

# **ASTRONAUT SCHEDULING ASSISTANT: A BIOMATHEMATICAL MODEL OF THE NEUROBEHAVIORAL PERFORMANCE CAPABILITY OF SPACE SHUTTLE CREWS**

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There is considerable evidence that sleep is chronically reduced in space flight operations, in spite of recommendations that astronauts sleep 6 to 8 hrs per night while in orbit. Space shuttle crews have reported average sleep durations of 5-6 hrs in space compared to 7-8 hrs on the ground. This chronic sleep reduction is related to a combination of factors such as operational demands, noise levels, and circadian disturbances. Such reductions have, in hundreds of ground-based experiments, been shown to produce waking neurobehavioral deficits, which include vigilance decrements, increased lapses of attention, cognitive slowing, short-term memory failures, deficits in frontal lobe functions, and rapid and involuntary sleep onsets. These neurobehavioral performance deficits and alertness degradations can potentially have serious consequences on the effectiveness, health and safety of space shuttle crews.

In addition to the chronically disrupted sleep during space flight, the 90-minute orbital cycle of the space shuttle (which causes rapid changes in ambient light exposure), combined with rest/activity schedules that deviate significantly from the normal 24 hours, have the potential to produce a misalignment between the phase of the circadian pacemaker and the sleep-wake cycle. This will invariably lead to circadian desynchronization. In addition, light-exposure levels which are critical for the alignment of human circadian rhythms vary greatly inside of the shuttle. Operational studies have shown that it is not atypical for the light levels to be low in the compartments where space shuttle crews spend the majority of the working day and for light levels to be variable and high on the flight deck. Therefore, if crew members are exposed to the high light levels present on the flight-deck, especially during their time off in the evening, this evening light exposure in combination with the low levels during the day in the space lab could be expected to compromise circadian synchronization. Such circadian disruption would serve to exacerbate fatigue and hypovigilance in space due to its effects on sleep and the difficulties associated with working and maintaining alertness at an adverse circadian phase.

In view of the fact that sleep/wake (homeostatic) and circadian processes influence sleep propensity and waking alertness and performance, it is essential to accurately quantify the impact of these factors in order to: 1) predict the times at which skilled performance is most likely to be maintained at acceptable levels; 2) establish the times that are most suitable for restful on-board recovery sleep; and 3) determine the impact of proposed crew work/rest schedules on overall mission performance. Predicting fluctuations in alertness and performance is the key to developing schedules that are both safe and productive. Mathematical modeling holds a high degree of promise for making such predictions.

This project will create an astronaut scheduling tool that will be based on an accurate biomathematical model of human performance determined from empirical data collected in laboratory and field settings. Data will be derived from the published scientific literature and from experimental investigations already completed by NASA Ames Research Center. Data may also be collected from other organizations that have conducted a variety of sleep, circadian-rhythm, fatigue, and fatigue-countermeasures studies relevant to performance in the aerospace environment.

In order to fully characterize the functional capacity of an astronaut, it is necessary to consider a wide array of variables. Mission performance is not only a function of the accuracy with which one or two tasks are completed, but it is also a product of psychological, cognitive, and psychomotor factors that must be assessed in different ways. Thus, for the present effort, data representing basic performance capabilities, basic cognitive/psychomotor skills, and general subjective psychological status will be included.

The model will focus on: 1) the performance and alertness effects of the homeostatic sleep mechanism which is dependent on the number of hours of continuous wakefulness; 2) the performance and alertness effects of the body's circadian processes which are a function of internal neurophysiological and biochemical rhythms; and 3) the performance and alertness effects of the sleep-inertia mechanism which influences operational readiness upon awakening from a given sleep episode. External (environmental) factors that exert an impact on these 3 basic processes will be considered as well. For instance, the influence of ambient lighting may be included as a relevant factor as well as alterations caused by nutritional and/or pharmacological compounds. Individual and group variability in terms of fatigue susceptibility, sleep propensity, circadian stability, and innate sleep requirements could ultimately be included as well.

Once the model is developed, a user-friendly, computerized software tool will be created that accepts user inputs about scheduling parameters and provides both graphic and tabular outputs of predicted alertness/performance levels at various points in time. Using this tool, it will be possible to determine times during which mission critical tasks may be compromised by excessive fatigue levels. In addition, the tool will predict the most efficacious sleep periods in terms of ensuring rapid sleep onset with the most restorative sleep architecture. Finally, the tool will establish times at which ambient light exposure should be either minimized or maximized in order to avoid or attenuate circadian disruptions. The model will also be expanded to include the effects of fatigue countermeasures such as activity, napping, and/or pharmacological agents. The Astronaut Scheduling Assistant will be developed over a three year period beginning with a complete literature review and a biomathematical modeling workshop. This will provide an assessment of state-of-the-art fatigue and circadian models, selection of the most relevant model, and determination of the specific implementation approach. The model of the experimentally obtained data on varying sleep and circadian variables will then be implemented into a software program that will be beta tested in the laboratory. Based on the beta testing results, appropriate modifications will be made to the model

prior to complete validation testing. The final computerized, user-friendly software will be accompanied by a complete user guide.

In light of the fact that fatigue resulting from insufficient sleep and/or circadian disruptions is known to compromise vigilance, cognition, reaction time, psychomotor skill, judgement, and decision making, any tool that would help to minimize or avoid such problems can be expected to improve both safety and efficiency. An objectively-based prediction of neurobehavioral functioning in the space environment will permit the development of work/rest schedules that are optimal for individual missions. Thus, it is expected that this modeling effort will manage fatigue, improve crew-member capabilities and individual well-being, and ultimately result in improved productivity with a higher probability of overall mission success.