[A more readable copy

W.T.

Summary of Proposed Sensory Adaptation Studies on STS-5

1. EOG Recording - MSs during launch/entry; personal magnetic recording of EOG/head turns.
2. EOG Evaluation - Standard test series on orbit by available crew.
3. Vestibular Thresholds - Linear and angular acceleration thresholds during flight.
4. Kinesthetic Accuracy - Simple test of ability to repeat position of a segment.
5. Tracking Task - Single axis tracking task.

1, 2, 3 are primarily visual, vestibular, and CNS evaluations (not experiments).

4, 5 are primarily somato-sensory/motor evaluations.

Crew Training/Timeline and Equipment Status/Cost summaries are included.

H. Thornton

## 1. STS-5 EOG Recording

Protocol:

The MSs (or mid-deck MS) will have horizontal and vertical[1] eye motion, horizontal head turns and exact time recorded by a personal minature four-channel tape unit during launch and reentry, and for as long thereafter as is convenient. Passive minature electrodes will record eye motion from the EOG. No action will be required on launch but it will be desirable for the mid-deck MS to make two or three sets of eye motions and several simple head turns during reentry. If it is possible for the flight deck MS to wear the recorder no actions at all will be required on his part. One or two pre-flight runs during simulations are desirable.

Rationale:

A variety of illusions including vertigo and tumbling have been described immediately after orbital insertion and at various points on reentry. Some of these sensations should be accompanied by nystagmus or other characteristic eye motions. The time of occurrence of such events can be correlated with G-loads, maneuvers, etc., and the accelerometer will simulataneously record all head turns.

There is great individual variation hence it is desirable to record from as many subjects as possible but this need must be consistent with operational constraints.

This data will document the presence or absence of abnormal eye motion, possibly identify its origin and correlation with provocative events. After a reasonable number of recordings the prevalence of such events may be estimated

---

[1] This will be dependent upon availability of a 4-channel recorder; a three channel unit is available and has been demonstrated.

Methodology:

The recorder planned is one of the commercially available "Holter" type units with two A.C. coupled .05 to 100 Hz channels for electro-oculograms (EOG) eye and head motion) and a time coder. Efforts are underway to obtain a four channel unit to allow horizontal and vertical eye motions, head turns, and time. A three channel unit, horzontal eye motion, head turns and time, is available and has been tested. A suitable accelerometer will be mounted on the helmet and five electrodes will be placed as shown. Minature disposable electrodes and a fine wire harness which does not interfere with vision or with the helmet seal will be used. The recorder may be easily stowed in a pocket. A single cassette and battery set lasts 24 hours hence no servicing will be required.

It is planned to reproduce the data on a page display unit with a time demodulator, monitored by the page display and hard copied on a standard direct writing recorder.

Hazards:

None known.

Status:

I am currently evaluating a borrowed set of the above equipment. I have also investigated (and will continue to do so) the feasibility and operational requirements of this procedure by making extended recordings of routine activities such as work, driving, sleep, and have as an extreme case successfully recorded eye motions of trampoline artists and a gymnanst in their routines. This is a simple unobtrusive procedure with high reliability.

## 2. EOG (electro-oculogram) Evaluation

Protocol:

The onboard OBS will be used to record small eye and head motions from electrodes and an accelerometer attached to the crewman. A pair of visual targets will provide simple visual tracking tasks. A series of simple, benign head and eye motions will produce characteristic eye responses. This data will be stored/transmitted via the standard communication links to the SSR where it will be recorded by the facilities already available. It would be desirable to record from each crewman for a period of less than 10 minutes once daily but this will be precluded by operational requirements and a practical schedule is discussed.

Rationale:

Although SMS and the vestibular systems have been virtually the only area of concern in the nervous system to date it must be recognized that SMS is the extreme of a continuous range of adaptive responses and that while the vestibular system may be a key area it is only one of many subsystems. Further, prior investigations centered on producing symptoms, including nausea, without identifying cause or subsystem response.

The recording of eye motions by EOG during a series of benign maneuvers allows insight into the function of a number of major areas of the nervous system most likely to be disturbed by adaptation. The rationale is given for each particular maneuver.

Methodology, general

Electrodes will be placed as shown and connected through a harness and switch arrangement to the OBS preamplifier (signal conditioner) and OBS telemetry system. A horizontal angular accelerometer will be mounted on a headband and to the OBS through a switching arrangement. Downlink and initial graphic recording will use existing facilities.

Gaze Test

The seated subject will look for ~ 30 seconds at selected points, center, right, left, up and down.

Rationale: This procedure determines the stability of fixed visual tracking and if a severe disturbance is present, nystagmus may be elicited on deviation of the eyes.

Additional Equipment: None.

Calibration, Saccadic Tracking

A series of lights accurately spaced in the horizontal and vertical planes will be sequentially lit and tracked by the subject.

Rationale: This produces visual step responses which allow angular calibration of the entire system. In addition the maximum angular rate of the eyes may be determined as well as errors in position, drifts or other abnormalities which may be induced from disturbances in the CNS or from abnormal vestibular or other peripheral inputs. Response time can be measured by comparison of the time of illuminating a new target position to the eye's movement to it. A time index from the light control will be added to the signal stream for this.

Equipment: A headband will be used to attach the calibration jig which will use flexible lightweight spring steel wire and may be rolled in a circle for stowage. The lights will be LED's driven by a small battery powered I.C. mounted on the calibration jig. I have constructed a working version of the above and a flight unit can be made available in a week. The electrodes should be small disposable units and a search is under way for suitable units. A harness and switch for the electrodes and accelerometer must be constructed. A mid-deck launch seat would be a suitable location.

While the existing SSR equipment is adequate for the initial graphic recording, a simultaneous high fidelity tape recording would be advantageous.

Status/Cost: See Chart.

Pendulum Tracking

A simple elastic wire with masses and a visual target will be tracked by the eyes and eye motion recorded. The accelerometer will be attached to the pendulum for comparison to eye motion. By moving the accelerometer to various distances along the pendulum, its frequency may be varied. A few seconds of recording at 3-4 frequencies is desired.

Rationale: This tracking task, especially if quantitated as above, is a sensitive indicator of the function of the visual tracking loop and more importantly here, of any disturbances from the CNS or the periphery (vestibular, etc.) Wolf, et al, have shown the value of this test which has largely supplanted the caloric stimulation test at the USAF's SAM.

Equipment: OBS system, electrodes and harness, accelerometer and spring steel wire pendulum (for weight and stowage) with target.

Status/Cost: See Chart.

Head Position

The electrodes for recording horizontal eye motion will be attached as previously and the accelerometer mounted on the headband. With eyes open the subject will gaze straight ahead and then turn the head right, center, left, center, down, center; holding each position for approximately 10 seconds and then repeat the sequence with eyes closed.

Rationale: This sequence examines the eye's response to impulse commands from the visual, vestibular and cervical (neck) control loops. All

three will be operative with eyes open and the vestibular and cervical loops only with eyes closed. This is one area in which significant differences were noted in the crewman who had SMS symptoms on STS-4.

Equipment: Only horizontal eye motion will be recorded with one channel of the OBS while the accelerometer will record head motions on the other channel.

Status/Cost: See Chart.

Vestibulo-Ocular Reflex Performance

Horizontal eye and head motion will be recorded as previously while the head is oscillated at small angles and at several frequencies under the following circumstances:

a. Eyes open and fixed on external object.

b. Eyes closed, mentally fixed.

c. Eyes open and fixed on an object which moves with the head.

Rationale: The gain and frequency/phase response of the visual-vestibulo-ocular and vestibulo-ocular loops are well characterized. If there are significant CNS or peripheral (vestibular, somato-sensory, etc.) abnormalities, these may be expected to alter the normal eyes-open tests. The eyes-closed portion is largely dependent upon a normal vestibular reflex hence should be sensitive to any upsets in this area. N.B.--These are well known standard procedures and while they are normally made with a torsional chair, the simple head oscillations are a documented acceptable alternative.

Equipment: The usual electrodes/harness and OBS will be used to record eye and head position and a pointer may be attached to the headband for eye fixation.

Status/Cost: See Chart.

## 3. Vestibular Threshold

Simple methods for oscillating the subject in rotatory (yaw) and linear (longitudinal) modes, using on-board apparatus for efficiency, with an accelerometer to measure input. Both subjective and objective responses (EOG) will be used to determine thresholds and any change in thresholds. This will be a two-man task.

Rationale:

It has been postulated that in the presence of reduced gravity/acceleration forces the pertinent receptors would increase in sensitivity. This certainly occurs in other areas of the nervous system and would be consistent with observations from previous STS flights. It thus becomes of considerable importance to know the magnitude and time course of such changes which can be determined by doing the above procedure throughout the mission and especially prior to reentry.

Procedures:

The subject will have an eye shield and ear plugs to exclude visual and audible cues. To reduce tactile stimulus and provide a constant posture, a rescue harness on board will be placed between two sets of light rubber bungees, also standard equipment, such that he can be oscillated either rotationally or longitudinally by the second crewman. The exact frequencies and amplitudes will be recorded by an accelerometer. Eye motion will be detected EOG's recorded by the OBS. Amplitude and if necessary frequency will be increased until motion is detected by the subject. Repeated runs will allow the time course of any changes to be followed.

Equipment:

No equipment in addition to that specified for the EOG evaluation will be required except for the eye and ear shields. The bungees and harness are on board.

## 4. Kinesthetic Accuracy

A sheet of paper with suitable backing will be placed at right angles to a typical hinge joint of the body, say the elbow, and a stylus attached to the extremity. An arbitrary point in the range of motion is selected, marked, and then with eyes averted the body segment is moved and returned as closely as possible to the original position and marked. This will be repeated several times to establish error. A constant unidirectional load will then be applied and the procedure repeated.

Rationale:

The body has a variety of "position" sensors such that one is able to reposition an arm to some arbitrary position within $1\text{-}2^{o}$ in many cases. With removal of many customary forces from the body it would not be surprising if such sensibilities were altered by weightlessness. This simple test should document any significant change in such capacity during weightlessness and the effects of adding a simulated gravitational load.

Procedure:

A sheet of paper suitably backed will be attached to the mid-deck MS seat or other support which allows flexion of the arm at the elbow, a partial flexion will be made and the position marked by a sharp stylus. With eyes averted the arm will be flexed/extended and then returned as close as possible to the original position and marked. This will be done 3-5 times and a new

position chosen. In several typical positions the procedure will be repeated but with a glovelet and attached to a long bungee simulating weight of the arm. It would be desirable for the mid-deck MS to repeat this during reentry after g-loads have become appreciable.

Equipment:

Sheets of paper of suitable size would be attached to on-board support items. A small sharp stylus such as a posterboard pin would be required

## 5. Tracking Task

A programmed command pen moving in a single axis would be directly and manually tracked by a second pen. A continuous graphic record would be made. During orbit a glovelet with a single axis constant force would intermittantly used. It would be desirable for the mid-deck MS to perform the task during maneuvers on reentry.

Rationale:

There appears to be a major change in sensation of the rate and magnitude of commanded maneuvers. It is important to know whether this results from reaction to the resulting maneuver, a change in perception of magnitude of response to the maneuver or both. This simple task, by comparing rate and magnitude errors should document any changes in perception of the required task. The effects of weight both simulated on orbit and actual during reentry allow an estimation of kinesthetic perception. Recordings throughout the adaptation would document the time course of any changes.

Hardware/Procedures:

The paper and pen drive from standard servo-recorder would be removed and a manual writing pen added. A small set of memory functions would be added including various amplitudes, rates, and patterns. On-board bungees would be used to add the simulated weight. The record would be analyzed postflight for various error modes.

Status:

The basic concept has been reviewed and approved by the USAF expert in the field at the SAM. The necessary modifications to the recorder are straightforward and easily achieveable by flight time.

## Crew Time/Training

1. EOG Recording - Approximately 15 minutes with 1/2 cue card; five disposable electrodes must be applied in non-critical locations and unit turned on prior to reentry -- estimate 10 minutes. Unit must be doffed and stowed after removal -- estimate 5 minutes.

2. EOG Evaluation - While it would be desirable for each member to participate it may be well to exclude the pilot in view of emotions involved. It now appears that the first 2 days will be consumed by PAM operations, but as many crewmen recording approximately 10 minutes for each day possible thereafter is desired (10 minutes set up will be required). The initial set up will require 15-30 minutes. A cue card should be used. An hour per crewman preflight which would include a baseline recording will suffice.

3. Vestibular Threshold - The same considerations apply here as for EOG recording. The initial set up will require 30-45 minutes and subsequent ones approximately 15 minutes. Recording time is approximately 10 minutes. An hour/crewman preflight training would be adequate.

4. Kinesthetic Accuracy - Preflight - 15 mins, Inflight - 10 mins.

5. Tracking Task - Training preflight would require 1 hour, inflight - any crewman available once a day whenever possible for 5-minute session. A 5-minute session by the mid-deck mission specialist on entry is desirable.

## Components/Cost/Schedule

EOG Recording

| | | Size | Weight | Cost | Status | Delivery |
|---|---|---|---|---|---|---|
| 2 ea | Oxford recorders with batteries, tape, etc. | 1½ x 3½ x 4½" | 14 oz | $2680 | N.B.-These units could be borrowed but this is not good practice | 1 wk from stock |
| 1 ea | Oxford replay and Paging Display (PMD-12) | N/A | N/A | $29,450 | Since only a brief recording will be made, would recommend using a distributor's replay facility | Currently available |
| | Time unit (VB-4,VM-1) | N/A | N/A | $ 2,895 | | |
| | 4-channel direct writer | N/A | N/A | - | There are dozens of such units on site | Currently available |
| | Accelerometer | 1 inch$^3$ | ½ oz | $1000 est | This unit is in selection process | An available unit will be chosen |
| | Harness | 1 inch$^3$ | 1½ oz | - | This unit would be fabricated locally from acceptable materials | Estimate 8 hours fabrication time |
| | Electrodes | ½ inch$^3$ | 1/3 oz | < $50 | Available units are being researched and evaluated | An available item will be chosen |

---

Tracking Tasks

| | | | | | |
|---|---|---|---|---|---|
| Basic off-the-shelf recorder, battery powered | 12" x 4" x 4" | 3 lbs (est) | $5000 | Modifications in house | 6 weeks |

Above prices are typical of available hardware

## Hardware Status - EOG Evaluation

| Item | Size (stow) | Weight | Cost | Status | Delivery |
|---|---|---|---|---|---|
| Head harness | 3" x 3" x 3" | 3 oz. | Fabricate locally in P. E. Shop | | Estimate 1 week from start |
| 100 electrodes | 1" x 2" x 3" | 1 oz. | approx. $50 | Currently searching | Instock item will be chosen |
| Harness to subject & OBS | 3" x 4" x 4" | 8 oz. | Fabricate locally from special material | | Estimate 2 weeks from start |
| 1 each angular accelerometer | 1" x 1" x 1" | 1/2 oz. | approx. $1000 | Same item use in recording during launch, reentry | |
| 1 each target light assembly with control | 8" circles x 1/2 | 2 oz. | Local fabrication | I have a working prototype - very simple checkout | 1 week from start |
| 1 each pendulum | 8" circles x 1/2 | 2 oz. | Local fabrication | Will consist of spring steel wire | 1 week from start |
| 2 each OBS pre-amps (signal conditioners) | The units used for EKG monitoring during launch will not be but in trash return as usual but saved for recording. A gain adjustment will be made after EKG monitoring as was done on STS-4 | | | | |

---

### Threshold Sensitivity

| | | | | | |
|---|---|---|---|---|---|
| Eye Shield | 1" x 1" x 1" | 1 oz. | < $5 | - | Available |
| Ear Plugs | 1/2 cu. in. | << 1 oz. | < $5 | - | Available |
| Harness and Bungees | Standard STS Equipment | | | Procedures, tie points, etc., will be developed | On-board already |

Dvg. S.D. Fuge

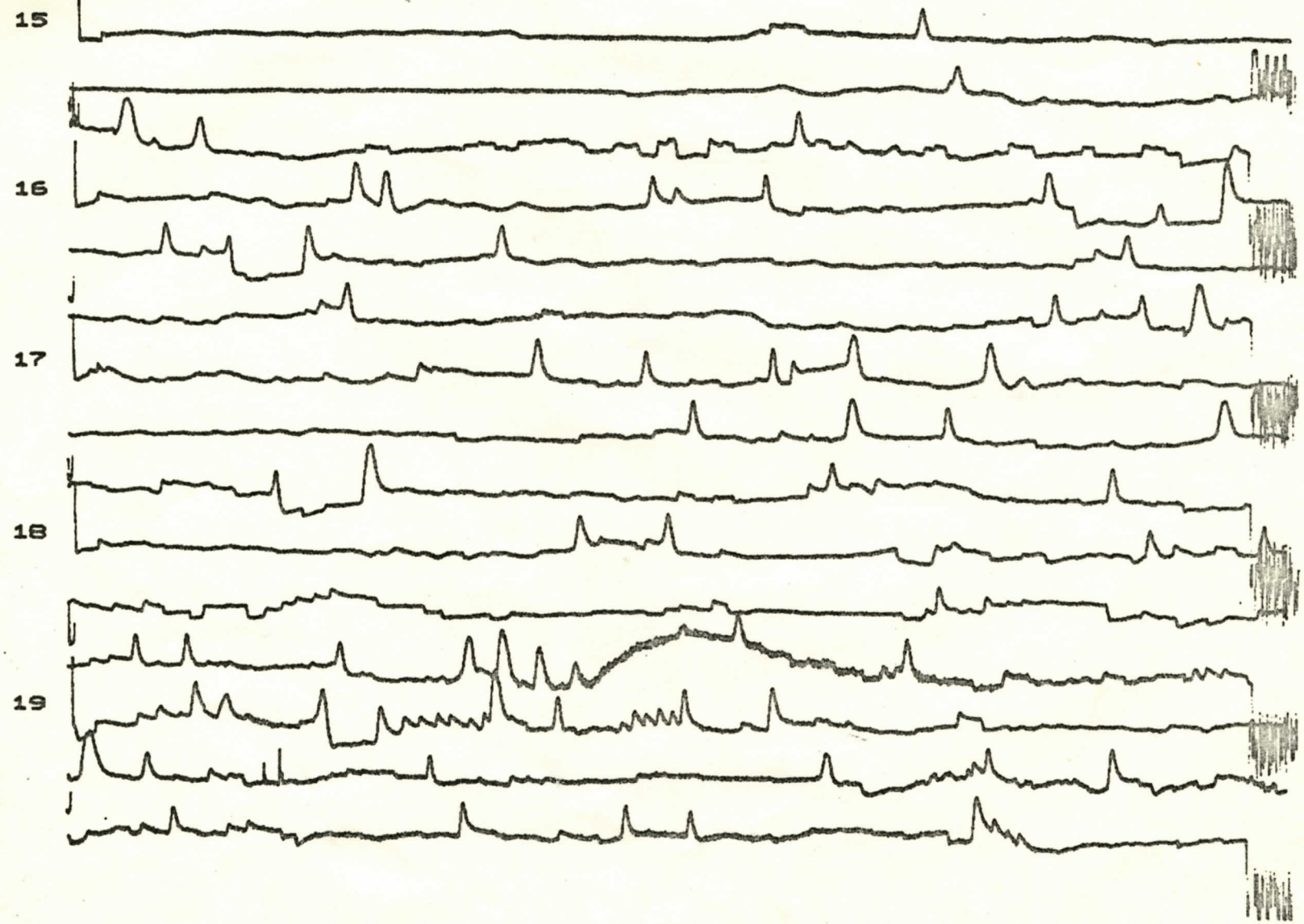
WT/DVG/V

Vert.

Vert.
~~Horiz~~

up ↑

CH2 | 9:15PM TO 9:20PM D1 PATIENT W.T. MD DATE 31 Jul 80 DMA 1981

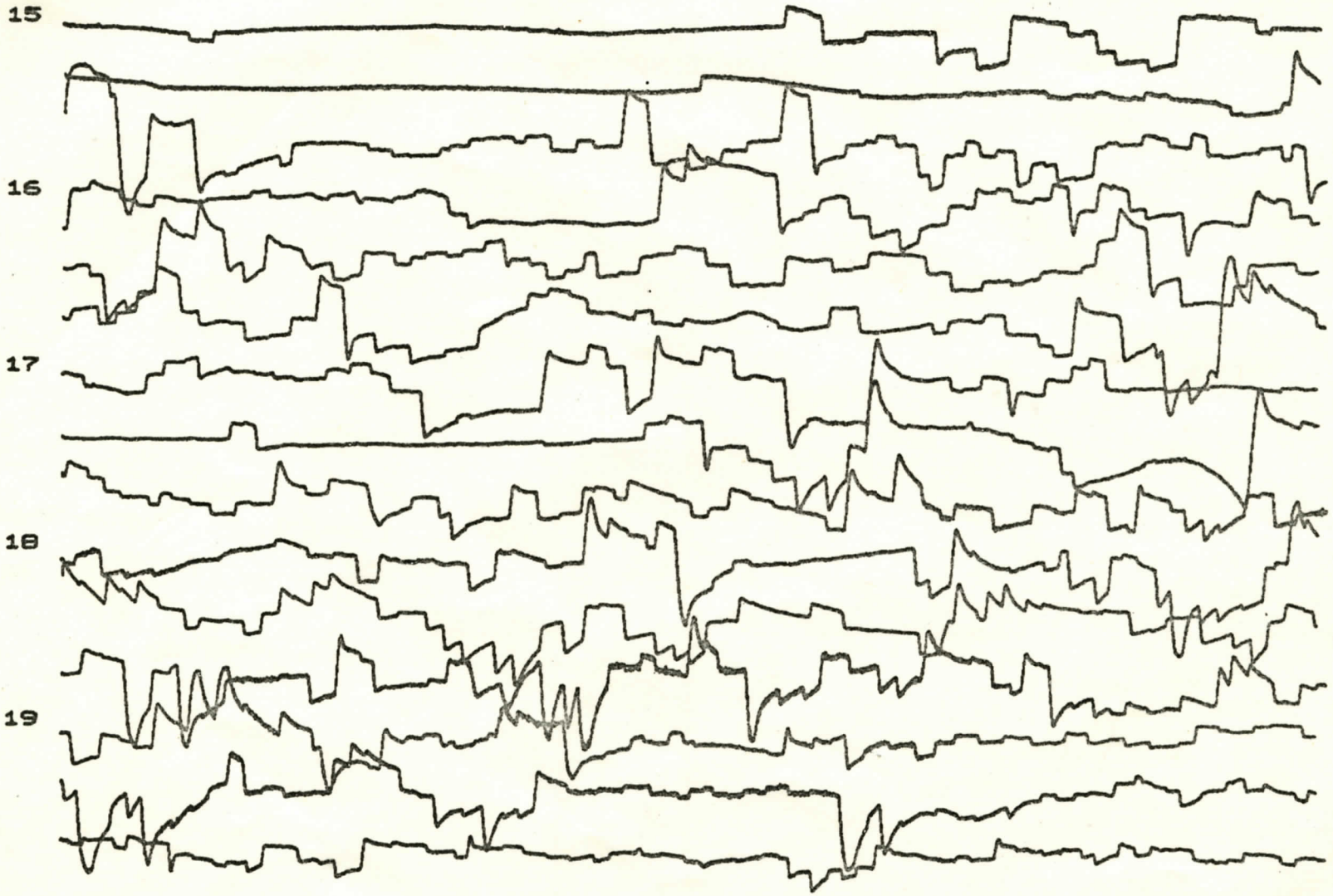


EOG, Driving

Dvg. San Diego Fway- WT/DVG/H

R ↑
Horiz.

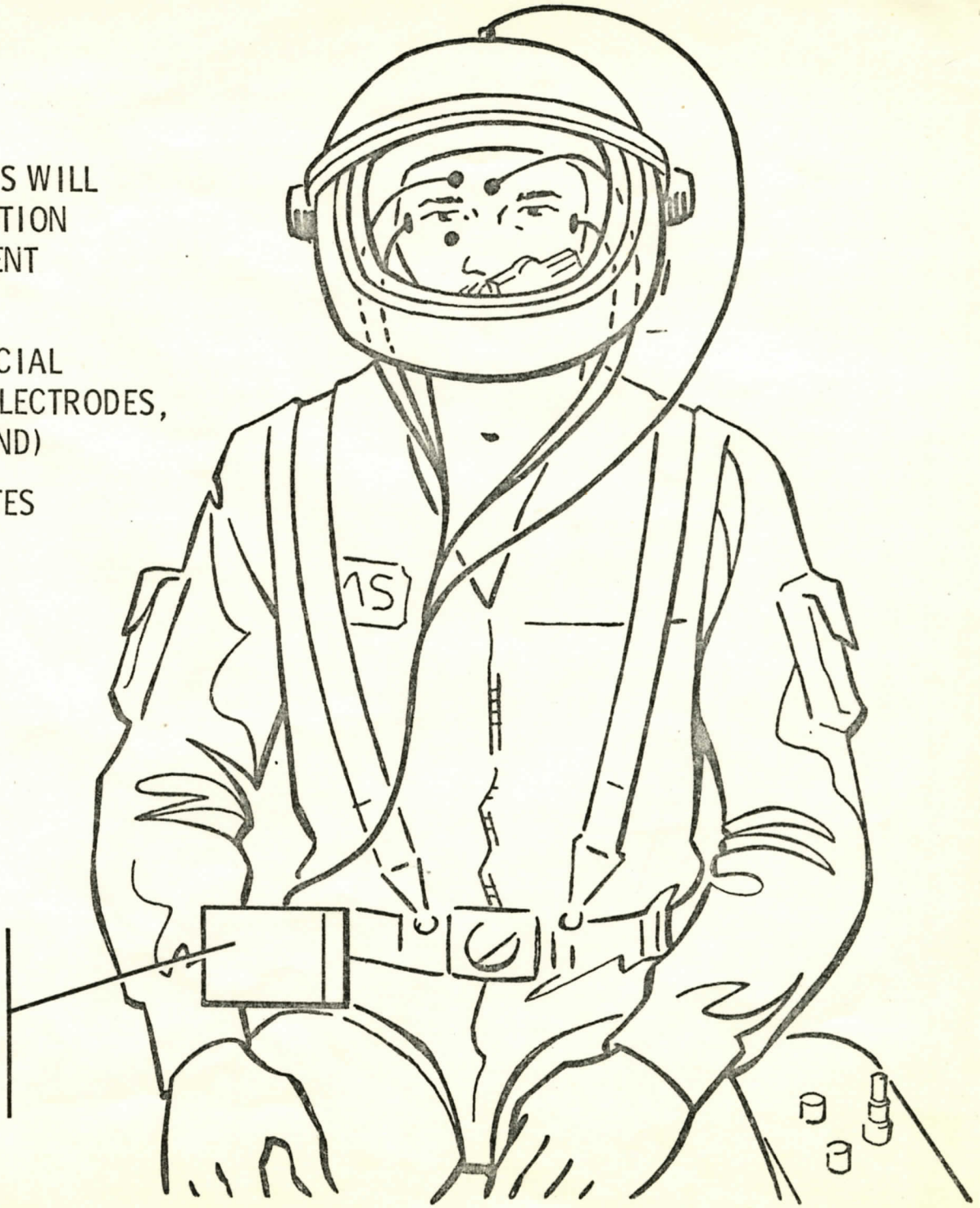
CH1 9:15PM TO 9:20PM D1 PATIENT Thornton MD DATE 31JJ1 8 DMA 1981



# ASCENT/ENTRY

- MINIATURE PERSONAL RECORDERS WILL DOCUMENT EYE AND HEAD MOTION FROM THE MS's DURING ASCENT AND ENTRY
- REQUIRES 2 STANDARD COMMERCIAL RECORDERS, HARNESS AND ELECTRODES, PLUS PLAYBACK UNIT (GROUND)
- CREW TRAINING TIME 30 MINUTES
- DON/DOFF TIME 10 MINUTES
- SIZE 2 x 3 1/2 x 5 IN.
- WEIGHT <1 LB/UNIT

HORIZONTAL EYE MOTION
VERTICAL EYE MOTION
HEAD ROTATION
TIME (g-LOAD, VEHICLE MOTION)



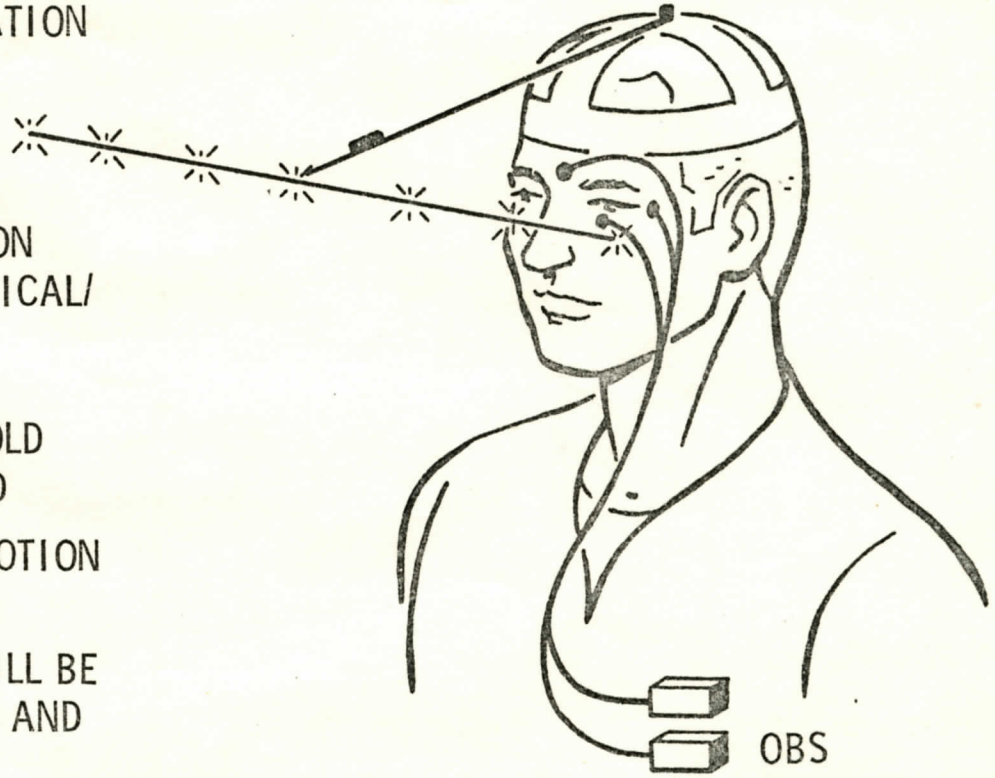
# ON ORBIT

- DAILY (AS SCHEDULE PERMITS) EOG EVALUATION

  OF: VISUAL SYSTEM STABILITY
  VISUAL TRACKING FUNCTION
  (IMPULSE AND CYCLIC)
  EFFECTS OF IMPULSE ACCELERATION
  ON VESTIBULO/OCULAR, CERVICAL/
  OCULAR LOOPS
  VESTIBULO OCULAR REFLEX
  ANGULAR ACCELERATION THRESHOLD
  LINEAR ACCELERATION THRESHOLD

  DOCUMENT ABNORMALITIES IF 'MOTION
  SICKNESS' OCCURS

  USE 2 CHANNELS OF OBS (1 CHANNEL WILL BE
  SHARED BETWEEN ACCELEROMETER AND
  EYE MOTION)



OBS
CHANNEL
1 AND 2

- ADDED EQUIPMENT
  CALIBRATION LIGHTS, OPTOKINETIC DRUM (COLLAPSIBLE), ACCELEROMETER,
  CABLE AND SWITCH, TRACKING PENDULUM, DISPOSABLE ELECTRODES
- STOWAGE SIZE 8 IN. DIAM X 3 IN. WEIGHT 2 LB
- TRAINING TIME ~1 HOUR
- INITIAL SET UP TIME 30 MINUTES
  SUBSEQUENT RUN TIME 10-15 MINUTES

# ACCELERATION SENSITIVITY
## ANGULAR AND LINEAR

- USE ON BOARD RESCUE HARNESS AND BUNGEES
- 2° SUBJECT DISPLACES AND RELEASES SUBJECT – ACCELERATION MEASURED – EOG AND VERBAL RECORD DETECTS THRESHOLD
- INITIAL SET UP 30 MINUTES
- 2 CREWMEN – 15 MINUTES TOTAL