end of each morning and afternoon session. It is felt that this will serve the additional advantage of providing panel coverage of each subject category, since for the most part morning and afternoon sessions are generally identifiable by subject matter. It is recognized, however, that this does not always hold, and therefore any participant may invite questions at the end of his talk if he so desires.

As we discussed, we plan to have a syllabus consisting of outlines of all lectures ready for distribution to course attendees at the beginning of the first morning session. Outlines should be informative and rather detailed; not simply a cataloguing of subject headings. It is estimated that they will average approximately two to five pages in length, although there is

This letter sent to all guest lecturers
Col. James P. Henry - 9 Oct 64 -

no hard and fast rule. Considering the time required for printing and assembling, it will be necessary for me to have these outlines in hand by 1 September 1964.

In addition, the course material will be published as a book under the same title. In order to accomplish this within a reasonable length of time after the course is presented, it would be very much appreciated if lecture narratives together with graphic material were submitted to me by the last day of the course. Although royalties are not anticipated to be much more than miniscule, participants employed by the government may wish to write their contributions for publication on their own time.

I will communicate with you further with reference to travel and other arrangements. Should there be any questions or problems, please do not hesitate to get in touch with me.

Your participation in this endeavor is greatly appreciated. I am confident that it will be a source of pride to all of us.

Sincerely yours,

S. F. Vinograd, M.D.
Chief, Medical Science and Technology
Directorate of Space Medicine
Office of Manned Space Flight

Phone: WOrth 2-0435

Enclosures
1. Brochure
2. Course schedule

D. W. Course

27 November 1964

Dr. Loren Carlson
University of Kentucky
Physiology Department
Lexington, Kentucky

Dear Loren:

Thank you for your note of November 20. Thank you, too, for the completion of your manuscript of your very fine lecture given at the George Washington University course. Publication is still most emphatically planned, but I do not know at the moment whether the publisher will get permission to reproduce figures or not since the publisher has not as yet been selected. I will certainly let you know as soon as I do, but I think it would make things easier all around if we arranged with the publisher that he obtain permissions where required in view of the fact that there will be so many contributors.

Your motel reservations have been made at the Skyline Inn, 10 I Street, S.W. for the nights of the 30th of November and 1st of December. They have been informed of the fact that you will arrive very late so that there should be no problem. However, if you find yourself confronted with one when you arrive, please don't hesitate to give me a jingle no matter what time it is, and I will be delighted to come get you and have you share our bed and board.

Sincerely,

/S/

S. P. Vinograd, M.D.
Director, Medical Science and Technolog
Space Medicine
Office of Manned Space Flight

UNIVERSITY OF KENTUCKY LEXINGTON, KENTUCKY 40506

CENTENNIAL 1865-1965

MEDICAL CENTER
DEPARTMENT OF PHYSIOLOGY AND BIOPHYSICS

November 20, 1964

S. P. Vinograd, M.D.
Directorate of Space Medicine
NASA
Washington, D. C. 20546

Dear Sherm:

I now have a manuscript of my lecture given at the George Washington University course. Is publication still planned? If so, will the publisher get permission to reproduce figures or should I?

Did your secretary find a room for me on November 30? If so please ask her to be certain that it is for late arrival (11 p.m.). O.K. Ple

Skyline Inn, 10 I St, SW

Sincerely yours,

Loren

Loren D. Carlson
Professor and Chairman

LDC/s

THE GEORGE WASHINGTON UNIVERSITY
WASHINGTON 6, D. C.

November 23, 1964

Sherman P. Vinograd, M.D.
NASA Headquarters
Washington 25, D. C.

Dear Dr. Vinograd:

On behalf of The George Washington University, I want to thank you for your participation as Course Instructor and Special Lecturer in "Engineering Aspects of Space Medicine" during the period October 19-30.

You not only demonstrated a high degree of professional knowledge and skill, but in addition provided the direction and guidance essential to the success of this highly important project. You are to be commended and congratulated upon your outstanding accomplishment.

It was a great privilege to have you identified with this University. I feel that you have made a significant contribution to a most important field of technology and to the advancement of scientific knowledge which we all seek so earnestly.

Sincerely,

John Anthony Brown Jr.

John Anthony Brown, Jr.
Vice President and Dean
of Faculties

JAB/dk

November 9, 1964

2-5820-1-1

Dr. G. E. Mueller
Office of Manned Space Flight
NASA Headquarters
801-19th Street N. W.
Washington, D. C.

Dear Dr. Mueller:

Recently Mr. R. A. Glaser and three other members of The Boeing Company attended the course in "Engineering Aspects of Space Medicine", presented by The George Washington University and organized by your Dr. Sherman P. Vinograd. Mr. Glaser has reported to me a uniform sense of satisfaction with the course from all members of the Boeing contingent. The course was well organized, the speakers were both interesting and well informed, and the course fully met the objectives originally set forth. Dr. Vinograd is especially to be complimented for a fine job of organization and presentation.

Please be assured that, should additional courses of this general nature be contemplated, The Boeing Company will welcome the opportunity to participate once again.

Very truly yours,

THE BOEING COMPANY
Aero-Space Division

ORIGINAL SIGNED BY

George H. Stoner,
Vice President
Assistant Division Manager

C 1094 COMMUNICATION CONTROL RECORD
REPLACES IN THE USAF DD FORM 278 WHICH MAY BE USED.

AF FORM FEB 59 388 ☆ GPO : 1962 - 647819

FROM: G.H.Stoner, Boeing Co.

SUSPENSE DATE: NR

DATE: 9 Nov 64

NUMBER: 1564/4

SUMMARY

Ltr to Dr. Mueller fwd to us fm Dr. Stoner re the Engineering Aspects of Space Medicine Lecture Series by Vinograd and how valuable it was in their opinion.

TO	TO	TO	TO	TO
Knauf	Vinograd			
DATE	DATE	DATE	DATE	DATE
17 Nov 64				

ACTION TAKEN *(Answered or other)*

NASA HEADQUARTERS ROUTING SLIP

	CODE	NAME *(if necessary)*		ACTION
				APPROVAL
1.	M	Mueller		CONCURRENCE
				FILE
2.	MM	Kraus		INFORMATION
				INVESTIGATE AND ADVISE
3.				NOTE AND FORWARD
				NOTE AND RETURN
4.				PER REQUEST
				RECOMMENDATION
5.				SEE ME
				SIGNATURE
6.				REPLY FOR SIGNATURE OF:
7.				

REMARKS:

FROM:	CODE:	NAME:	DATE:
	M	H. H	11/13/62

NASA Form 26 (Rev. July 1959) U.S. GOVERNMENT PRINTING OFFICE : 1959 OF—513026

THE BOEING COMPANY
AERO-SPACE DIVISION · P.O. BOX 3707 · SEATTLE 24, WASHINGTON

November 9, 1964

IN REPLY REFER TO

2-5820-1-1

Dr. G. E. Mueller
Office of Manned Space Flight
NASA Headquarters
801-19th Street N. W.
Washington, D. C.

Dear Dr. Mueller:

Recently Mr. R. A. Glaser and three other members of The Boeing Company attended the course in "Engineering Aspects of Space Medicine", presented by The George Washington University and organized by your Dr. Sherman P. Vinograd. Mr. Glaser has reported to me a uniform sense of satisfaction with the course from all members of the Boeing contingent. The course was well organized, the speakers were both interesting and well informed, and the course fully met the objectives originally set forth. Dr. Vinograd is especially to be complimented for a fine job of organization and presentation.

Please be assured that, should additional courses of this general nature be contemplated, The Boeing Company will welcome the opportunity to participate once again.

Very truly yours,

THE BOEING COMPANY
Aero-Space Division

George H. Stoner,
Vice President
Assistant Division Manager

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT · U.S.A.

November 6, 1964

Sherman P. Vinograd, M.D.
Chief, Medical Science and Technology Branch
Space Medicine Division
NASA Office of Manned Space Flight
Washington, D. C.

Dear Sherm,

Herewith, my belated comment and recommendation.

I thought the course was excellent for my purposes, but possibly a bit redundant for some of those who had been longer in the field.

This prompts me to suggest that next year's course could be improved by making it incremental in bringing people up to date. A basic fund of knowledge would be needed and this can be achieved by ensuring that attendees are sent, at least two weeks prior to the course, the printed lectures given this year.

Sincerely,

RBL:T

R. B. Laning
Ass't to the Division Vice President

30 Oct 64

① The course was inappropriately named. It did not cover the engineering aspects of space medicine but rather the medical aspects of space flight operations.

② I do not consider the two weeks time well spent since I have previously been exposed to approximately 90% of the material covered. I would not recommend this course for USAF or DOD physicians. It possibly might be of limited value to civilian physicians who had never been exposed to flight test or manned space operations.

Burt Jensen
Col USAF MC

Mechanical Aspects
1. Configuration
2. Attachment

Electrical
1. Electrolytic Pastes
2. Materials
3. General Considerations

Amplifiers

General
1. Size
2. Weight
3. Construction
4. Power

Specific
1. Electrocardiograph
2. Impedance Pneumograph
3. Oral Temperature
4. Blood Pressure

Power
1. Voltage
2. Regulation

Wiring

Internal Harness

Connectors

Spacecraft Interface

UNMANNED BIOLOGICAL FLIGHTS

Dr. Dale Jenkins
Bioscience Programs Division
Office of Space Science and Applications

Following exploratory biological experimentation in orbiting spacecraft by Russian and American scientists preparatory to manned space flight, the United States has developed a Biosatellite Program with a second generation series of critical experiments. Many of these have required several years of baseline study and engineering development. Comprehensive evaluation of effects of dynamic flight factors was required to permit accurate analysis of the biological effects of unique space environmental factors.

Thirty experiments have been selected for flight from 175 submitted by the U.S. scientific community, to study the effects of weightlessness and decreased gravity at the cellular, tissue, organ, and organism levels from 3 to 30 day orbital periods. The experiments include a wide variety of plants and animals from single celled organisms to higher plants and animals, including primates.

Experiments have been selected to study the effects of weightlessness combined with a known source of radiation to determine if there are any antagonistic or synergistic genetic or somatic effects on various organisms. Experiments are included to study the effects of the unique environment of the earth-orbiting satellite and removal from the Earth's rotation in relation to biological rhythms of plants and animals.

Pigtail monkeys have been instrumented with deep brain probes to study weightlessness effects on the neorological system. A cardiovascular experiment has been developed to measure cardiac output using a dye dilution method with indwelling arterial and venous catheters. Metabolic and calcium loss experiments have also been included. Primates and other animals, plants, and microorganisms have been exposed in ground tests to simulated dynamic forces of flight profiles including acceleration, spin, and deceleration.

1. No advance information — Bld., room no, time of classes, hotels, restaurants, etc.

2. First day was disorganized; partly from above and from equip. lack

3. I listed speakers as excellent, average and poor. There were seven excellent ones and eight poor ones. The poor ones (1) didn't know their subject in relation to others, (2) couldn't present data well or (3) were too biassed on their own subject.

4. Organization of speakers could have been improved, with programs and broad aspects covered before specific data.

5. I'm still not sure who should take this course. I do believe, contrary to the prospectus, M.D's should not take the course.

6. The course, as given, was for engineers and was concerned with the medical aspects of aerospace engineering. There were few engineering principles discussed.

7. It was an opportunity to meet and hear from the people NASA is using as consultants and experts.

8. The course was a refresher course for me and did show my personal voids in current concepts.

Don Rosenbaum

EXCELLENT COURSE — ABOUT 90% EFFECTIVE

SUGGEST:

1. CONSOLIDATE COURSE FOR ONE WEEK PRESENTATION — FOR INCREASED ENROLLMENT POTENTIAL

ACHIEVE BY:

2. SLANT COURSE TOWARD BOTH ENGINEERS & MANAGERS
   a) EMPHASIZE MAN'S ROLE FOR MANAGERS.
   b) HISTORICAL PROBLEMS OF HARDWARE DESIGN FOR ENGINEERS

3. EMPHASIS ON PROBLEMS — PAST, PRESENT & FUTURE.
   a) PROPOSED APPROACH TO THESE PROBLEMS
   b) BY CORRELATION OF ANTICIPATED DESIGN PROBLEMS e.g. ORIENTATION OF MAN TO VEHICLE, NEED FOR CENTRIFUGE, ETC.

RECOMMENDATION FOR COMPRESSED ONE WEEK COURSE - BY SUBJECT AND PRIORITY

		MON	TUES	WED	THURS	FRI
1ST WEEK	A.M.	1	1	1	1	2
	P.M	1	1	2	1	2
2ND WEEK.	AM	1	1	3	2	3
	PM	1	3	3	3	3

1 MANDATORY
2 DESIRABLE
3 LESS DESIRABLE

K. S. BROSSEL

1. Excellent overall

2. If possible shorten course to one week - (Send copy of your book to each registered student approx. two weeks prior to course.) I think this would attract more students.

3. General administration & facilities provided by Geo. Wash. Univ. i.e. letter room, telephone, parking facilities.

4. Perhaps a social get together at end of first day. Have it scheduled immediately after class for an hour or so. People get acquainted & I suspect the panel discussions might become more lively.

Keating

5. Mail a week before course start send out a flyer covering general info with a list of attendees.

Comments on Course:

M. W. Greene (Beckman Instruments, Inc)

I was able to attend the sessions of Wed, Thurs afternoon, and Friday (of the second week), only. My comments should be viewed in this light.

The high temperature and hard seats made it difficult to maintain a high degree of attention. In my particular case, I was about 80% familiar with the subject matter of most talks, making it extra difficult to remain alert enough to pick-up the additional information. Even so, and in spite of the brevity of my attendence, I feel that the overall picture of planned future operations was very helpful to me. A large part of my prior information was largely disconnected and poorly relatable.

In some cases, I would have been interested in greater detail. For example, as an "instrument man" it was a relief to learn that the limited value of the measured Biomedical parameters was well recognized. A detailed development of the theoretical justification of the EKG method and apparatus being employed would have been very interesting to me, but I recognize that such detail would be difficult to justify ~~for~~ in a course of this nature.

In general, I think such a course should be very helpful in answering the ferquently asked questions regarding "why don't (or why do) they do it ~~this~~ WAY". The mere recognition of the fact that it was necessary to freeze the program plans and mechanical designs at some point in time in order to ever have a program has been lacking on the part of a number of engineers in industry. As a result, we have had instances of impatience with design restrictions and seemingly unrealistic requirements which have reduced the efficiency of some of the efforts with which I have been associated.

OCT. 30, 1964

1. THE SCOPE OF MATERIAL, SELECTION OF SUBJECTS AND THE RELATIONSHIPS BETWEEN ENGINEERING AND MEDICINE WERE VERY GOOD. IT IS "DE TROP" TO SAY THAT THE SPEAKERS WERE EXCELLENT

2. FOR A "LIFE SCIENCES TYPE", MORE ENGINEERING AND LESS SPACE MEDICINE WOULD HAVE BEEN SOME IMPROVEMENT - IF THERE IS ROOM FOR ANY.

3. CONGRATULATIONS TO DR SHERMAN VINOGRAD FOR HAVING PUT TOGETHER THIS COURSE.

C. L. BOMMARITO

4. P.S. SEE WHAT CAN BE DONE TO IMPROVE PHYSICAL FACILITIES FOR FUTURE PRESENTATIONS OF THE COURSE.

C.L.B.

Critique G.W.U.

Program Scope - almost all inclusive, little should be added or deleted.

Program Depth - comprehensive treatment of the topics - time spent on generalities and hypotheses could be better used on specific and current problems

Speakers - generally very good to excellent preparation and delivery. Several lecturers had difficulty in their presentations. Only 2 seemed to be poorly prepared.

G.W.U. facilities - adequate but not comfortable - noise problem on several days. - proximity to hotels and restaurants not good

Misc. Suggestions & Comments.

1. Overlap in lectures may be avoided by distributing abstracts to those with common material.
2. Monotony which tends to set in may be avoided by a) changing classrooms occasionally b) demonstrations of hardware & techniques by lecturers c) more informal discussions with the speakers

ENGINEERING ASPECTS OF SPACE MEDICINE

Student Comments

1. This was a truly excellent course, completely fulfilling my expectations. The practice of selecting speakers of prominent position and knowledge-ability, who were also skillful speakers, made this course particularly interesting and informative.

2. Considering the variety and concentration of material, daily sessions ran too long for my tastes. I suggest, for next time, something like 8:30 - 12:00, 1:00 - 4:30, with lunch time not encroached upon.

3. Shorter sessions could be realized, without compromising the course, by cutting out most of the organizational, operations, facilities, and missions lectures. These did not contribute as much to the stated purpose of the course as the proportion of time alloted to them. The essentials of this material were brought out in other lectures anyway. A number of students found it useful, however, and I suggest a booklet of this type of background material could be handed out.

4. In view of facilities available in this area, and perhaps at GW itself, better lecture room facilities would have been a real help in view of the lengthy, continuous course sessions. The high noise level from inside and outside the building, uncomfortable chairs, and poor ventilation caused a great deal of unnecessary fatigue and strain to both students and lecturers.

John L. Hammersmith

John L. Hammersmith

General Comments

1. Overall impression – excellent. Well and thoughtfully organized – only a minimum redundancy noted.
2. Logistics and ambient conditions supplied by G. W. C. sub-standard; noise, lighting, comfort etc.
3. Will recommend to my Company that they get behind any future program of this nature.
4. Two weeks session seems O.K. – however, if cut to, say, 1 week, would remove from the course the non-medical presentations, E.g. communications and other electronic considerations and any obvious redundancy.
(However, I believe there was only about 10% redundancy anyway, so both between these suggestions you might save only 20% of time)
5. Glossary of terms might be prepared for advance distribution.

R. A. Glaser
Boeing Co.

∴ 80% successful in meeting the objectives I had assumed at the outset – and that's a pretty good record!

30 Oct 64

Dear Dr. Vinograd

Enclosed is a list of the people who wanted tapes and a list of those either paid or to be paid. It appears that you should be quite a bit in the black although I don't know how NASA's going to look at it - what they don't know won't hurt them.

I wish to thank you for the course and I'm sure that I speak for everyone - A JOB WELL DONE - I derived much from the course and I hope I can put it to some use either thru CONSULTING or how about a job with one of your panels on a part time basis? I realize that my work is quite remote, but I have a questioning mind and might be able to contributed something from the Engrs or Scientists point of view.

By the way - I didn't get to ask you - is the body temperature 98.6 <u>everywhere</u> or are there small difference in the organs - cells or some where? I am still trying to see how these bones would decay if an equivalent amount of exercise is substitated in a similar or analogous fashion.

Another thing - I think I owe you an apology for running out so quickly Friday after class - It was

rude of me - I'am sorry - I got to the plane - as it turned out - about 35+ minutes ahead of time - so I could have helped you out some more. I guess a ~~[illegible]~~ such wife & kids are bothering me - although they should probably be fine by now. I sort of promised I'd be home Friday evening - anyway - I could of helped you more then & tiel.

I have marked in my notes the tape numbers & the speakers. I suggest one thing I didn't get done - Mark the reels with the tape number with masking tape or such.

Can I help you in any way with your book, or something of this nature?

Please extend my thanks to your wife and kids (they sure are nice) for a very enjoyable Thursday Evening - If you're in Cleveland and don't look us up - ~~[illegible]~~ That's an insult -

Take it easy - ulcers are worth all the money or $ important jobs in the world (I'am still trying to convince myself of that).

Thanks for every thing

HENDRICKS

People to be paid or something?

✓DR. Earl Wood - 1147 2nd St. NW., Rochester, Minnesota

✓Dr Robert Forster - 501 Oakley Rd, Haverford, Pa

(?) ✓Dr. John Brown - 2312 N 52nd St., Philadelphia, Pa (?)

✓Capt. N.W. Allenbach - Starlake, Warrington Fla.

✓Dr. James Warren - The Ohio State Univ. - Columbus No home address

✓Dr. Loren Carlson - U. of Kentucky - No home address

✓Dr. Henry (?) (?)

✓Dr. JA Buesseler - 813 Maupin Rd, Columbia Missouri - will send expenses

✓Dr. Franz Halberg - Miss Koltes has his expenses

✓Dr. Otto Schmitt (?) (?)

✓Dr. Bayern (Honarium?)

I think my $3000 estimate was high based on these figures. Anyway the original allotment for travel was over subscribed by a factor of two. I guess NASA sure took the brunt of the financial load I hope the people return as much in the over all space Effort.

May I remind you of the paper by Townsend which you said you would send me — Thanks

People wanting a copy of the tape or a typed copy

1. Dr. Baldwin - left after his lecture - however he spoke sans-notes ∴ perhaps he needs a tape or typing
2. Dr. Graybiel - didn't say much about a recording, however I think he was one who mentioned, he would like a typed text from tape
3. Dr. Brown - wanted a tape - this talk - was re-recorded
4. Dr. Graham - ~~wrote~~ wanted a copy (typed version)
~~5.~~ Col J. P. Stapp - wants a tape
6. Dr. S. B. Sells - re-recorded tape must be edited
7. Dr. Hess - re-recorded
8. Dr. Rosenbluth - you said he wanted a tape I think

People who submitted Expenses

1. Dr. John Broom – 290 miles @ 10¢, 29.00 + 15.00 + 50.00 = 94.00 — 94.00

2. Dr. Joseph KUBIS
37-18 88th St. Jackson Heights 72, NY. — 85.48
30.48 + 15. + 50

3. Dr. Ross McFarland 54.85 + 9 + 6 + 15 + 50 — 134.85
17 Fresh Parkway, Cambridge 38, Mass

4. Dr. Milton Grodsky 130 @ 10¢ 13 + 65 + 50 — 78.00
2313 Pot Spring, Timonium, MD.

5. Dr. Douglas Grahn 87.40 — 152.46
5720 Carpenter St. ~~Downers~~ DOWNERS GROVE Ill.

6. ~~Dr.~~ Col. John P Stapp 72.62 + 6.50 + 15.00 = 94.12 — 94.12
USAF (MC) 51323A
BOX 4193 AMD
BROOKS AFB, SAN ANTONIO, TEXAS

7. Dr. H. Von Gierke 66.10 + 15.50 — 131.10
1325 Medow Lane, Yellow Springs, Ohio

8. Dr. S Natelson 76 + 50 — 126.00
15 Parkwold Dr. West, Valley Stream LI, N.Y.

9. DR SB Sells 172.20 + 15.50 — 237.20
3204 Sweetbriar Lane, Fort Worth, Texas, 76109

10. Dr. Marvin Rosenbluth 189.80 + 50

2125 EAST WILLOWDELL, SEABROOK, TEXAS —— 239.80

11. Dr. Vinograd —————————— #'s of sweat

12. Dr. A H Schwichtenberg

1418 Hertz Dr. SE.

Albuquerque, N.M. —————— 50,00

13. Dr. Townsend (address?) travel +50 —— 50.00

(some question here again as to the travel?
he left in such a hurry that I didn't have
a chance to obtain it — it would be small)

10. Dr. Marvin Rosenbluth 189.80 + 50

2125 EAST WILLOWDELL, SEABROOK, TEXAS —— 239.80

11. Dr. Vinograd —————————— #'s of sweat

12. Dr. A H Schwichtenberg

1418 Hertz Dr. SE.
Albuquerque, N.M. —————— 50.00

13. Dr. Townsend (address?) travel t/so —— 50.00

(some question here again as to the travel?
he left in such a hurry that I didn't have
a chance to obtain it — it would be small)

"ENGINEERING ASPECTS OF SPACE MEDICINE"
October 19-30, 1964

ABELES, Fred J.
38 Chenango Drive
Jericho, Long Island
New York
Howard Johnson's Motor Lodge
Virginia Avenue
Grumman Aircraft Engineering Corp.
Design Engineer
Environmental Control and
Life Support

BABICH, Anthony Mathew
574 Central Avenue
Massapequa, New York
Airborne Instruments Laboratory
Electronic Engineer
Med. & Bio. Physics

BOMMARITO, Ciro Lawrence
5144 South Myrtle Street
Seattle, Washington 98124
Roger Smith Hotel
18th and Pennsylvania Avenue
Room 423
The Boeing Company
Physiologist
Physiology

BROSSEL, Kenneth S.
Rt. 2, Box 432
Vashon, Washington
Roger Smith Hotel
18th and Pennsylvania Ave.
The Boeing Company
Design Supervisor
Product Design Development

DUBIN, Jack
8519 Stevenswood Road
Baltimore, Maryland 21207
12051 Tech Road
Silver Spring, Maryland
Beckman Instruments, Inc.
Eastern Contracts Manager
General Life Sciences

Lawrence Dunkelman
Institute for Defense Analyses
400 Army Navy Drive
Arlington, Va.

EASTWOOD, Charles Robert
1600 S. Joyce Street
C-1609
Arlington, Virginia 22202
NASA
Inventions and Contributions Board
General Field of Subject

GAFFORD, Robert Doster
12152 Skyline Drive
Santa Ana, California
Dupont Plaza Hotel
Beckman Instruments, Inc.
Project Manager
Space Engineering

M. W. Greene
467 E. Benwood Street
Covina, California
Beckman Instruments, Inc.
Sr. Project Engineer
Space Engineering

GIBBONS, Larry Valgene
1029 Madison
St. Charles, Missouri
Gramercy Inn
1616 Rhode Island
McDonnell Aircraft
Aerospace Medicine
Physiologist

GLASER, Raymond Arthur
8234 N. E. 122nd
Kirkland, Washington
Madison Hotel
The Boeing Company
Manager, NASA Orbital Laboratories
Programs
Electronics

HAMMERSMITH, John Leo
3356 Eric Street, S. E.
Washington, D. C. ~~20520~~ 20020
Gemini Program Office
Office of Manned Space Flight
NASA Headquarters, AST (Flight Systems)
Gemini Systems Engineering

HANSEN, Julius Thomas
7710 Maryknoll Avenue
Bethesda, Maryland 20034
Department of Defense
Physiologist

HARTWIG, Quentin Leroy
3123 Calverton Boulevard
Beltsville, Maryland
The George Washington University
1335 H Street, N. W.
Physiologist

HETHCOTE, George Michael
3150 Hargrove
Florissant, Missouri
Grammercy Inn
McDonnell Aircraft
Supervisor of Bio-Med Data
Bio-Med

KEATING, Robert Edward Colonel
4302 Baldwin Drive
McLean, Virginia
Pentagon
Operational Aspects of Space Systems

KELLER, George Adam
7702 Chadwell Road, S. W.
Huntsville, Alabama
Marshall Space Flight Center
Deputy Chief, Technology Office
D. C. -- Park Arlington
Propulsion & Vechicle Engineering

KERELUK, Karl
2018 S. E. 154th Avenue
Bellevue, Washington
Madison Hotel
Room 221
The Boeing Company
Sr. Bioscientist
Microbiology, Exobiology,
Sterilization

LANDSTROM, Walter Gordon
11792 Argyle
Los Alamitos, California
Roger Smith Hotel
18th and Pennsylvania Ave.
North American Aviation
Project Engineer
Lunar & Planetary Systems

LANING, Richard B.
893 Farmington Avenue
West Hartford, Connecticut
4410 Chain Bridge Road
McLean, Virginia
Hamilton Standard
Asst. to President
Space and Life Sciences Dept.
Physiology Research

LEESE, Chester E.
704 Butternut Street, N. W.
Washington, D. C. 20012
The George Washington University
Professor of Physiology
Physiology

MALONEY, John Ward
3730 Locust Avenue
Long Beach 7, California
North American Aviation
Project Engineer
Spacecraft Systems

ROSENBAUM, Donald Arthur
71 N. Smithville Road
Dayton 3, Ohio
Roger Smith Hotel
Room 426
WPAFB, Ohio
Physiologist
Aviation Physiology

ROWEN, Burt Colonel, USAF, MC
1529 Birchwood Drive
Fairborn, Ohio
Roger Smith Hotel
Room 626
Aerospace Medical Research
Laboratories
Wright-Patterson AFB
Aerospace Bioastronautics

SHAFER, William Albert
454 Sea Lane
La Jolla, California
Executive House
General Dynamics Astronautics
Aero Space Medicine

SIRKIS, Joseph
6207 Rockhurst Road
Bethesda, Maryland
FAA
Bio Engineer
Office of Aviation Medicine
Man-Machine Systems

TEMPLE, George Ernest
72 Lawrence Avenue
Avon, Connecticut 06001
The Roger Smith Hotel
18th and Pennsylvania
Hamilton Standard
Space & Life Systems
Engineering Aerospace

VAN DER BLIEK, Jan Adriaan
106 Crestwood Drive
Tullahoma, Tennessee
George Washington Hotel
15th & Pennsylvania
[redacted], [redacted]Arnold AF Station, Aro, Inc.
Staff Engineer
Space Stimulation

WORTZ, Edward -- R. H. Lee in lieu of & N. Loos
1625 Eye Street, N. W. O. Balcom
Washington, D. C.
Garrett Corp.
Air Research Mfg. Division
Physiologist
Physiology

Williams, Richard B.
601 Stone Blvd.
Tullahoma, Tenn.
Aro, Inc., Arnold AF Station
Aerospace Enviornmental Facility

UNIVERSITY OF SOUTHERN CALIFORNIA
KERCKHOFF LABORATORIES
734 WEST ADAMS BOULEVARD
LOS ANGELES, CALIFORNIA 90007

SCHOOL OF MEDICINE
DEPARTMENT OF PHYSIOLOGY

RICHMOND 8-2311
EXT. 581 OR 582

28 October 1964

Dr. Sherman Vinograd
Chief Medical Science & Technology Branch
Office of Manned Space Flight
HQ, NASA
Washington 25, D.C.

Dear Sherm:

I appreciated very much the opportunity to talk to your group and enclose a list of books which have come out in the recent past. Each has its own merits. Basic Astronautics is a good over-view. Graveline writes in Bourne, Wood and Welch in Brown, also similarly for Geoffrey Bourne and Chambers.

Here is a list of twelve books I mentioned.

Sincerely,

Jim

James P. Henry, M.D.
Department of Physiology

JPH/br

Encl. Book list

BIBLIOGRAPHY

1. Clarke, Arthur C., and the Editors of Life
Man and Space (Life Science Library)
Time Incorporated, New York (Stonehenge Book) 1964

2. Bourne, Geoffrey H.
Medical and Biological Problems of Space Flight
Academic Press, New York and London, 1963

3. Brown, J. H. U.(Editor)
Physiology of Man in Space
Academic Press, New York and London, 1963

4. Gerathewohl, Siegfried J.
Principles of Bioastronautics
Prentice-Hall, Inc., Englewood Cliffs, New Jersey

5. Hardy, James D. (Editor)
Physiological Problems in Space Exploration
Charles C. Thomas, Publisher, Springfield, Illinois

6. Morgan, Clifford T., Cook, Jesse S., Chapanis, Alphonse, and Lund, Max W. (Editors)
Human Engineering Guide to Equipment Design
McGraw Hill

7. Armstrong, H. G. (Editor)
aerospace medicine
Bailliere, Tindall and Cox, Ltd., London, 1961

8. Gauer, Otto H., Zuidema, George D.
Gravitational Stress in Aerospace Medicine
Little, Brown and Company, Boston, 1961

9. Slager, Ursula T.
Space Medicine
Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1962

10. Ordway, Frederick I., Gardner, James Patrick, Sharpe, Mitchell R.
Basic Astronautics
Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1962

11. Schaefer, Karl E. (Editor)
Bioastronautics
The MacMillan Company, New York, 1963

12. National Aeronautics and Space Administration
Mercury Project Summary Including Results of the
Fourth Manned Orbital Flight, May 15 and 16, 1963
NASA SP-45

UNIVERSITY OF Minnesota

MEDICAL SCHOOL
DEPARTMENT OF PATHOLOGY · MINNEAPOLIS, MINNESOTA 55455

October 24, 1964

Dr. S. P. Vinograd
Director, Medical Science and Technology
Office of Space Medicine
National Aeronautics and Space Admin.
Washington 25, D. C.

Dear Doctor Vinograd:

I wish to thank you for the opportunity to talk to your interesting audience. At the same time let me say again that I should appreciate receiving a copy of materials that you have reproduced thus far for your course, for distribution to students.

Finally I enclose a schedule of my expenses roughly as I gave them over the telephone, presumably to your secretary. As far as available, receipts are also enclosed.

Sincerely,

Franz Halberg
Professor

FH:jr
Enc.

EXPENSES OF FRANZ HALBERG FOR LECTURE WITHIN THE FRAMEWORK OF A COURSE ON ENGINEERING ASPECTS OF SPACE MEDICINE

Airfare, tax exempt	106.45 +
	3.90 (added fare for jet return)
TOTAL	110.35
Cabs	
Minneapolis from and to airport	12.00
Washington Airport to Hotel (receipt)	2.60
Same for return	2.60
Hotel to George Washington University	1.00
Insurance	2.00
Per Diem	20.00
TOTAL	$ 150.55

Hulbert
UNIVERSITY OF Minnesota
MEDICAL SCHOOL
DEPARTMENT OF PATHOLOGY
MINNEAPOLIS, MINN. 55455

AIR MAIL

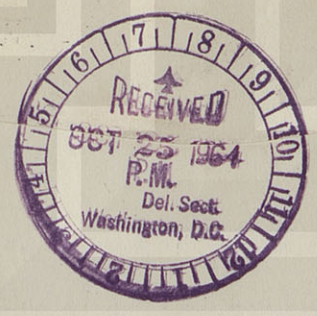
Special Delivery

N.A.S.A.
RECEIVED DUTY OFFICE
TIME 1130 pm
DATE 25 OCT 1964
BY JDW

24 OCT 1964

NASA Mail Sec. OCT 26 1964
TO: MM
☐ FOR ACTION ☐ FOR INFORMATION
ACTION COPY TO
INFORMATION COPY TO

Dr. S. P. Vinograd
Director, Medical Science and Technology
Office of Space Medicine
National Aeronautics and Space Administration
Washington 25, D. C.



CONDITIONS OF CONTRACT

(1.) As used in this contract, "Convention" means the Convention for the Unification of Certain Rules relating to International Carriage by Air, signed at Warsaw, October 12, 1929, or that Convention as amended by The Hague Protocol, 1955, whichever may be applicable to carriage hereunder, "ticket" means "Passenger Ticket and Baggage Check", "carriage" is equivalent to "transportation", and "carrier" includes the air carrier issuing this ticket and all air carriers that carry or undertake to carry the passenger or his baggage hereunder or perform any other service incidental to such air carriage; "damage" includes death, injury, delay, loss or other damage of whatsoever nature arising out of or in connection with carriage or other services performed by carrier incidental thereto. Carriage to be performed hereunder by several successive carriers is regarded as a single operation.

(2.) (a) Carriage hereunder is subject to the rules and limitations relating to liability established by the Convention unless such carriage is not "international carriage" as defined by the Convention. (See carrier's tariffs, conditions of carriage for such definition). Carrier's name may be abbreviated in the ticket, the full name and its abbreviation being set forth in carrier's tariffs, conditions of carriage, regulations or timetables; and carrier's address shall be the airport of departure shown opposite the first abbreviation of carrier's name in the ticket; and for the purpose of the Convention the agreed stopping places (which may be altered by carrier in case of necessity) are those places, except the place of departure and the place of destination, set forth in this ticket and any conjunction ticket issued herewith, or as shown in carrier's timetables as scheduled stopping places on the passenger's route.

(b) To the extent not in conflict with the foregoing, all carriage hereunder and other services performed by each carrier are subject to (i) applicable laws (including national laws implementing the Convention or extending the rules of the Convention to carriage which is not "international carriage" as defined in the Convention), government regulations, orders and requirements, (ii) provisions herein set forth, (iii) applicable tariffs, and (iv) except in transportation between a place in the United States and any place outside thereof, and also between a place in Canada and any place outside thereof, conditions of carriage, regulations and timetables (but not the time of departure and arrival therein) of such carrier, which are made part hereof and which may be inspected at any of its offices and at airports from which it operates regular services.

(c) Unless expressly so provided, nothing herein contained shall waive any limitation of liability of carrier existing under the Convention or applicable laws.

(3.) Insofar as any provision contained or referred to herein may be contrary to a law, government regulation, order or requirement, which severally cannot be waived by agreement of the parties, such provision shall remain applicable and be considered as part of the contract of carriage to the extent only that such provision is not contrary thereto. The invalidity of any provision shall not affect any other part.

(4.) Subject to the foregoing: (a) Liability of carrier for damages shall be limited to occurrences on its own line, except in the case of checked baggage as to which the passenger also has a right of action against the first or last carrier. A carrier issuing a ticket or checking baggage for carriage over the lines of others does so only as agent. (b) Carrier is not liable for damage to passenger or unchecked baggage unless such damage is caused by the negligence of carrier. (c) Carrier is not liable for any damage directly and solely arising out of its compliance with any laws, government regulations, orders or requirements, or from failure of passenger to comply with same. (d) Any liability of carrier is limited to 250 French gold francs (consisting of 65½ milligrams of gold with a fineness of nine hundred thousandths) or its equivalent per kilogram in the case of checked baggage, and 5,000 such French gold francs or its equivalent per passenger in the case of unchecked baggage or other property, unless a higher value is declared in advance and additional charges are paid pursuant to carrier's tariffs or regulations. In that event the liability of carrier shall be limited to such higher declared value. In no case shall the carrier's liability exceed the actual loss suffered by the passenger. All claims are subject to proof of amount of loss.

(e) Any exclusion or limitation of liability of carrier under these conditions shall apply to agents, servants or representatives of the carrier acting within the scope of their employment and also to any person whose aircraft is used by carrier for carriage and his agents, servants or representatives acting within the scope of their employment.

(5.) Checked baggage carried hereunder will be delivered to the bearer of the baggage check upon payment of all unpaid sums due carrier under carrier's contract of carriage or tariff.

(6.) When validated, this ticket is good for carriage from the airport at the place of departure to the airport at the place of destination via the route shown herein and for the applicable class of service and is valid for one year from the date of commencement of flight except as otherwise provided in carrier's tariffs or regulations. Each flight coupon will be accepted for carriage on the date and flight for which accommodations have been reserved; when flight coupons are issued on an "open date" basis, accommodations will be reserved upon application subject to availability of space.

(7.) Carrier undertakes to use its best efforts to carry the passenger and baggage with reasonable dispatch, but no particular time is fixed for the commencement or completion of carriage. Subject thereto, carrier may without notice substitute alternate carriers or aircraft and may alter or omit the stopping places shown on the face of the ticket in case of necessity. Times shown in timetables or elsewhere are approximate and not guaranteed, and form no part of this contract. Schedules are subject to change without notice. Carrier assumes no responsibility for making connections.

(8.) The passenger shall comply with all government travel requirements, present all exit, entry, and other documents required by the law, and arrive at the airport by the time fixed by carrier or, if no time is fixed, sufficiently in advance of flight departure to permit completion of government formalities and departure procedures. Carrier is not liable for loss or expense due to passenger's failure to comply with this provision.

(9.) No agent, servant or representative of carrier has authority to alter, modify or waive any provision of this contract.

(10.) No action shall lie in the case of damage to baggage, unless the person entitled to delivery complains to the carrier forthwith after the discovery of the damage, and, at the latest, within seven days from the date of receipt; and in the case of delay, unless the complaint is made at the latest within 21 days from the date on which the baggage has been placed at his disposal. Every complaint must be made in writing and dispatched within the times aforesaid. Where carriage is not "international carriage" as defined in the Convention, failure to give notice shall not be a bar to suit where claimant proves that (i) it was not reasonably possible for him to give such notice, or (ii) that notice was not given due to fraud on the part of carrier, or (iii) the management of carrier had knowledge of damage to passenger's baggage.

(11.) Any right to damages against carrier shall be extinguished unless an action is brought within two years reckoned from the date of arrival at the destination, or from the date on which the aircraft ought to have arrived, or from the date on which the carriage stopped. The method of calculating the period of limitation shall be determined by the law of the court seized of the case.

SOLD SUBJECT TO TARIFF REGULATIONS

PRICE OF THIS TICKET IS SUBJECT TO CHANGE PRIOR TO COMMENCEMENT OF TRAVEL.

ISSUED BY NORTHWEST AIRLINES, INC., ST. PAUL, MINNESOTA, 55111, U. S. A.

ISSUED BY

NORTHWEST AIRLINES, INC.

SOLD SUBJECT TO CONDITIONS OF CONTRACT ON PASSENGER'S COUPON

If the passenger's journey involves an ultimate destination or stop in a country other than the country of departure, the Warsaw Convention may be applicable and the Convention governs and in most cases limits the liability of carriers for death or personal injury and in respect of loss of or damage to baggage.

PASSENGER TICKET AND BAGGAGE CHECK
PASSENGER'S COUPON

DATE OF ISSUE

FOR ISSUING OFFICE ONLY — FROM/TO | CARRIER | FARE CALCULATION

AIRLINE FORM SERIAL NUMBER: 012 24 2 572 887

PASSENGER NAME: Mr. F. Halberg — NOT TRANSFERABLE

ORIGIN

DESTINATION

ISSUED IN EXCHANGE FOR: 012-595-131-855

DATE AND PLACE OF ORIGINAL ISSUE: 10-12-64

VALID UNTIL

TICKET DESIGNATOR

ACCT. DEPT. USE ONLY

NOT GOOD FOR PASSAGE	FARE BASIS	CARRIER	FLIGHT	DATE	TIME	STATUS	ALLOW.
FROM MPLS-STP	Fx	NW	832	10/22	2:30 PM	OK	
TO Chic 895	To AA		492 T	10/22	4:13	OK	
WASH DC.							

BAGGAGE	PCS.	UNCK. WT.	PCS.	UNCK. WT.
CHECKED				
UNCHECKED	WT.		WT.	

FARE: 106.45 T.E.

TOTAL: $106.45

ROUTE CODE

CPN.

TICKET NUMBER

CONJUNCTION TICKET(S)

FORM OF PAYMENT: Rr routs Rule 75

ENDORSEMENTS

DATE AND PLACE OF ISSUE OF THIS TICKET

OCT 22 '64 MPLS-ST PAUL MINN.

CONDITIONS OF CONTRACT

(1.) As used in this contract, "Convention" means the Convention for the Unification of Certain Rules relating to International Carriage by Air, signed at Warsaw, October 12, 1929, or that Convention as amended by The Hague Protocol, 1955, whichever may be applicable to carriage hereunder, "ticket" means "Passenger Ticket and Baggage Check", "carriage" is equivalent to "transportation", and "carrier" includes the air carrier issuing this ticket and all air carriers that carry or undertake to carry the passenger or his baggage hereunder or perform any other service incidental to such air carriage; "damage" includes death, injury, delay, loss or other damage of whatsoever nature arising out of or in connection with carriage or other services performed by carrier incidental thereto. Carriage to be performed hereunder by several successive carriers is regarded as a single operation.

(2.) (a) Carriage hereunder is subject to the rules and limitations relating to liability established by the Convention unless such carriage is not "international carriage" as defined by the Convention. (See carrier's tariffs, conditions of carriage for such definition). Carrier's name may be abbreviated in the ticket, the full name and its abbreviation being set forth in carrier's tariffs, conditions of carriage, regulations or timetables; and carrier's address shall be the airport of departure shown opposite the first abbreviation of carrier's name in the ticket; and for the purpose of the Convention the agreed stopping places (which may be altered by carrier in case of necessity) are those places, except the place of departure and the place of destination, set forth in this ticket and any conjunction ticket issued herewith, or as shown in carrier's timetables as scheduled stopping places on the passenger's route.

(b) To the extent not in conflict with the foregoing, all carriage hereunder and other services performed by each carrier are subject to (i) applicable laws (including national laws implementing the Convention or extending the rules of the Convention to carriage which is not "international carriage" as defined in the Convention), government regulations, orders and requirements, (ii) provisions herein set forth, (iii) applicable tariffs, and (iv) except in transportation between a place in the United States and any place outside thereof, and also between a place in Canada and any place outside thereof, conditions of carriage, regulations and timetables (but not the time of departure and arrival therein) of such carrier, which are made part hereof and which may be inspected at any of its offices and at airports from which it operates regular services.

(c) Unless expressly so provided, nothing herein contained shall waive any limitation of liability of carrier existing under the Convention or applicable laws.

(3.) Insofar as any provision contained or referred to herein may be contrary to a law, government regulation, order or requirement, which severally cannot be waived by agreement of the parties, such provision shall remain applicable and be considered as part of the contract of carriage to the extent only that such provision is not contrary thereto. The invalidity of any provision shall not affect any other part.

(4.) Subject to the foregoing: (a) Liability of carrier for damages shall be limited to occurrences on its own line, except in the case of checked baggage as to which the passenger also has a right of action against the first or last carrier. A carrier issuing a ticket or checking baggage for carriage over the lines of others does so only as agent. (b) Carrier is not liable for damage to passenger or unchecked baggage unless such damage is caused by the negligence of carrier. (c) Carrier is not liable for any damage directly and solely arising out of its compliance with any laws, government regulations, orders or requirements, or from failure of passenger to comply with same. (d) Any liability of carrier is limited to 250 French gold francs (consisting of 65½ milligrams of gold with a fineness of nine hundred thousandths) or its equivalent per kilogram in the case of checked baggage, and 5,000 such French gold francs or its equivalent per passenger in the case of unchecked baggage or other property, unless a higher value is declared in advance and additional charges are paid pursuant to carrier's tariffs or regulations. In that event the liability of carrier shall be limited to such higher declared value. In no case shall the carrier's liability exceed the actual loss suffered by the passenger. All claims are subject to proof of amount of loss.

(e) Any exclusion or limitation of liability of carrier under these conditions shall apply to agents, servants or representatives of the carrier acting within the scope of their employment and also to any person whose aircraft is used by carrier for carriage and his agents, servants or representatives acting within the scope of their employment.

(5.) Checked baggage carried hereunder will be delivered to the bearer of the baggage check upon payment of all unpaid sums due carrier under carrier's contract of carriage or tariff.

(6.) When validated, this ticket is good for carriage from the airport at the place of departure to the airport at the place of destination via the route shown herein and for the applicable class of service and is valid for one year from the date of commencement of flight except as otherwise provided in carrier's tariffs or regulations. Each flight coupon will be accepted for carriage on the date and flight for which accommodations have been reserved; when flight coupons are issued on an "open date" basis, accommodations will be reserved upon application subject to availability of space.

(7.) Carrier undertakes to use its best efforts to carry the passenger and baggage with reasonable dispatch, but no particular time is fixed for the commencement or completion of carriage. Subject thereto, carrier may without notice substitute alternate carriers or aircraft and may alter or omit the stopping places shown on the face of the ticket in case of necessity. Times shown in timetables or elsewhere are approximate and not guaranteed, and form no part of this contract. Schedules are subject to change without notice. Carrier assumes no responsibility for making connections.

(8.) The passenger shall comply with all government travel requirements, present all exit, entry, and other documents required by the law, and arrive at the airport by the time fixed by carrier or, if no time is fixed, sufficiently in advance of flight departure to permit completion of government formalities and departure procedures. Carrier is not liable for loss or expense due to passenger's failure to comply with this provision.

(9.) No agent, servant or representative of carrier has authority to alter, modify or waive any provision of this contract.

(10.) No action shall lie in the case of damage to baggage, unless the person entitled to delivery complains to the carrier forthwith after the discovery of the damage, and, at the latest, within seven days from the date of receipt; and in the case of delay, unless the complaint is made at the latest within 21 days from the date on which the baggage has been placed at his disposal. Every complaint must be made in writing and dispatched within the times aforesaid. Where carriage is not "international carriage" as defined in the Convention, failure to give notice shall not be a bar to suit where claimant proves that (i) it was not reasonably possible for him to give such notice, or (ii) that notice was not given due to fraud on the part of carrier, or (iii) the management of carrier had knowledge of damage to passenger's baggage.

(11.) Any right to damages against carrier shall be extinguished unless an action is brought within two years reckoned from the date of arrival at the destination, or from the date on which the aircraft ought to have arrived, or from the date on which the carriage stopped. The method of calculating the period of limitation shall be determined by the law of the court seized of the case.

SOLD SUBJECT TO TARIFF REGULATIONS

PRICE OF THIS TICKET IS SUBJECT TO CHANGE PRIOR TO COMMENCEMENT OF TRAVEL.

ISSUED BY NORTHWEST AIRLINES, INC., ST. PAUL, MINNESOTA, 55111, U. S. A.

Airport Transport, Inc.

Washington National Airport — Washington 1, D. C.

RECEIVED FROM:

NAME R. SMITH $ 2.60

TRANSPORTATION TO

DATE OCT 22 19 — AIRPORT TRANSPORT, INC., DRIVER

24 HOUR PICKUP SERVICE EX. 3-3060

ISSUED BY

NORTHWEST AIRLINES, INC.

SOLD SUBJECT TO CONDITIONS OF CONTRACT ON PASSENGER'S COUPON

If the passenger's journey involves an ultimate destination or stop in a country other than the country of departure, the Warsaw Convention may be applicable and the Convention governs and in most cases limits the liability of carriers for death or personal injury and in respect of loss of or damage to baggage.

PASSENGER TICKET AND BAGGAGE CHECK
PASSENGER'S COUPON

DATE OF ISSUE

FOR ISSUING OFFICE ONLY

AIRLINE FORM 012: 29 SERIAL NUMBER 3:137:855

PASSENGER NAME DR. F. HALBERG — NOT TRANSFERABLE

ORIGIN MSP

DESTINATION MSP

ISSUED IN EXCHANGE FOR

VALID UNTIL

TICKET DESIGNATOR

ACCT. DEPT. USE ONLY

DATE AND PLACE OF ORIGINAL ISSUE

FROM/TO	CARRIER	FARE CALCULATION
MSP		
DCA	NW	50.45
MSP	NW	55.80

FARE 106.45

DATE AND PLACE OF ISSUE OF THIS TICKET

OCT 16 '64 ST. PAUL 1, MINN.

CONJUNCTION TICKET(S)

FORM OF PAYMENT AGENT

ENDORSEMENTS

NOT GOOD FOR PASSAGE	FARE BASIS	CARRIER	FLIGHT	DATE	TIME	STATUS	ALLOW.
FROM MPLS-ST. PAUL	T X	NWA	70 T	10/21	5P 20	OK	40
TO WASHINGTON DCA/DIA	K5 O	NWA	77 R	10/24	1 05 P	OK	40
TO MPLS-ST. PAUL							

BAGGAGE CHECKED — PCS. — WT. — UNCK. WT.

UNCHECKED — PCS. — WT. — UNCK. WT.

FARE	TOTAL	ROUTE CODE	CPN.	TICKET NUMBER
106.45	# 106.45			

TAX Exempt

EQUIV. AMT. PD.

7

SENSORY AND PERCEPTUAL PROBLEMS IN SPACE FLIGHT*

JOHN LOTT BROWN, PH.D.

INTRODUCTION

At this stage in our space program it seems evident that the men who man our space vehicles should play an active role in the performance of their missions. Man has a variety of valuable capabilities and it would be wasteful of valuable space and fuel to send him on any mission if his capabilities were not somehow utilized. When some of the functions which must be performed in space and the completely automatic equipment required to perform them are considered objectively, it is clear that man can play an important role. Estimates of the over-all reliability of space systems, with and without the inclusion of a man as an essential element, suggest substantially higher reliability when man is included. The first American orbital flight made by John Glenn provided a dramatic example of the way a human pilot can take over control and successfully complete a mission when automatic equipment functions improperly.

If man is to play more than a passive role in space, it is necessary to provide him with considerably more than the essential physiological requirements. His sensory and motor capabilities and the demands which may be imposed on them must also be evaluated. Man must be provided with the equipment required to match his

* The preparation of this chapter was supported by U. S. Public Health Service Award No. GM-K3-15277-C2.

Reprinted from *Physiological Problems in Space Exploration*

capabilities to the characteristics of other elements of the system.[4] He must be provided with information via his senses. This he will evaluate in relation to other current information and his knowledge of the mission. Then, when necessary, he will act upon that information via his motor response capabilities.

It is the purpose of this chapter to consider the sensory and perceptual capabilities of man in relation to the possible tasks which he may be called upon to perform during space flight.[7] Some of the hazards to sensory processes which may be encountered are also discussed.

VISION

Vision will be the principal available distance receptor in space in the absence of a sound transmitting atmosphere. Its importance in this capacity will therefore be greater than ever. It will be of equal importance for the receipt of information from displays within the space vehicle, however. Its various applications can best be reviewed by considering them in relation to the various stages of space missions.

Launch

During initial stages of the launching of a space flight mission, man may be called upon for the performance of several tasks. He will undoubtedly be required to monitor the progress of the launch with respect to changing velocity, altitude and flight-path angle during successive stages of rocket firing. He may also be called upon to monitor and possibly control vehicle attitude in roll and yaw and to make corrections in pitch in order to achieve the desired flight path angle at burnout.[5] He could conceivably be called upon to time initiation and termination of firing of a given rocket stage. Such activities, if required, will probably be accomplished by reference to panel indicators within the space vehicle. External references such as horizon will be of limited value by reason of the high order of precision which will be required. For example, in order to come within 6000 miles of the planet Mars, a rocket launched from the earth may require a velocity at rocket

burnout which is accurate to within 1 fps and a flight path angle which is accurate to within 0.001°.[37] The exact requirement will depend upon the precise relation of the two planets at the time of launch. Even under optimum conditions, precision requirements will be so high at this stage, however, that man will probably perform only a "back-up" function in case of emergency. The nature of space flight for some time to come will be such that all stages of flight will be carefully pre-planned.[1, 37] The crew of space vehicles will not exercise discretion as to the course to be followed. There will only be one correct course for a given destination, and once the launch has been initiated the crew will be committed either to follow this course or to "abort" the mission.

Visual problems which arise during launch will relate to the selection of appropriate methods of displaying information so that it can be interpreted rapidly and accurately. Information will include vehicle speed, altitude, attitude and flight-path angle, in addition to engineering information on the status of various components in sub-systems of the vehicle. The crew of a rocket may also be required to look for external indications of proper vehicle function during launch such as steam clouds which will indicate proper function of reaction control nozzles. Deleterious effects of acceleration on vision may represent a hazard during this stage of flight. Such effects must also be considered during recovery and landing. They are discussed further in a subsequent section.

Orbit

On orbital missions, once the launch has been completed, the space vehicle will be rotating about the earth at a speed such that centrifugal force developed will balance the gravitational attraction of the earth. The altitude of an orbital flight will probably fall within 100 and 500 miles. The minimum is determined by the retarding effect of the earth's atmosphere which will be encountered at lower altitudes. The maximum altitude is imposed by the dangerous amounts of radiation exposure (Van Allen Belt) which may be encountered at altitudes above 500 miles.

Reconnaissance: During orbital flight man may be called upon to make observations of the surface of the earth. It must not be

supposed that he will be able to observe human activities, however. The resolution capacity of the eye is such that a minimum angular separation of between 1 and 10 min of arc can be discriminated for a wide range of illuminations. Thus, for an object to be identified, the dimensions of its distinguishing characteristics must be sufficiently great that they will subtend a visual angle of between 1 and 10 min of arc at the eye of an observer in orbit. The required length in feet to meet the criterion of 10 min of arc is equal to fifteen times the distance of the observer in miles. Thus, at an altitude of 100 miles, the distinguishing elements of clearly recognizable objects must have dimensions of 1500 ft. Many man-made objects, including fairly large buildings, will be too small to be detected. After his recent orbital flight, Glenn remarked that an object such as a bridge could not be picked out with any certainty. A river can be seen from an altitude of 100 miles, however, and when a spot is seen on the river there is a tendency to assume there is a bridge.

With the aid of a telescope, objects can be magnified but there will be a concomitant reduction in the size of the over-all field of view and a substantial reduction in the time during which any particular object remains in the field of view. It has been found experimentally that the probability of detecting an object in a stationary pattern increases appreciably with duration of viewing for up to 12-sec.[3] If relatively small objects (20 to 30 ft in length) are magnified sufficiently to be identified, the time for which they are visible may be reduced to 1 sec or less. Identification will be rendered even more difficult by reason of the fact that objects will be part of a moving, constantly changing pattern. It may be concluded that a man with unaided vision will not be capable of performing any important reconnaissance function from an orbital altitude of 100 miles or greater.[43] He will be able to discriminate such things as lakes and rivers, coastlines and islands which may enable him to localize his position, however. These observations will provide a method of noting the time at which various check points are reached.

Attitude Control: During orbit it will be possible for a man to control the attitude of his craft by external visual reference. In the

Mercury capsule, the normal attitude is such that there is a direct view of the horizon. This provides a reference for control of roll. A wide-angle periscope provides a view of the ground below out to the horizon in all directions. At an altitude of 100 miles the horizon is at a distance of approximately 900 miles. Thus, the visible surface of the earth represents a circular area with a diameter of 165° of visual angle subtended at the vehicle. In the Mercury capsule the periscope field is so positioned that vehicle attitude in pitch and roll are correct when the earth's visible surface is centered in the field. At 18,000 mph, at an altitude of 100 miles, the vehicle will be traversing 5 miles on the earth's surface every second. If any pattern is discriminable on the earth's surface as seen in the periscope field, orientation of the vehicle in yaw may be observed in terms of the relative motion of the pattern. If no surface pattern is discriminable, control of yaw may be accomplished by reference to star patterns. Outside observation will be complicated during orbit by a daylight and darkness cycle of approximately 90 min. The horizon may be visible continuously, either as a band of light or as a discontinuity between star patterns and the blackness of the earth, but in general the earth's surface will only be visible during the daylight half of the cycle. Light from population centers may be seen, and occasionally in the case of a city located on the shore of a lake or ocean the light pattern may have a distinctive contour.

During the dark part of the cycle the observation of stars will be of increased importance as a basis for controlling vehicle attitude. Continuing reference to instruments within the vehicle will also be required, however. Thus, a system of illumination which permits instrument visibility but at the same time does not reduce sensitivity of the eye excessively is essential. This has been provided in the Mercury capsule.[30] When red instrument illumination is employed, it is possible to observe stars of the fifth magnitude without difficulty. Some precautions must be taken during the daylight portion of orbital flight to prevent excessive light adaptation. In the Mercury vehicle this is accomplished with the aid of a red filter and an opaque screen which can readily be positioned over the window.

Detection: The possibility of detecting other space vehicles or objects in space during an orbital flight may be considered remote, except where contact has been specifically planned. The relative velocity between two objects will be considerable unless they are in similar orbits. Relative velocity will increase with increased deviation of orbits and the time during which an object the size of a space vehicle would be visible will decrease commensurately. Some of the problems associated with the detection of objects moving in space both transverse to the line of sight[38] and in depth[2] have been studied experimentally. Vehicles will not be placed in orbit to search for other vehicles that are not already known to be in a specific orbit.

Detection of objects in space will not necessarily be limited by their size in relation to the resolution capacity of the eye. An object will be visible as a point source of reflected light against a dark background. The distance over which it may be detected will therefore depend solely on the total amount of luminous energy which is reflected or emitted. There is no minimum resolvable visual angle for a point source of light against a dark background. Detectibility of point sources of light will be improved by the fact that the outside atmospheric luminance of the sky background will be only 10 per cent of the luminance of the sky on a moonless night.[41] Results of a recent experiment suggest that detection of a light spot against a dark sky within a pattern of stars will not be a simple matter unless it is markedly brighter than the surrounding stars.[26]

At least one of the visibility problems which confront the pilot of a high altitude aircraft should not exist for the occupant of a space vehicle. That is the problem of space myopia.[12, 50] During daylight at altitudes between 40,000 and 60,000 ft there may be nothing visible outside an aircraft other than the homogeneous sky illumination. Under these circumstances, with no external cue for distance accommodation, the eye tends to accommodate for near objects. It is thus effectively myopic in relation to the problem of detecting objects in space. As altitude is increased, however, and the atmosphere becomes thinner, the ambient sky illumination is reduced. At an orbital altitude of 100 miles, sky illumination will

be sufficiently reduced that stars will be visible and these will provide adequate cues for distance accommodation.

Astronomical Observations: Observations of stars from an orbital vehicle may be of importance for the purpose of fixing position and controlling vehicle attitude. An orbital vehicle which is above the earth's atmosphere will receive approximately 30 per cent more visible light from the stars than the amount which reaches the earth's surface, and observations will not be subject to atmospheric shimmer.[41] There are other factors which will minimize the importance of astronomical observations for scientific purposes, however. It will not be possible to include telescopes which begin to approach the size of large terrestrial telescopes in orbiting vehicles. The degree of stabilization required for precise astronomical observation will also be difficult to achieve in a manned orbital vehicle of moderate size.

Direct observations of stars through a window will be limited by the transmittance of the materials from which the window is constructed. These will be dictated to some extent by the structural integrity requirements of the vehicle. It will also be desirable to attenuate ultra violet light and direct sunlight for the protection of the man. Following his orbital flight, Glenn reported that he was able to see fewer stars than he had expected. He tentatively attributed this to the attenuation of light by the window of the Mercury capsule. The transmittance of the window of this capsule is between 35 and 50 per cent in the visible spectrum for a normal viewing angle, but it is reduced to 15 or 25 per cent for a viewing angle of 60°.[30]

Rendezvous: One extremely challenging problem which will occur in future space flight missions will be that of rendezvousing with a vehicle which is already in orbit. It will not only be necessary to achieve the same orbit, but the same point in that orbit. The accuracy required with respect to timing, control of trajectory and burnout velocity will be considerable.[20] Corrections will undoubtedly be required even under optimum conditions. Terminal rendezvous will require a system which can assess the error between the orbit of the rendezvousing vehicle and that of its target and compute the appropriate method of reducing the error to zero.

It is possible that a man, employing direct vision, might be able to play some role in the final stages of the problem. On the other hand, estimates of shape, size and the distance of objects are strongly dependent on familiarity of the object and its appearance in relation to other objects in the visual field.[28] In empty space, such estimates may be difficult to make with sufficient accuracy for control of precise maneuvers.

Lunar and Interplanetary Flight

Vision Outside the Vehicle: During earth-lunar and interplanetary flights, external visual observations of the stars and planets may be employed to determine position and course as a check on the stellar guidance system which probably will be used. Such observations will require training in the recognition of celestial patterns and the nature of changes in the relative positions of planets which will occur during a specific flight. The location of a space vehicle in its orbital path about the earth, the sun or some target planet can be determined by simultaneous or successive observations of two or more known bodies.[1, 31] Simultaneous, multiple observations will afford the highest precision. It will be necessary to develop special techniques and devices to aid him if man is to make such observations visually.

Orientation: For the major portion of lunar and interplanetary flights, there will be no available horizon or ground plane such as there is on orbital flights to provide a stable frame of reference. Occupants of a space vehicle will therefore be more dependent on points of reference within the vehicle. In the absence of any gravitational field, certain novel problems may arise. It has been suggested that the interior design of a vehicle to be used for a prolonged space mission should be conventional, i.e., with a floor, walls and ceiling, and with instruments and controls arrayed in much the same way that they would be for use in the presence of a field of gravity.[27] It is argued that a conventional environment will be easier to work in and more compatible because of the extensive training and experience which man has had in such an environment on the earth's surface. The use of magnetic shoes and adhesive materials could be employed to aid in the stabilization of

the "up" and "down" character of the interior of such a vehicle. On the other hand, it will not be necessary for a vehicle which will be in a condition of zero gravity for extended periods to have any floors and ceilings as such. Occupants will be quite capable of moving in any direction within the vehicle, and not just with reference to a specific ground plane. Restrictions as to body positions which apply at the earth's surface will not apply. The most efficient design of work spaces and the integration of activities of several occupants of a compartment might lead to a design which is quite unique in relation to conventional terrestrial design. Stations of crew members may be oriented such that these individuals are at unique angles with respect to one another.

It is to be expected that man's training and experience in earthly surroundings will cause him some difficulty in such a novel environment. He is accustomed to a rectangular organization of the enclosures in which he lives on the surface of the earth and even minor deviations from such right-angle organization may result in considerable confusion. A good example is the disorientation experienced by most newcomers to the Pentagon. As the Ames demonstrations show very clearly[28] judgments of distance, size and shape of quite familiar objects may suffer remarkable distortion when they are observed in rooms which deviate from the usual rectangular design. These disorientations and distortions are greatest when the appearance of deviation from conventional design is least, however. The unconventionality of the most efficient interior design of a space vehicle may be sufficiently obvious that the interference effects of prior training and experience will be minimized. In any case, there is some evidence that man can compensate very rapidly for novel perceptual situations[32] even in the face of excessive prior training and experience which are not compatible.

Visual Display Problems: If a novel interior design is employed which does not provide a consistent "up," certain instrument display problems may arise as a result. The interpretation of conventional visual displays is frequently dependent to some extent on their orientation with respect to the environment, and particularly with respect to the observer. The possible location

of observers in a variety of unique positions with respect to a visual display will require a display design such that its interpretation is not dependent on its position with respect to the background against which it appears or with respect to the observer. Individual elements within the display must have unique, recognizable characteristics which are independent of their position. Visual coding by color and shape will be of importance.

Landing

In many circumstances, landing will be initiated from a condition of orbital flight by firing a rocket which is oriented to reduce orbital velocity. Timing of the firing of a retro-rocket must be carefully controlled in order to land in a desired location. Such timing can best be controlled from ground stations where precise fixes of orbital vehicle position can be made. Ground support will not always be available, however. In its absence, rocket firing may be timed by an occupant of the vehicle in relation to the transit of some recognizable landmark on the surface below. With fairly simple sighting equipment, man should be able to accomplish this within an accuracy of 250 to 500 milliseconds.[51] For an earth orbit at an altitude of 100 miles, this corresponds to a variation in final landing point of 1.25 to 2.5 miles.

Landing from orbit upon a relatively unknown planet or moon will be somewhat more difficult than landing on earth. There won't be any recognizable landmarks. Several reconnaissance orbits may be necessary in order to obtain some basis for selecting a landing sight. Visual observation will be of only limited value in assessing the nature of the surface, however. Such observation may be aided by the use of low, off-set flares which will illuminate the surface in such a way that surface irregularities will cast long, discriminable shadows.

If there is a gaseous atmosphere and the landing vehicle is capable of maneuvering within it in the fashion of a conventional aircraft, then direct visual observation of the surface may be of considerable importance in the selection of a landing site and control of the vehicle during the final stages of the landing. On the other hand, if the landing is accomplished by deceleration of

a "high-drag" vehicle such as the Mercury capsule, although some control of flight path will be possible by alterations of capsule attitude, there will be relatively little which an occupant can do to influence the landing. Parachute release will probably be automatic, but it may be timed on the basis of visual observations of the surface. This will be difficult over water and other areas with relatively homogeneous surfaces.

In the absence of a suitable combination of atmosphere, gravitational field, and vehicle design, landing will be accomplished with the aid of a deceleration rocket which will slow the vehicle as it approaches the surface. The vertical component of velocity must be reduced sufficiently at the moment of contact that there will be no damage to the vehicle or injury to vehicle occupants. It will be wasteful of energy to reduce it too rapidly. The satisfactory solution of this problem will require continuous information concerning altitude, velocity, and deceleration during descent. It seems unlikely that it can be solved by a man on the basis of direct visual observation of the surface, but given appropriate instrument information he may perform a significant role.

Hazards to Vision

High Illumination Level: Illumination of the sun, unattenuated by the earth's atmosphere, is approximately 12,000 to 14,000 ft candles in the region of the earth. [25, 29, 45] In the absence of any atmospheric dispersion the brightness of the sky is lower than that observed on the surface of the earth on a moonless night, however (on the order of 10^{-5} nit).[41] Therefore much greater contrast occurs between illuminated objects and their surroundings.[50] The range of luminances in the visual field may be expected to be greater and irritation from glare will be greater than that which occurs on the earth's surface.[36] High contrast effects need not necessarily be a problem within a space vehicle, however. They can be reduced by the use of painted surfaces of high reflectance which will scatter the light.

During observation outside a space vehicle there will be the possibility of injury to the eyes as a result of excessive exposure to sunlight.[6] Formation of an image of the sun on the retina by

optical elements of the eye results in a concentration of visible and infra-red energy sufficient to cause a retinal burn after less than a minute's observation at the earth's surface.[16] Beyond the 30 per cent attenuation of the earth's atmosphere the required duration will be shorter, perhaps 15 sec, and the closer the sun is approached, the shorter will this time become. An exposure duration of seconds represents a fairly long time, however, and it should be possible to avert the eyes in ample time to prevent damage if they are suddenly exposed to the sun. Of course, the attenuation introduced by the window material of the space vehicle will provide a considerable margin of safety.

Eye injuries caused by exposure to excessive illumination may be of two kinds.[21] Thermal injuries may occur to any part of the eye with excessive exposure to visible and infra-red radiation. Non-thermal or abiotic effects may result from exposure to shorter wavelengths (365 mμ down to below 300 mμ). These effects include erythema with severe itching and burning sensations of the eyes which may last for several weeks. The retina is not affected because virtually all the energy of these shorter wavelengths is absorbed by cornea and lens. Effects of repeated exposures to short wavelength radiation may be cumulative over a 24 hr period. Fortunately, short wavelength radiation may be almost completely absorbed by the windows of a space vehicle.

Ionizing Radiation: It has long been known that excessive ionizing radiation can cause ocular damage.[17] Cataracts can readily be produced in normal eyes by irradiation with x-rays. The younger the organism, the greater is the susceptibility. Irradiation of the lens damages anterior epithelial cells, and if cells which are capable of division are damaged, i.e., those which lie in a ring about 1 mm in front of the lens equator, cataracts may result.[39] Cataract is actually formed when damaged cells, the fibers of which are opaque to light, are moved back toward the posterior pole of the lens and subsequent cell division occurs. The effects of irradiation may be cumulative for up to four months, which is the approximate time required for recovery from irradiation effects.

There will be a variety of possible sources of radiation hazard which may be encountered in space flight. These will include the Van Allen radiation belt, cosmic rays, auroral displays and possible solar sources[40] in addition to nuclear propulsion systems of the future.[33] Structural and chemical shielding should provide adequate protection of the crew of a rocket vehicle from radiation of its own power plant. In addition, it will be necessary to plan flights such that minimum amounts of time are spent in zones of high radiation.

Exotic Fuels: Some of the constituents of the chemical fuels which will be employed in rocket flight for some time to come may be extremely toxic when absorbed or inhaled. Specific effects on vision may occur if precautions are not taken to protect the occupant of the space vehicle from the fumes of such fuels.[42]

Acceleration: Man may be exposed to high levels of acceleration both during launch and landing of a space vehicle. When the acceleration includes a positive component, i.e., one which is oriented along the long axis of the body such that flow of blood to the head is impeded, impairment of visual function may frequently result. Definite subjective visual symptoms ranging from the apparent dimming of light up to complete loss of vision are noted in the range between 3.5 and 6.0 positive *G*. The level at which these effects occur is highly variable in different individuals and in a given individual from one time to another.[14] Reaction time to visual signals is prolonged by exposure to positive acceleration[9] in the same levels where subjective symptoms are observed. White and his colleagues have found increased errors in dial reading,[49] decreased visual acuity,[48] and an elevation of light detection threshold[46] with increases in positive acceleration. Visual acuity showed impairment with increased level of acceleration, independent of the orientation of the acceleration vector. Such impairment has been attributed to mechanical effects of acceleration on optical elements of the eye.[47] Increased errors in dial reading and elevations of visual threshold may reflect interference with retinal circulation.[18] To some extent, impairment of visual functions can be offset by an increase in the level of illumination provided for the performance of visual

tasks.[47] On space flight missions, visual impairment as a result of acceleration exposure should not be a serious problem. Occupants of a space vehicle will be supported by special couches which will be oriented at right angles to the line of action of acceleration. The positive acceleration component which gives rise to the most serious visual effects will therefore be kept sufficiently low that it should not cause difficulty.

HEARING

In space flight, hearing will depend almost entirely on artificial aids. It will be a most important sensory modality, nonetheless, in that it will provide the most important link between man in space and the surface of the earth. The maintenance of this link will be extremely important, not only for the exchange of information but also for the psychological support of the man.

Normal speech sounds may be altered in a variety of ways without becoming unintelligible, and it has been demonstrated that information capacity of speech is dependent on a relatively small proportion of the total band width occupied by normal speech. Any method which can be employed to effect economies in the power requirements for communication in space will be of considerable importance.[7] A careful evaluation of the effects of modification of speech sounds on intelligibility must accompany the introduction of any new methods, however.

In addition to its importance for communication, hearing may prove of considerable importance for purposes of recreation and relaxation. For example, the ability to listen to music may assume an unimagined degree of importance for the occupant of a space vehicle on a protracted flight.

Hazards

Noise and vibration may constitute specific hazards for hearing within a space vehicle. These effects can be expected to be prominent only during launch and recovery, and can be minimized during these phases of flight by appropriate engineering design. The use of head-phones in sound-shielding mounts will

afford additional protection. Acceleration apparently has no important specific effect on hearing and therefore does not constitute a specific hazard.[11]

VESTIBULAR SENSE

There has been much concern over the possible effects of exposure to zero gravity in space flight. One basis for such concern is the fact that the pattern of stimulation of the vestibular mechanism will be very different in the absence of the earth's gravitational field. The utricular system of the vestibular apparatus contains otoliths, calcareous "stones" which are of a greater density than surrounding tissue. Variations in the orientation of a gravitational field results in a variation of the way in which these otoliths are displaced with respect to the associated macula.[8] There is an accompanying variation in the pattern of discharge of the afferent neural connections of the utricles.[23] At zero gravity, changes in body position will no longer be associated with the same changes in the pattern of utricular discharge. In addition, the perceptual results of stimulation of the semi-circular canals may be altered in the absence of the terrestrial response patterns of the utricles. These effects will be manifested by their influence on visual perception and orientation. The stability of the visual world in spite of head and body movements is related to vestibular signals which effect a stabilization of visual perception.[44] Such stabilization is partly the result of compensatory eye movements but it also depends in part upon the integration of visual and vestibular inputs at some more central location. The evidence available at present indicates that although there may be individual differences, it probably will be possible for man to adapt to a zero gravity environment fairly quickly. When vision is not impaired good adjustment to complete destruction of the vestibular apparatus occurs rapidly.[35] Placing a man in a zero gravity environment represents a much less extreme situation.

The possibility of rotating a space vehicle in order to create an artificial "gravitational field" has been considered.[34] In addition to presumed physiological advantages, certain physical reasons

are sometimes put forward in support of this kind of system. It has been said that liquids will be more readily manageable in a gravitational field, that convection currents which result in circulation of air will depend upon the presence of the gravitational field, and that the physics of the circulation of the blood require the action of a gravitational force during long term confinement. Man has difficulty tolerating rotational rates greater than 5 or 6 rpm. Although some adaptation occurs, nausea and disorientation are frequent results of exposure to a rotating environment.[13, 24] Illusory effects accompany any movement of the head. Unless the radius is substantial, only a relatively low acceleration component can be achieved by rotation at 5 or 6 rpm. Additional problems would arise in connection with external observations from a rotating vehicle.

The vestibular apparatus, by reason of differences in the density of its components, can be injured or destroyed by exposure to acceleration. In one experiment, subjects reported vertigo for up to 48 hr following exposure up to 15 transverse G for up to 5 sec. Edema of the vestibular apparatus was suggested as a tentative explanation.[19] In a later experiment[10] in which transverse accelerations of nearly 12 G were investigated, one of the subjects noted some disorientation following exposure which increased during the course of the experiment. Disorientation and vertigo persisted for some time after the completion of the experiment and disorientation was precipitated by sudden head movements for a period of several weeks. There is some evidence that disorientation following exposure to transverse acceleration of as high as 20 G may be reduced following repeated exposures.[15] The levels of acceleration required to cause irreversible damage are relatively high, and this should not pose a problem in space flight.[35]

OTHER SENSES

Kinesthetic Sense

The regulation of complex motor performance such as that which may be required by the occupants of space craft is dependent to a large extent on kinesthetic feedback from the muscle groups which are involved.[4] In a gravitational field the position

of a limb, its orientation, and its component of motion in the direction of action of the gravitational field all influence patterns of tension on the musculature involved in a way which is dependent upon the strength and line of action of the gravitational force. It is difficult to predict the extent to which highly coordinated motions may depend on this kind of feedback. It is possible that certain types of motor performance may be extremely difficult when kinesthetic cues dependent upon gravity are absent. The problem may become particularly important in connection with the manipulation of objects and tools in the unusual ways which may be required for maintenance operations in space. Preliminary studies can be conducted on the surface of the earth in which changes in motor performance capabilities are observed when organisms trained at one level of acceleration are placed in an environment at a different level of acceleration. The important limitation of studies of this kind conducted on centrifuges lies in the fact that accelerations of less than 1 G cannot be achieved for any significant duration. "Weightlessness" can be achieved, within limitations, by immersion in water, however.[8] Although the weightlessness achieved in water immersion is radically different from that which will occur under zero gravity, water immersion may nevertheless be of considerable value for training purposes prior to actual space flight.

Tactual Sense

In recent years, tactual signal systems have received considerable attention. The efficiency of these systems has been demonstrated for the receipt of information at relatively high rates.[22a] Such systems may prove useful in space craft where large numbers of non-interfering information channels will be required. On long missions it may be desirable to make some provision for the presentation of tactual stimulation in the form of low amplitude vibrations. These could be applied as a form of massage to maintain peripheral circulation and muscle tone.

Olfactory Sense

Man is limited in the number of senses available to him but his integration as a component of a space vehicle system may require