

Mr. Vinograd

PRESENTATION ON SPACE MOTION SICKNESS
BY
THE OFFICE OF LIFE SCIENCES

29 APRIL 1977

SPACE MOTION SICKNESS

BACKGROUND

SIGNIFICANCE FOR SHUTTLE

CURRENT STATUS

APPROACHES TO THE PROBLEM

FUTURE EFFORTS

SPACE MOTION SICKNESS

- BASIC SYMPTOMATOLOGY NOT UNLIKE SICKNESS RESULTING FROM EXPOSURE TO UNUSUAL MOTION ON SHIPS, CARS AND AIRCRAFT
- SYMPTOMS IN INCREASING ORDER OF SEVERITY
 - DECREASED MENTAL ALERTNESS/LETHARGY
 - VOLUNTARY RESTRICTION OF PHYSICAL ACTIVITY
 - DIZZINESS/VAGUE DISORIENTATION
 - HEADACHE
 - DECREASED APPETITE
 - STOMACH AWARENESS
 - COLD SWEATING/SUBJECTIVE WARMTH
 - PALLOR
 - NAUSEA
 - VOMITING
- INDIVIDUALS VARY GREATLY IN SUSCEPTIBILITY
- SPECIFIC CAUSES NOT WELL UNDERSTOOD; HOWEVER, MOST EVIDENCE POINTS TO SYNDROME AS HAVING ITS ORIGIN IN THE VESTIBULAR SYSTEM

MERCURY AND GEMINI PROGRAMS

- CONCERNS EXPRESSED PRIOR TO MERCURY PROGRAM ABOUT POSSIBLE DEBILITATING EFFECTS OF EXPOSURE TO WEIGHTLESSNESS
- SUBJECTIVE REPORTING BY CREWMEN INDICATED NO MOTION SICKNESS DURING ANY OF 6 MERCURY OR 10 GEMINI FLIGHTS
- ANTI-MOTION SICKNESS DRUG MAREZINE AVAILABLE TO CREWMEN BUT NOT USED
- VESTIBULAR EXPERIMENT M-9 (OCULAR COUNTERROLLING AND SPATIAL ORIENTATION) ON GEMINI V AND GEMINI VII CREWMEN PRODUCED NEGATIVE RESULTS

APOLLO PROGRAM

- 11 CREWMEN REPORTED MOTION SICKNESS TYPE SYMPTOMS; SEVERITY RANGED FROM MILD TO SEVERE (3 EXPERIENCED FRANK VOMITING)
- SYMPTOMS TYPICALLY MANIFESTED WITHIN HOURS AFTER ORBITAL INSERTION, WERE AGGRAVATED BY HEAD MOVEMENTS AND GRADUALLY DISSIPATED WITHIN 2-3 DAYS
- PREFLIGHT AEROBATICS INSTITUTED BY ASTRONAUTS FOLLOWING APOLLO 9
- ANTI-MOTION SICKNESS DRUGS MAREZINE AND SCOPOLAMINE-DEXEDRINE USED SPARINGLY AND WITH UNCERTAIN SUCCESS
- CAUSE OF RELATIVELY HIGH INCIDENCE (ABOUT 33%) OF MOTION SICKNESS APPARENTLY DUE TO INCREASED MOBILITY IN COMMAND MODULE AND LUNAR MODULE
- NOVICE CREWMEN HAD SLIGHTLY GREATER TENDENCY TO DEVELOP SYMPTOMS THAN VETERAN ASTRONAUTS
- APOLLO MARKED FIRST U.S. FLIGHT EXPERIENCE WITH SPACE MOTION SICKNESS; IT WAS THE FIRST U.S. SPACECRAFT PERMITTING FREE MOVEMENT OF THE CREW WITHIN IT.

SKYLAB PROGRAM

- 5 OF 9 CREWMEN EXPERIENCED SYMPTOMS
- OPERATIONAL EFFICIENCY OF SEVERELY AFFECTED CREWMEN IMPAIRED DURING FIRST DAYS OF FLIGHT
- COMPLETE RECOVERY REQUIRED 3-5 DAYS
- ANTI-MOTION SICKNESS (AMS) DRUGS USED OF QUESTIONABLE THERAPEUTIC VALUE
- VALUE OF T-38 AEROBATICS BY SL-4 CREW UNCERTAIN BECAUSE OF PROPHYLACTIC USE OF AMS MEDICATION AND OTHER FACTORS
- UNEXPECTEDLY M131 EXPERIMENT REVEALED VIRTUAL IMMUNITY TO MOTION SICKNESS AFTER ADAPTATION TO WEIGHTLESSNESS HAD OCCURRED
- MOTION SICKNESS (SEA SICKNESS) EXPERIENCED BY SL-2 SPT AND PLT FOLLOWING SPLASHDOWN; SL-3 AND SL-4 CREWS MEDICATED PRIOR TO DE-ORBIT TO PREVENT SYMPTOMS

APOLLO-SOYUZ TEST PROJECT (ASTP)

- PREFLIGHT TESTING INDICATED CREW MODERATELY TO HIGHLY RESISTENT TO MOTION SICKNESS IN 1-G
- NO INFLIGHT OR POSTFLIGHT VESTIBULAR FUNCTION TESTING PERFORMED
- NO VESTIBULAR DISTURBANCES REPORTED DURING FLIGHT OR POSTFLIGHT
- SCOPOLAMINE-DEXEDRINE USED PROPHYLACTICALLY BY COMMAND MODULE PILOT EARLY DURING FIRST DAY OF FLIGHT
- BOTH COSMONAUTS EXPERIENCED SPACE MOTION SICKNESS

INCIDENCE OF SPACE MOTION SICKNESS IN US AND USSR

MANNED SPACE FLIGHT PROGRAMS

USA			USSR		
PROGRAM	NUMBER OF CREWMEN	INCIDENCE OF MOTION SICKNESS	PROGRAM	NUMBER OF CREWMEN	INCIDENCE OF MOTION SICKNESS
MERCURY	6	0	VOSTOK	7	1 - <u>Vom</u>
GEMINI	20*	0	VOSKHOD	5	3 - <u>Vom</u>
APOLLO	33*	11**	SOYUZ	36#	19## - 9 <u>Vom</u>
SKYLAB	9	5	ASTP	2	2 - 1 <u>Vom</u>
ASTP	3	0			

TOTALS

16 ASTRONAUTS (Frank Vomiting in 6)

25 COSMONAUTS

(Frank Vomiting in 15)

* INCLUDES 4 CREWMEN WHO FLEW TWICE DURING PROGRAM

** INCLUDES 1 CREWMAN WHO EXPERIENCED SYMPTOMS ON BOTH OF TWO FLIGHTS

INCLUDES 6 CREWMEN WHO FLEW TWICE DURING PROGRAM

9 WITH MAJOR SYMPTOMS; 10 ADDITIONAL WITH MINOR SYMPTOMS

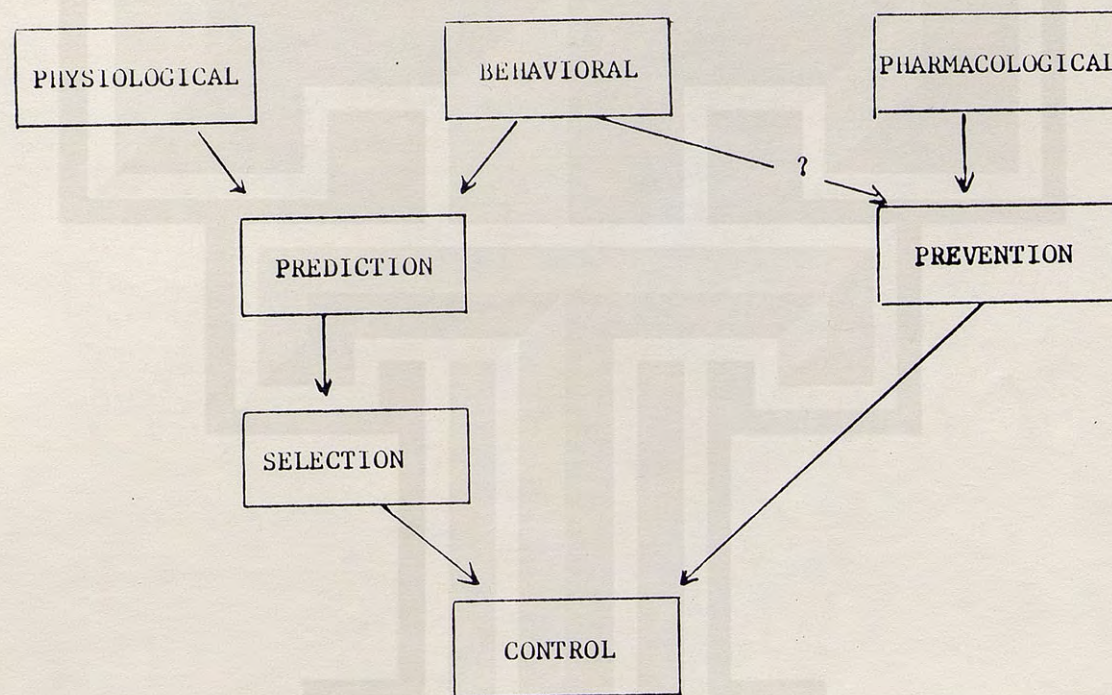
SIGNIFICANCE OF SPACE MOTION SICKNESS FOR SHUTTLE

- FREQUENCY AND SEVERITY OF SYMPTOMS PRESENT POTENTIAL
THREAT TO WELL-BEING AND OPERATIONAL EFFICIENCY OF
SHUTTLE CREWMEN AND PASSENGERS
- FACTORS AMPLIFYING CONCERN
 - LARGE NUMBER OF HIGH WORKLOAD/SHORT DURATION FLIGHTS
 - INTRODUCTION OF NOVICE CREWMEMBERS INEXPERIENCED WITH
UNUSUAL GRAVITATIONAL-INERTIAL FORCE ENVIRONMENTS
 - VEHICLE CONFIGURATION PERMITS EXTENSIVE MOVEMENT BY
CREWMEN
 - KNOWLEDGE OF ETIOLOGY AND METHODS FOR RELIABLE
PREDICTION, PREVENTION AND TREATMENT OF SYNDROME
CURRENTLY NOT OPTIMAL

CURRENT POSITION

- O NO SOUND BASIS FOR PREDICTION
 - PHYSIOLOGICAL MECHANISMS IN ZERO G NOT UNDERSTOOD
 - POOR CORRELATION BETWEEN MOTION SICKNESS IN DIFFERENT ENVIRONMENTS
- O NO PROVEN METHOD FOR PREVENTION
 - MARKED INDIVIDUAL VARIATION IN DRUG RESPONSE
 - BIOFEEDBACK TECHNIQUES LOOK PROMISING
- O HIGH LEVEL OF CONFIDENCE THAT WE CAN WORK AROUND THE PROBLEM

SR&T PROGRAM



INVESTIGATIVE APPROACH

KEY FACTORS -

- o DEVELOPMENT OF SOLUTIONS FOR PROBLEMS IDENTIFIED WILL REQUIRE A BROAD BASED PROGRAM OF INTERDISCIPLINARY STUDIES USING HUMAN AND ANIMAL SUBJECTS
- o FUNDAMENTAL AND APPLIED ASPECTS OF THE MAJOR PROBLEM AREAS MUST BE INVESTIGATED IN PARALLEL
- o FINAL VALIDATION OF TECHNIQUES FOR PREDICTING, PREVENTING AND TREATING THIS SYNDROME WILL NOT BE POSSIBLE UNTIL SEVERAL SHUTTLE FLIGHT EXPERIMENTS HAVE BEEN CONDUCTED

SPACE MOTION SICKNESS RESEARCH PROGRAM

- PROBLEMS AND TASKS -

- A. Etiology and Mechanisms of Space Motion Sickness
 - 1 - Evaluation of Fluid Shift Theory of Etiology; Conflict Theory; Others
 - 2 - Anatomical and Microelectrical Studies; Neurological Biochemistry
 - 3 - Functional Studies; Behavioral Factors
 - 4 - Mathematical Modeling
- B. Determination of Individual Predisposition (Selection)
- C. Development of Training Techniques to Diminish Susceptibility
- D. Improved Countermeasures
 - 1 - Improvement of Anti-Motion-Sickness Drugs
 - 2 - Identification of Modifying Factors for Use in Prevention (Example: Biofeedback)
 - 3 - Other Preventive/Therapeutic Techniques (Examples: In-Flight Adaptation Procedures, Fluid Shift Control)
- E. Bioinstrumentation and Methodology Development
- F. Preparation of Flight Experiments

GROUND BASED RESEARCH WITH MAN

- o MAJOR EMPHASIS ON SENSORY CONFLICT AND MOTION SICKNESS INVOLVING OTOLITHS
- o INCLUDED ARE INVESTIGATIONS OF
 - o CANAL-OTOLITH INTERACTION
 - o VISUAL-VESTIBULAR INTERACTION
 - o VESTIBULO-SPINAL REFLEXES
 - o PROPRIOCEPTIVE MECHANISMS
 - o SENSORY HABITUATION
- o STUDIES UTILIZE VARIETY OF STIMULUS GENERATION (INCLUDING PARABOLIC FLIGHT) AND RESPONSE MEASUREMENT TECHNIQUES
- o ROLL OF FLUID SHIFT REQUIRES FURTHER ANALYSIS
- o RESEARCH INVOLVING NEUROLOGICAL, PSYCHOPHYSIOLOGICAL AND BIOCHEMICAL FACTORS CURRENTLY LIMITED IN SCOPE
- o DEVELOPMENT OF IMPROVED RESPONSE MEASUREMENT TECHNIQUES MUST EVOLVE FROM THESE PROGRAMS

HUMAN RESEARCH IN SPACE

- o EMPHASIS ON PRE-, IN- AND POSTFLIGHT TESTS OF OTOLITH FUNCTION
- o RELATED PRE-, IN- AND POSTFLIGHT EVALUATIONS OF
 - o SEMICIRCULAR CANAL FUNCTION
 - o NEUROMUSCULAR AND PROPRIOCEPTIVE FUNCTION
 - o MOTION PERCEPTION AND SPATIAL ORIENTATION
- o SPECIAL TESTS TO EVALUATE FLUID SHIFT AND OTHER SECONDARY POTENTIATING FACTORS
- o MAJORITY OF EXPERIMENTS MUST BE CONDUCTED IN DEDICATED SPACELABS - WILL REQUIRE SOPHISTICATED HARDWARE AND EXTENSIVE CREW PARTICIPATION

GROUND BASED RESEARCH WITH ANIMALS

- o NEUROPHYSIOLOGICAL, BEHAVIORAL, ANATOMICAL AND HISTOLOGICAL STUDIES OF VESTIBULAR, PROPRIOCEPTIVE AND VISUAL SYSTEMS
- o ADVANTAGES OF USING ANIMALS
 - o INVASIVE PROCEDURES
 - o LARGE N
- o EMPHASIS ON RESPONSES MEASURED IN SENSORY CONFLICT SITUATIONS
- o PARABOLIC FLIGHT STUDIES TO EVALUATE RESPONSES TO HYPER AND HYPOGRAVIC STIMULI
- o EVALUATION OF SPECIFIC PHENOMENA VIA INVASIVE TECHNIQUES
 - o FLUID SHIFT MECHANISMS
 - o ALTERATION OF NEURAL IMBALANCE WITH DRUGS
- o STUDIES DESIGNED TO COMPLIMENT HUMAN RESEARCH AND DEFINE REQUIREMENTS FOR ANIMAL FLIGHT EXPERIMENTS
- o WORK IS UNDERWAY IN ABOVE AREAS

ANIMAL RESEARCH IN SPACE

- o ANIMAL EXPERIMENTS SHOULD COMPLEMENT HUMAN INFLIGHT EXPERIMENTS WERE POSSIBLE
- o IDENTIFY SPECIES WITH EASILY MEASURED MOTION SICKNESS RESPONSE
- o ELECTROPHYSIOLOGICAL TECHNIQUES TO MEASURE DISCHARGE OF CRITICAL COMPONENTS OF CENTRAL AND PERIPHERAL NERVOUS SYSTEM
 - o PRIMARY AFFERENTS
 - o VESTIBULAR EREFERENCE
 - o VESTIBULAR NUCLEI
 - o RETICULAR SYSTEM
 - o SPINAL CORD MOTONEURONS
- o RESOLVE FLUID SHIFT QUESTION
- o SOPHISTICATED CORE REQUIRED, INCLUDING LINEAR ACCELERATOR AND CENTRIFUGE

PREVENTION

- o TWO BASIC APPROACHES UNDER INVESTIGATION
 - o PREHABITUATION
 - FUNDAMENTAL QUESTIONS REGARDING APPROPRIATENESS OF VARIOUS TECHNIQUES MUST BE ANSWERED
 - TIME AND SOPHISTICATED FACILITIES REQUIRED MAY BE LIMITING FACTORS
 - o ANTI-MOTION SICKNESS DRUGS
 - EFFICACY AS WELL AS SIDE EFFECTS MUST BE EVALUATED
 - SITE OF DRUG ACTION SHOULD BE BETTER UNDERSTOOD

TREATMENT

- o ANTI-MOTION SICKNESS DRUGS PRIMARY REMEDY USED IN PAST
- o LIMITED ATTEMPTS WITH SPECIAL INFLIGHT HABITUATION PROCEDURES NOT SUCCESSFUL
- o EFFORTS IN PROGRESS FOCUSING ON
 - o IMPROVED DRUG THERAPY
 - o OPERATIONALLY ACCEPTABLE INFLIGHT HABITUATION PROCEDURES, POSSIBLY AIDED WITH DRUGS
 - o MINIMIZATION OF MOVEMENT THROUGH IMPROVED PROCEDURAL CHECK LISTS, WORK LOAD REQUIREMENTS AND TASK GEOMETRY

DRUG THERAPY

I. SCIENTIFIC/CLINICAL OBJECTIVES

- a. IDENTIFY MOST APPROPRIATE AND EFFECTIVE DRUGS FOR MS TREATMENT.
- b. CONSERVE CREW MEMBERS ABILITY TO PERFORM COMPLEX TASKS DURING THE EARLY PHASES OF THE MISSIONS.

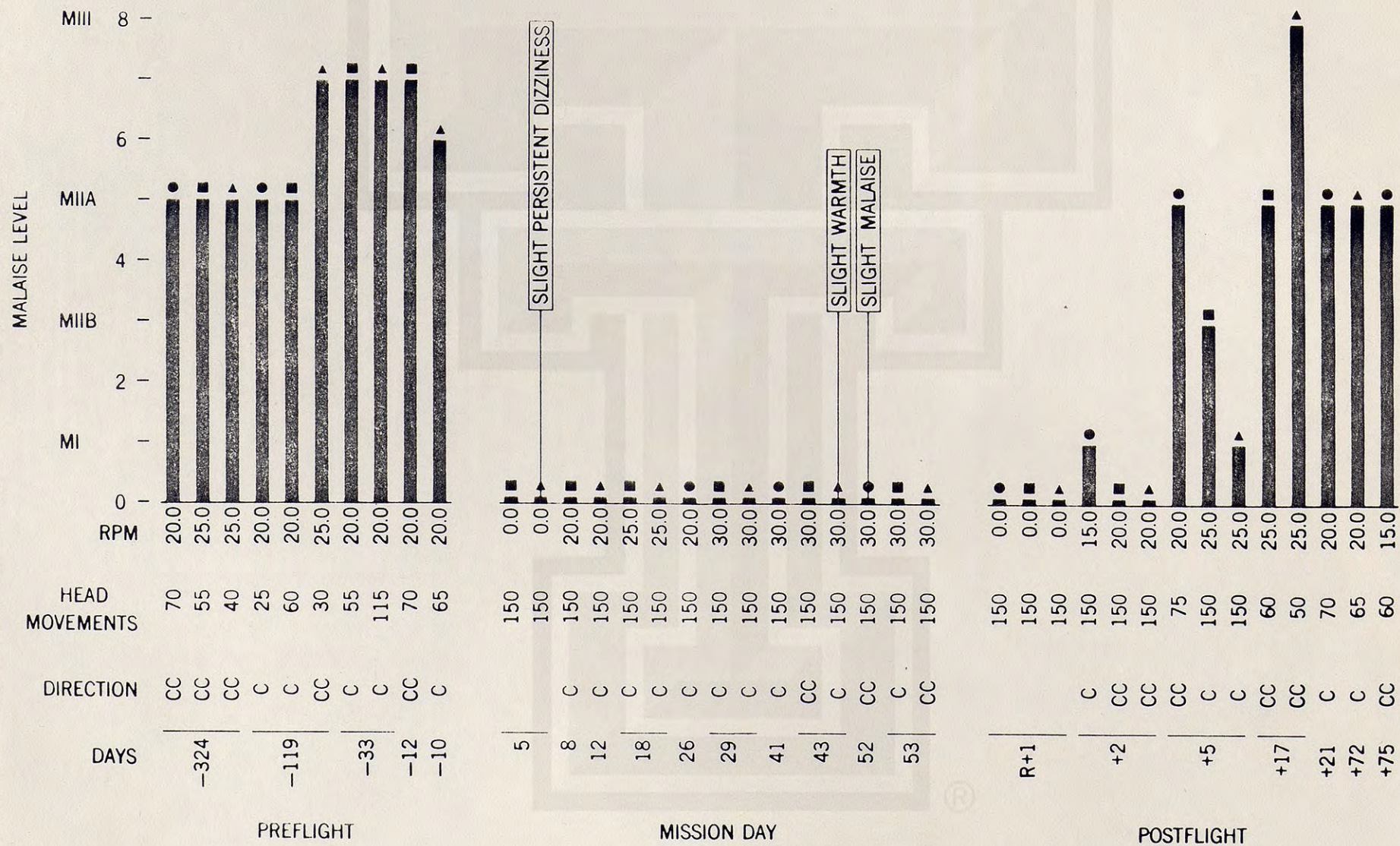
II. INVESTIGATION APPROACH

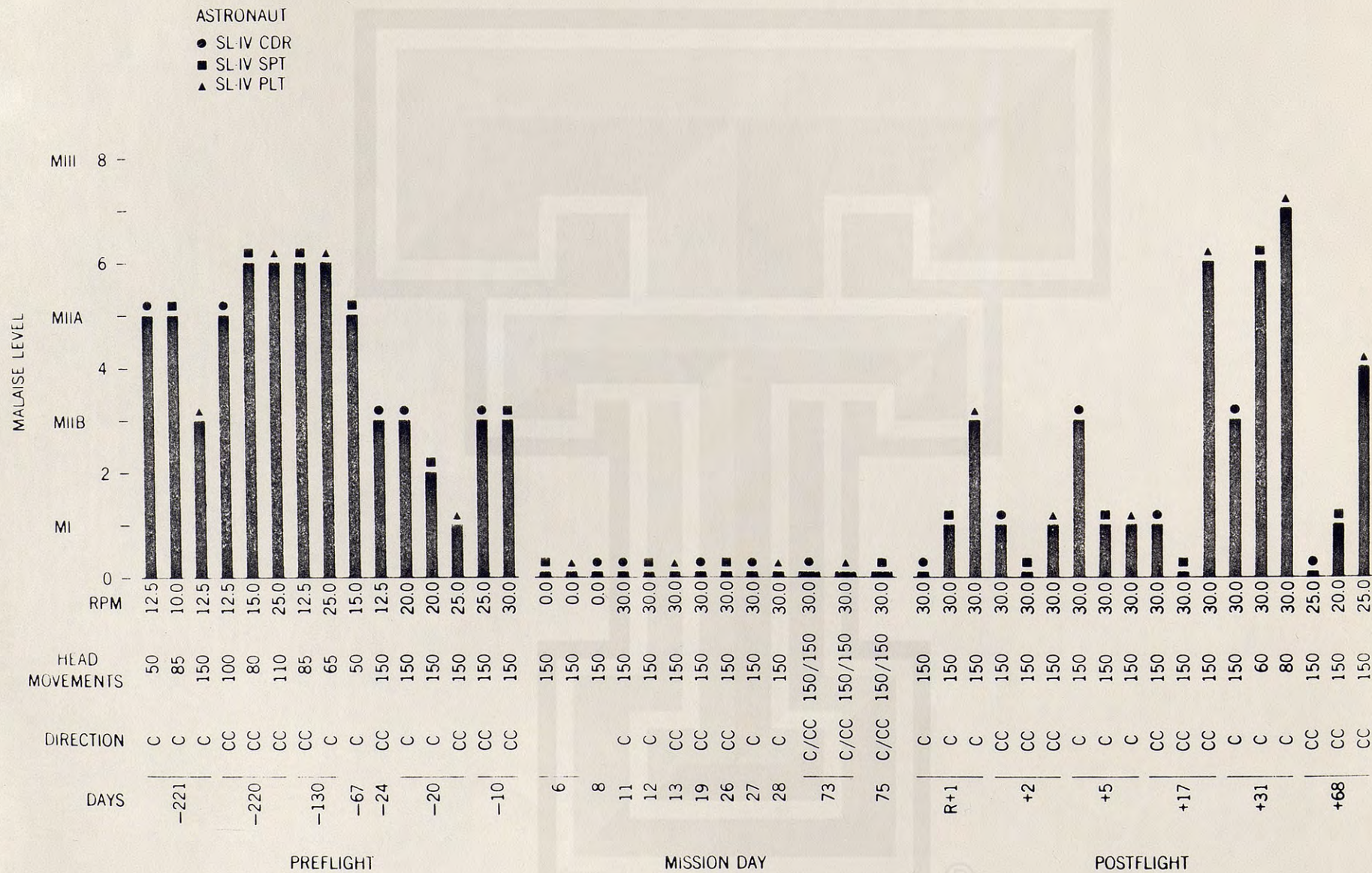
- a. TESTING OF NEW DRUG AND/OR COMBINATION OF DRUGS IN SRR AND KEPLERIAN FLIGHTS.
- b. IDENTIFYING INDIVIDUAL TOLERANCES TO DRUGS.
- c. SIDE EFFECTS
- d. IDENTIFYING PSYCHOMOTOR PERFORMANCE AFTER DRUG ADMINISTRATION.

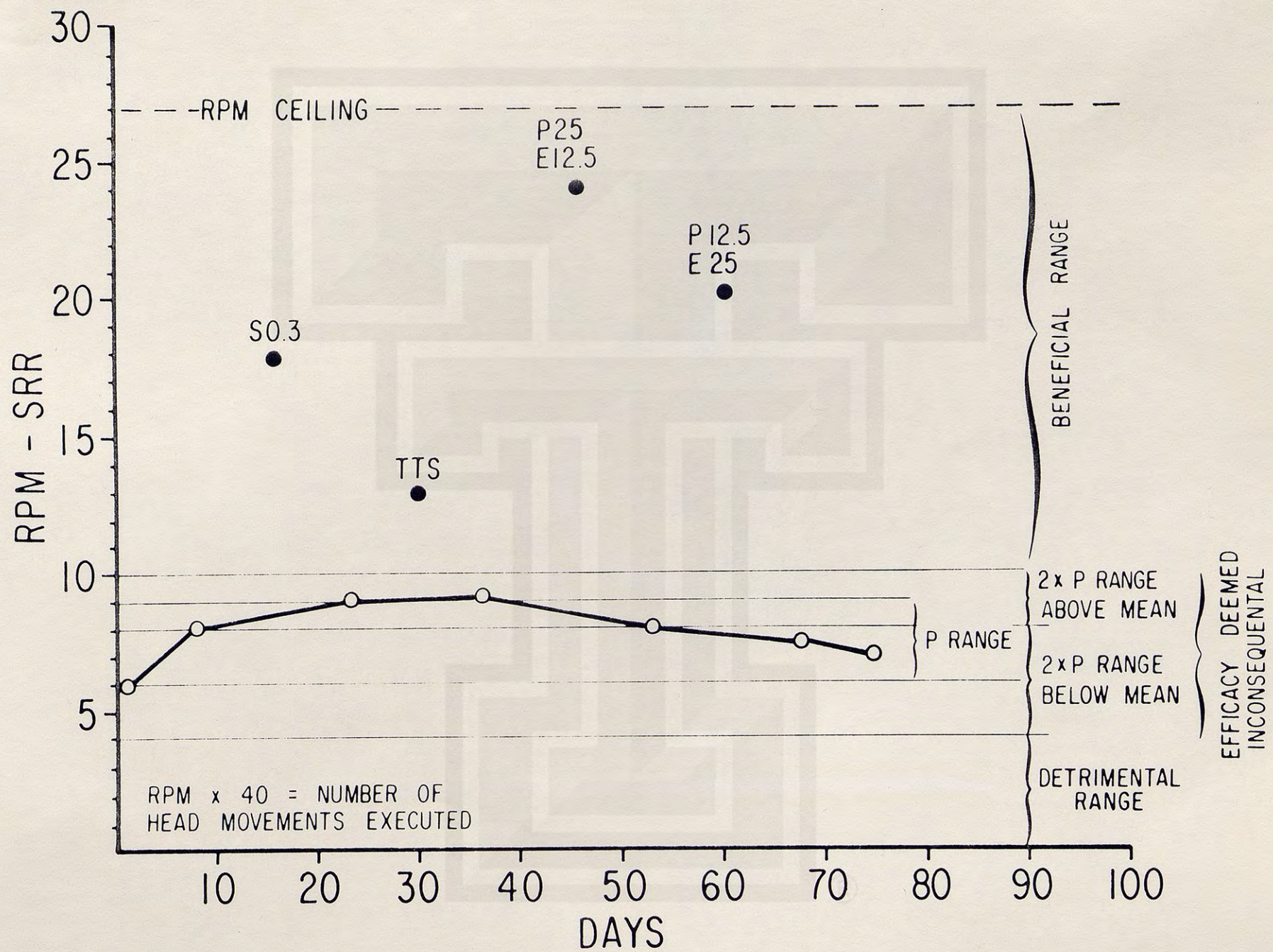
III. EVALUATION OF EFFECTIVENESS - OBJECTIVE & QUANTITATIVE

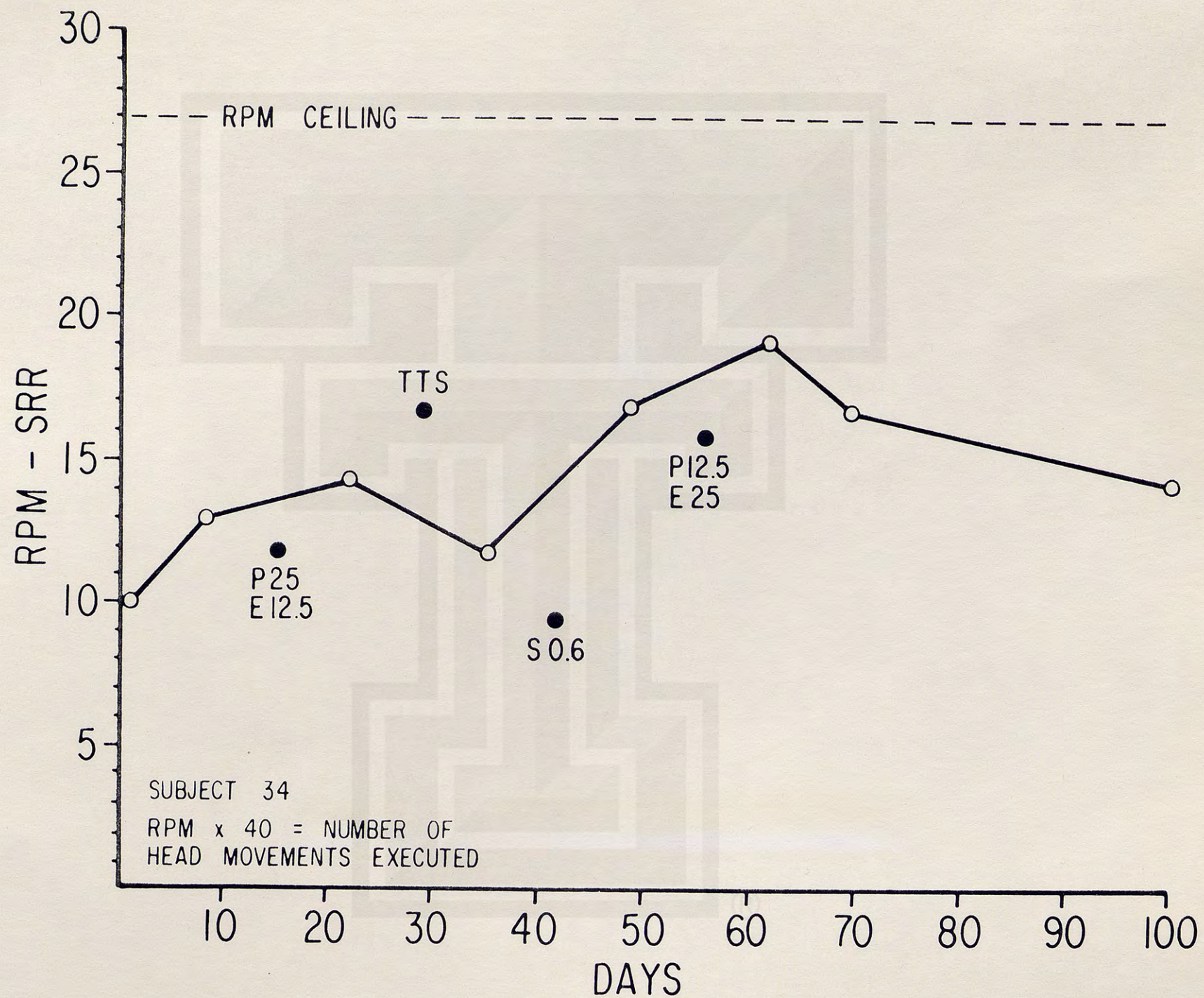


- SL-III CDR
- SL-III SPT
- ▲ SL-III PLT





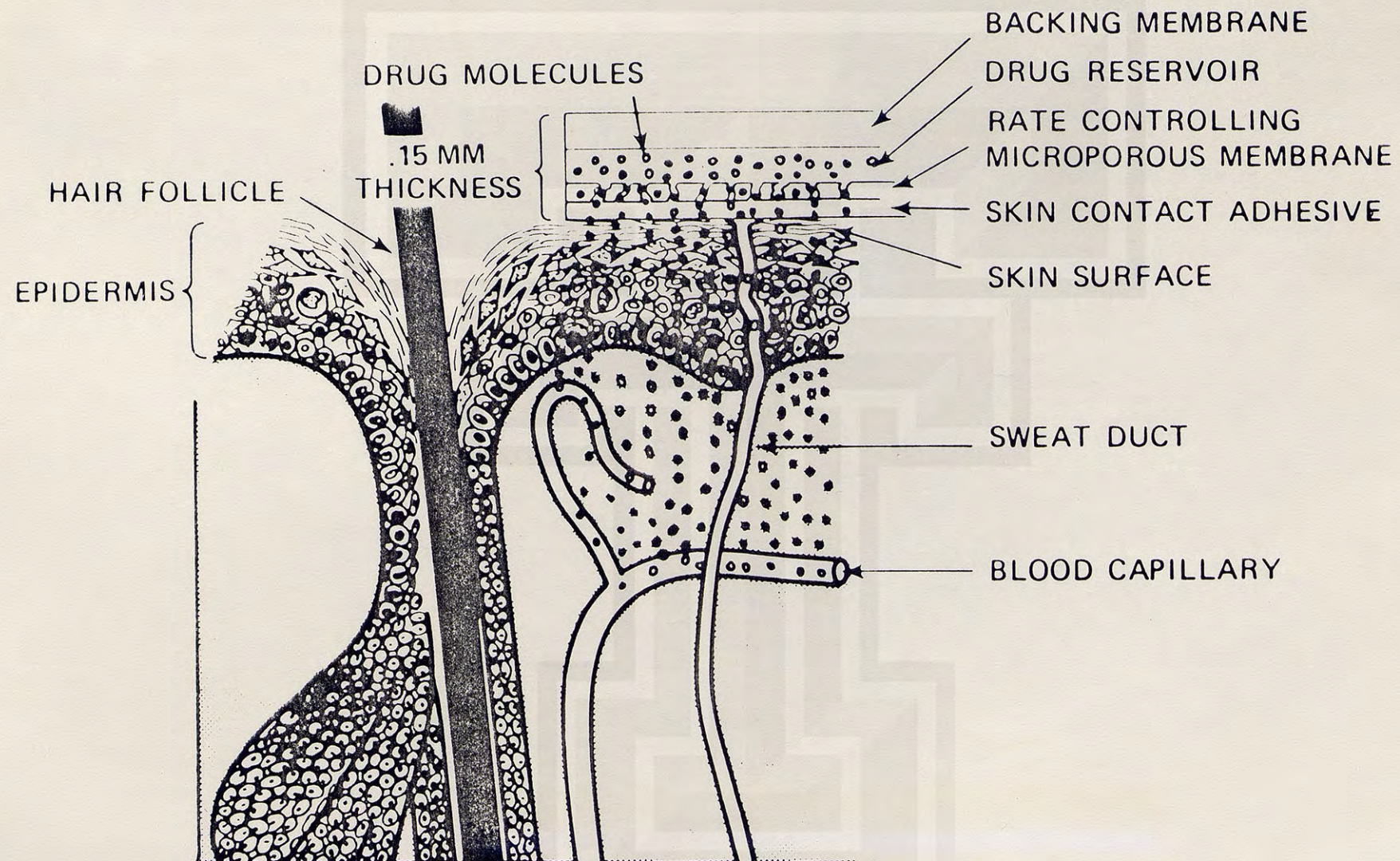




Responses to Three Antimotion Sickness Remedies Administered Intramuscularly During Sorties in the KC-135

Subj.	Trial	Promethazine 25 mg			Scopolamine 4.3 mg			Dimenhydrinate 50 mg		
		1st FS* prior to injection	Inj.	Subsequent FS	1st FS prior to injection	Inj.	Subsequent FS	1st FS prior to injection	Inj.	Subsequent FS
19	1st	16**	21	38	12	12	0	12	13	24,29
	2nd	17	19	21,22				6	6	26
	3rd	23	25	0						
	4th	23	25	0						
	5th	26	26	0						
	6th				10	11	0			
33		11	13 ⁺	14,15						
47	1st	30	30	30	12	12	0	24	25	29,32,40
	2nd				26	28	0			
8	1st	21	23	0						
	2nd	22	30	0						
10	1st	10	24	0	8	8	0			
	2nd	32	32	0						
	3rd	10	13	0						
16		15	19	22,23,38						
17	1st	0	11	13,17						
	2nd	9	10	0						
	3rd	0	10	13						

*FS = frank sickness; **16th parabola; ⁺ promethazine 50 mg.



B A C K G R O U N D

A. THERE ARE CURRENTLY TWO MAJOR TECHNIQUES FOR TRAINING VOLITIONAL CONTROL OF AUTONOMIC RESPONSES

1. BIOFEEDBACK - DEVELOPED BY DR. NIEL MILLER

2. AUTOGENIC THERAPY - DEVELOPED BY DR. WOLFGANG LUTHE

THIS RESEARCH COMBINES THE TWO TECHNIQUES.

B. THE CORIOLIS SICKNESS SUSCEPTIBILITY INDEX (CSSI) FOR DETERMINING THE LEVEL OF MALAISE EXPERIENCED DURING CORIOLIS ACCELERATION DEVELOPED BY DR. EARL MILLER AND DR. ASHTON GRAYBIEL.

THE BIOFEEDBACK LOOP



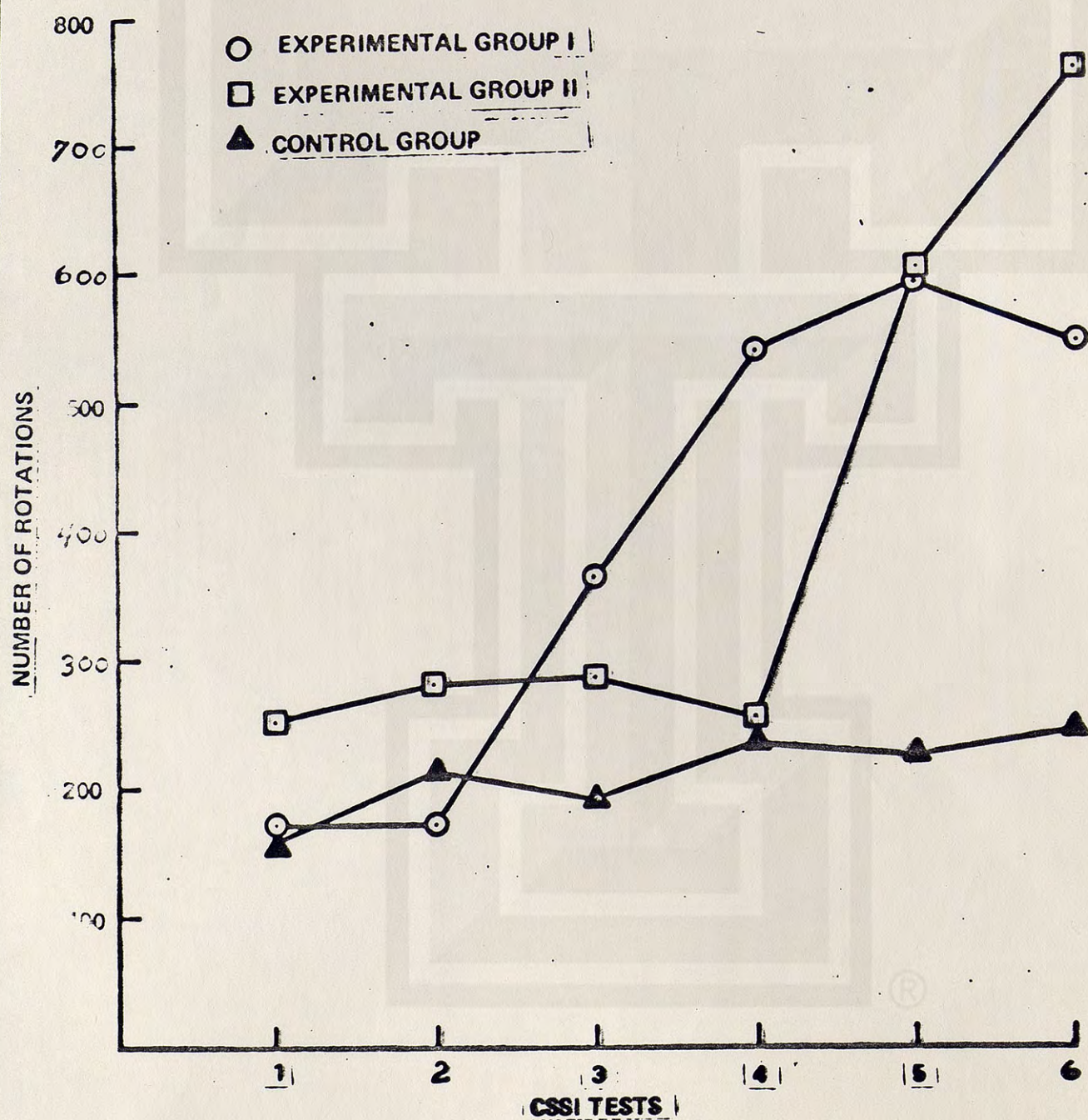
OBJECTIVES

- A. TO DEVELOP AN EFFECTIVE TECHNIQUE FOR TRAINING HUMAN SUBJECTS TO VOLITIONALLY CONTROL A NUMBER OF THEIR OWN AUTONOMIC RESPONSES SIMULTANEOUSLY.
- B. TO DETERMINE WHETHER THIS LEARNED CONTROL CAN BE APPLIED TO REDUCE THE SEVERITY OF MOTION SICKNESS SYMPTOMS PRODUCED BY CORIOLIS ACCELERATION.

AUTOGENIC CONTROL (STUDY I)

1. OBJECTIVES - SUPPRESS SYMPTOMS OF MS BY PRIOR CONDITIONING
2. METHOD - LEARNING TO CONTROL AUTONOMIC MANIFESTATIONS OF MS BY SUPPRESSING EVOQUED VISCERAL RESPONSES (HR, RR, PERIPHERAL BLOOD FLOW)
3. CONCLUSIONS -
 - a. FIVE HOUR CONDITIONING RESULTED IN SUBJECT'S ABILITY TO WITHSTAND THE CORIOLIS STRESS SIGNIFICANTLY LONGER THAN PRIOR TO TRAINING
($p < .001$)
 - b. INDIVIDUAL'S AUTONOMIC RESPONSE PATTERNS MAY HAVE PREDICTIVE VALUE FOR MS SUSCEPTIBILITY AND AUTONOMIC LEARNING TASKS.
 - c. POSSIBLE MEAN TO IDENTIFY SLOW AND FAST ADAPTERS TO NEW STRESS SITUATIONS.

**NUMBER OF ROTATIONS ACHIEVED DURING EACH
CSSI TEST-GROUP MEANS**



AUTOGENTIC CONTROL (STUDY II)

1. OBJECTIVE - COMPARISON OF PATTERN FEEDBACK (SINGLE INPUT) VS. INDIVIDUAL RESPONSE FEEDBACK (MULTIPLE INPUTS).
2. METHOD -
 - a. TWO GROUPS OF SUBJECTS EXPOSED TO LINEAR, ANGULAR AND OPTOKINETIC STIMULI.
 - b. ONE GROUP RECEIVING A FEEDBACK ARRAY (MULTIPLE INPUT) ON HR, RR, BLOOD FLOW: THE SECOND GROUP RECEIVING ONLY ONE COMBINED FEEDBACK (SINGLE INPUT).
3. CONCLUSIONS -
 - a. CONTROL OF MS SYMPTOMS DUE TO CORIOLIS APPLIES TO OTHER STIMULI AS WELL.
 - b. SYMPTOM PATTERN DIFFERS WITHIN SUBJECTS WHO ARE EXPOSED TO DIFFERENT STIMULI.
 - c. INDIVIDUAL'S AUTONOMIC PROFILE IS CONSISTANT.
 - d. SUBJECTS RECEIVING ONE FEEDBACK SIGNAL TRAIN FASTER.

AUTOGENIC CONTROL (STUDY III)

1. OBJECTIVES: DETERMINE THE ADVANTAGES OF BIDIRECTIONAL TRAINING
(AROUSAL ALTERNATING WITH RELAXATION) VS. UNIDIRECTIONAL CONTROL
(RELAXATION):
 - a. IF BIDIRECTIONAL CONTROL WILL ALLOW A GIVEN SUBJECT TO RECOGNIZE
THE DEGREE AND PROGRESSION OF MS.
 - b. IF BIDIRECTIONAL CONTROL IS MORE EFFECTIVE.
 - c. IF BIDIRECTIONAL CONTROL TRAINING APPLIES TO OTHER STRESSFUL
STIMULI.
2. STUDY IS IN PROGRESS.

ORBITAL FLIGHT TESTS - PRE-FLIGHT TRAINING FOR THE
PREVENTION OF SPACE MOTION SICKNESS

I. SPECIFIC OBJECTIVES - SUMMARY

1. TO REDUCE THE SYMPTOMATOLOGY ASSOCIATED WITH MS AND IMPROVE THE OPERATIONAL EFFICIENCY OF CREW MEMBERS IN SPACE.
2. TREATMENT WILL BE EFFECTED BY PRE-FLIGHT TRAINING (OPERANT CONDITIONING OF MULTIPLE AUTONOMIC RESPONSES COMBINED WITH AUTOGENIC THERAPY) AND INFLIGHT APPLICATION OF LEARNED AUTONOMIC CONTROL BY CREW MEMBERS.
3. DEVELOPMENT OF PREDICTIVE CRITERIA (BASED ON AUTONOMIC PATTERN PROFILES) FOR DETERMINING SUSCEPTIBILITY TO MS AND INDIVIDUAL AUTONOMIC LEARNING ABILITY TO SUPPRESS THESE SYMPTOMS.

NASA-S-76-5548

SPACE MOTION SICKNESS IN THE SHUTTLE ERA

PRESENTATION TO
NASA ADMINISTRATOR
OCTOBER 4, 1976

OVERVIEW

- DEFINITION OF SPACE MOTION SICKNESS
- HISTORY OF MOTION SICKNESS IN SPACE FLIGHT
 - MERCURY AND GEMINI
 - APOLLO
 - SKYLAB
 - ASTP
 - USSR
- SIGNIFICANCE OF SPACE MOTION SICKNESS FOR SHUTTLE
 - VIP CONSIDERATIONS
- RESEARCH THRUSTS
 - ETIOLOGY
 - PREDICTION
 - PREVENTION
 - TREATMENT

186-2

SPACE MOTION SICKNESS SYNDROME

- ☐ MOTION SICKNESS IN 1G
- ☐ MOTION SICKNESS IN OG
- ☐ ARE THEY THE SAME?

SPACE MOTION SICKNESS

- BASIC SYMPTOMATOLOGY NOT UNLIKE SICKNESS RESULTING FROM EXPOSURE TO UNUSUAL MOTION ON SHIPS, CARS AND AIRCRAFT
- SYNDROME MAY INCLUDE VARIETY OF BEHAVIORAL AND PHYSIOLOGICAL RESPONSES
 - DECREASED MENTAL ALERTNESS/LETHARGY
 - VOLUNTARY RESTRICTION OF PHYSICAL ACTIVITY
 - DIZZINESS/VAGUE DISORIENTATION
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186-3

DIAGNOSTIC CATEGORIZATION OF DIFFERENT LEVELS OF SEVERITY OF ACUTE MOTION SICKNESS

CATEGORY	PATHOGNOMONIC 16 POINTS	MAJOR 8 POINTS	MINOR 4 POINTS	MINIMAL 2 POINTS	AQS* 1 POINT
NAUSEA SYNDROME	NAUSEA III, + RETCHING OR VOMITING	NAUSEA II	NAUSEA I	EPIGASTRIC DISCOMFORT	EPIGASTRIC AWARENESS
SKIN		PALLOR III	PALLOR II	PALLOR I	FLUSHING/SUBJECTIVE WARMTH =II
COLD SWEATING		III	II	I	
INCREASED SALIVATION		III	II	I	
DROWSINESS		III	II	I	
PAIN					HEADACHE (PERSISTENT) =II
CENTRAL NERVOUS SYSTEM					DIZZINESS (PERSISTENT) EYES CLOSED =II EYES OPEN III

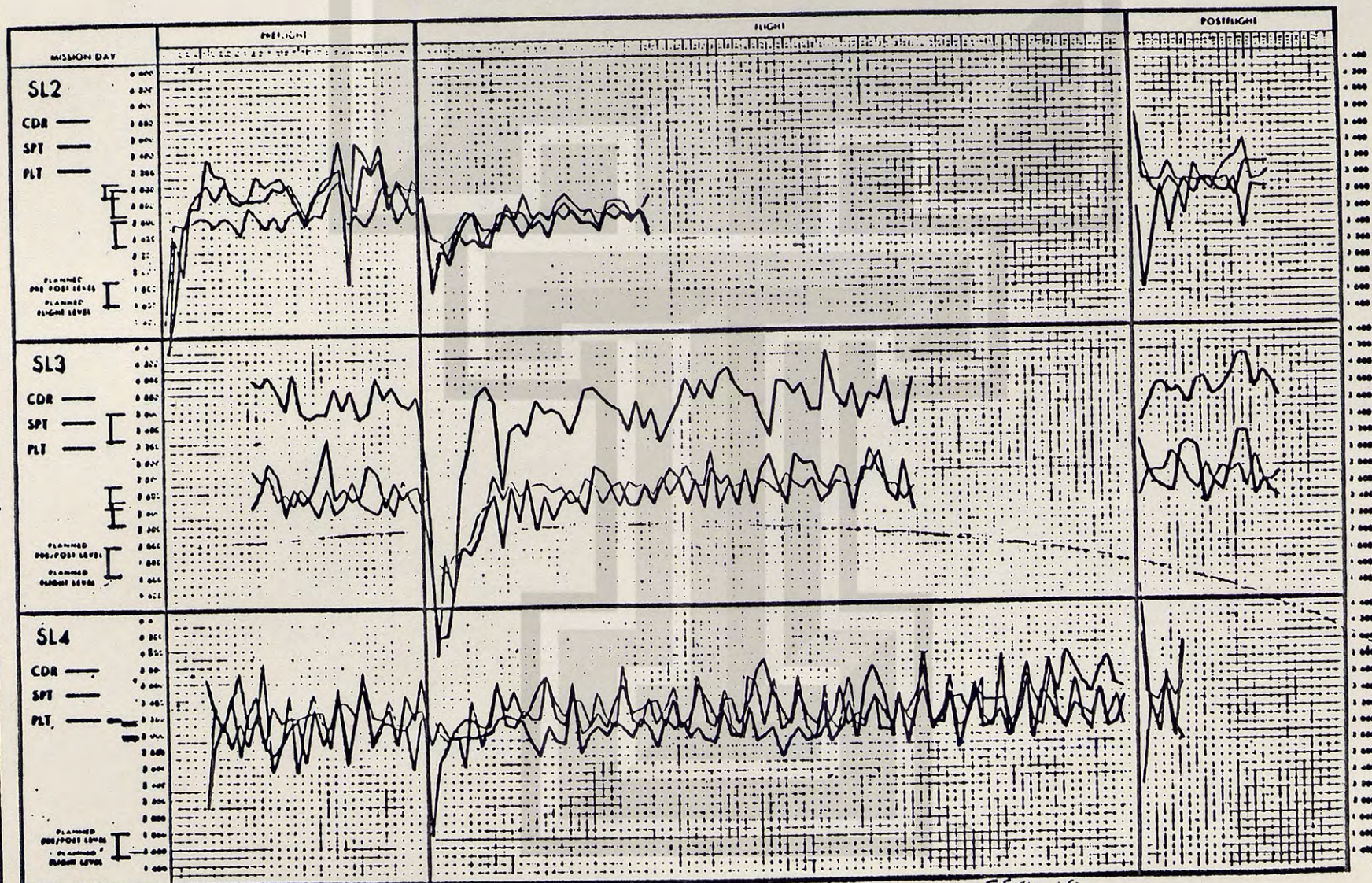
LEVELS OF SEVERITY IDENTIFIED BY TOTAL POINTS SCORED

FRANK SICKNESS	SEVERE MALAISE	MODERATE MALAISE A	MODERATE MALAISE B	SLIGHT MALAISE
(FS)	(M III)	(M IIA)	(M IIB)	(M I)
=16 POINTS	8 - 15 POINTS	5 - 7 POINTS	3 - 4 POINTS	1 - 2 POINTS

*AQS - ADDITIONAL QUALIFYING SYMPTOMS

+III - SEVERE OR MARKED, II - MODERATE, I - SLIGHT

SKYLAB CREW HEALTH TREND - CALORIE INTAKE (CAL/DAY)



FEB 19

MERCURY AND GEMINI PROGRAMS

- CONCERNS EXPRESSED PRIOR TO MERCURY PROGRAM ABOUT POSSIBLE DEBILITATING EFFECTS OF EXPOSURE TO WEIGHTLESSNESS
- SUBJECTIVE REPORTING BY CREWMEN INDICATED NO MOTION SICKNESS DURING ANY OF 6 MERCURY OR 10 GEMINI FLIGHTS
- FAILURE TO RECOGNIZE SYMPTOMS MAY ACCOUNT FOR LACK OF POSITIVE REPORTS
- ANTI-MOTION SICKNESS DRUG MAREZINE AVAILABLE TO CREWMEN BUT NOT USED
- WITH ONE EXCEPTION NO QUANTITATIVE CREW VESTIBULAR DATA OBTAINED
- SPECIAL TESTS (OCULAR COUNTERROLLING AND SPATIAL ORIENTATION) ON GEMINI V AND GEMINI VII CREWMEN PRODUCED NEGATIVE RESULTS

*no symptoms
reported*

APOLLO PROGRAM

- HEAVY RELIANCE PLACED ON SUBJECTIVE REPORTING BY CREWMEN
- 11 INSTANCES OF MOTION SICKNESS TYPE SYMPTOMS REPORTED; SEVERITY RANGED FROM MILD TO SEVERE
- SYMPTOMS TYPICALLY MANIFESTED WITHIN HOURS AFTER ORBITAL INSERTION, WERE AGGRAVATED BY HEAD MOVEMENTS AND GRADUALLY DISSIPATED WITHIN 2-3 DAYS
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- NOVICE CREWMEN HAD SLIGHTLY GREATER TENDENCY TO DEVELOP SYMPTOMS THAN VETERAN ASTRONAUTS
- APOLLO FIRST EMPHASIZED MOTION SICKNESS AS POTENTIAL BIOMEDICAL PROBLEM

APOLLO MOTION SICKNESS GENERAL SUMMARY

NUMBER OF CREWMEN

MOTION SICKNESS (MS) HISTORY AND INFLIGHT MS

TOTAL APOLLO CREWMEN	33
POSITIVE MS HISTORY	27
POSITIVE MS HISTORY WITH INFLIGHT MS	9
POSITIVE MS HISTORY WITH NO INFLIGHT MS	18
NEGATIVE MS HISTORY	6
NEGATIVE MS HISTORY WITH INFLIGHT MS	2
NEGATIVE MS HISTORY WITH NO INFLIGHT MS	4
TOTAL CREWMEN WITH INFLIGHT MS	11

SEVERITY OF INFLIGHT SYMPTOMS

OCCURRENCES OF MILD MS (STOMACH AWARENESS)	6
OCCURRENCES OF MODERATE MS (STOMACH AWARENESS, NAUSEA)	2
OCCURRENCES OF SEVERE MS (STOMACH AWARENESS, NAUSEA, VOMITING)	3

PREVIOUS SPACE FLIGHT EXPERIENCE

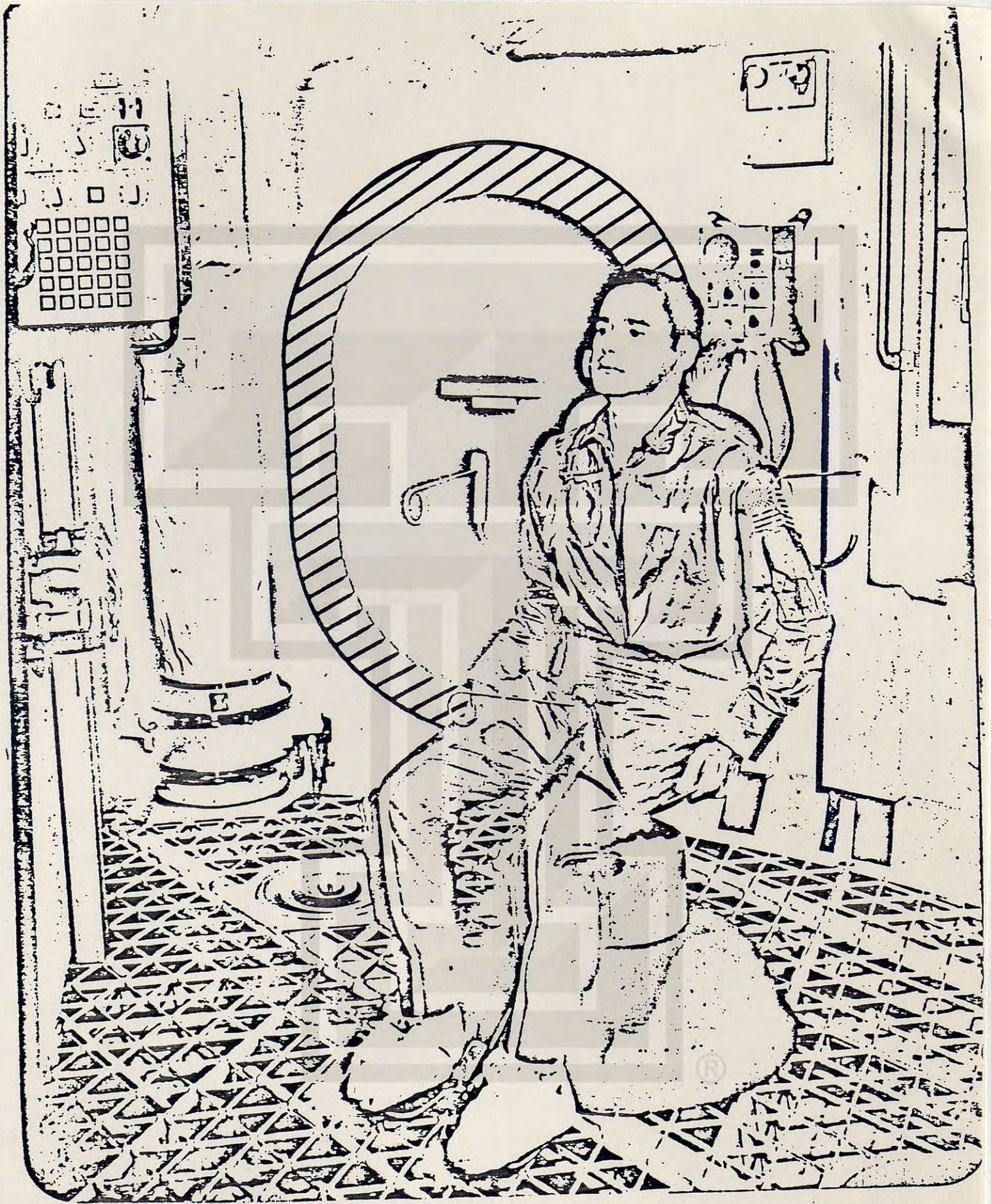
CREWMEN (FIRST SPACE FLIGHT)	15
CREWMEN (FIRST SPACE FLIGHT) WITH INFLIGHT MS	6
VETERAN CREWMEN (ONE OR MORE SPACE FLIGHTS)	18
VETERAN CREWMEN WITH INFLIGHT MS	5

SKYLAB PROGRAM

- ① 5 OF 9 CREWMEN EXPERIENCED SYMPTOMS
- ② OPERATIONAL EFFICIENCY OF SEVERELY AFFECTED CREWMEN IMPAIRED DURING FIRST DAYS OF FLIGHT
- ③ COMPLETE RECOVERY REQUIRED 3-5 DAYS
- ④ ANTI-MOTION SICKNESS (AMS) DRUGS USED OF QUESTIONABLE THERAPEUTIC VALUE
- ⑤ VALUE OF T-38 AEROBATICS BY SL-4 CREW UNCERTAIN BECAUSE OF PROPHYLACTIC USE OF AMS MEDICATION AND OTHER FACTORS
- ⑥ UNEXPECTEDLY M131 EXPERIMENT REVEALED VIRTUAL IMMUNITY TO MOTION SICKNESS AFTER ADAPTATION TO WEIGHTLESSNESS HAD OCCURRED
- ⑦ MOTION SICKNESS (SEA SICKNESS) EXPERIENCED BY SL-2 SPT AND PLT FOLLOWING SPLASHDOWN; SL-3 AND SL-4 CREWS MEDICATED PRIOR TO DE-ORBIT TO PREVENT SYMPTOMS

SKYLAB EXPERIMENT M131 HUMAN VESTIBULAR FUNCTION

- PURPOSE OF EXPERIMENT WAS TO INVESTIGATE THE EFFECTS OF PROLONGED EXPOSURE TO WEIGHTLESSNESS ON THE HUMAN VESTIBULAR SYSTEM. PRE-, IN-, AND POSTFLIGHT MEASUREMENTS WERE PERFORMED TO ASSESS:
 - SEMICIRCULAR CANAL SENSITIVITY
 - SUSCEPTIBILITY TO MOTION SICKNESS
 - SPATIAL ORIENTATION



DIAGNOSTIC CATEGORIZATION OF DIFFERENT LEVELS OF ACUTE MOTION SICKNESS

	PATHOGNOMONIC	MAJOR	MINOR	MINIMAL	AQS *
CATEGORY	16 POINTS	8 POINTS	4 POINTS	2 POINTS	1 POINT
NAUSEA SYNDROME	NAUSEA III,† RETCHING OR VOMITING	NAUSEA II	NAUSEA I	EPIGASTRIC DISCOMFORT	EPIGASTRIC AWARENESS
SKIN		PALLOR III	PALLOR II	PALLOR I	FLUSHING/ SUBJECTIVE WARMTH ≥ II
COLD SWEATING		III	II	I	
INCREASED SALIVATION		III	II	I	
DROWSINESS		III	II	I	
PAIN					HEADACHE (PERSISTENT) ≥ II
CENTRAL NERVOUS SYSTEM					DIZZINESS (PERSISTENT) - EYES CLOSED ≥ II EYES OPEN - III

.....
LEVELS OF SEVERITY IDENTIFIED BY TOTAL POINTS SCORED

FRANK SICKNESS (FS)	SEVERE MALAISE (M III)	MODERATE MALAISE A (M IIA)	MODERATE MALAISE B (M IIB)	SLIGHT MALAISE (M I)
- 16 POINTS	8 - 15 POINTS	5 - 7 POINTS	3 - 4 POINTS	1 - 2 POINTS

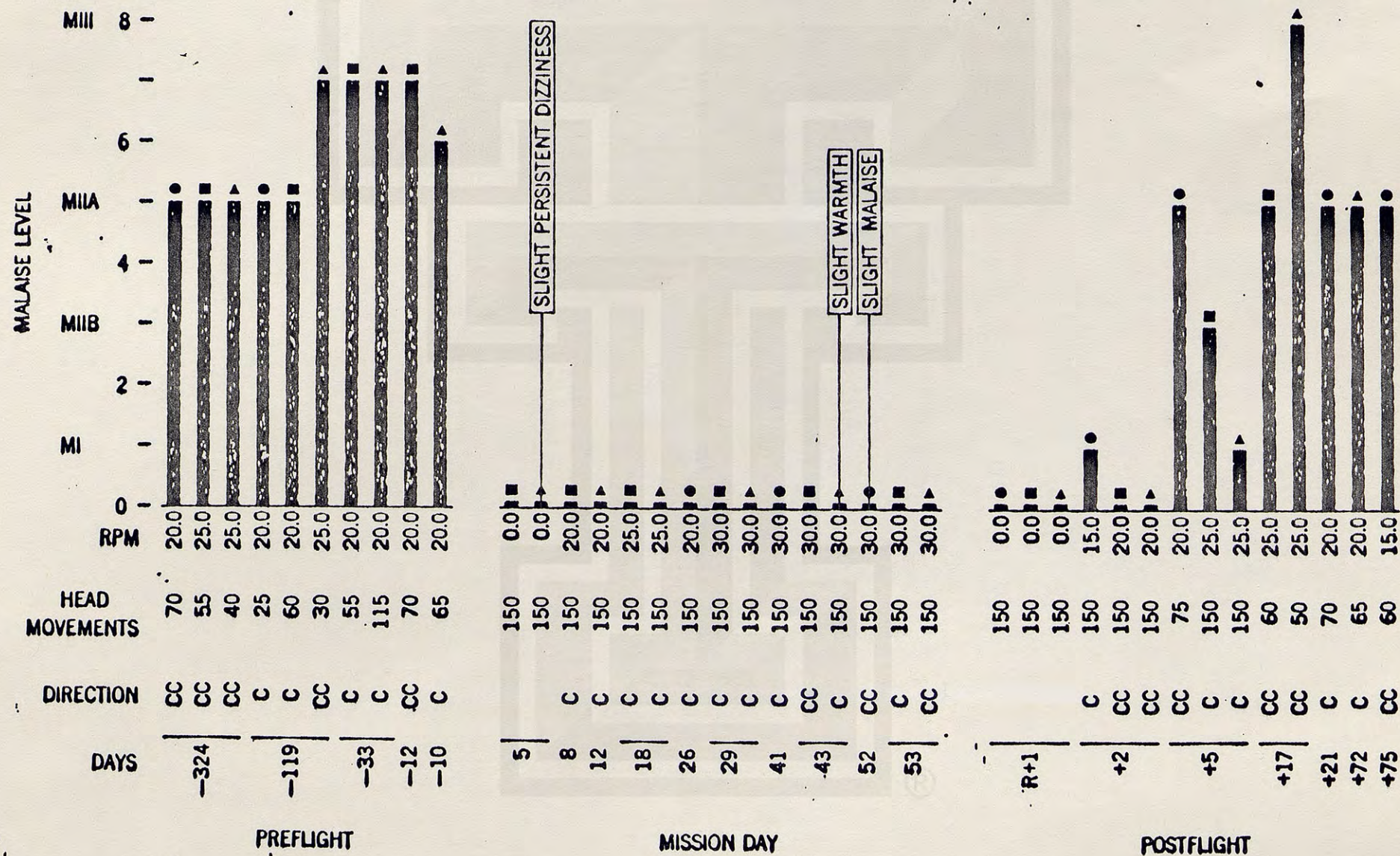
* AQS - ADDITIONAL QUALIFYING SYMPTOMS

III - SEVERE OR MARKED, II - MODERATE, I - SLIGHT

SKYLAB M-131 EXPERIMENT RESULTS SECOND MANNED MISSION

ASTRONAUT

- SL-III CDR
- SL-III SPT
- ▲ SL-III PLT



APOLLO-SOYUZ TEST PROJECT (ASTP)

- PREFLIGHT TESTING INDICATED CREW MODERATELY TO HIGHLY RESISTENT TO MOTION SICKNESS IN 1-G
- NO INFLIGHT OR POSTFLIGHT VESTIBULAR FUNCTION TESTING PERFORMED
- NO VESTIBULAR DISTURBANCES REPORTED DURING FLIGHT OR POSTFLIGHT
- SCOPOLAMINE-DEXEDRINE USED PROPHYLACTICALLY BY COMMAND MODULE PILOT EARLY DURING FIRST DAY OF FLIGHT
- BOTH COSMONAUTS EXPERIENCED SPACE MOTION SICKNESS

MANNED SPACE FLIGHT PROGRAMS

USA			USSR		
PROGRAM	NUMBER OF CREWMEN	INCIDENCE OF MOTION SICKNESS	PROGRAM	NUMBER OF CREWMEN	INCIDENCE OF MOTION SICKNESS
MERCURY	6	0	VOSTOK	7	1 - <u>Vom.</u>
GEMINI	20*	0	VOSKHOD	5 /	3 - <u>Vom.</u>
APOLLO	33*	11**	SOYUZ	36#	19## - 9 <u>Vom.</u>
SKYLAB	9	5	ASTP	2	2 - 1 <u>Vom.</u>
ASTP	3	0			

* INCLUDES 4 CREWMEN WHO FLEW TWICE DURING PROGRAM

** INCLUDES 1 CREWMAN WHO EXPERIENCED SYMPTOMS ON BOTH OF TWO FLIGHTS

INCLUDES 6 CREWMEN WHO FLEW TWICE DURING PROGRAM

9 WITH MAJOR SYMPTOMS; 10 ADDITIONAL WITH MINOR SYMPTOMS

USSR PREFLIGHT VESTIBULAR TRAINING

RATIONALE: RAISING VESTIBULAR THRESHOLD TO MOTION SICKNESS SUSCEPTIBILITY

1) GROUND BASED (2-3 TIMES/WEEK)

- ROTATING LITTER CHAIR/STABILITY TEST
- ROTATING LITTER CHAIR/CORIOLIS
- SWING TEST
- WATER ACROBATICS

2) KEPLERIAN FLIGHTS

- MOTION SICKNESS QUESTIONNAIRE
- MOTOR COORDINATION TESTS
- GALVANIC STIMULATION OF THE VESTIBULAR APPARATUS
- LITTER CHAIR

SIGNIFICANCE OF SPACE MOTION SICKNESS FOR SHUTTLE

- FREQUENCY AND SEVERITY OF SYMPTOMS PRESENT POTENTIAL
THREAT TO WELL-BEING AND OPERATIONAL EFFICIENCY OF
SHUTTLE CREWMEN AND PASSENGERS
- FACTORS AMPLIFYING CONCERN
 - LARGE NUMBER OF HIGH WORKLOAD/SHORT DURATION FLIGHTS
 - INTRODUCTION OF NOVICE CREWMEMBERS INEXPERIENCED WITH
UNUSUAL GRAVITATIONAL-INERTIAL FORCE ENVIRONMENTS
 - VEHICLE CONFIGURATION PERMITS EXTENSIVE MOVEMENT BY
CREWMEN
 - KNOWLEDGE OF ETIOLOGY AND METHODS FOR RELIABLE
PREDICTION, PREVENTION AND TREATMENT OF SYNDROME
CURRENTLY NOT OPTIMAL

SHUTTLE OFT PASSENGER (VIP) CONSIDERATIONS

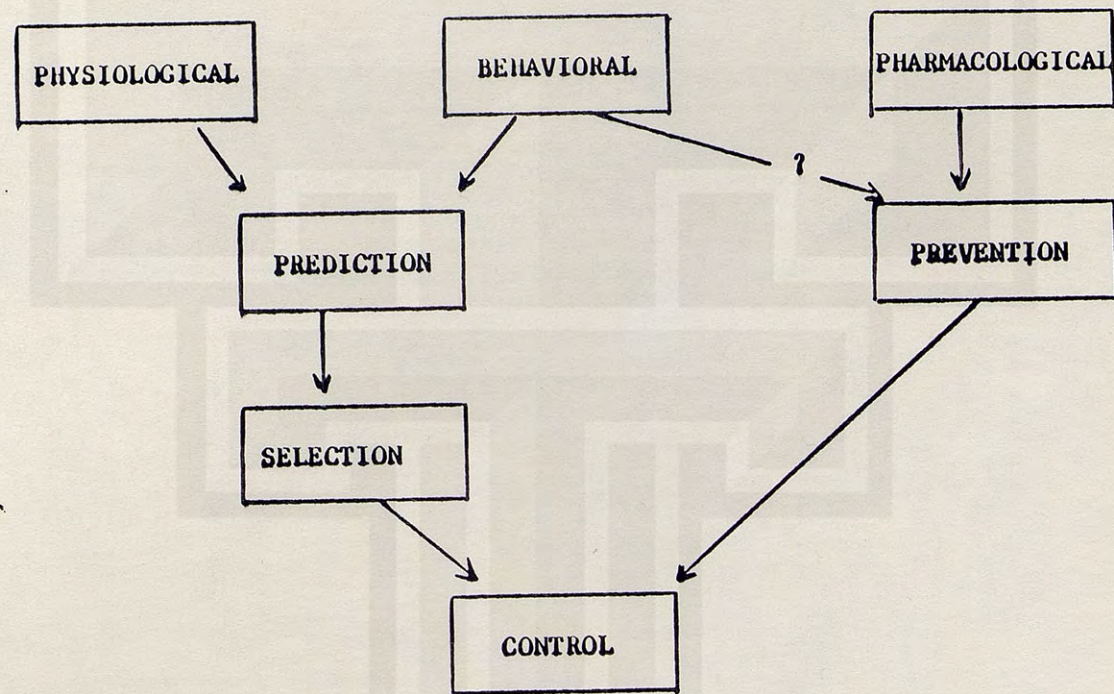
- CONDUCT PREFLIGHT PERSONAL INTERVIEW
 - OBTAIN MOTION SICKNESS HISTORY
 - CONVEY RELEVANT STATE-OF-THE-ART KNOWLEDGE ABOUT SPACE MOTION SICKNESS
- PERFORM MINIMUM LABORATORY TESTS
 - EVALUATE INTEGRITY OF VESTIBULAR SYSTEM FUNCTION
 - DETERMINE MOTION SICKNESS SUSCEPTIBILITY THRESHOLD AND ACQUAINT INDIVIDUAL WITH RECOGNITION OF SYMPTOMS
 - IDENTIFY MOST EFFICACIOUS ANTI-MOTION SICKNESS (AMS) DRUG AND DOSE LEVEL
- EXPOSE INDIVIDUAL TO ZERO-G PARABOLIC FLIGHT (OPTIONAL)
 - PERMIT FAMILIARIZATION WITH UNUSUAL INERTIAL FORCE ENVIRONMENT AND ZERO G
 - FURTHER EVALUATE AMS DRUG EFFICACY/DOSAGE
- ENCOURAGE PROPHYLACTIC USE OF OPTIMUM AMS DRUG PRE-LAUNCH AND EARLY INFLIGHT

RESEARCH THRUSTS

- ETIOLOGY
 - EXTENSIVE INTERRELATED HUMAN AND ANIMAL STUDIES
DIRECTED TOWARD ELUCIDATION OF PHYSIOLOGICAL AND
BEHAVIORAL PROCESSES UNDERLYING DEVELOPMENT OF
SYNDROME
- PREDICTION
 - DEVELOP AND VALIDATE SPECIALIZED TECHNIQUES TO DETECT
SUSCEPTIBILITY TO SPACE MOTION SICKNESS
- PREVENTION
 - PREHABITUATION
 - CREW TIME AND SPECIAL FACILITIES REQUIRED ARE
LIMITING FACTORS
 - ANTI-MOTION SICKNESS DRUGS
 - EVALUATION OF EFFICACY AND SIDE EFFECTS
- TREATMENT
 - IMPROVED DRUG THERAPY (TYPE, DOSE AND DELIVERY METHOD)
 - ACCEPTABLE INFLIGHT ADAPTATION PROCEDURES
 - TASK PROFILES WHICH MINIMIZE HEAD MOVEMENTS


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graph TD; A[PHYSIOLOGICAL] --> C[PREDICTION]; B[BEHAVIORAL] --> C; B --> D[PREVENTION]; B --> E[?]; C --> F[SELECTION]; F --> G[CONTROL]; D --> G; E --> D;
```

The diagram is a flowchart with six rectangular boxes. At the top, there are three boxes: 'PHYSIOLOGICAL' on the left, 'BEHAVIORAL' in the center, and 'PHARMACOLOGICAL' on the right. Below 'PHYSIOLOGICAL' is a box labeled 'PREDICTION'. Below 'BEHAVIORAL' are two boxes: 'PREDICTION' on the left and 'PREVENTION' on the right. Below 'PHARMACOLOGICAL' is a box labeled 'PREVENTION'. Below 'PREDICTION' (under 'PHYSIOLOGICAL') is a box labeled 'SELECTION'. Below 'SELECTION' is a box labeled 'CONTROL'. Below 'PREVENTION' (under 'BEHAVIORAL') is a box labeled 'CONTROL'. Arrows point from 'PHYSIOLOGICAL' to 'PREDICTION', from 'BEHAVIORAL' to 'PREDICTION', from 'BEHAVIORAL' to 'PREVENTION', from 'BEHAVIORAL' to a question mark, from the question mark to 'PREVENTION', from 'PREDICTION' to 'SELECTION', from 'SELECTION' to 'CONTROL', and from 'PREVENTION' to 'CONTROL'.



SUMMARY

O NO SOUND BASIS FOR PREDICTION

- PHYSIOLOGICAL MECHANISMS IN ZERO G NOT UNDERSTOOD
- POOR CORRELATION BETWEEN MOTION SICKNESS IN DIFFERENT ENVIRONMENTS

O NO PROVEN METHOD FOR PREVENTION

- MARKED INDIVIDUAL VARIATION IN DRUG RESPONSE
- BIOFEEDBACK TECHNIQUES LOOK PROMISING

O HIGH LEVEL OF CONFIDENCE THAT WE CAN WORK AROUND THE PROBLEM

RECOMMENDATION

O CONTINUE INTENSIVE SR&T PROGRAM

- MORE TECHNOLOGICAL LIMITED THAN DOLLAR LIMITED

O USE SPACE SHUTTLE POPULATION TO ASSESS THE VALIDITY OF
OUR PREDICTIVE AND PREVENTIVE MEASURES

- FLIGHT CREWS FOR CONTROLS

- PAYLOAD SPECIALISTS/SCIENTIST PASSENGERS AS
EXPERIMENTAL SUBJECTS

PHYSIOLOGICAL CHANGES
OF NO MEDICAL CONCERN FOR SHUTTLE

<u>SYSTEM</u>	<u>INFLIGHT</u>	<u>POST FLIGHT</u>	<u>PREVENTION</u>
CARDIOVASCULAR	- o CHANGES IN DYNAMICS - o CHANGES IN MECHANICS (FLUID SHIFTS) - o ↓ BLOOD VOLUME	↓ ORTHOSTATIC TOLERANCE	- o SELECTION - o EXERCISE - o COUNTERPRESSURE GARMENT - o HYDRATION
METABOLIC	- o ↓ MUSCLE MASS - o ↓ TOTAL BODY Ca - o WEIGHT LOSS	NO SIGNIFICANT PROBLEMS AFTER MISSIONS OF 3 MONTHS DURATION	- o CALORIC & ELECTROLYTE INTAKE - o PROPER EXERCISE - o COUNTERMEASURES
HEMATOPOIETIC	o ↓ Rbc MASS	NO SIGNIFICANT PROBLEMS AFTER MISSIONS OF 3 MONTHS DURATION	NONE REQUIRED

SPACE MOTION SICKNESS

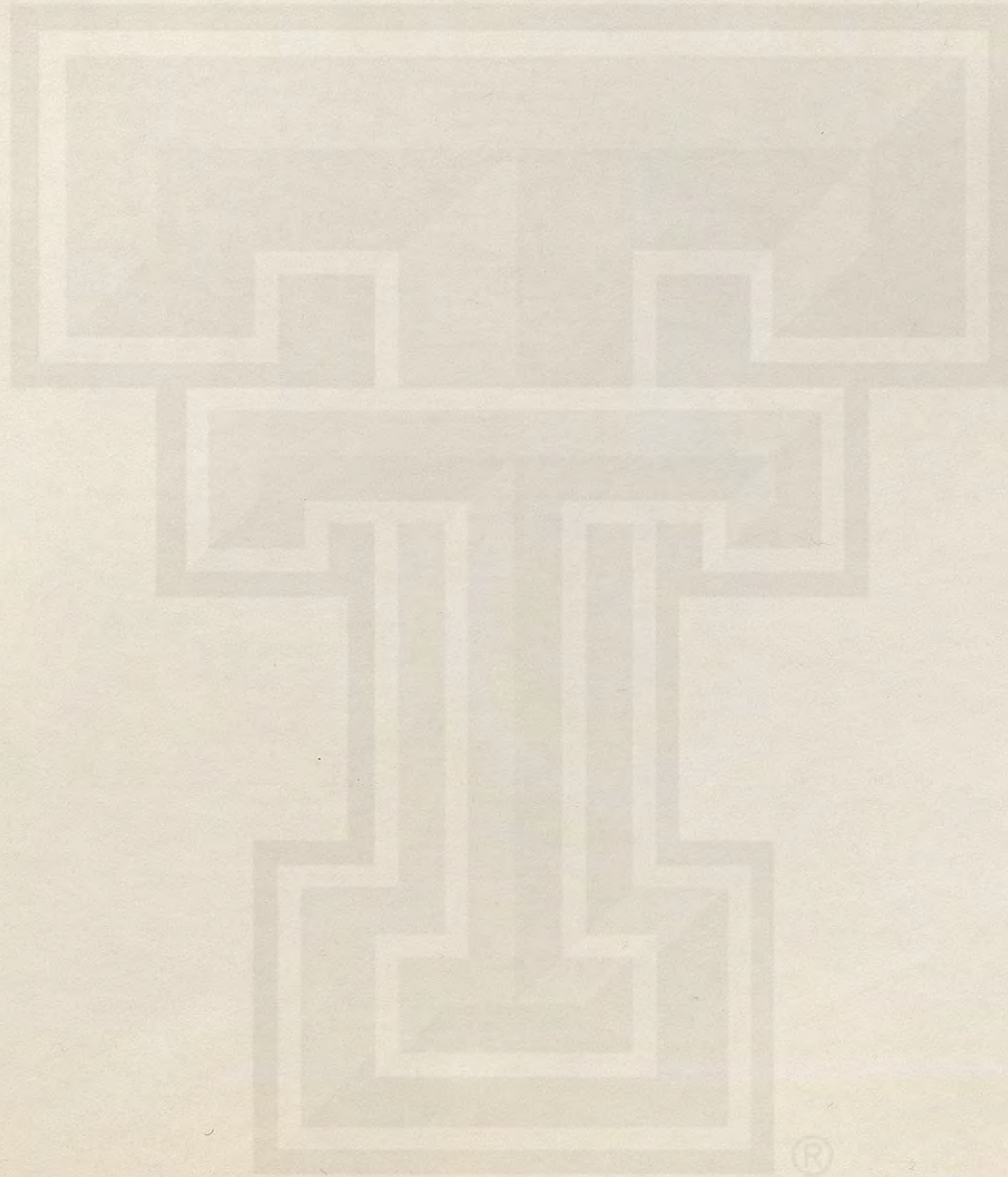
- Review and Current Status -

December, 1976

SPACE MOTION SICKNESS

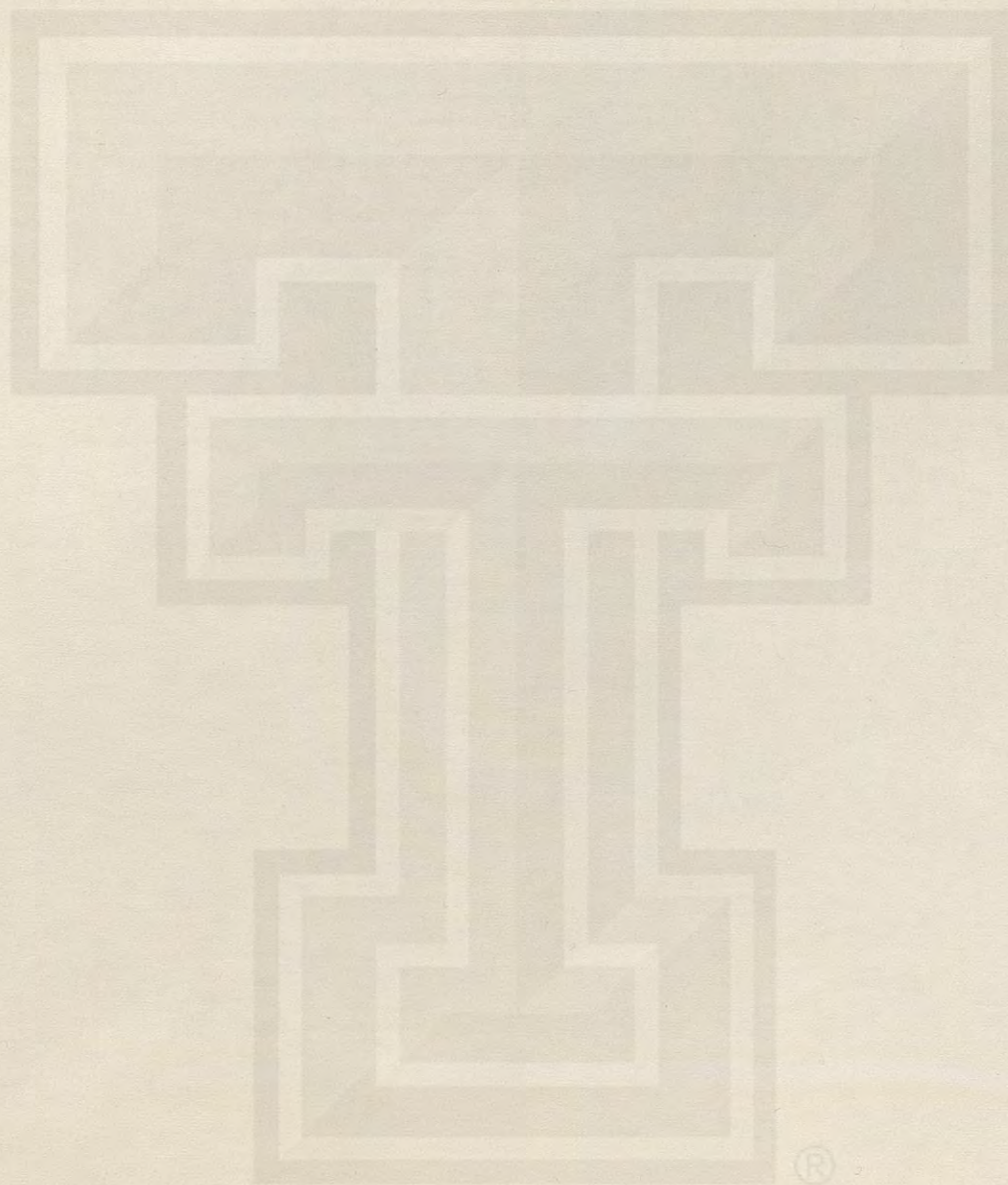
- INDEX -

1. SPACE MOTION SICKNESS - DESCRIPTION OF THE SYNDROME
2. INCIDENCE AND FLIGHT EXPERIENCE
3. RELATIONSHIP TO SHUTTLE OPERATIONS
4. SR&T APPROACH
5. PROGRAM MILESTONES



SPACE MOTION SICKNESS

- BASIC SYMPTOMATOLOGY NOT UNLIKE SICKNESS RESULTING FROM EXPOSURE TO UNUSUAL MOTION ON SHIPS, CARS AND AIRCRAFT
- SYMPTOMS IN INCREASING ORDER OF SEVERITY
 - DECREASED MENTAL ALERTNESS/LETHARGY
 - VOLUNTARY RESTRICTION OF PHYSICAL ACTIVITY
 - DIZZINESS/VAGUE DISORIENTATION
 - HEADACHE
 - DECREASED APPETITE
 - STOMACH AWARENESS
 - COLD SWEATING/SUBJECTIVE WARMTH
 - PALLOR
 - NAUSEA
 - VOMITING
- INDIVIDUALS VARY GREATLY IN SUSCEPTIBILITY
- SPECIFIC CAUSES NOT WELL UNDERSTOOD; HOWEVER, MOST EVIDENCE POINTS TO SYNDROME AS HAVING ITS ORIGIN IN THE VESTIBULAR SYSTEM



®

MERCURY AND GEMINI PROGRAMS

- CONCERNS EXPRESSED PRIOR TO MERCURY PROGRAM ABOUT POSSIBLE DEBILITATING EFFECTS OF EXPOSURE TO WEIGHTLESSNESS
- SUBJECTIVE REPORTING BY CREWMEN INDICATED NO MOTION SICKNESS DURING ANY OF 6 MERCURY OR 10 GEMINI FLIGHTS
- ANTI-MOTION SICKNESS DRUG MAREZINE AVAILABLE TO CREWMEN BUT NOT USED
- VESTIBULAR EXPERIMENT M-9 (OCULAR COUNTERROLLING AND SPATIAL ORIENTATION) ON GEMINI V AND GEMINI VII CREWMEN PRODUCED NEGATIVE RESULTS

APOLLO PROGRAM

- 11 CREWMEN REPORTED MOTION SICKNESS TYPE SYMPTOMS; SEVERITY RANGED FROM MILD TO SEVERE (3 EXPERIENCED FRANK VOMITING)
- SYMPTOMS TYPICALLY MANIFESTED WITHIN HOURS AFTER ORBITAL INSERTION, WERE AGGRAVATED BY HEAD MOVEMENTS AND GRADUALLY DISSIPATED WITHIN 2-3 DAYS
- PREFLIGHT AEROBATICS INSTITUTED BY ASTRONAUTS FOLLOWING APOLLO 9
- ANTI-MOTION SICKNESS DRUGS MAREZINE AND SCOPOLAMINE-DEXE~~T~~DRINE USED SPARINGLY AND WITH UNCERTAIN SUCCESS
- CAUSE OF RELATIVELY HIGH INCIDENCE (ABOUT 33%) OF MOTION SICKNESS APPARENTLY DUE TO INCREASED MOBILITY IN COMMAND MODULE AND LUNAR MODULE
- NOVICE CREWMEN HAD SLIGHTLY GREATER TENDENCY TO DEVELOP SYMPTOMS THAN VETERAN ASTRONAUTS
- APOLLO MARKED FIRST U.S. FLIGHT EXPERIENCE WITH SPACE MOTION SICKNESS; IT WAS THE FIRST U.S. SPACECRAFT PERMITTING FREE MOVEMENT OF THE CREW WITHIN IT.

**Vestibular-Related Symptoms Experienced
by Apollo Astronauts**

Mission	Astronaut	Motion Sickness History			Illusions/Motion Sickness Symptoms in Space Flight			
		In Land, Air and Sea Vehicles	In Zero-G Parabola	In S/C Egress or Egress Training	Tumbling Illusions	Stomach Awareness	Nausea	Vomiting
7	A	X		X				
	B	X	X	X				
	C	X		X	X			
8	D	X				X	X	X
	E	X	X	X		X	X	
	F	X	X			X		
9	G			X		X		
	H			X	X	X		
	I	X	X	X		X	X	X
10	J	X						
	K	X						
	L	X				X		
11	M	X	X	X				
	N	X	X	X				
	O	X	X					
12	P	X						
	Q							
	R			X				
13	S(E)	X	X	X				
	T					X	X	X
	U					X		
14	V	X						
	W	X						
	X							
15	Y(H)			X				
	Z		X		X	X		
	AA							
16	BB(X)	X						
	CC	X	X					
	DD	X	X					
17	EE(L)	X	X			X		
	FF	X	X			X		
	GG	X	X					

SKYLAB PROGRAM

- 5 OF 9 CREWMEN EXPERIENCED SYMPTOMS
- OPERATIONAL EFFICIENCY OF SEVERELY AFFECTED CREWMEN IMPAIRED DURING FIRST DAYS OF FLIGHT
- COMPLETE RECOVERY REQUIRED 3-5 DAYS
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- NO VESTIBULAR DISTURBANCES REPORTED DURING FLIGHT OR POSTFLIGHT
- SCOPOLAMINE-DEXEDRINE USED PROPHYLACTICALLY BY COMMAND MODULE PILOT EARLY DURING FIRST DAY OF FLIGHT
- BOTH COSMONAUTS EXPERIENCED SPACE MOTION SICKNESS

INCIDENCE OF SPACE MOTION SICKNESS IN US AND USSR

MANNED SPACE FLIGHT PROGRAMS

USA			USSR		
PROGRAM	NUMBER OF CREWMEN	INCIDENCE OF MOTION SICKNESS	PROGRAM	NUMBER OF CREWMEN	INCIDENCE OF MOTION SICKNESS
MERCURY	6	0	VOSTOK	7	1 - <u>Vom</u>
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APOLLO	33*	11**	SOYUZ	36#	19## - 9 <u>Vom</u>
SKYLAB	9	5	ASTP	2	2 - 1 <u>Vom</u>
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TOTALS

16 ASTRONAUTS (Frank Vomiting in 6)

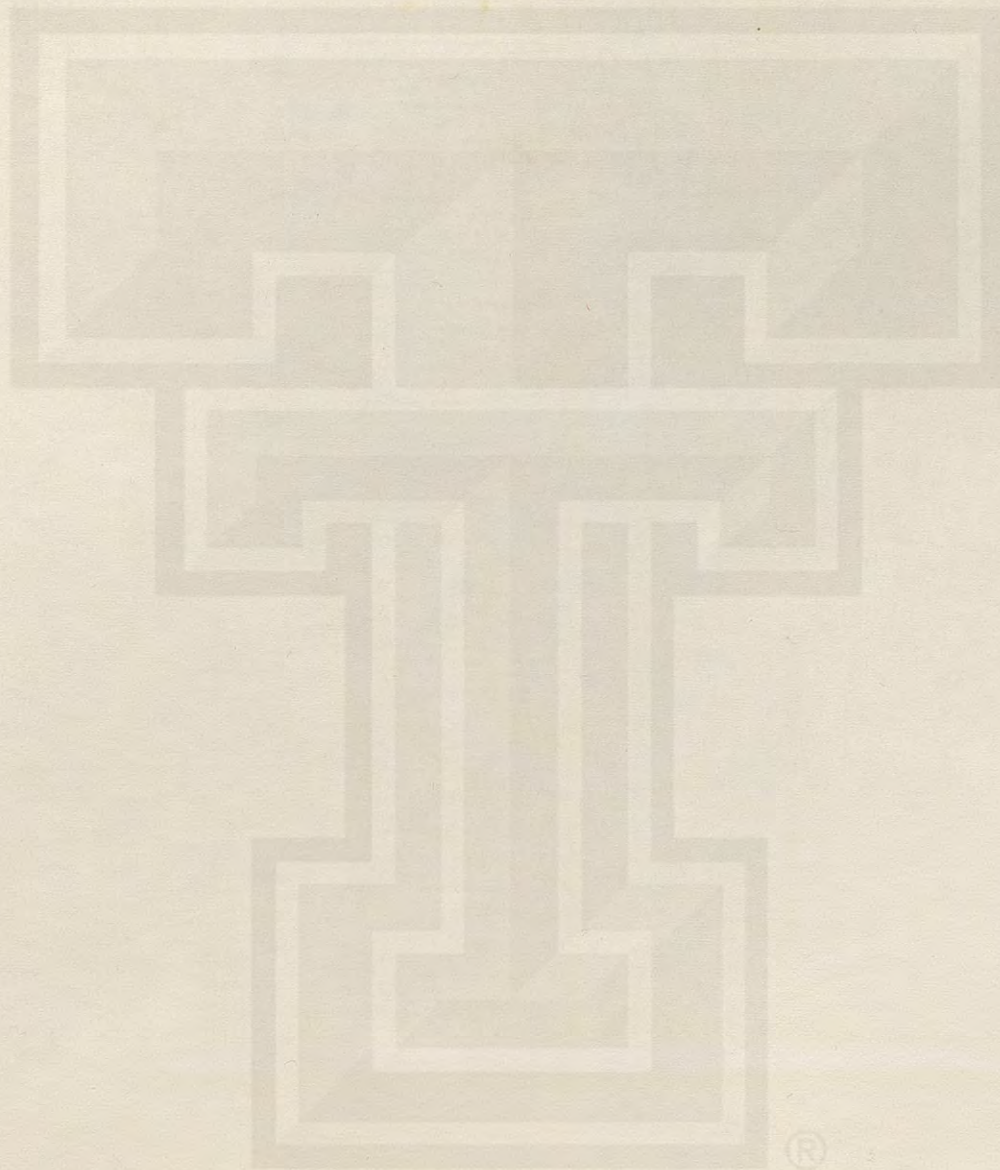
25 COSMONAUTS
(Frank Vomiting in 15)

* INCLUDES 4 CREWMEN WHO FLEW TWICE DURING PROGRAM

** INCLUDES 1 CREWMAN WHO EXPERIENCED SYMPTOMS ON BOTH OF TWO FLIGHTS

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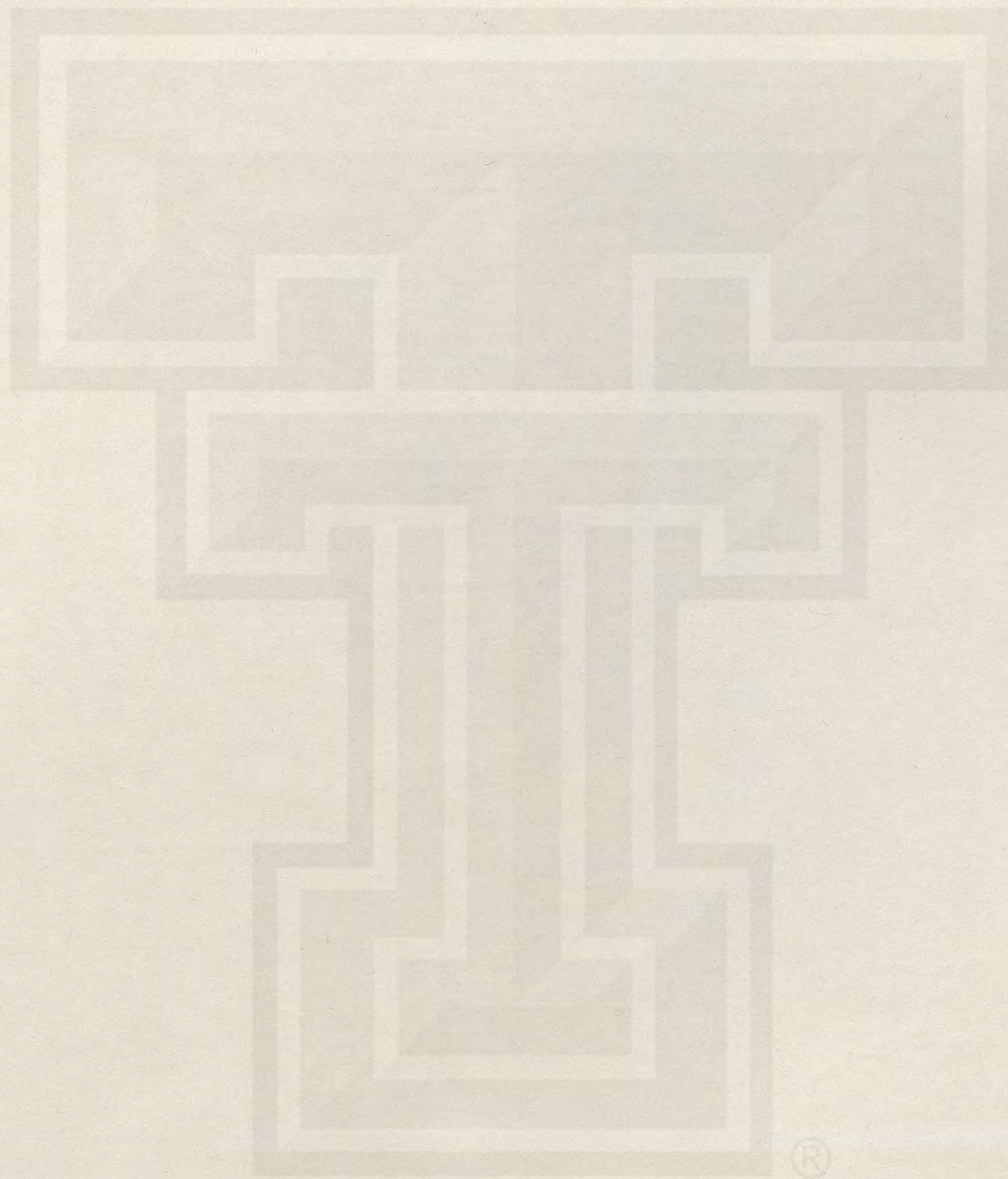
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SIGNIFICANCE OF SPACE MOTION SICKNESS FOR SHUTTLE

- **FREQUENCY AND SEVERITY OF SYMPTOMS PRESENT POTENTIAL
THREAT TO WELL-BEING AND OPERATIONAL EFFICIENCY OF
SHUTTLE CREWMEN AND PASSENGERS**
- **FACTORS AMPLIFYING CONCERN**
 - **LARGE NUMBER OF HIGH WORKLOAD/SHORT DURATION FLIGHTS**
 - **INTRODUCTION OF NOVICE CREWMEMBERS INEXPERIENCED WITH
UNUSUAL GRAVITATIONAL-INERTIAL FORCE ENVIRONMENTS**
 - **VEHICLE CONFIGURATION PERMITS EXTENSIVE MOVEMENT BY
CREWMEN**
 - **KNOWLEDGE OF ETIOLOGY AND METHODS FOR RELIABLE
PREDICTION, PREVENTION AND TREATMENT OF SYNDROME
CURRENTLY NOT OPTIMAL**

TENTATIVE OPERATIONAL PLANNING FOR SHUTTLE
OFT PASSENGERS RE SPACE MOTION SICKNESS PROBLEM

- CONDUCT PREFLIGHT PERSONAL INTERVIEW
 - OBTAIN MOTION SICKNESS HISTORY
 - CONVEY RELEVANT STATE-OF-THE-ART KNOWLEDGE ABOUT SPACE MOTION SICKNESS
- PERFORM MINIMUM LABORATORY TESTS
 - EVALUATE INTEGRITY OF VESTIBULAR SYSTEM FUNCTION
 - DETERMINE MOTION SICKNESS SUSCEPTIBILITY THRESHOLD AND ACQUAINT INDIVIDUAL WITH RECOGNITION OF SYMPTOMS
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 - FURTHER EVALUATE AMS DRUG EFFICACY/DOSAGE
- ENCOURAGE PROPHYLACTIC USE OF OPTIMUM AMS DRUG PRE-LAUNCH AND EARLY INFLIGHT



®

CURRENT POSITION

- O NO SOUND BASIS FOR PREDICTION
 - PHYSIOLOGICAL MECHANISMS IN ZERO G NOT UNDERSTOOD
 - POOR CORRELATION BETWEEN MOTION SICKNESS IN DIFFERENT ENVIRONMENTS
- O NO PROVEN METHOD FOR PREVENTION
 - MARKED INDIVIDUAL VARIATION IN DRUG RESPONSE
 - BIOFEEDBACK TECHNIQUES LOOK PROMISING
- O HIGH LEVEL OF CONFIDENCE THAT WE CAN WORK AROUND THE PROBLEM

INVESTIGATIVE APPROACH

KEY FACTORS -

- o DEVELOPMENT OF SOLUTIONS FOR PROBLEMS IDENTIFIED WILL REQUIRE A BROAD BASED PROGRAM OF INTERDISCIPLINARY STUDIES USING HUMAN AND ANIMAL SUBJECTS
- o FUNDAMENTAL AND APPLIED ASPECTS OF THE MAJOR PROBLEM AREAS MUST BE INVESTIGATED IN PARALLEL
- o FINAL VALIDATION OF TECHNIQUES FOR PREDICTING, PREVENTING AND TREATING THIS SYNDROME WILL NOT BE POSSIBLE UNTIL SEVERAL SHUTTLE FLIGHT EXPERIMENTS HAVE BEEN CONDUCTED

SPACE MOTION SICKNESS RESEARCH PROGRAM

- PROBLEMS AND TASKS -

- A. Etiology and Mechanisms of Space Motion Sickness
 - 1 - Evaluation of Fluid Shift Theory of Etiology; Conflict Theory; Others
 - 2 - Anatomical and Microelectrical Studies; Neurological Biochemistry
 - 3 - Functional Studies; Behavioral Factors
 - 4 - Mathematical Modeling
- B. Determination of Individual Predisposition (Selection)
- C. Development of Training Techniques to Diminish Susceptibility
- D. Improved Countermeasures
 - 1 - Improvement of Anti-Motion-Sickness Drugs
 - 2 - Identification of Modifying Factors for Use in Prevention (Example: Biofeedback)
 - 3 - Other Preventive/Therapeutic Techniques (Examples: In-Flight Adaptation Procedures, Fluid Shift Control)
- E. Bioinstrumentation and Methodology Development
- F. Preparation of Flight Experiments

GROUND BASED RESEARCH WITH MAN

- o MAJOR EMPHASIS ON SENSORY CONFLICT AND MOTION SICKNESS INVOLVING OTOLITHS
- o INCLUDED ARE INVESTIGATIONS OF
 - o CANAL-OTOLITH INTERACTION
 - o VISUAL-VESTIBULAR INTERACTION
 - o VESTIBULO-SPINAL REFLEXES
 - o PROPRIOCEPTIVE MECHANISMS
 - o SENSORY HABITUATION
- o STUDIES UTILIZE VARIETY OF STIMULUS GENERATION (INCLUDING PARABOLIC FLIGHT) AND RESPONSE MEASUREMENT TECHNIQUES
- o ROLE OF FLUID SHIFT REQUIRES FURTHER ANALYSIS
- o RESEARCH INVOLVING NEUROLOGICAL, PSYCHOPHYSIOLOGICAL AND BIOCHEMICAL FACTORS CURRENTLY LIMITED IN SCOPE
- o DEVELOPMENT OF IMPROVED RESPONSE MEASUREMENT TECHNIQUES MUST EVOLVE FROM THESE PROGRAMS

HUMAN RESEARCH IN SPACE

- o EMPHASIS ON PRE-, IN- AND POSTFLIGHT TESTS OF OTOLITH FUNCTION
- o RELATED PRE-, IN- AND POSTFLIGHT EVALUATIONS OF
 - o SEMICIRCULAR CANAL FUNCTION
 - o NEUROMUSCULAR AND PROPRIOCEPTIVE FUNCTION
 - o MOTION PERCEPTION AND SPATIAL ORIENTATION
- o SPECIAL TESTS TO EVALUATE FLUID SHIFT AND OTHER SECONDARY POTENTIATING FACTORS
- o MAJORITY OF EXPERIMENTS MUST BE CONDUCTED IN DEDICATED SPACELABS - WILL REQUIRE SOPHISTICATED HARDWARE AND EXTENSIVE CREW PARTICIPATION

GROUND BASED RESEARCH WITH ANIMALS

- o NEUROPHYSIOLOGICAL, BEHAVIORAL, ANATOMICAL AND HISTOLOGICAL STUDIES OF VESTIBULAR, PROPRIOCEPTIVE AND VISUAL SYSTEMS
- o ADVANTAGES OF USING ANIMALS
 - o INVASIVE PROCEDURES
 - o LARGE N
- o EMPHASIS ON RESPONSES MEASURED IN SENSORY CONFLICT SITUATIONS
- o PARABOLIC FLIGHT STUDIES TO EVALUATE RESPONSES TO HYPER AND HYPOGRAVIC STIMULI
- o EVALUATION OF SPECIFIC PHENOMENA VIA INVASIVE TECHNIQUES
 - o FLUID SHIFT MECHANISMS
 - o ALTERATION OF NEURAL IMBALANCE WITH DRUGS
- o STUDIES DESIGNED TO COMPLIMENT HUMAN RESEARCH AND DEFINE REQUIREMENTS FOR ANIMAL FLIGHT EXPERIMENTS
- o WORK IS UNDERWAY IN ABOVE AREAS

ANIMAL RESEARCH IN SPACE

- o ANIMAL EXPERIMENTS SHOULD COMPLEMENT HUMAN INFLIGHT EXPERIMENTS WHERE POSSIBLE
- o IDENTIFY SPECIES WITH EASILY MEASURED MOTION SICKNESS RESPONSE
- o ELECTROPHYSIOLOGICAL TECHNIQUES TO MEASURE DISCHARGE OF CRITICAL COMPONENTS OF CENTRAL AND PERIPHERAL NERVOUS SYSTEM
 - o PRIMARY AFFERENTS
 - o VESTIBULAR Efference
 - o VESTIBULAR NUCLEI
 - o RETICULAR SYSTEM
 - o SPINAL CORD MOTONEURONS
- o RESOLVE FLUID SHIFT QUESTION
- o SOPHISTICATED CORE REQUIRED, INCLUDING LINEAR ACCELERATOR AND CENTRIFUGE

PREDICTION (SELECTION CRITERIA)

- o TOTAL APPROACH TO RESOLUTION OF THIS PROBLEM CANNOT BE DEFINED AT PRESENT
- o SEVERAL POTENTIALLY FRUITFUL LINES OF INVESTIGATION CAN BE IDENTIFIED
 - o STUDIES UTILIZING CENTRIFUGES AND SLOW ROTATING ROOMS
 - o STUDIES UTILIZING LINEAR ACCELERATION TECHNIQUES
 - o AIRCRAFT PARABOLIC FLIGHT (ZERO-G) STUDIES
 - o DETERMINATION OF RATE OF ACQUISITION OF ADAPTATION
 - o DETERMINATION OF CORRELATIONS BETWEEN MOTION SICKNESS SUSCEPTIBILITY AND OTHER MEASURABLE VESTIBULAR AND NON-VESTIBULAR RESPONSES
 - o ATTENTION TO AGE AND SEX FACTORS

VALIDATION OF SELECTION CRITERIA AND COUNTERMEASURES

- o GROUND BASED STUDIES WILL NOT PRODUCE IRREVOCABLE RESULTS
- o FINAL VALIDATION WILL NOT BE POSSIBLE UNTIL A NUMBER OF SHUTTLE MISSIONS HAVE OCCURRED
- o ESSENTIAL THAT CREWMEMBERS BE ASSIGNED TO EXPERIMENTAL AND CONTROL GROUPS
- o LARGE SAMPLE SIZES REQUIRED FOR VALID STATISTICAL ANALYSIS AND INTERPRETATION
- o OPERATIONAL PROBLEMS WITH THIS APPROACH MUST BE CONSIDERED
- o EVALUATIONS SHOULD NOT REQUIRE SPECIAL INFLIGHT HARDWARE, CREW INFLIGHT INVOLVEMENT SHOULD BE MINIMAL

PREVENTION

- o TWO BASIC APPROACHES UNDER INVESTIGATION
 - o PREHABITUATION
 - FUNDAMENTAL QUESTIONS REGARDING APPROPRIATENESS OF VARIOUS TECHNIQUES MUST BE ANSWERED
 - TIME AND SOPHISTICATED FACILITIES REQUIRED MAY BE LIMITING FACTORS
 - o ANTI-MOTION SICKNESS DRUGS
 - EFFICACY AS WELL AS SIDE EFFECTS MUST BE EVALUATED
 - SITE OF DRUG ACTION SHOULD BE BETTER UNDERSTOOD

TREATMENT

- o ANTI-MOTION SICKNESS DRUGS PRIMARY REMEDY USED IN PAST
- o LIMITED ATTEMPTS WITH SPECIAL INFLIGHT HABITUATION PROCEDURES NOT SUCCESSFUL
- o EFFORTS IN PROGRESS FOCUSING ON
 - o IMPROVED DRUG THERAPY
 - o OPERATIONALLY ACCEPTABLE INFLIGHT HABITUATION PROCEDURES, POSSIBLY AIDED WITH DRUGS
 - o MINIMIZATION OF MOVEMENT THROUGH IMPROVED PROCEDURAL CHECK LISTS, WORK LOAD REQUIREMENTS AND TASK GEOMETRY

SPACE MOTION SICKNESS

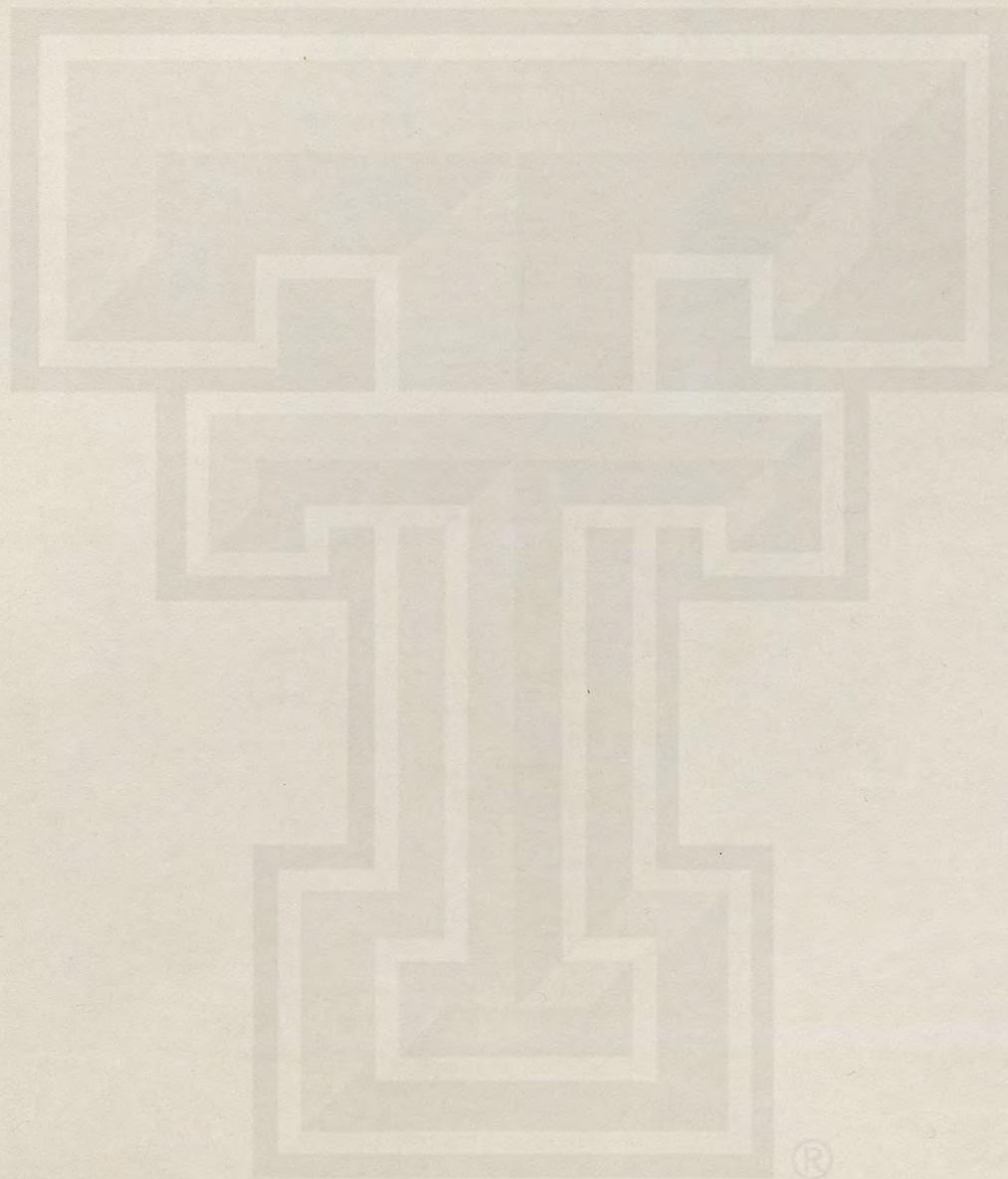
CURRENT SR&T PROGRAM (FY77)
BY PROBLEM AND TASK

TASKS FROM THIS RTOP

RESEARCH PROBLEM AREA	PRIMARY OBJECTIVE OF TASKS:	A MAJOR OBJECTIVE OF TASKS:
A. Etiology and Mechanisms of Space Motion Sickness		
1. Evaluation of Fluid Shift Theory of Etiology	1-03 Homick 1-04 Parker	
2. Anatomical and Micro- electrical Studies	1-07 Correia 2-05 Perachio 2-07 Ebbesson 2-08 Goldberg	2-10 Daunton 2-11 Bizzi 2-12 Nauta 2-13 Markham 2-21 Brizze
3. Functional Studies	1-03 Homick 1-04 Parker 1-05 Igarashi 2-04 Teuber 2-05 Perachio	2-10 Daunton 2-11 Bizzi 2-12 Nauta 2-13 Markham 2-25 Sadoff 1-02 Frost 2-16 Young
4. Mathematical Modeling	1-06 Cohen 1-07 Correia	2-11 Bizzi
B. Determination of Indivi- dual Predisposition (Selection)	1-01 Graybiel 2-16 Young	1-03 Homick
C. Development of Training Techniques to Diminish Susceptibility		1-01 Graybiel 2-16 Young

SPACE MOTION SICKNESS (CONT'D)

RESEARCH PROBLEM AREA	TASKS FROM THIS RTOP	
	PRIMARY OBJECTIVE OF TASKS:	A MAJOR OBJECTI OF TASKS:
D. Improved Countesmeasures		
1. Drugs	1-09 TBD 2-21 Brizze	1-01 Graybiel 1-03 Homick 1-07 Correia
2. Identification (and Prevention) of Modify- ing Factors	2-18 San Jose	1-03 Homick
3. Other	2-18 San Jose	1-05 Igarashi
E. Bioinstrumentation and Methodology Department	1-02 Frost 2-05 Perachio	1-03 Homick 1-04 Parker
F. Preparation of Flight Experiments		1-05 Igarashi 2-05 Perachio



SPACE MOTION SICKNESS

PROGRAM MILESTONES

Late Spring, 1977	AO for Dedicated Life Sciences Spacelabs
July, 1977	AIBS Vestibular Research Program Review
July, 1977	Completion of Ground Based Animal Investigations of Fluid Shift Hypothesis (Parker)
October, 1977	US/USSR Discussion of Space Motion Sickness (One of the Subjects to be Discussed)
March, 1978	Completion of Ground Based Human Investigations of Fluid Shift Hypothesis (Homick, Parker, and Greenleaf)
July, 1978	Completion of Preliminary Ground Based Evaluations of Predictive Tests of SMS Susceptibility; Establish Tentative Test Battery
October, 1978	Completion of Preliminary Ground Based Evaluations of Preconditioning (Training) Techniques to Minimize In-Flight SMS; Establish Tentative Training Plan
January, 1979	Completion of Ground Based Evaluations of New Drugs for Control of SMS
Fall, 1980	Conduct Selected Human Vestibular Flight Experiments on SL-1 (Young, Homick)
Fall, 1982	Complete Preliminary In-Flight Validation of Training, Predictive Tests and Countermeasures

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STARPAHC — OPERATIONAL FINDINGS

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STARPAHC - OPERATIONAL FINDINGS

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Abstract

Delivery of quality health care to passengers of extended-mission spacecraft and to remote populations on Earth (a major national problem) requires extending the knowledge and skills of the physician many kilometers distant from his physical location. The STARPAHC telemedicine system accomplishes this by using physician's assistants complemented with space technology in communications, data handling, and systems engineering. It is presently in operation and undergoing a 2-year evaluation on the Papago Indian Reservation, Arizona. Results have established its feasibility as a solution for remote area health care on Earth, while providing information useful to the planners of advanced manned spacecraft missions.

I. Introduction

A primary goal of the joint NASA/HEW STARPAHC (Space Technology Applied to Rural Papago Advanced Health Care) project is to develop a solution to one of the nation's foremost problems, that of delivering quality health care to people in remote geographical areas. Maldistribution of physicians, the low percentage of general practitioners among new medical school graduates, and the dwindling ranks of existing generalists diminished by retirement and expiration, compounded with the time and travel demands imposed by population distribution and a variety of associated negative economic aspects, have resulted in a scarcity of physicians and in health care not being readily available to many remote areas.

Health care delivery onboard extended-mission spacecraft also constitutes a "remote area case," having many similarities to the "on Earth" situation. Thus, another goal of STARPAHC is to derive information valuable to NASA planners and designers, from the implementation of a system that practically demonstrates health care delivery to remote areas on Earth.

In STARPAHC, a combination of capabilities derived from space technology in communications, data processing, and systems engineering enables the physician to direct trained allied health professionals located in remote fixed and mobile clinics. The resultant health services team effectively extends the physician's skills, knowledge, and capabilities many kilometers from his physical location, to the point of patient encounter. This demonstrative telemedicine system has been installed and is in a 2-year evaluation phase on the Papago Indian Reservation, Arizona.

The STARPAHC system is briefly described and the first year's operational highlights are summarized in this paper.

II. Guidelines for the STARPAHC Approach

Studying the many facets that comprise delivery of health care to remote areas has produced the criteria and guidelines that must be considered necessary to potential solutions. The most prominent of these are as follows.

1. A "mechanism" is needed to extend the expertise of physicians (and other health professionals) to compensate for both scarcity and maldistribution. The need exists to extend the physician's capability, knowledge, and skills a great distance from his physical location; in essence, the physician becomes the director of a health care team. To use his highly precise professional skills effectively, the physician must receive direct and related information - visible, audible, and tactile. Thus, if the physician at his location many kilometers from the patient can see and talk to the patient and can acquire corresponding supporting data in the form of analytic laboratory results, microscopic slide examination, patient history information, electrocardiograms, X-rays, heart and lung sounds, et cetera, timely diagnosis and treatment can be implemented effectively.

2. Easily accessible points of entry into the health care establishment are needed. Methods must exist to screen and route patients so they are efficiently placed under the supervision and care of the most appropriate health care professional.

3. Unique applications of technology and management are needed to relieve health care professionals of time-consuming tasks that require lesser levels of training and knowledge. This can be accommodated through the use of paramedical personnel (such as graduates of physician's assistant programs) as extensions of physicians, in conjunction with the use of communications technology to provide the consultation, supervision, and attention of a physician that is required to deliver quality health care at the point of patient encounter. Visible and audible communications with the physician establish the rapport required to eliminate the stigma of "second-class" health care and maximize the use of the physician's time and capabilities.

4. Appropriate combinations of fixed and mobile facilities are required to meet the varying needs dictated by population density, terrain, existing transportation systems, and socioeconomic characteristics of different areas. Staffed by physician's assistants in direct communication with physicians, these facilities can very easily increase the number of entry points into existing health care establishments.

5. A successful approach involves making maximum use of existing medical establishments and capabilities, so as to complement existing health care establishments without being redundant to them. And the approach must recognize the restraints imposed by unique social, economic, and health characteristics of the locality under consideration.

6. System design must be amenable to orderly, expeditious extension. Using optimal modularity and standardization techniques that utilize existing technologies can result in nonrecurring developmental activities that are cost effective. Basic design should try to accommodate eventual application to all remote area situations.

III. System Description

The STARPAHC approach combines the utilization of space technology and the use of trained, remotely located, allied health professionals (such as physician's assistants at the point of patient encounter) working under the direction of a physician. To evaluate this approach, a system has been assembled and installed on the 11 137-square-kilometer (4300 square mile) Papago Indian Reservation in Arizona (Fig. 1). The goals of the program are to determine the effectiveness and exportability of this technique for improving the delivery of health care to remote populations and to gain information that will be valuable for the development of health care systems for future manned spacecraft.

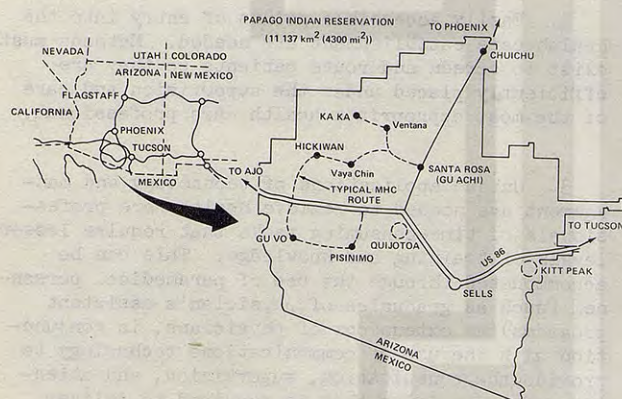


Figure 1.- STARPAHC test site.

The STARPAHC system is now undergoing a 2-year operational evaluation of daily health care delivery by the Indian Health Service (IHS). The STARPAHC serves approximately 10 000 permanent residents of 75 villages on the Papago reservation and 2000 to 4000 persons who live outside the reservation's boundaries but return to the reservation for health care. The system is staffed by IHS medical personnel, who throughout the 2-year period are receiving technical support from the onsite contractor (Lockheed Missile and Space Company (LMSC)) technicians. The IHS personnel are being trained to assume the technician duties when the 2-year evaluation period has been completed. It is anticipated that the program operation will be continued past the initial 2-year test period by the IHS.

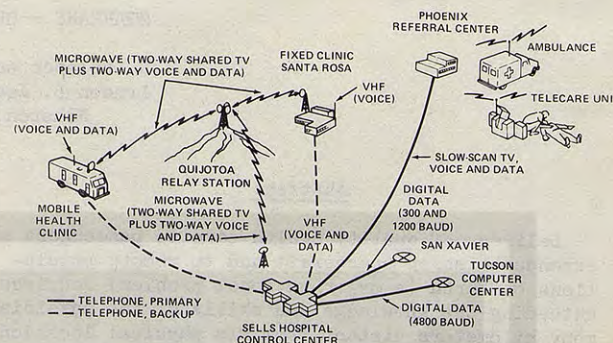


Figure 2.- STARPAHC system configuration.

The STARPAHC system (Fig. 2) includes a control center located in the Sells Hospital, a fixed clinic at Santa Rosa, a mobile health clinic (MHC), and a referral center in the Indian Health Hospital in Phoenix (for access to specialists by television (TV) data and voice links with the control center). The Tucson computer center provides STARPAHC access to the IHS-established health-information data base. Television, voice, and data transmissions are routed between system elements through a strategically located relay station (Fig. 3). A Telecare unit (a portable electronic vital signs monitor) is used for house calls and emergency treatment.

The MHC is a clinically equipped van (Fig. 4) that visits villages on a preselected route and schedule. Staffed by physician's assistants called community health medics (CHM's) and by laboratory technicians, the MHC gives the physician a flexible "outreach" capability through its color TV, black-and-white TV, voice communication, and computerized data information links with physicians at Sells Hospital.

The fixed clinic (Fig. 5), staffed by CHM's and laboratory technicians, offers the medical services afforded by the MHC as well as more extensive treatment capability.

This combination of capabilities enables patients at the remote clinics to be diagnosed by the physician at the hospital and to be immediately treated by the CHM's in the clinic under the physician's direction. The patient visits are accomplished in minimum time and the patient does not have to travel a considerable distance to obtain medical care.

The physician's console in the control center at the Sells Hospital (Fig. 6) is the focal point of the system. As the control center for the system, it provides physicians with the displays and controls required to perform their comprehensive functions. The controls and displays were selected to give physicians command flexibility and a maximum amount of information with minimum technical functions. Most important to the physician's visual examination of the patient are the capabilities to remotely control the TV cameras at the MHC and the fixed clinic from his console, to display pertinent patient medical data, to control privacy in voice and TV communications, and to read X-rays or slides by TV.

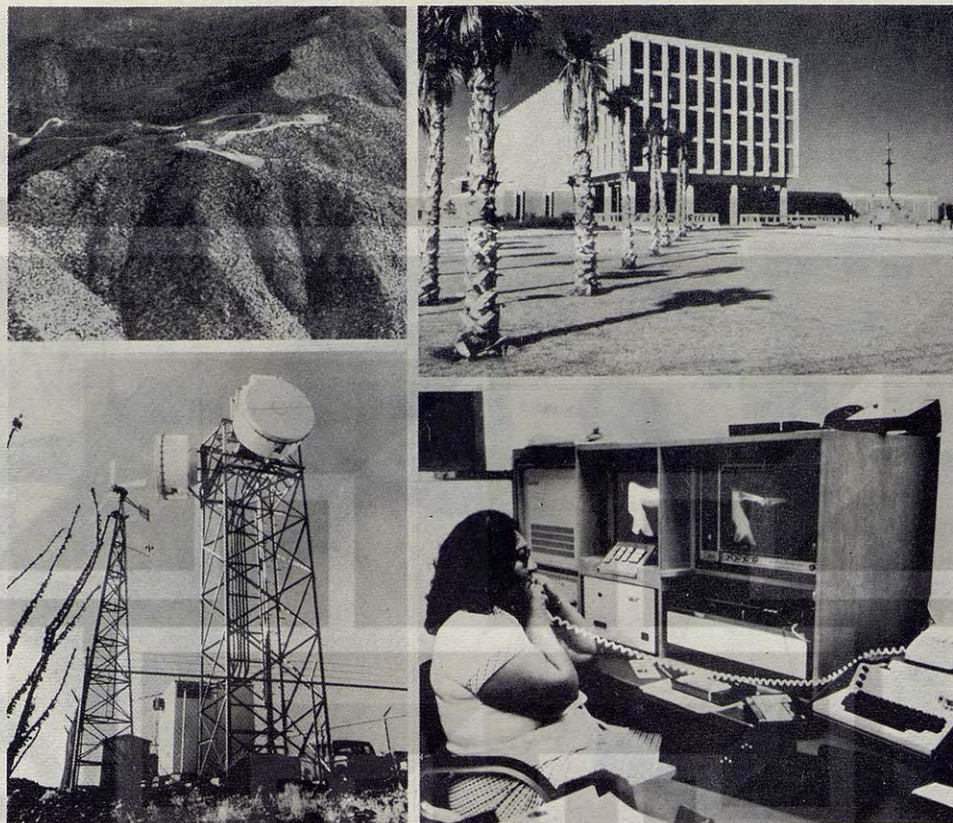


Figure 3.- Quijota relay station and Phoenix Indian Medical Center.

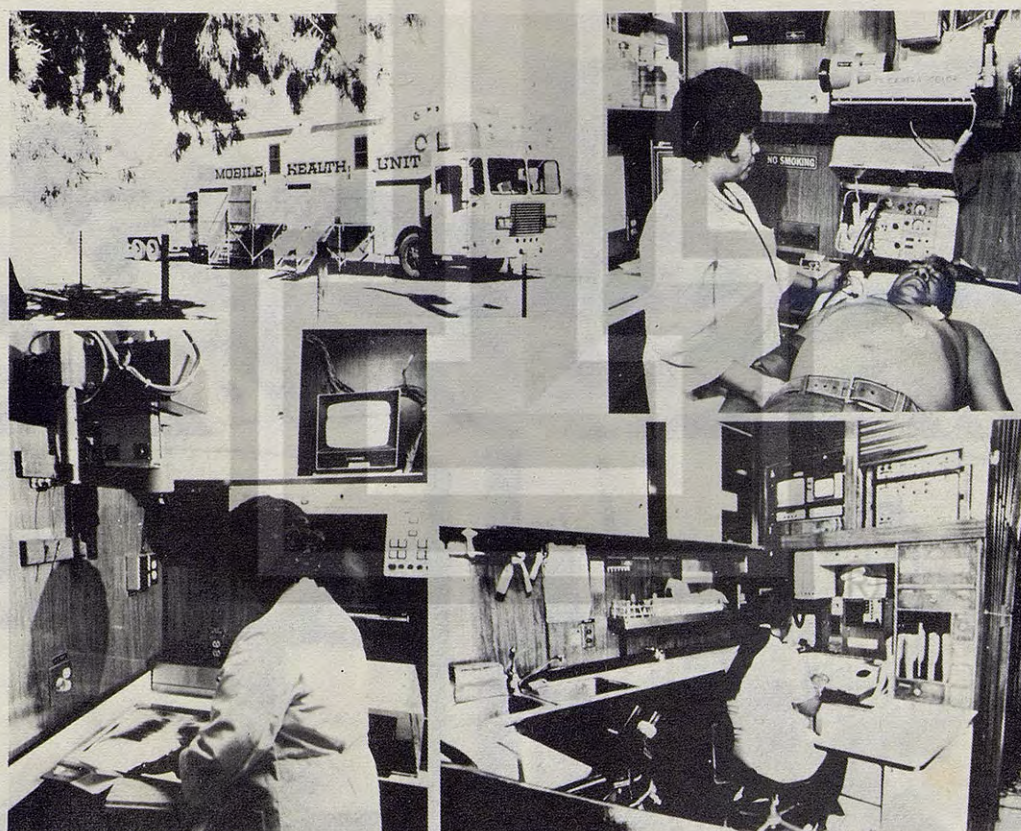


Figure 4.- Mobile health clinic.

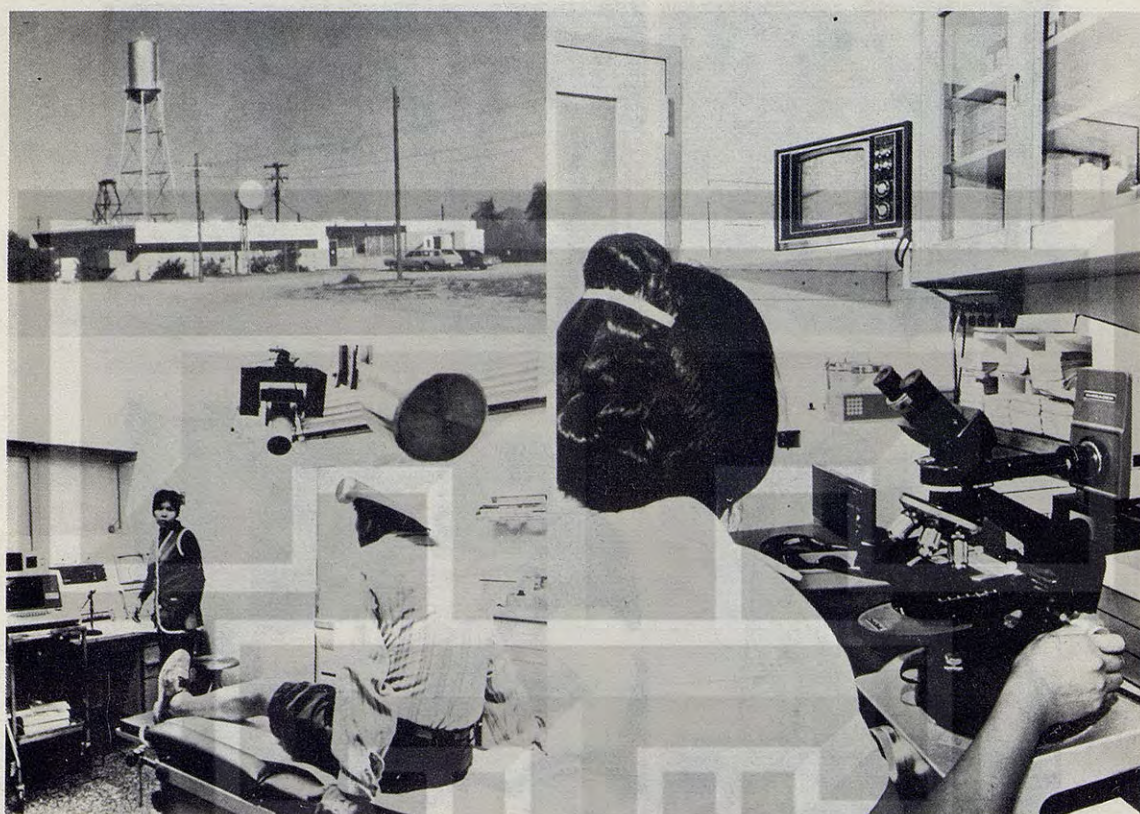


Figure 5.- Fixed health clinic at Santa Rosa.

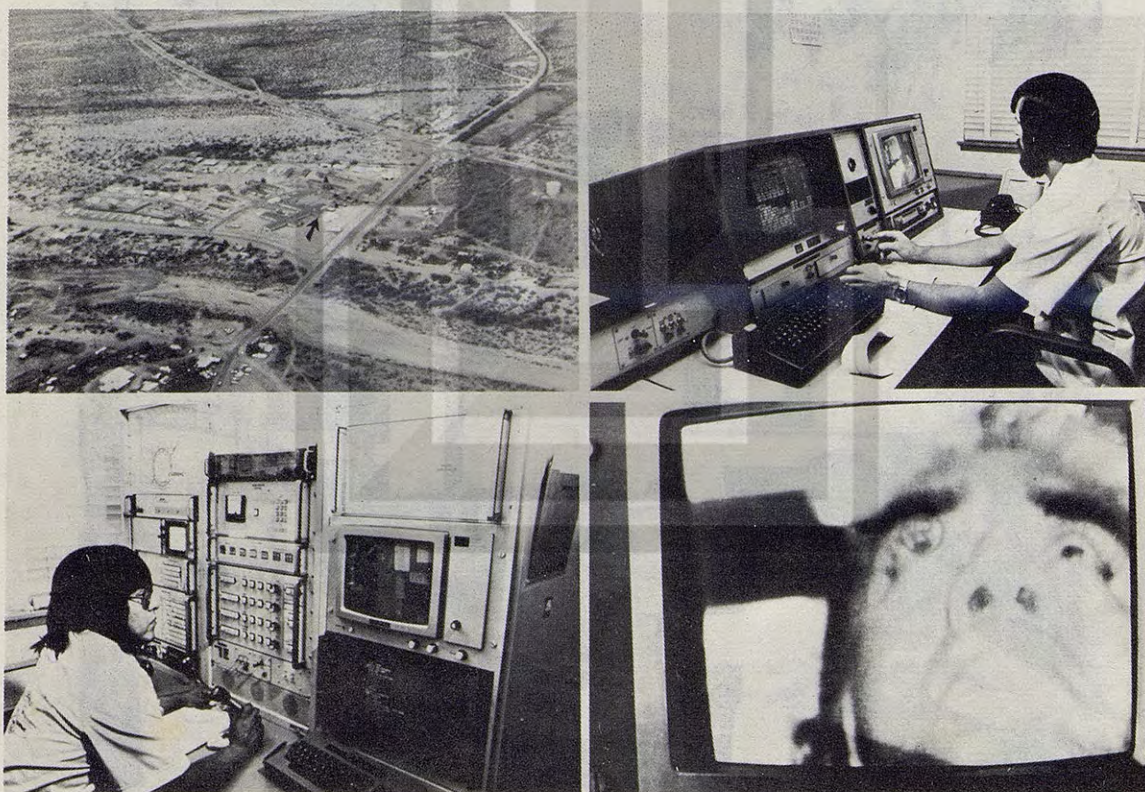


Figure 6.- Support Control Center at Sells Hospital.

Another outstanding innovation in STARPAHC is the slow-scan video system. Using "dial-up" telephone lines, single-frame color and black-and-white video can be transmitted to the Phoenix Referral Center for study of the subject matter by medical specialists. In routine use, X-rays, microscopic slides, and views of patients are transmitted on real-time TV from the mobile and fixed clinics to the control center at the Sells Hospital (or originated at Sells), where they can be transmitted via the dial-up, slow-scan video link to Phoenix for additional study and consultation. When received at Phoenix, the video images are displayed on monitors and/or recorded on a disk and video tape recorder for later playback and study, if required. This capability is proving to be an extremely valuable tool for consultation (and teaching) and one that gives the patient in the most remote area direct, timely access to some of the finest physicians and specialists.

IV. Operational Findings

General

The first year of operations was divided into two 6-month evaluation periods, which proved to be extremely worthwhile, for the first months of operation were truly an operational "shakedown" period during which equipment, personnel, and procedures problems were experienced. During the fifth and sixth months, personnel and equipment performance improved and became somewhat stabilized. Operational experience and data to date support the following statements.

1. The STARPAHC concept is indeed an effective, realistic method of administering quality health care to people in remote areas.

2. One important lesson is the capability for interaction among consultants, physicians, physician's assistants, and paramedical personnel who have telemedicine systems available. Evaluation data show that physician's assistants communicate so well verbally with physicians that the video medicine system is not required as often as it would be if a nurse or emergency medical technician were communicating medical information to a physician's assistant or physician. Information about interaction of providers using telemedicine systems (Fig. 7) is specifically valuable for planning future space missions and for determining the level of medical talent required relative to the crew and passenger complement and the nature and extent of the mission.

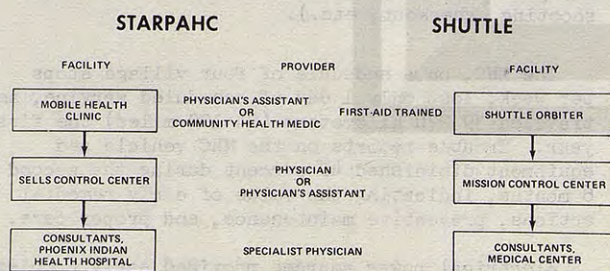


Figure 7.- Typical relationship of STARPAHC to space mission.

3. Physician direction has been effective in diagnosing and/or treating patients by telemedicine in cases of fractures, lacerations, minor surgery, throat lesions, skin ulcers, snake bites, respiratory infections, gastroenteritis, et cetera. Physician and CHM users have reported that the TV capability has been important in 89 percent of the teleconsultations.

4. Performance and evaluation data and cost-analysis information will permit selection of cost-effective subsystems for synthesizing and "exporting" specific versions of STARPAHC to suit other areas and needs.

5. The benefits to education and welfare programs that STARPAHC capabilities afford as spin-offs are just beginning to be realized. The capability to communicate periodically (over video and audio links) with the people of remote villages will enable teaching and instruction of all kinds to support such programs as environmental health, sanitation, nutrition, disease control, and so forth. In addition, this capability accommodates general community discussions (with the control center area) and provides for transmittal of other information such as news and orientations of tribal, state, and national activities.

Evaluation

The ongoing evaluation of STARPAHC is being conducted by concentrating on those performance aspects most meaningful to the end goals (Fig. 8). Accordingly, the medical evaluation assesses frequency and effectivity of use, effect on health care delivery, response of the community, and acceptance by the users and providers. Hardware (and software) factors being evaluated include determination of performance, reliability, quality, maintainability, man-machine interfaces, utilization, and logistics. Cost evaluation includes (medical and hardware) operating and capital cost studies at both the subsystem and system levels.

A STARPAHC systems evaluation report correlating and interpolating all evaluation data will be produced after the 2 years of field operations are concluded. During the 2-year evaluation period, however, ongoing analyses of data being collected permit timely remedial actions and define the need for meaningful improvements.

A summary of other significant findings attributable to the first year of field operations¹ follows.

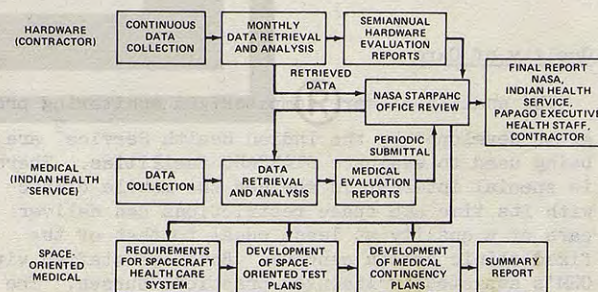


Figure 8.- Evaluation information reporting.

User Acceptance

User acceptance has been outstanding as evidenced by a progressive increase in user dependence on key system elements and functions. The fixed and mobile clinics have experienced an increase of 18.5 percent in patient visits in the second 6 months, over the relatively high rate of visits in the first 6 months. The MHC is averaging 18 patients/day, with a daily high of 44 holding the record. Village residents are, in fact, becoming very dependent on the MHC's scheduled visits. The fixed clinic, which increased its service from 2 days/week to 5 days/week with the onset of STARPAHC, is averaging 22 patients/day. During the year, a total of 8590 patient visits was recorded for both clinics.

During the early months, as the village patients began using the STARPAHC remote clinics, a decided decrease in outpatient visits to the Sells Hospital was noted. As the "health care awareness" and education expanded in the towns and villages of the reservation, visits to the physician providers at the hospital increased 10.5 percent in the second 6 months. Throughout the year, however, proportionally more patients were being seen by providers other than physicians. A large share of the credit for community acceptance and health care awareness must be given to the Papago Executive Health Staff, who have labored long and diligently to orient and educate the Papago community.

Provider Acceptance

Provider acceptance has been, for the most part, good, with the allied health professionals (community health medics) indicating a higher rate of acceptance than the physicians. In value judgments, for 487 consultations, the providers rated 89 percent as "critical for the proper care of patients and important or useful." Physicians have consistently rated the value of remote consultations lower than have the CHM's. Physicians rated 25 percent of teleconsultations as "of little or no value," while CHM's rated only 2.6 percent of the same consultations negatively. However, as operations continue, physician acceptance is evidently increasing. All providers reported changes in treatment plans because of a teleconsultation. Three indicated they have changed their way of treating patients, and with STARPAHC they are more cautious. Providers have both negative and positive attitudes; they have problems accepting equipment failures and making time for consultations. However, they do appreciate that the Papago people are getting better access to care.

Quality of Care

The quality-of-care computerized monitoring programs developed by the Indian Health Service² are being used to evaluate STARPAHC facilities. There is special interest in whether the mobile clinic with its time and space restrictions can deliver care of a quality at least equal to that of the fixed clinic health centers. Both are staffed with CHM's assisted by licensed practical nurses. The quality of care was determined by the number and type of procedural steps provided the patient for diagnosis and treatment.

Results indicate that the quality of health care provided at the MHC is competitive with or better than the care delivered at other facilities. To further enhance the capability to deliver quality health care to these remote areas, the recent addition of the slow-scan TV link to the physician specialists at the Phoenix Indian Medical Center enables transmission of video data (X-rays, microscopic slides, still photographs) from the remotely located mobile and fixed clinics through the control center at Sells, to the specialists at the Phoenix Indian Medical Center, thereby permitting consultation.

In two of the initial nine X-ray transmissions used in patient consultations, the Phoenix radiologist read the transmitted X-ray image differently than the Sells physician, who concurred in the resulting revised diagnosis. After this initial verification of value, there have been other indications of the importance to the Papago patient of the specialist's skills and knowledge that are directly accessible through STARPAHC.

Equipment Performance

The STARPAHC system equipment performed exceptionally well, after the early months of shakedown were over. Significantly, the use of reasonably priced (commercial) off-the-shelf equipment has been a firm program ground rule. Historical reliability performance data on this equipment are sparse, contrary to popular belief, and their quality control is largely indeterminable. These factors contributed in large measure to early equipment failures, to the necessity of a "burn-in" period to establish performance, and to the importance of thorough integrated system testing. Results to date strongly indicate that off-the-shelf equipment can be synthesized into a reasonably dependable and maintainable telemedicine system.

Performance of 22 telecommunications equipment subassemblies was monitored during the first year of operation. Of the 3998 uses, there were 76 failures (33 during the second 6 months). The resulting performance acceptability ratio (PAR) was 98.1 percent for the entire first year. Telecommunications equipment usage increased 2 percent during the second 6 months, but failures were reduced by 23.3 percent without any reduction in the quality of transmission. In the second 6 months, there was an increase of 12.4 percent (to 61.5 percent) in use for medical purposes alone, and a corresponding 12.8 percent reduction in use of this equipment for purposes other than medical (troubleshooting, checkout, etc.).

The MHC, on a schedule of four village stops per week, lost only 1 day of scheduled service, and traveled 39 270 kilometers (24 100 miles) the first year. Trouble reports on the MHC vehicle and equipment diminished 42 percent during the second 6 months, indicating the value of early remedial actions, preventive maintenance, and proper care.

Electrical power sources provided early problems at two places, the relay station and the Sells Hospital control center. At the relay station, difficult-to-maintain propane generators were replaced with a wind-driven turbine generator as

The problem was different at the Sells Hospital, where the utility power was extremely difficult to regulate and control, especially during the months when the reservation experienced frequent thunderstorms. In those periods, power outages and brown-outs were daily occurrences and caused considerable downtime (11.1 percent), major computer system problems, and maintenance difficulties. An uninterruptible power source (UPS) was installed to provide precision power input control and to allow controlled shutdowns. The solution has proven extremely effective; only 5 hours of controlled maintenance downtime have been experienced in the 4.5 months since installation of the UPS.

Costs

The use of cost as an evaluating factor must be carefully considered in the proper perspective. Providing quality health care to people in remote areas is a national and international problem. Offering physicians excessive monetary rewards has not been the solution (although in isolated cases it may have been an acceptable temporary stopgap measure). Therefore, when cost is being used as a decision and/or evaluation factor, it must be considered relative to the value and need for a solution to the problem of remote area health care delivery.

To provide objective, accurate cost data, STARPAHC is conducting a continuous, thorough cost analysis, considering both the recurring and non-recurring costs for the system and each of its major elements and functions. Existing data reveal that the "cost per outpatient visit" figures are most meaningful and do equate favorably with costs for outpatient visits in comparable facilities without telemedicine capability.

For example, the total recurring costs of NASA, IHS, and the contractor during the second 6 months for all maintenance and operations support was \$198,972. On a per-patient-visit basis, the cost was \$42.71. It is reasonable to assume that, irrespective of the second year's inflationary factors, this cost will be further reduced in progressive increments during the next 2 years until operational costs become somewhat stabilized.

per outpatient. In view of these potential operational changes, one must carefully assess the environment in which the system operates and recognize that cost per outpatient can be directly proportional to the number of outpatient visits, which can vary widely dependent on the application of the system.

V. Conclusions

1. The STARPAHC approach to providing access to health care at remote locations may be a model for other health care delivery systems. Verification is being provided by the operational results of this demonstration system.
2. Those charged with the responsibility of providing quality health care to remote areas — local community, state, Federal, and international — should begin planning to implement programs that use the knowledge and data being gained through STARPAHC.
3. Feasibility determination of the STARPAHC concept for remote area health care delivery is indicative of future growth potential. As a first-step, one-of-a-kind, demonstration system, its possibilities for exportability, growth, and expansion appear to be very good.

Any combination of the major system elements can be used singly or multiply to accommodate each area's specific needs. The present and near-future communication satellite capabilities enable any degree of partial or total service networks to be synthesized (as indicated in Fig. 9), and to go beyond regional medical centers to national medical centers, and perhaps, international medical centers.

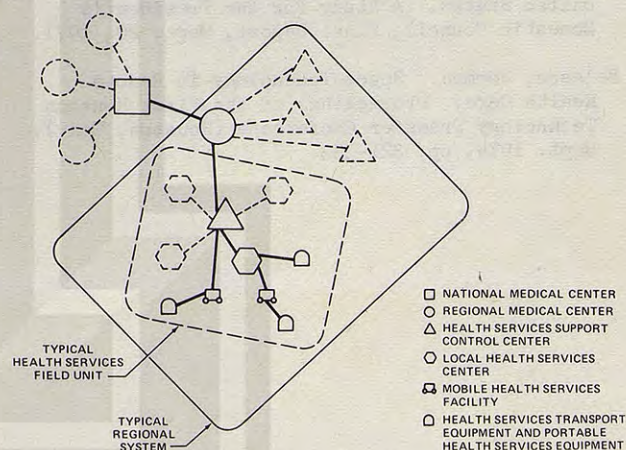


Figure 9.- Concept for a health services network.

For example, future implementation of the STAR-PAHC concepts may include such networks as remote island health facilities in the wide expanse of the Trust Territories, linked directly with health services control centers on major islands and, in turn, with a regional medical center in the Hawaiian Islands. The regional center may be linked to a national medical center on the U.S. mainland, as well as other countries. Thus, the

allied health professional administering to patients in remote Pacific island areas may communicate and exchange visual data with physicians and other medical experts throughout a vast network.

Acknowledgment

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