Neurological Task Force Report on Countermeasures

Neurological issues were addressed by the Vestibular Countermeasures Task Group which was formed to provide a report to the Task Force on Countermeasures about the current understanding of neurologic adaptation to space flight and return to earth, and the development and implementation of countermeasures to lessen or alleviate adverse effects.

I. Nature of the Problem:

The Task Group determined the nature and scope of the problems associated with neurological adaptation to space flight, based on the available data. "Vestibular problems" for space flight have not disappeared with the introduction of promethazine injections to treat acute episodes of space motion sickness early after entry into weightlessness. Observations continue to suggest that several important problems remain affecting astronaut health and safety for short and long duration space flight.

A number of specific, measurable sensorimotor alterations have been identified that occur due to space flight. These include the following:

1) There are alterations in eye-head coordination, including changes in horizontal, vertical and linear VOR function, and combined eye-head smooth pursuit target tracking

2) Decrements occur in postural equilibrium control and locomotion, including disruption in vestibular contribution to postural control changes in head-trunk coordination.

3) Sensory illusions occur such that the perception of head tilt is reinterpreted as translation (otolith tilt translation phenomenon), and phase lag, gain and directional illusions may occur.

4) Changes in spatial orientation ability occur.

5) State transition problems occur. For example, during readaptation to a 1-g environment the recovered adaptive state is fragile and instantaneous state transitions can occur between 0-g and 1-g adaptive states, leading to sudden motor control dysfunction.

6) There are changes in proprioceptive function, related primarily to passive localization.

7) Modification in vestibulospinal reflex function occurs.

8) Optokinetic reflex function is transiently impaired.

9) Increased visual dependency occurs following transitions to and from microgravity.

10) Anatomical vestibular end organ changes occur in experimental animals.

11) Space motion sickness occurs in the first few days of flight.

II. Concerns:

Problems associated with multi-sensory and multi-system interactions (e.g., otolith-cardio linkage) and integration exist. Also, attempts to maintain or improve performance of a physiological system may cause or exacerbate problems in other physiological systems. As a result, there may be operational problems due to sensorimotor alterations. These include:

1) Control of Shuttle Landing: alterations in eye-head coordination and sensory illusions might be thought to lead to difficulties in reading flight instruments, checklists, interpreting ground-based landing aides, estimation of altitude, and making gaze transitions between inside and outside the flight deck. However, analysis of pilot landing performance on all shuttle flights to date fails to identify any correlation between mission duration and accuracy of landing speed, position, or touchdown velocity. This finding does not preclude the possibility of problems associated with higher workload or difficulty in overcoming illusions. The situation bears further monitoring, including post-flight debriefs aimed at identifying such problems.

2) Unaided Egress: decrements in postural and locomotor control, as well as motion sickness, may lead to impaired egress ability including difficulty in leaving the seat (getting out of restraints), moving to the hatch, and moving away from the Orbiter in an emergency or in setting up habitats and shelters on a distant planet.

3) Extravehicular Activity(EVA): Sensory illusions during EVA may cause crew members to become disoriented. Sensory illusions could also cause crew members to provide incorrect directions to RMS operators during joint EVA-RMS operations.

4) Space Motion Sickness (SMS): This problem leads to decreased efficiency early in flight, and could cause some difficulties during re-entry and immediately after landing.

III. Countermeasures to the Problem and Associated Recommendations:

Ideally, countermeasures to any problem should undergo an evolution including: a) basic science rationale and laboratory research; b) efficacy research/clinical evaluation; c) cost effectiveness evaluation; risk/benefit evaluation; d) operational effectiveness; e) assessment of potential interference with other countermeasures or shuttle operations; f) acceptance (with continuing “fine-tuning” as new data become available). In the context of these issues the underlying assumption is that the evaluation of the efficacy of countermeasures should focus on the functional link between sensorimotor alterations and real operational deficits (e.g. changes in eye-head coordination and dynamic visual acuity).

The Task Group evaluated the existing countermeasures for neurological perturbations caused by space flight. The neurosensory problems addressed by existing countermeasures include: 1) space motion sickness (SMS), which occurs primarily during the initial days of a space mission; 2) disturbances associated with an ill-defined but operationally important "entry/landing syndrome"; and 3) more severe and varied disturbances following long-duration (+2 months) microgravity exposure. The Task Group determined that the existing countermeasures aimed at these conditions can be divided into 2 categories:

Category 1 countermeasures are designated as tried, "proven" (in the U.S. program) currently-accepted and used procedures. Category 2 countermeasures include those procedures that are used informally and essentially based on personal communication among astronauts, as well as between astronauts and flight surgeons. These procedures also include those for which apparatus and procedures have been developed, but for which ground research is incomplete and/or efficacy has not been established. (Table 1 presents the two categories of existing countermeasures aimed at the three conditions. Charts presenting detailed information about each countermeasure and providing a recommendation associated with its use can be found in Appendix E).

Recommendations For Early-inflight SMS:

Recommendations for Category 1 countermeasures include: 1) continue and improve crew training, briefing, and timeline adjustment based on current best-available information; 2) further evaluation of promethazine route of administration, inflight side-effects and development of alternative drug interventions that are closer to 100% effective; 3) development of predictors to identify individuals who

Table 1: EXISTING NEUROLOGICAL COUNTERMEASURES

	CATEGORY 1	CATEGORY 2

	Tried, "Proven", Accepted and Used	**Developed, Protocols in place but not implemented, Anecdotal**
Early Shuttle Missions SMS	1. Oral & Promethazine Injections 2. Crew Training / Briefings 3. Timeline Adjustments	1. PAT: TTD/DOME 2. WETF Experience 3. Training in unusual attitude environments
Shuttle Landing Phase "Landing Syndrome"	4. Crew Training / Briefings 5. Recency of training 6. Operational Recommendations 7. In-flight Exercise	4. Medications during/after entry and landing 5. PILOT[1] simulator 6. Performing head movements during entry 7. Crew Assisted Egress 8. Preflight Adaptation Training (PAT)
Long Duration Missions	8. Assisted Egress	

[1] Portable Inflight Landing Operations Trainer

might benefit from additional or alternative interventions; 4) and development of coping procedures for the few individuals who fail to adapt for prolonged periods.

Recommendations for Category 2 countermeasures include: 1) evaluation of the efficacy of the proposed SMS-alleviation procedure using the Preflight Adaptation Training (PAT) devices, and 2) increase unusual attitude experience base, especially SCUBA experience, and use of WETF and DOME PAT for familiarization with the shuttle in unusual attitudes.

<u>Recommendations Concerning Entry/Landing Disturbances:</u>

Recommendations for Category 1 countermeasures include: (1) continue and improve crew briefings based on best available information, (2) continue to provide adequate training close to flight, and inflight (3) continue to modify operational landing requirements to create best "vestibular" environment, and (4) define best exercise protocols to prevent anti-gravity muscle loss.

Recommendations for Category 2 countermeasures include: (1) continue and refine crew briefing on risks / benefits of head movements during entry and immediately post landing, (2) evaluate entry / post-landing head movements, as compared to no head movements, and develop an appropriate protocol, (3) continue to use, improve and evaluate inflight landing task simulators, (4) egress training should include scenarios for assisting ill crew members, (5) meclezine / phenegran treatment should be evaluated and (6) efficacy of the PAT devices using the dual-adaptation protocol should be assessed.

<u>Recommendations Concerning Entry/Landing Disturbances After Long-duration (2+ months) Missions:</u>

For problems following long-duration missions, the only accepted countermeasure is assisted egress.

<u>Generic Recommendations:</u>

The Task Group also generated the following additional generic recommendations that should be addressed:

1) Contributions of fluid loading to postflight vomiting should be assessed.

2) An objective scale in order to quantify possible relationships among in-flight exercise, pre-flight rotation tolerance, and post-landing postural control should be developed.

3) A possible neurosensory down-side to recumbency during entry should be addressed.

4) Data from crew debriefs should be quantified and published to facilitate countermeasure development

Future Countermeasure Strategies

The Task Group identified several potential countermeasures which could be effective in counteracting the vestibular-sensorimotor affects of space flight. Below is a summary of these potential countermeasures for the three key stages of a mission: 1) the transition to orbit; 2) on orbit; and 3) the landing stages of a mission. Findings and recommendations are provided. Detailed reports on the identified countermeasures are presented in Appendix E.

<u>Transition To Orbit:</u>

Train crew to adapt head movement strategies that minimize SMS and thus avoid medications. Base these upon predictive tests that identify individual propensities, provocative movements.

Consideration should be given to designing an ultralight, miniaturized head movement monitoring system for training and dynamic restraint. (See Head Movement Monitoring/Dynamic Restraint/Training Systems in Appendix E)

Development of ground-based programs designed to train crew members to orient and navigate in 3 dimensions, including techniques for them to learn to recognize objects and spacecraft interiors from arbitrary ("agravic") body orientations, should be considered. Examples include various VR based approaches, e.g. PAT and more portable head mounted VE systems, neutral buoyancy EVA training facilities, e.g. WETF, and reorientable simulator modules for both shuttle and station, and parabolic flight aircraft .

<u>On Orbit</u>

There is considerable experimental evidence that the prediction of sensorimotor patterns by the brain plays a central role in control of posture, eye movements and equilibrium. It is therefore likely that with appropriate training astronauts could learn to maintain two neuro-vestibular adaptive states--one appropriate for the terrestrial environment, one appropriate for a microgravity environment. Specifically, the group recommends that procedures and equipment be provided on orbit that allow astronauts to practice moving their heads or bodies under conditions that approximate those on earth. The goal is to allow them to maintain the terrestrial adapted state on orbit thereby minimizing problems during landing and egress. Two protocols are recommended:

1) The maintenance of the capacity of the vestibular system to function in a terrestrial environment could be accomplished with a centrifuge facility that allows the crew to make active head movements in a 1 g field on orbit while minimizing or avoiding Coriolis and cross-coupling. An ideal configuration would allow pitch and roll head

movements in a body vertical (g_z) centrifugal field. This would require a large radius, human rated centrifuge. It is possible that at least partial benefits could be obtained with a smaller centrifuge. Ground-based research is required to investigate options.

2) The use of a modified treadmill system is recommended to maintain posture and kinematic strategies formed by proprioceptive and visual cues that are appropriate for 1g. The recent progress in vibrotactile devices for orientation and motion feedback should be reviewed and suitable countermeasure proposals based on these findings should be developed. (See Appendix E)

Landing

Induce dual adaptation to both 1-g and 0-g environments using a 4 meter radius centrifuge. This device could preserve appropriate predictive processing of vestibular signals in 1g and would allow the active head and possibly body movements required to develop dual adaptation on orbit.

Maintain musculoskeletal (proprioceptive, kinematic) postural strategies via a special purpose treadmill designed to allow linked inverted pendulum movements for reproduction of terrestrial postural control including pitch plane body kinematics.

Development of a quick-release equipment system to aid egress should be considered.

IV Overarching issues

The Task Group identified two overarching issues related to neurological adaptation to space flight and countermeasures aimed at addressing them.

Issue 1: The problems are crewmember specific, depending on their role in the flight (Space Station and Exploration Scenario).

There are three categories of affected crew members:

1) Long-Term On-Board Scientist: This crew member's duties involve performing inflight experimental procedures. The potential risks experienced by this individual include: a) difficulties performing emergency egress; and b) long-term or potentially permanent changes in sensorimotor function

2) Long-Term Operator: This crew member is responsible for Station operation (EVA, RMS etc.) or planetary exploration and could be responsible for performing a contingency Soyuz return from the International Space Station; but nominally would be returning with no operational duties. The potential risks experienced by this individual include: a) difficulties performing non-Earth planetary and/or emergency egress; b) long-

term or potentially permanent changes in sensorimotor functions; d) problems with station operation, including EVA, RMS, contingency procedures; e) spacecraft operational difficulties during contingency return.

3) Short-Term Operator: These crew members arrive on Shuttle and are docked to the Station for a 1 to 2 week duration. Their responsibilities include ferrying the long-term crew members back to Earth and performing Shuttle/Station operations. The potential risks experienced by this individual include: SMS; difficulties performing emergency egress; and shuttle operations (rendezvous, EVA, RMS, and re-entry).

It is recommended that countermeasures should be tailored to crew member's duty.

Issue 2: There exists a large body of relevant data that have not been analyzed. These include: a) data from STS flights that are not readily available. Additionally, physiological data have not been correlated with operational performance measures (e.g., Do short landings correlate with the commander's report of sensory illusions ?); b) a substantial Russian experience with long-duration flight that is not readily available.

It is recommended that future efforts should include collation, review, and evaluation of existing extensive operational and experimental databases. The operational databases (e.g., medical records, STA databases) would need to be analyzed by appropriate persons (e.g., flight surgeons, aircraft operations, respectively) to group the data and eliminate individual attributions and retain compliance with Privacy Act provisions.