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FLIGHT CONTROLLER ALERTNESS AND PERFORMANCE DURING MOD SHIFTWORK OPERATIONS

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ABSTRACT

Decreased alertness and performance associated with fatigue, sleep loss, and circadian disruption are issues faced by a diverse range of shiftwork operations. During STS operations MOD personnel provide 24 hr. coverage of critical tasks. A joint NASA Johnson Space Center and NASA Ames Research Center project was undertaken to examine these issues in flight controllers during MOD shiftwork operations. An initial operational test of procedures and measures was conducted during STS-53 in December, 1992. The study measures included a Background Questionnaire, a subjective daily logbook completed on a 24 hr. basis (to report sleep patterns, work periods, etc.), and an 8 minute performance and mood test battery administered at the beginning, middle, and end of each shift period. Seventeen flight controllers representing the 3 Orbit shifts participated. The initial results clearly support further data collection during other STS missions to document baseline levels of alertness and performance during MOD shiftwork operations. Countermeasure strategies specific to the MOD environment are being developed to minimize the adverse effects of fatigue, sleep loss, and circadian disruption engendered by shiftwork operations. These issues are especially pertinent for the night shift operations and the acute phase advance required for the transition of day shift personnel into the night for shuttle launch. Implementation and evaluation of the countermeasure strategies to maximize alertness and performance is planned. As STS missions extend to further EDO (extended duration orbiters) timelines and planning for 24 hour Space Station operations continues, alertness and performance issues related to sleep and circadian disruption will remain highly relevant in the MOD environment.

INTRODUCTION

The Mission Operations Directorate (MOD) at the Johnson Space Center (JSC) in Houston, Texas has been responsible for manned space operations since 1965. The center for operations at Houston is the Mission Control Center (MCC), and the operators are designated as Flight Controllers. All flight operations are handed over to the Mission Control Center (MCC) immediately after launch occurs. Prior to that point, the Kennedy Space Center in Florida has control authority from their Launch Control Center (LCC).

Early human space operations required limited 24 hour support from Flight Controllers, due to both the simplicity of the space vehicles, and the very limited duration of the missions. The overwhelming drive of the early programs was to establish a U.S. human presence in space, and to extend the capabilities of that presence to a length that would support a lunar landing and return.

The first U.S. space station, the Skylab program, posed significant challenges to the agency. The majority of space vehicle hardware did not prove to be a significant technical challenge. However, the operations community was significantly challenged, as once the vehicle was launched, 24 hour monitoring would be required for the life of the program. These challenges included maintainability issues for a control center designed for short flights, and budget limitations that prohibited increased hiring of Flight Controllers to staff the MCC. Since 24 hour operations were not prevalent at that time in industry, the management of the Mission Operations Directorate did not have experience bases to draw upon.

Significant anecdotal reports exists on the effects of 24 hour operations on the Skylab Flight Controller population. High turnover and divorce rates are still commonly cited, almost twenty years after the program. One primary concern to management was morale among the Flight Controllers, since historically this has been a highly motivated and extremely dedicated group.

Current shuttle flights are relatively short in duration, but the trend is quickly moving toward longer duration missions. The intent is to increase both the science return from a given flight and the operations experience for long duration missions in preparation for an orbiting space station.

Another factor has been the large demographic changes that have occurred since the early programs. The original Flight Controller population, similar to the original astronauts, were almost exclusively white males, and highly educated in a focused area of expertise. The current Flight Controller population is male and female, with very diverse educational and experience backgrounds.

PROBLEM IDENTIFICATION

Shuttle shiftwork support is dictated by both the mission objectives and the standards and policies of the Mission Operations Directorate. Since the mission objectives are used to decide a launch date, as well as time of day, these are directly reflected in the support schedule designed by the Lead Flight Director for the given flight.

For flights scheduled shorter than 10 days, three Flight Control Teams (FCTs) are used to provide 24 hour operations support. For the orbit phase of flight, the teams are typically designated Orbit 1, Orbit 2 and Orbit 3. Shift lengths vary, but require a hand-over both at the beginning of a shift and the end of a shift. Daily shift lengths of 10 hours are not uncommon. For flights of 10 days and longer, a fourth Flight Control Team (FCT) is added for the purpose of relief. The fourth team is rotated into the flight support schedule to allow each of the other three FCTs time off. The number of days off, and the specifics of the fourth team rotation are driven by the goals and length of the mission.

The Flight Controllers are responsible for a wide range of cognitive tasks, from sustained trend analysis to rapid response emergency actions. Multiple voice channels must be monitored concurrently by each controller for effects by other activities to their system. The demanding nature of the task requires that cognitive processing levels and vigilance remain high, as even small mistakes can be operationally significant.

The Lead Flight Director must consider a diverse number of other constraints when developing the shift work schedule for a given flight. For example, the launch time, landing time, mission goals, in-flight crew schedule, and training for a given FCT are all considerations. The clock hour difference between the launch and landing times determines if the FCTs must phase advance or phase delay their schedule. The launch time of day is dependent on the day of the year the launch is to occur, requiring the schedule to be flexible and dynamic. Since all FCTs are not trained to support all activities, when a launch slips the FCTs must also slip an appropriate period of time. Each FCT is essentially tied to flight activities that occur at a specific Mission Elapsed Time (MET).

The Mission Operations Directorate became proactively interested in assessing cognitive performance levels, as well as potential countermeasures, as part of continuing efforts to assure safe flight operations. MOD management became aware of NASA supported activities to address sleep and circadian issues with the astronaut flight crews, and subsequently initiated efforts directed at the Flight Controller population.

MOD PROJECT DEVELOPMENT

MOD management was aware of a workshop sponsored by the Johnson Space Center Space and Life Sciences Directorate held in Houston in 1991. The workshop involved Flight Surgeons, Flight Directors, Astronauts and circadian rhythm and sleep researchers from academia and within NASA. The focus of the workshop was to address some of the shiftwork issues raised as part of the Roger's Commission report on the Challenger accident, specifically, the hours of service required of Launch and Flight Controllers. At this workshop MOD operations personnel provided background on both crew and Flight Controller flight support requirements for the pre- and during flight time frames. Initial efforts focused on flight crew support, as the Health Stabilization Program provided greater control over the astronaut preflight schedules than over Flight Controller schedules.

However, the Flight Controllers shiftwork issues continued unsupported. The concerns of MOD management were heightened by the increase in flight durations and the subsequent increase in comments received by management from Flight Controllers regarding shiftwork issues. To address these concerns, an effort was initiated within MOD by forming an MOD lead project to include the appropriate institutional personnel from MOD, the Space and Life Sciences Directorate, and Ames Research Center/Fatigue Countermeasures Program.

MOD intent was to capitalize on the expertise of each organization, by recognizing each had a role in supporting the project from a study phase through to a fully operational support program. Various meetings were held between MOD and the other participants to delineate areas of responsibility and expertise. These efforts resulted in the initial operational test described here, the first to document Flight Controller performance levels during actual operations support. The final group of Principal Investigators included MOD personnel, Fatigue Countermeasures Program personnel from Ames Research Center, and Ames' collaborators from the University of Pennsylvania.

PROJECT PLAN

The complete project is composed of three distinct phases: Phase I Operational Test, Phase II Assessment, and Phase III Intervention. Since the project represents the first time an investigation of the human element is occurring in the Mission Control Center during operations, a conservative but progressive approach was planned.

The Phase I Operational Test was designed to identify the constraints and practicality of conducting a study in the unique environment of the MCC. The leading concern of both the investigative team and the Flight Director's Office was to assure that the study did not interfere with usual operations, and "safety valves" were provided to ensure that interference did not occur.

These issues were addressed at all levels of participation. The Flight Controllers were instructed to withdraw from participation at any point if operations support was in jeopardy. Each member of the Data Collection Team had the authority to suspend data collection at anytime, either temporarily or permanently, if operations support was in jeopardy. The Data Collection Team during the Operational Test was composed of experienced MOD personnel. The Flight Director on each of the three shifts also had the authority to suspend the project at any time.

The Phase II Assessment, which has not yet been conducted, is designed to provide more detailed and refined measures of the most significant factors identified during the Phase I Operational Test. More specific performance evaluation and refined subjective measures will be incorporated. Performance evaluation methods will be enhanced to allow near-real-time analysis of the data. Phase II is designed to be conducted during several future flights, to assure a representative sample of the Flight Controller population under a number of operational conditions.

The Phase III Intervention is designed to provide the most promising and operationally relevant interventions tailored to the requirements of MOD operations and currently available for implementation. Preference will be given to strategies implemented and demonstrated effective in a field setting. Evaluation of the Phase III Intervention will be conducted using the same data collection methods and measures obtained during the Phase II Assessment. Efforts will be made to differentiate the effectiveness of distinct strategies employed during the Phase III Intervention.

PHASE I OPERATIONAL TEST: METHODS

The Phase I Operational Test was conducted during STS-53 flight operations in December, 1992. The specific measures obtained and data collection procedures are described below.

Measures

The operational test utilized measures modified from previous field studies conducted by the Ames Fatigue Countermeasures Group (Rosekind et al., 1993, Gander et al., in press, Rosekind et al., in press). The measures used included a background questionnaire, MOD Controller Daily Logbook, and a MOD Shiftwork Evaluation packet. Measures were modified to collect information on the unique features posed by MOD Flight Controller operations during a shuttle mission. Some modifications were required due to the limited time available from Flight Controllers pre-, during and post-flight, as well as time constraints agreed upon with the Flight Director's Office. Data was collected at all phases of flight operations except the launch and landing time frames.

The selection of the specific measures was guided by subject availability and operational constraints. Extensive baseline data collection was not practical in part due to preflight training and other preflight responsibilities. During the mission, evaluation time was limited to minimize interference with flight support operations.

Background Questionnaire: The background questionnaire was originally designed for use in short- and long-haul flight operations studies (Gander et al., in press). The MOD Flight Controller Background Questionnaire for this study consisted of 192 questions in a variety of formats and took approximately 45 minutes to complete. It examined factors associated with fatigue, including sleep/wake cycles, nutrition, life-style, attitudes toward work and certain personality profiles. Sections of the inventory assessed basic demographics, including MOD and shiftwork experience, general health, home sleep quality, quantity and timing, and self-ratings of personality characteristics.

MOD Controller Daily Logbook: The MOD Controller Daily Logbook was modified from a "Pilot's Daily Logbook," used extensively by the NASA Ames Fatigue Countermeasures Program (Gander et al., in press, Rosekind et al., in press). Consistent parameters were obtained for later comparisons between the Flight Controller data and the existing NASA Ames Fatigue

Countermeasures Program Pilot database. The total number of questions was reduced, though sampling rate was increased.

The MOD Controller Daily Logbook was used to obtain information on bed and wake-up times, sleep patterns (quantity and quality), exercise, shift information (i.e., duty time), naps, meals and beverages, smoking behavior, medication use, and physical symptoms. The logbook also contained questions and analog scales for rating workload and fatigue factors that were completed during the shift period.

MOD Shiftwork Evaluation of Performance and Mood Packet: The MOD Shiftwork Evaluation of Performance and Mood Packet included measures of performance and alertness selected according to three criteria: (1) their sensitivity to sleep loss, circadian variation and fatigue from shiftwork; (2) the extent to which they reflected fundamental elements in the cognitive work demands of Flight Controllers; and (3) their brevity and unobtrusiveness for use as probes during flight operations. Objective performance measures included a probed-recall memory (PRM) test (Dinges et al., 1993), a two-digit serial addition (SA) test, and a word fluency (WF) test. Subjective measures included traditional psychometrics with different constructions (e.g., Likert-type, adjective checklist, analog), as well as tailored ratings of performance and effort required to perform during shift, and ratings of factors that interfered with performance during shift. Examples included 100-mm visual analog ratings of eight subjective dimensions; the Stanford Sleepiness Scale (SSS: Hoddes et al., 1973); the activation-deactivation adjective checklist (AD-ACL; Thayer, 1978); and ratings of performance and effort required to perform during performance bouts (Dinges et al., 1992).

Procedures

Data obtained preflight included the 45 minute MOD Flight Controller Background Questionnaire and the MOD Controller Daily Logbook. Also in the preflight time frame, administrative requirements, such as performance packet practice sessions and informed consent were obtained. Most information and performance practice sessions were conducted in groups, however, due to preflight workload some individual sessions were required.

The subjects were requested to initiate entries into the MOD Controller Daily Logbook one week prior to flight. The flight slipped, therefore, the actual period documented preflight was greater than planned. One period of interest was the transition from pre-flight to during flight shift support. All subjects completed the entries for this period.

During the flight, the Flight Controllers continued completing the MOD Controller Daily Logbook, including sections that were completed in the first and second halves of shifts. The shift sections provided a second independent source of data that was used to examine any unusual finding in the MOD Shiftwork Evaluations.

Data collection personnel were assigned to each of the three shifts. Since the STS-53 flight represented the last Department of Defense classified flight, and was also the proof of concept operational test, it was decided to use MOD personnel with MCC experience for data collection.

Actual data collection started on the first shift after launch and was terminated on the shift scheduled to monitor the deorbit burn. No efforts were made to obtain data during the entry and landing phases of flight. Though clearly of interest, it was determined that data collection would have adversely affected operations during these phases.

During each shift, an MOD Shiftwork Evaluation Packet was completed by each volunteer Flight Controller at the beginning, middle and end of a shift. The evaluations were centered around 1.5 hours into the shift, the mid-point of the shift, and 1.5 hours from the scheduled end of the shift. The Performance Evaluations initially took about 9 minutes to complete, and as the subjects became more familiar with the procedures evaluation time decreased to approximately 7 minutes. The specific timed components of the Evaluation Packet were carefully timed by stopwatch and logged by data collection personnel.

The volunteer Flight Controllers completed the Daily Logbook for a minimum of three days post-flight. Many of the volunteers completed the logbooks beyond this period and therefore provided data on the readaptation process.

Due to scheduling constraints, for most volunteers the process of baseline performance and alertness evaluations was also done in the post-flight time frame and paralleled the methodology used during the flight.

Data Analyses

Background Questionnaire data were analyzed descriptively for overall variable means, including population demographics and sleep/wake reports. The Daily Logbook was also analyzed descriptively for duty parameters, subjective ratings of sleepiness and boredom, and sleep/wake parameters during the mission.

Performance and alertness data were analyzed descriptively. Graphic displays were made of each shift's mean value on each variable for all three time points within each of six days of the mission. Analysis of variance and t-tests were used to compare performance and mood variables among shifts, although sample sizes were considered too small to yield statistically reliable outcomes for the Phase I Operational Test. Positive results at this Phase do serve, however, a hypothesis-generating function for the Phase II Assessment.

PHASE I OPERATIONAL TEST: RESULTS

Subjects

Seventeen volunteer Flight Controllers participated in the Phase I Operational Test. They included 5 Flight Controllers on Orbit 1, 7 Flight Controllers on Orbit 2, and 5 Flight Controllers on Orbit 3. During STS-53, Orbit 1 corresponded to a day shift, Orbit 2 corresponded to an evening shift, and Orbit 3 corresponded to the night shift.

MOD Flight Controller Background Questionnaire Results

Demographic Data: Demographic data describing the 10 male and 7 female volunteer Flight Controllers are portrayed in Table 1. Table 1 provides data for the overall group and by Orbit. The average age for all volunteers was 28.6 years with an average of 4.1 years at Johnson Space Center.

Table 1. Background Questionnaire: Demographic Data (10 M, 7 F)

	Overall	Orbit 1	Orbit 2	Orbit 3
Age (mean yr.)	28.6	28.0	30.0	27.2
Yr. at JSC	4.1	4.9	3.4	4.4
Yr. on console	2.7	3.8	1.6	3.1
Yr. at status	2.2	2.0	1.8	3.2
Height (in.)	68.8	70.8	66.7	69.8
Weight (lb.)	156.7	172.6	148.7	151.8

Subjects: Orbit 1 = 5; Orbit 2 = 7; Orbit 3 = 5.

These data demonstrated that the Flight Controller population was a relatively young group with experience at JSC ranging from 3.4 to 4.9 years. There was a greater range of years experience on console with the Orbit 2 individuals at roughly half (ave. 1.6 yr.) the other 2 Orbits.

Sleep/Wake Parameters. On the Background Questionnaire, the volunteer Flight Controllers reported their usual sleep/wake patterns at home. This included information about time-in-bed, time-out-of-bed (for both weekdays and weekends), average time to fall asleep (i.e., sleep latency), average total sleep time (hr.), and number of awakenings per night. These retrospective, subjective data portrayed the average sleep/wake patterns in the Flight Controllers usual home environment. These results are portrayed in Table 2.

Table 2. Background Questionnaire: Sleep/Wake Parameters

	Overall	Orbit 1	Orbit 2	Orbit 3
InBed: weekdays (24-hr. clock)	23.2	22.9	23.1	23.5
OutBed: weekdays (24-hr. clock)	6.5	6.6	6.3	6.7
InBed: weekends (24-hr. clock)	24.0	23.8	24.2	23.9
OutBed: weekends (24-hr. clock)	8.6	8.3	8.3	9.4
Sleep latency (min.)	22.1	19.0	20.7	27.0
Total sleep time (hr.)	7.3	7.8	7.1	7.2
Number awakenings	1.0	0.4	1.3	1.2

The Sleep/Wake data showed a classic weekday vs. weekend pattern. Overall, the group reported getting into bed earlier and awakening earlier during the work week (ave. 7.3 hr.) compared to weekend nights when getting into bed later and sleeping later (ave. 8.6 hr.). This pattern also suggested a compensatory lengthening of weekend sleep to offset a probable cumulative sleep debt that accrued during the work week.

MOD Controller Daily Logbook Results

Duty parameters. The MOD Controller Daily Logbook included data on shift duration and breaks during the duty period. The results are portrayed in Table 3.

Table 3. Daily Logbook: Duty Parameters

	Overall	Orbit 1	Orbit 2	Orbit 3
Shift duration (hr.)	9.5	10.0	8.7	9.8
Duty breaks (#)	0.5	0.9	0.5	0.1

The data revealed that while the overall average shift duration was 9.5 hr., there was a considerable range across Orbits. Orbit 3 night shift at 9.8 hr. was very close to the average daytime shift duration (10 hr.), while the Orbit 2 evening shift averaged 8.7 hr. The data regarding breaks during a shift revealed that the Orbit 1 day shift took an average of 1 break per shift, while during the Orbit 3 night shift (of approximately equal duration to Orbit 1) Flight Controllers averaged 0.1 breaks per shift.

Sleep/Wake Parameters. In the MOD Controller Daily Logbook Flight Controllers reported data about their daily sleep/wake patterns, including the time it took to fall asleep (sleep latency), total sleep time, number of awakenings during sleep, and other sleep episodes (e.g., naps). The Sleep/Wake parameter results from the Daily Logbook are portrayed in Table 4.

Table 4. Daily Logbook: Sleep/Wake Parameters

	Overall	Orbit 1	Orbit 2	Orbit 3	Pre	Duty	Post
Sleep latency (min.)	22.1	26.5	24.4	14.8	25.6	21.9	18.8
Total sleep time (hr.)	6.5	6.6	6.7	6.1	6.4	6.3	6.8
Number awakenings	1.2	0.9	1.2	1.4	1.2	1.3	1.0
Sleep Efficiency (%)	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Total daily sleep (hr.)	7.6	7.8	7.2	7.8	7.7	7.3	7.7

Overall, the group reported obtaining an average of 6.5 hr. of sleep with a distinct range between Orbits. The Orbit 3 night shift Flight Controllers averaged 6.1 hr., while the other two Orbits averaged 6.6 to 6.7 hr. As a group, the lowest average total sleep occurred during the mission (6.3 hr.) with an apparent compensatory rebound to 6.8 hr. post-mission. This reflects the average sleep obtained in Flight Controllers' primary sleep period. However, overall the group obtained about 1 hr. more sleep per day by taking sleep episodes (e.g., naps) at other times of the day. This suggests that the Flight Controllers acknowledged the decreased sleep obtained in the primary sleep period and sought other sleep opportunities to supplement their total daily sleep. With the "extra" sleep, the group averaged a total daily sleep of 7.6 hr., though this decreased to 7.3 hr. during the mission.

MOD Shiftwork Evaluation of Performance and Mood Results

Effects of acute phase advance on day 1 of mission. Subjective measures of sleepiness, alertness, and fatigue showed similar trends on day 1 of mission, regardless of the type of psychometric used. On the first day of mission, Orbit 1 tended to average higher ratings of sleepiness relative to Orbits 2 and 3. This was especially evident for ratings made midway in shift, as shown in Table 5. The elevated sleepiness appeared to be a direct result of the 3-hr. acute phase advance of the start time for the Orbit 1 shift on day 1 of mission. This was confirmed by the fact that the median time of evaluation of Orbit 1 midway through their day 1 shift was 0715 hr. (range 0640-0734 hr.), compared to a median mid-shift time of 1537 hr. (range 1510-1610 hr.) for Orbit 2 and 2240 hr. (range 2222-2254 hr.) for Orbit 3.

Table 5. Mean sleepiness/fatigue ratings midway in shift on mission day 1					
Psychometric	Orbit 1	Orbit 2	Orbit 3	F2.14	p value
Stanford Sleepiness Scale	3.20	2.02	2.20	1.95	.178
AD-ACL deact-sleepiness	13.20	8.10	9.60	2.62	.107
Analog alert/sleepy	5.84	2.68	4.08	4.33	.034
Sleepy/fatigue on shift	1.00	0.33	0.20	3.18	.072

The results of the objective performance measures revealed trends similar to those for subjective sleepiness on day 1 of mission, but there were no significant differences among shifts on day 1.

Effects of shift for days 2-6 of Mission. Subjective measures of sleepiness, alertness, and fatigue showed similar trends between shifts across mission days 2-6, regardless of the type of psychometric used. Conspicuous in all metrics was the marked elevation of sleepiness and fatigue (and diminution of alertness and energy) on Orbit 3 at the midway and final phase of shift time points, especially on days 2 and 3 of mission. Table 6 displays ratings taken near the end of shift on day 2. The elevated sleepiness near the end of shift for Orbit 3 appeared to occur at a time of increased circadian propensity for sleepiness. This was confirmed by the fact that the average time of evaluation of Orbit 3 near end of the day 2 shift was 0330 hr. (range 0303-0349 hr.), compared to the average time of 2030 hr. (range 2007-2126 hr.) for Orbit 2 and 1108 hr. (range 1048-1140 hr.) for Orbit 1.

Table 6. Mean sleepiness/fatigue ratings near end of shift on mission day 2					
Psychometric	Orbit 1	Orbit 2	Orbit 3	F2.14	p value
Stanford Sleepiness Scale	2.40	2.34	3.80	2.93	.086
AD-ACL deact-sleepiness	12.20	10.70	16.40	2.73	.099
Analog alert/sleepy	4.30	4.02	5.88	1.12	.353
Sleepy/fatigue on shift	0.20	0.78	1.20	2.69	.102

Ratings of motivation level and performance during the evaluation bouts showed a differential pattern near the end of shift assessment on day 2 for Orbit 3, indicating that Orbit 3 subjects were less motivated and that they felt they did less well on the performance probes. These data are shown in Table 7.

Table 7. Performance-related ratings near end of shift on mission day 2					
Psychometric	Orbit 1	Orbit 2	Orbit 3	F2.14	p value
Analog motivation level	5.58	7.46	4.20	3.50	.058
Performance self-evaluate	7.40	7.33	5.80	6.44	.010

Consistent with subjective assessments of sleepiness and fatigue, objective performance of cognitive (arithmetic) speed, memory, and word fluency, also showed some evidence of trends toward lower performance efficiency in Orbit 3 subjects (relative to Orbits 1 and 2) near the end of shift on mission days 2 and 3. These results are contained in Tables 8 and 9.

Table 8. Mean performance near end of shift on mission day 2

Performance	Orbit 1	Orbit 2	Orbit 3	$F_{2,14}$	p value
SA test (# completed)	16.20	15.37	11.80	2.89	.089
PRM test (# correct)	3.60	3.44	2.60	1.73	.213
WF test (# completed)	40.00	42.87	34.80	2.14	.154

Table 9. Mean performance near end of shift on mission day 3

Performance	Orbit 1	Orbit 2	Orbit 3	$F_{2,14}$	p value
SA test (# completed)	16.80	15.57	13.60	0.64	.541
PRM test (# correct)	3.20	3.71	2.60	2.22	.145
WF test (# completed)	40.00	40.00	29.00	3.35	.064

Two factors appeared to contribute to the variability in cognitive performance. The first was substantial inter-individual variability. This information will be important in calculating the sample sizes required for the Phase II Assessment, and possibly in helping to develop assessments that identify Flight Controllers who are more resilient to night work. The second factor was intra-subject variability learning, which resulted in systematic improvements in performance across days of mission, especially on the serial addition and word fluency tests. To reduce this source of variance in Phase II, pre-mission training would need to be completed on tasks. Even in this case, however, some learning would likely occur across missions days. Since even the simplest tests of cognitive speed tend to have prolonged learning curves (Dinges & Kribbs, 1991), a better solution would be to utilize probes that have been demonstrated to be devoid of learning effects. A more difficult version of the probed-recall memory test (Dinges et al., 1993) and the psychomotor vigilance task (Dinges & Powell, 1985, 1988; Rosekind et al., in press), both of which have been well validated to be sensitive to sleep loss and circadian variation, appear to be reasonable solutions to the problem of learning curves.

Finally, many non-fatigue related factors showed no differences among shifts. These include ratings of workload, work equipment problems, stress, boredom, anxiety, personal worries, co-worker problem, happiness, hunger and thirst. Thus, we do not have reason to believe that these factors contributed to the trends we observed in fatigue-related variables. When differences did emerge among shifts they tended to cluster in the domain of sleepiness/fatigue/alertness, on both subjective and objective measures, and they appeared to be associated, as expected, with night shift operations. The fact that both Orbit 1 and Orbit 3 experienced fatigue when engaged in night work suggests that the trends observed were not idiosyncratic to one shift of Flight Controllers. On the other hand, the differences observed among Orbits appeared to diminish across the 6 days of mission, suggesting the possibility that some adaptation is occurring to the night shift. We conclude that Flight Controllers working night shift either acutely or chronically may be at increased risk of lowered alertness and reduced performance capacity, especially during the first few days of mission. The Phase II Assessment is aimed at providing a detailed documentation of this hypothesis, and of pointing to practical countermeasures to performance degradation for testing in Phase III. The Phase I Operational Test demonstrated clearly that it is possible to safely and efficiently acquire objective data through periodic probes of performance and alertness in Flight Controllers, during shifts and across mission days, without interfering with mission goals or operations. This makes it possible to mount and sustain a program of self-evaluation aimed at promoting the highest levels of performance in Flight Controllers.

DISCUSSION

Overall, the results of the Phase I Operational Test support several observations. During the STS-53 shuttle mission, the volunteer Flight Controllers reported an average of 6.5 hr. sleep during their primary sleep period. The lowest reported average was 6.1 hr. of sleep for Orbit 3 Flight Controllers. This sleep was supplemented with an average of 1.1 hr. of "other" sleep (e.g., naps) obtained at other times of the day. The average total sleep obtained during the mission was less than pre and post-mission levels. The Orbit 3 night shift duration equalled Orbit 1 (i.e., about 10 hr.), though Orbit 3 personnel averaged 0.1 breaks per shift compared to the 1 break per shift obtained on the Orbit 1 day shift. The subjective measures demonstrated an increase in reported sleepiness on Orbit 3 compared to Orbits 1 and 2. Performance evaluation measures suggested decreased cognitive performance on Orbit 3 compared to Orbits 1 and 2. The data also suggested specific periods of vulnerability during transition from pre-launch status to mission operations.

All objectives of the Phase I Operational Test were met during STS-53 in December, 1992. The investigation was viewed as a success by Flight Controllers for its minimal intrusion in usual MOD operations. The results clearly established the feasibility of conducting the Phase II Assessment and the subsequent Phase III Intervention. This demonstration also solidified an effective and coordinated Johnson Space Center/Ames Research Center collaboration. The investigation team was able to utilize the combined group expertise to identify specific issues, develop a project plan, implement and complete data capture, and follow through with data analysis, reporting, and further recommendations. The results of the Phase I Operational Test support the planning and implementation of the Phase II Assessment and the subsequent Phase III Intervention.

Recommendations for the Phase II Assessment include an appropriate broader baseline training period, larger N per Orbit, implement a refined performance battery (with attention to issues of sensitivity and learning curves), and consideration of inter-individual variability. The Phase III Intervention should target areas specifically identified in the more complete Phase II Assessment. Intervention recommendations might include shiftwork education and training, the development of preventive strategies prior to and during mission, and the development of operational countermeasures to maintain alertness and performance during missions (Rosekind et al., 1991). Finally, it would be critical to develop a core for future program development and implementation during STS short and long duration flights and Space Station operations.

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