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24/7 OPERATIONAL EFFECTIVENESS TOOLSET: MISSION SCHEDULER INTERFACE

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While the objective of every aircrew is to accomplish their mission, every effort must be made to ensure the safety of the crew. Air Force Air Mobility Command (AMC) has been flying more and longer missions with fewer pilots and fatigue has become a potential safety issue. Safety is compromised when aircrews are performing their mission tasks in a fatigued state. A fatigue assessment and management tool built on a scientifically based model of sleep and cognitive performance can be helpful in managing the fatigue problem. The purpose of this report is to document a portion of the work conducted under a Phase 3 SBIR contract to develop a web-based, fatigue management tool with interfaces for diverse user applications. The Fatigue-Performance Assessment System (F-PAS) was derived from the Fatigue, Avoidance Scheduling Tool (FAST™), which contains the Sleep, Activity, Fatigue, and Task Effectiveness (SAFTE) model that forecasts cognitive performance level based on sleep, circadian rhythm, and sleep inertia. Specifically, this report describes the Mission Scheduler Interface of the 24/7 Operational Toolset to be used by AMC schedulers, pilots, and flight surgeons. The interface was designed to aid in the scheduling of military missions and duty periods such that the effects of mental fatigue on human performance are minimized. Aircrew and flight surgeons can use the tool to evaluate pharmaceutical fatigue countermeasures when sufficient sleep cannot be scheduled for a critical long duration or nighttime mission. Aircrew can also use the tool to evaluate the fatigue impact of changes to an interrupted mission schedule. A task-centered, system design involving task analysis was used to develop the requirements for the interface. The report includes task descriptions, an interface description, and usability results, which revealed that the early Beta implementation of F-PAS was effective for determining fatigue effects on performance.

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PREFACE

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Additional thanks go to Beth Barker for handling financial relationships with the government and our subcontractors. Special thanks to Juan Mendez for assistance in locating publications and debugging software.

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SUMMARY

While the objective of every aircrew is to accomplish their mission, every effort must be made to ensure the safety of the crew. Air Force Air Mobility Command (AMC) has been flying more and longer missions with fewer pilots and fatigue has become a potential safety issue. Safety is compromised when aircrews are performing their mission tasks in a fatigued state. A fatigue assessment and management tool built on a scientifically based model of sleep and cognitive performance can be helpful in managing the fatigue problem. Minor changes to a schedule may eliminate or mitigate crew fatigue. The purpose of this report is to document a portion of the work conducted under a Phase 3 SBIR contract to develop a web-based, fatigue management tool with interfaces for diverse user applications. The Fatigue-Performance Assessment System (F-PAS) was derived from the Fatigue, Avoidance Scheduling Tool (FAST™), which contains the Sleep, Activity, Fatigue, and Task Effectiveness (SAFTE™) model that forecasts cognitive performance level based on sleep, circadian rhythm, and sleep inertia. Specifically, this report describes the Mission Scheduler Interface of the 24/7 Operational Toolset to be used by AMC schedulers, pilots, and flight surgeons. The interface was designed to aid in the scheduling of military missions and duty periods such that the effects of mental fatigue on human performance are minimized. Once sleep times are determined the tool projects performance effectiveness for critical points within a mission. Aircrew and flight surgeons can use the tool to evaluate pharmaceutical fatigue countermeasures when sufficient sleep cannot be scheduled for a critical long duration or nighttime mission. Aircrew can also use the tool to evaluate the fatigue impact of changes to an interrupted mission schedule. The investigators' used a task-centered, system design involving task analysis to develop the requirements for the interface. The interface design approach was iterative, involving meetings among subject matter experts from each of the three user groups, interface software designers, and evaluators. The report includes task descriptions, an interface description, and usability results, which revealed that the early Beta implementation of F-PAS was effective for determining fatigue effects on performance. Incomplete or unfinished features of the software were not tested.

INTRODUCTION

This report describes the Mission Scheduler Interface of the 24/7 Operational Toolset. The toolset was based upon the Sleep, Activity, Fatigue, and Task Effectiveness (SAFTE™; Hursh et al., 2004). The SAFTE™ model predicts cognitive performance level based upon sleep, circadian rhythm, and sleep inertia. This specific interface of the toolset was designed to aid in the scheduling of military missions and duty periods such that the effects of mental fatigue on human performance are minimized. The interface design approach was iterative, involving several meetings among subject matter experts (SMEs), interface software designers and evaluators. Research revealed that Air Mobility Command (AMC) would likely be the primary user of a fatigue management product because of the multi-day missions they routinely fly.

In our interactions with potential users, the first meeting was for the purpose of requirements analysis, in which the investigators elicited task information from the SMEs. Three user groups were interviewed, schedulers, pilots, and flight surgeons. The second meeting included a walk-through of storyboarded and preliminary software, in which the SMEs provided feedback to the investigators and evaluators. The final meeting was for the purpose of an "inspection evaluation" of the interface by SMEs and evaluators. The report begins with a general review of scheduling procedures for mobility aircraft, the primary context within which the interface may be used. The task analysis of the scheduler's tasks is followed by comments from users of the PC-based product, the Fatigue Avoidance scheduling Tool (FAST™). Following a description of the methods used in the task analysis, the results are presented including usability testing. The report ends with recommendations and suggestions for incorporating a fatigue-assessment decision aid into a mission scheduling process.

SCHEDULING PROCEDURES FOR MOBILITY AIRCRAFT

While the objective of every aircrew is to accomplish their mission, every effort must be made to ensure the safety of the crew. Safety is compromised when aircrews are performing their mission tasks in a fatigued state. Minor changes to a schedule may eliminate or mitigate crew fatigue.

The Air Mobility Command (AMC) was created June 1, 1992. AMC provides America's ability to reach around the world. This rapid, flexible and responsive air mobility promotes stability in regions by keeping America's capability and character highly visible.

Air Mobility Command's mission is to deliver maximum war-fighting and humanitarian effects for America through rapid and precise global air mobility. The command plays a crucial role in providing humanitarian support at home and around the world. AMC Airmen--active duty, Air National Guard, Air Force Reserve, and civilians--provide airlift and aerial refueling for all of America's armed forces. Many special duty and operational support aircraft and stateside aeromedical evacuation missions are also assigned to AMC.

United States (US) military forces must be able to provide a rapid, tailored response with a capability to intervene against a well-equipped foe, hit hard, and terminate quickly. Rapid global mobility lies at the heart of US strategy in this environment--without the capability to project forces, there is no conventional deterrent. As US forces stationed overseas continue to decline in numbers, global interests remain, keeping the unique capabilities AMC can provide in demand.

As the air component of the U.S. Transportation Command, AMC serves many customers and, as the single manager for air mobility, AMC's customers have only one number to call for Global Reach. Air lifters provide the capability to deploy armed forces anywhere in the world and help sustain them in a conflict. Air refueling aircraft are the lifeline of Global Reach. Since Air Force tankers can also refuel Navy, Marine and many allied aircraft, they leverage all service capabilities on land, sea and in the air. These aircraft also have an inherent cargo-carrying capability--maximizing AMC's lift options.

AMC's mission encompasses nearly 140,000 active-duty and Air Reserve Component military and civilian personnel. They include approximately 46,700 active duty, 8,300 civilians, 46,600 Air Force Reserve and 38,300 Air National Guard.

AMC's provides mobility aircraft such as the C-5 Galaxy, KC, C-130 Hercules, and KC-135 Stratotanker (see Figure 1) and operational support aircraft such as the C-9, C-20, and UH-1.

Figure 1. A KC-135 Stratotanker from the 100th Air Refueling Wing, Mildenhall, England (U.S. Air Force photo/Master Sgt. Mark Bucher).

AMC has one numbered air force, the 18th Air Force, which is charged with tasking and executing all air mobility missions[1]. Units reporting to 18th Air Force include all Air Mobility Command wings and groups based in the continental United States, as well as two expeditionary mobility task forces--the 15th EMTF and the 21st EMTF. The 15th and 21st EMTFs serve as

[1] http://www.amc.af.mil/library/factsheets/factsheet.asp?id=231, current as of June, 2007.

lead agencies for conducting mobility operations worldwide. They are critical to the execution phase of war fighting by providing worldwide expeditionary mobility support. The 618th Tanker Airlift Control Center (TACC), also reports to 18th Air Force and serves as the organization's air operations hub, planning and directing tanker and transport aircraft operations around the world. AMC also has a number of active-duty bases and one major direct reporting unit, the USAF Expeditionary Center which serves as the Air Force's premier organization for expeditionary innovation, education, training and exercises.

A new era in air power history began June 1, 1992 when the Military Airlift Command and the Strategic Air Command were inactivated and Air Mobility Command formed from elements of these two organizations. AMC melded a worldwide airlift system with a tanker force that had been freed from its commitments by the collapse of the Soviet Union. AMC has undergone considerable change since its establishment. Focusing on the core mission of strategic air mobility, the command divested itself of infrastructure and forces not directly related to Global Reach. On Oct. 1, 2003, AMC underwent a major restructuring, bringing a war fighting role to its numbered air force. AMC reactivated 18th Air Force and re-designated its two former numbered air forces as the 15th EMTF, and the 21st EMTF.

The AMC Fact Sheet for 2007 provides the following information on AMC's ability to provide global reach on a daily basis. From providing fuel, supplies and aeromedical support to troops on the frontline of the Global War on Terrorism, to providing humanitarian supplies to hurricane, flood, and earthquake victims both at home and abroad, AMC has been engaged in almost nonstop operations since its inception. Command tankers and airlifters have supported peacekeeping and humanitarian efforts in Afghanistan, Bosnia, Iraq, Cambodia, Somalia, Rwanda and Haiti, and continue to play a vital role in the ongoing Global War on Terrorism. These many examples of the effective application of non-lethal air power indicate that air mobility is a national asset of growing importance for responding to emergencies and protecting national interests around the globe.

Overall Mission Scheduling Processes

AMC schedulers create itineraries for their aircraft and crews to accomplish missions required for combat operations, base needs, the Pentagon, other DoD authorities, or civilian emergencies. Reserve and National Guard units create schedules for TACC and for their own operations locally. The tools they use for their own schedules are scattered about in manuals, books, pamphlets, on the World Wide Web, and in their heads from training and experience. However, they also select crews and aircraft to accomplish missions mandated by TACC, who plans the basic mission.

AMC schedulers in the regular AF generally are located at Scott AFB and use the Global Decision Support System (GDSS). This Web-based system is AMC's force-level Command and Control (C^2) system supporting AMC/TACC execution authority for effective airlift mission management. GDSS consists of nodes located at different locations that continuously replicate information to keep each node updated with the latest information. The objective of the GDSS program is to improve AMC's C^2 force-level decision making by providing its users with automated capabilities to support airlift planning and execution, aircraft schedule dissemination, aircrew management, and mission management of AMC's airlift and air refueling missions. Its purpose is to provide a fully functional, operational system that satisfies the C^2 support requirements of AMC. GDSS interfaces with several C^2 systems, including Command and Control Information Processing System (C^2IPS), the wing-level C^2 planning and execution system, AMC Deployment Analysis System (ADANS), and the USTRANSCOM Global Transportation Network (GTN).

The following information was taken from Air National Guard Instruction 10-207, 2004, Chapter 3, page 8. All AF units rely heavily on GDSS to maintain visibility of their airlift, tanker and Strat. missions. A large global USAF audience views GDSS and other AF software ties into and works off GDSS. The Command and Control Information Processing System (C^2IPS) is a unit level C^2 system that manages functions such as communications processing, message/data processing and display, and nodal data networking. At the wing level, it channels information between the air transportation, intelligence, maintenance, operations, supply, weather, and surgeon general functions. Unclassified information is passed between unclassified GDSS and C^2IPS Intelligent Messaging Units at Scott AFB, Illinois and Travis AFB, California. Unclassified GDSS passes schedule and execution data to C^2IPS. C^2IPS passes arrival and departure information to GDSS and the next three down-line stations. For missions consisting of more than three legs, GDSS passes that information to the other C^2IPS equipped down-line stations. C^2IPS transmits takeoff, landing, diversion, over-fly, schedule, diplomatic clearance, and Unit Line Number (ULN) information (number of passengers and tons of cargo) to unclassified GDSS. Units using C^2IPS input: mission departures, arrivals, deviations, recuts, diverts, overflys, delay codes, and advisories into the system. Unit Commanders develop procedures to assure that the Operations Center is provided en route times for each leg until a mission is terminated. It is a unit's responsibility to close their mission.

The Airlift Information and Reporting System (AIRS) was designed primarily to assist the unit scheduler in building missions and trips and, upon trip completion, producing after action reports. The AIRS was not designed to fully support C^2 flight following, however. Units must load their itineraries 14 days or more before departure for the system to function properly. At each departure time for airlift missions, the total passenger and/or cargo on board must be loaded into C^2IPS or AIRS. Times for transitory aircraft arriving or departing a location will be either updated via C^2IPS or reported to the Operations Center (Air National Guard Instruction 10-207, 2004).

Typical Last Minute Mission Schedule

Geoff Janes of the 100th Air Refueling Wing Public Affairs wrote a story published in the Air Force News about a last minute AMC refueling operation that is typical of rushed scheduling[2]. A synopsis of that story follows.

> *A late night call and a cancelled sortie led an aircrew from the 351st Air Refueling Squadron at Meldenhall, England to expedite medical care for more than a dozen severely injured troops being transported from Iraq to Andrews Air Force Base, Maryland, on Feb. 7, 2007. According to the 100th Operations Support Squadron scheduler, the refueling mission was far from the norm. They got a call around 2:30 a.m. asking if they could refuel a high-priority air-evacuation mission (en route) to the hospital at Andrews. Luckily they had a cancelled flight and a crew available. That captain and crew had been scheduled to fly his first mission as aircraft commander on a routine refueling mission over the Mediterranean Sea. The pilot said that they normally know 24 to 48 hours prior to a flight. However, when they showed up, their (mission) binder (still) had all the information from the previous (cancelled) flight. The aircraft commander said what information they did have on the new mission was the refueling track, the time of the rendezvous and the call sign of the receiver, a C-17 Globemaster III from the Mississippi Air National Guard that had left Iraq at about 1 a.m. Greenwich Mean Time (GMT). The Air Guard's mission was unique as the majority of the flights are to the Landstuhl Regional Medical Facility in Germany. A Mississippi Air National Guardsman spokesperson said that their crews are able to make changes to meet the needs of the Air Force as the mission dictates. However, there was a tremendous amount of work they had to do to make this mission happen.*
>
> *The same can be said of the crews at Mildenhall. The maintainers and aircrew worked unbelievably fast because they realized how critical the mission was. They basically planned it all from scratch. The KC-135 launched from RAF Mildenhall at 6:30 a.m., and passed more than 16,000 gallons of fuel to the C-17 over the England-Scotland border. The C-17 commander said that they arrived in Maryland just before 3 p.m. GMT. Figure 1 shows a KC-135 Stratotanker from the 100th Air Refueling Wing, taking off from Royal Air Force Mildenhall on Feb. 7, 2007 on an unscheduled mission to refuel a C-17 Globemaster III that was rushing injured troops from Iraq to Andrews Air Force Base, Maryland. The rendezvous saved the air-evacuation mission some three hours of flying time.*
>
> *On the trip back to RAF Mildenhall, the crew ran into a snow storm that required them to circle the base before landing on a runway that had just been cleared by a snow plow. The commander said the refueling mission saved the C-17 crew roughly three hours it would have taken for them to land and refuel. He said, "We weren't the ones carrying (the injured troops), but who knows? We might have saved them a few hours that made the difference between life and death. But then I thought to myself after we landed that I get to go home today while the guys in the back of that plane are fighting for their lives. It was sobering."*

This story of a hurry-up mission is not atypical of missions scheduled by AMC schedulers. In this case, they were blessed with a rested aircrew and an available plane to accomplish the

[2] Taken from a story written by Geoff Janes, 100th Air Refueling Wing Public Affairs, 2/14/2007 - Royal Air Force Mildenhall, England (AFNEWS).

mission. However, schedulers do not have any knowledge of the fatigue impact of the schedule they create for the crew and must do their planning based on a set of rules established over time that merely have historical precedence. The rules do not take into account the sleep the crew has received or their circadian rhythm, only that they have been given an opportunity for a prescribed amount of "crew rest," usually 12 hours. A model that takes into account the time and duration of the crewmembers' sleep can project their cognitive performance effectiveness for the mission and the return flight (Hursh et al., 2004). It can assess performance effectiveness during critical events like take-off, landing, and air refueling. Once a scheduler knows that performance effectiveness is poor for the critical events of a tentative mission, it may be possible to either better rest the crew for the mission, reschedule the events to a time when the crew is less fatigued, or implement other specific, fatigue-risk-mitigating operational risk management (ORM) procedures.

METHODS

A more detailed explanation of the methods used here may be viewed in the companion technical report, *24/7 Operational Effectiveness Toolset: Usability Assurance Plan* (Miller, Eddy & Moise, 2008).

REQUIREMENTS ANALYSIS

AMC Schedulers

We conducted a task analysis (TA) on three AMC Reservist schedulers to help us incorporate the fatigue management tool into the scheduler's workflow. We used a modified version of the TA methods described by Greenberg (2004) to uncover their scheduling goals, processes, and tasks. In addition, we reviewed documents recommended by the schedulers to understand their work processes. Subsequently, we used the data from the TA to identify where best to apply fatigue management in the scheduling process. Because we were aware of the information requirements of the fatigue management process, we were able to identify the scheduler's tasks from which the necessary information could be acquired. Once we extracted the necessary data from the workflow and entered into the fatigue management tool, the next step was to determine where in the workflow the fatigue analysis could best be presented to the scheduler. The TA allowed us to identify the mission scheduling processes that could benefit from this information, but would minimally impact the scheduler's other tasks.

Since the purpose of a flight schedule is to accomplish a specific mission, fatigue considerations of the schedule have always been secondary. That is, the flight events schedule is initially created to support the mission; it is not designed to avoid or minimize aircrew fatigue. Therefore, we must assume that, typically, fatigue analysis will follow event scheduling to support the mission. Given those priorities, the scheduler will need to conduct "What-If" analyses on the schedule, trying various modifications to mitigate fatigue, but being sure to allow effective and efficient mission accomplishment. Therefore, considerable effort was expended by all participants to identify how a scheduler would edit a schedule with minimal effort while maintaining the "Big Picture" of the overall mission and its objective(s).

We taught the subject matter expert (SME) schedulers how to use the Fatigue Avoidance Scheduling Tool (FAST™) to help them understand what the fatigue management tool required as input and what it could produce as output. We used the SBIR prototype product currently in use within the AF, Navy, and select commercial sites (Eddy & Hursh, 2001, 2006a, 2006b). The FAST™ software was introduced <u>after</u> the TA was conducted. This experience with FAST™ allowed the SMEs to see how and where its data and processes could fit into their scheduling processes and tasks.

A modified, Goal-Directed, Task-Centered System Design Approach was used fashioned after Greenberg's (2004) 4-step version of the method by Lewis & Rieman. After eliciting this information, the SMEs were trained on FAST™ so that they could see what information a fatigue management tool would need and what types of displays it could produce. They then inserted the data acquisition and output requirements for the tool into their scheduling tasks at the appropriate places.

Three Air Force Reserve Command (AFRC) schedulers sponsored by the HQ of the 22nd AF (AFRC) served as subject matter experts (SMEs) for the TA. Three different wings, the 315th AW, Charleston, AFB (AFRC), the 514th AMW, McGuire AFB (AFRC), and the 436th AW, Dover AFB (AMC) supported the effort, each sending a scheduler.

The three SMEs and five investigators/developers conducted the TA and all discussions in a small conference room at Brooks City-Base, Texas. At one end of the room a large projection screen was used to record the scheduler's processes and tasks from the structured TA. One of the four investigators led the TA; one recorded the information on a laptop computer in a Word™ table projected onto the screen. The other three investigators prompted the SMEs for additional information and took supplementary notes on the discussions. Three of the investigators were pilots and one was a reserve safety officer. Two investigators were fatigue management knowledgeable. Three of the investigators were fully familiar with FAST™.

After all of the SMEs had introduced themselves, the investigators stated the goals, objectives, and agenda for the meeting and answered questions. After introducing the TA procedures, the process began. The process started with a brief introduction to fatigue and its management using graphs to show how knowing about sleep and circadian rhythm provided critical information that predicted performance capability. Concepts from the Sleep, Activity, Fatigue, and Task Effectiveness (SAFTE™) model and FAST™ graphs (Eddy & Hursh, 2001, 2006b) illustrated fatigue and performance effects, but the FAST™ interface was not described at the time. We did not want to bias schedulers toward the current FAST™ interface, so we conducted the TA before teaching them anything about FAST™.

The essence of the TA plan was to have the SMEs walk through planning a mission describing the processes and information required while we created a visual recording of what they said. So that the schedulers could see what we were recording at all times and make corrections as necessary, we projected our recordings in a Word™ Table onto a large screen. This approach helped to counter the limitations of our working memories so we would not have to remember what was said earlier and we could see information in the context of previously discussed facts.

We met with the three schedulers for about 12 hours over one and a half days. We conducted the TA during the morning of the first day, spent the afternoon teaching them FAST™, had them review their inputs to the TA for two hours the second morning, and then conducted an abbreviated usability analysis on FAST™ during the last two hours of the second morning.

After the fatigue management introduction, we began our high-level, user-centered requirements analysis by having the schedulers tell us which types of users to include. Who are the target users for information on fatigue that could use it to save lives, make operations more efficient, and reduce stress on the aircrews? We had them tell us who absolutely must be included, who should be included if possible, and who should be excluded. Once we defined who the users of our product would be, we moved on to define what their skills and abilities were for creating a mission schedule. We also asked them what the training were for doing their mission-planning job. After this, we asked about how they did their job.

We started the TA process by asking them to conceptualize a specific mission that they may have planned recently. Then we asked them to back up to the beginning and tell us what was needed to plan such a mission. We ask them to provide us with the top-level processes they used and goals they followed as they assembled a mission. The processes we were looking for started from the time they obtained the directive to do a mission, to when that mission/flight was planned/accepted, and out the door. As they provided this information, we recorded it in the left column of a three-column table projected on a screen in front of them. The columns were labeled: Processes/Goals, Tasks to Accomplish, and Suggested Modifications to FAST™. The first column was completed before going to the second and third columns. As they created their schedule, we wanted to identify their goals and major processes before they described the associated individual tasks to accomplish them.

Once the major processes and goals were delineated, we asked them to tell us all the tasks that were required under each of the top-level processes. This often caused them to describe additional processes and goals or sub processes that were added to the Processes/Goals column. There was also some consolidation and reformulation of processes and goals as they described the tasks under the various processes. We told them that as we move through the design process and exercise, we are essentially trying to, like an onion, "peel away" the layers of a mission planner's knowledge and experience to understand the key points of "what" and "how" they do their job. Over the day and half we felt as though we learned the basics of what we needed to begin designing an interface for AMC schedulers.

On the second day, after the SMEs had received training on FAST™, we asked them to go back to the TA chart and correlate FAST™ features with their scheduling processes and tasks. The idea was to see what FAST™ processes met their schedule building task needs and what was lacking in the current tool. We also had them critique alternate ways of performing some of the FAST™ operations, such as editing schedules. This information was recorded in column 3 of the TA and Usability Chart projected before them. Afterward we asked them to establish priorities for the design constructs indicating those that they absolutely must have, those to do if budget and time permit, and those that are just nice to have. Also at the end, all SMEs and investigators were asked to verbalize—and write-- post-it notes and other notes as we reviewed the table of goals, processes, and tasks and make additional suggestions. This was to enable us to "capture" a lot of information quickly as it came to mind.

Caveats. We recognized that AFRC and AMC might have different needs, so our plan was to use AFRC to establish common ground regarding the interface, and then identify exceptions for AMC mission planners. Our underlying assumptions concerning the differences between AMC and AFRC were as follows:

- "AMC" refers to the overlying goal of being able to assess AMC-directed missions for "effectiveness" with regard to fatigue issues, and using the tool as a planning aid to assess, and perhaps mitigate fatigue-related problems within a mission and safety context.
- "AFRC" refers to the overlying goal of using the tool to optimize missions during planning for the Air Force Reserve Command components from a fatigue standpoint.

The question is how do we do a better job on the interface given ARFC user constraints to use the tool as a decision aid? This means the additional capability to assess "what if" scenarios.

- Peacetime operational constraints could permit optimization by AMC as well.

Pilots

The objective of our first meeting with AMC pilots was to conduct a task analysis of pilot activities before and during a mission to learn how they accomplish a mission and how they address fatigue. Also to learn how a fatigue analysis tool might help in their rescheduling and how it could fit seamlessly into their re-planning processes.

The meeting was held on October 13, 2006 from 0800-1230. The Chief of Safety for the 68th Airlift Squadron (AS), introduced the F-PAS development team to the four participating pilot/SMEs. In his introductory remarks, he indicated that the current AMC commander had stated that AMC could not continue as it has for decades with crews flying fatigued. "He wants change."

After SMEs introduced themselves, the goals and objectives of the meeting were stated with an opportunity for questions. We discussed fatigue management and asked the pilots about their experience with fatigue. We discussed the SAFTE™ model and answered questions. We then presented a FAST™ analysis of an AMC mission from a PowerPoint slide put together by a pilot from the 68th AS, to get the SMEs to thinking about fatigue. Generally, the pilots liked the ideas presented for evaluating schedules for their impact on fatigue, but felt that it would not make a difference in how missions were scheduled unless the Tanker and Airlift Command Center (TACC) schedulers at Scott AFB were using the tool also.

Thus, the meeting did not take the normal course and move into a task analysis as explained in the results section. The meeting was terminated shortly after 1200 without a task analysis, but with a better understanding of how AMC missions are scheduled and executed. The scheduling process as described by the pilots is described in the results section followed by notes from the development team.

Flight Surgeons

The first requirements assessment session for AF flight surgeons (FS) was conducted under the combined auspices of the USAF School of Aerospace Medicine (USAFSAM), the Residency in Aerospace Medicine (RAM) Program of USAFSAM, and the Biobehavioral Performance Branch of the Air Force Research Laboratory (AFRL 711 HPW/RHPF), Brooks City-Base, Texas. The session was held at USAFSAM in the RAM conference room on 7 September 2007. The director of the RAM program (USAFSAM/GE) and 14 RAM students participated in the discussions as subject-matter-experts (SME). Nearly all of the SMEs were aware of FAST™, but only three had actually used it to assess fatigue in an operational setting.

After the investigators introduced themselves, they stated their goals, objectives, and agenda for the meeting and answered questions. With only 90 minutes available to meet with the RAMs for a requirements assessment, an abbreviated agenda was used in the hope of acquiring information necessary to begin the design of the interface. Our plan was to familiarize the FS with FAST™, have them provide an overview of their tasks and background, introduce the task analysis (TA) procedures, and then conduct the task analysis. As we worked our way through FAST™ capabilities, it became clear that TA was not really needed since the FS did not want an interface specifically designed for them to explore fatigue countermeasure options. This is explained in the results section that highlights the ideas and conclusions of the session. Since the FS did not need an introduction to fatigue and performance, we focused on how using a model such as FAST™ could provide quantitative data and projections in time about how sleep and circadian rhythm predicted performance capability. Concepts from the SAFTE™ model and FAST™ graphs (Eddy & Hursh, 2001, 2006b) were used to illustrate fatigue and performance effects.

WALK-THROUGH

From the user task descriptions and the requirement assessment (RA), we created scenarios for user testing and review. In the walks through the draft interface, the investigators, potential end users, and evaluators worked together to step through typical tasks for which the interface was designed. Because the SME users were flight surgeons and were familiar with fatigue management terminology and fatigue effects, they were only given preliminary training on the capabilities of the new browser-based tool and on its draft mission-planning interface. The investigators demonstrated the tool by entering data for a fictitious scenario. Questions and discussions accompanied each screen of the tool.

We estimated roughly the total number of usability problems in the interface from the number of problems (E) identified during the walk-through. Assuming a detection rate of about 30% in the walk-through, the total number of problems would be about equal to E divided by 0.30 (Bailey, 1997).

INSPECTION EVALUATION

One inspection evaluation was conducted by NTI under the auspices of the Altitude Training group of USAFSAM (USAFSAM/ATA) and was held in their computer laboratory at Brooks City-Base, San Antonio, Texas. In the inspection evaluation, three flight surgeons with 7, 8, and 14 years of active duty from the USAFSAM Residency in Aerospace Medicine (RAM) program served as SMEs. They tried to do typical tasks with the interface while a investigator watched, listened, and took notes. We wished to identify usability problems, collect quantitative data on SMEs' performance, and determine the SMEs' satisfaction with the product. More specifically, we wished to learn:

- Could the SMEs complete the relevant tasks successfully?
- How long did it take the SMEs to do each subtask?
- Did the SMEs perform well enough to meet their usability objectives?
- How satisfied were the SMEs with the interface?
- What changes were needed to make sure that the interface would enable more users to perform more successfully?

These latter questions were addressed through the questionnaire shown in Appendix A. The observer collected detailed data using the scoring sheet shown in Appendix B. The user was provided with a separate document showing the 34 questions in the scoring sheet.

One goal of the contract effort was to allow schedulers to apply fatigue management to AMC missions through the incorporation of our tool into the workflow of their scheduling tasks. The tool we are creating for them can evaluate the impact of a mission schedule on the crew's ability to perform it, considering their opportunities for sleep before and during the mission. Our goal was that 90% of AMC schedulers using our computerized fatigue management tool should be able to do 90% of their fatigue-analysis tasks reasonably well with relatively little training beyond an introductory overview of our product.

RESULTS

REQUIREMENTS ANALYSIS

AMC Schedulers

To understand the scheduler who might use our tool, we first evaluated the answers to our initial questions about the potential users.

Who would the product users be, who should be included and who should be excluded?
For the AFRC SMEs, the schedulers were generally pilots who were working in the Wing HQ when a mission request arrived. Pilots are familiar with everything necessary to plan a mission and they are most aware of the issues the aircrew would confront while in the field. AMC users would be senior enlisted personnel or lieutenants at TACC. Their experience would be less than a pilot at a Reserve wing, but they would have greater resources to draw upon in planning the mission. The TACC has a comprehensive web-based program, the Global Decision Support System (GDSS), that links into many databases and information sources that facilitate planning a mission. Enlisted personnel E-5 and below will not likely plan missions or use the fatigue management product.

Generally, what knowledge, skills and abilities did schedulers need to accomplish mission planning?
Most schedulers are college graduates and/or able to read and write at the college level. They need those skills because of the considerable requirements for finding information, reading and understanding it, and applying it to the planning task.

What special skills/abilities do schedulers need for Scheduling/Planning missions?
Schedulers must understand the requirements and limitations of the aircraft for which they are planning. Such as items as fuel capacities and burn rates, distance limitations, runway lengths, hauling capacities, show times, loading and unloading times, post flight procedure times, etc. They must know the aircrew skill and training requirements for the various aircraft and for the various cargoes. They must understand air refueling rules and how to get tankers into position for air refueling. Schedulers must know about base and airport opening and closing times, restrictions, and each country's requirements for accommodating US military aircraft.

What training do schedulers need to do their mission-planning job?
Schedulers acquire the skills and knowledge listed above and other knowledge through AMC training courses and on-the-job training. Pilots get this information in the course of their initial and continuing aviation training.

The participant SMEs were asked to help us construct a tabular display of the realistic planning goals, processes, and tasks that they actually accomplished in designing a mission schedule. In the TA, the investigators/interviewers recorded the goals, processes, and tasks described by schedulers as they constructed a mission schedule. The information was displayed in a table projected on a large screen in real time that all could see. The first column of the table was for goals and processes, the second for tasks. This allowed the investigators to correct the information in real time. At the end of the day, SMEs reviewed, amended and corrected the recorded data.

While our goal was to understand how the schedulers create their mission schedules, a secondary goal was to see if FAST™ features matched up with their tasks in such a way that they could use FAST™-like output to prevent or reduce the fatigue on aircrew while still planning a successful mission. Table 1 contains the TA and FAST™ usability chart produced with the scheduler's inputs. It shows the resulting Goals, Processes, and Tasks created during the TA. As one moves down the rows of the table in the mission planning, time increases. Data in the columns, from left to right, include global processes and goals and then the specific tasks that were directly related to those stated processes and goals. From this analysis, we can see that the schedulers articulated eight, mostly independent, top-level processes or goals. These eight, top-level processes were:

1. User or Mission Requirements (what, where, when)
2. Resource Availability (aircraft, aircrew, destination suitability)
3. Constraints/Regulations/Waivers (schedule, Ops restrictions, airspace, servicing, clearances)
4. Operational Risk Management (covers many tasks)
5. Command & Control IPS Input (mission details)
6. Task Support Agencies (purser, XP/Mx, APS, life support, Ravens)
   Definitions:
   - Purser
   - XP/Mx
   - APS – Advanced Planning and Scheduling (APS) Pathfinder is an off-the-shelf technology used for supply chain planning and decision support functions.
   - Life Support
   - Ravens – Are a mobile force protection agency that provides aircraft security in unsecured ground locations while a mission is enroute.
7. Aircrew Requirements (augmented, special qualifications, mission commander, extra crew)
8. Supervisory Approval (for training missions)

Table 1. The Goals, Processes, and Tasks of AMC Schedulers

PROCESSES/GOALS STEPS	TASKS TO ACCOMPLISH	SUGGESTED FAST™ MODIFICATIONS
1. User (Mission?) requirements what where when via: JAATT planning conference ARMS (air refueling msns) AFRC AF Reserve Command) allocations OST (order & ship time) requirements	Read & understand tasking (Annex C) Revalidate/evaluate *timely tasking* (72hr notice? 24hrs?) Capacity, capability, resources, dynamics, complexity, compatibility,….etc. Airfield(s) *Latest Allowable Pickup/Delivery (LAP/LAD)*	Direct capture from GDSS for missions TACC has already planned Major Weapon System (MWS) default parameters Master program for # of legs, alert defaults, and rest period minimums, Augmented (naps) vs. Basic (no naps) crew rules, and critical events with drag & drop capability. Is the above backwards on naps? Allow user defined mission constraints (ex: NOTAM or quiet hour restrictions, LAP, LAD, waivers, etc.) that indicate conflicts but can be overridden Does any of the above duplicate other existing software program capabilities?
2. Resource availability (major elements) aircraft aircrew destination suitability	special configurations or modifications directed/req'd tail tasking (level/availability) ――― special quals (crew, MEGPs, Mx, Ravens, Purser, etc.) AATS ――― AP1/Giant report suitability *Ops Hours*/restrictions NOTAMS/PPR Weight Bearing Capacity Ground Support MHE & personnel Rest facilities avail/suitability	*Expected* sleep facility quality ratings: excellent, good, fair, poor

Table 1(continued). The Goals, Processes, and Tasks of AMC Schedulers

PROCESSES/GOALS STEPS	TASKS TO ACCOMPLISH	SUGGESTED FAST™ MODIFICATIONS
3. Constraints /regulations/waivers (details) Schedule Ops restrictions quiet hours day/night Airspace (ALTRV) Servicing Dip Clearances /FCG	Apply rules and regulations to optimally plan mission Crew rest/duty day/tactical events/transition training Consider stage/crew options ops restrictions ground times (Velocity Init?) quiet hours day/night Airspace (ALTRV) Servicing Dip Clearances/FCG CFP from TACC Flight planning calculations Winded leg lengths, AR duration, etc.	Duty day BRAVO standby User defined mission constraints monitor user inputs (ex: NOTAM or quiet hour restrictions, LAP, LAD, waivers, etc.) and flag conflicts but can be overridden

4. ORM	worksheet/matrix/checklist *long vs short days* *augmented vs basic* *departure & arrival time of day* mission complexity/difficulty combat? Tactics? AR? Formation? Cargo hazards? Crew rest *Duration* *Facilities suitability* Meals Transportation	Color coded mean effectiveness for overall mission and for critical events Clean, user-defined summary report output to aircrew scheduler/aircraft commander <u>Note:</u> current output in minutes should covert to hours + minutes (15 minute increments) Drag & drop all objects (sleep, work, and events) Right click to modify object attributes or times Mouse over to read object detail Future enhancements: Crewmember 1, 2 etc. assessments Click and drag curve to improve performance and suggest fatigue risk mitigation (ie: meds, crew rest, task reduction, etc) Display choices for illustration capture (ex: all data (cluttered), 1 level de-clutter (critical events only), and another level declutter (basic)

Table 1(continued). The Goals, Processes, and Tasks of AMC Schedulers

PROCESSES/GOALS STEPS	TASKS TO ACCOMPLISH	SUGGESTED FAST™ MODIFICATIONS
5. C2 IPS input	Enter mission specifics (type into computer program) Itinerary Remarks Push to GDSS	FAST™ score summaries Whole mission Critical events Low performance times
6. task support agencies Purser XP/Mx APS Life support Ravens	6. Communicate e-mail phone Air Order of the Day (AOD) Determine/specify priorities meeting *required changes?* final paper copy	Command Post (execution phase) access to file for modification and new FAST™ assessment
7. Aircrew requirements Augmented? Special qual? Mission Commander? Extra crew/DH?	*Determine taskable squadron(s)* Special Qual Bean count Bookie 1.0 (access database) Pain level AATS website (TACC)	
8. Supervisory Approval for training missions	AFRC (if applicable) Unit DO	User defined reports Suggest possible mitigation options?

Notes: This Table starts with mission planning and progresses through to the end of mission planning. Data in each column move from left to right, from global Process/Goals, to specific Tasks that are directly related to those stated processes/goals. The last column addresses how the current FAST™ related to the tasks that met the goals of the mission. The phrases in italics were considered particularly important.

The tasks for these processes and goals vary widely. Some include verifying the information received from TACC with the mission order, looking up the latest information on airfields and aircraft, considering optional solutions to accomplish the mission, assessing the complexity of a mission, crew rest opportunities, and a commander's idiosyncrasies. Column 2 in Table 1 lists all the tasks associated with the top-level processes and goals.

Several of FAST™'s capabilities fulfill the needs of the schedulers, but other requirements are lacking. For example, FAST™ nicely forecasts performance effectiveness for an entire mission, critical events, and highlights low performance times. However, it would be a big improvement if FAST™ could directly capture a mission from GDSS when TACC has already planned a mission instead of requiring a scheduler to key all the information into the fatigue analysis tool.

User Design Recommendations and FAST™ Usability

The recommendations coming from the TA as summarized by the investigators follow.

1. Quick Manual Entry: As of this writing, a mission cannot be read directly into FAST™ (NTI has not yet been given the file export capabilities of GDSS) for our new web-based tool. Therefore, the interface should be designed to allow a scheduler to quickly and easily build a mission directly using pre-existing mission legs (T/O (takeoff), Critical Events (CE; purpose of stop), Aerial Refueling (AR), and Touchdown (TD) – see more about this in the next section). The scheduler filling in the information required in a general template that could be expanded or shrunk could assemble the mission. Using a general template that could be expanded or shrunk to fit any mission requirements, a scheduler could assemble a mission by filling in the required information.
    - A longer-term goal should be to import the mission tasking directly from GDSS data, with little additional editing. Direct capture from GDSS/GDSS-2 for AMC-directed missions (TACC) should be planned for the future. Another alternative would be to export a data file from GDSS and import it for an automatic schedule build in the fatigue analysis tool.

2. In this conceptualization, a master screen showing a mission template would be available on the display that has placeholders for mission events and entry boxes for T/O, CE, AR, and TD times.
    - If an enroute stop occurs, then it should be possible to input and recall the purpose of the stop easily. Generally, an entry format should match mission fragments for ease of use.

    The program would ask, "How many proposed legs should there be?" A leg is a general term that a user defines by selecting a platform (aircraft type). Schedulers for different platforms may use different terminology for the equivalent of a leg. In the software, a leg should be an object that can contain the following other objects all with unique icon types: T/O, AR, CE, and TD. Legs may have only one T/O and one landing, but may have any number of ARs or CEs including none. A leg can have a show time and post landing time as well. T/Os, landings, and ARs have a latitude and longitude (lat/lon), date, and time. CEs have a date and time.

    Figure 2 is a schematic example of the objects in a mission. Mission XYZ is composed of two legs each with various elements, but always having one T/O and one TD. Notice the legs each have a beginning and an end. They are independent objects that are contained within the mission object, "XYZ."

```
MISSION "XYZ"
    LEG 1
        T/O (lat/lon, date/time)
        AR1 (lat/lon, date/time)
        AR2 (lat/lon, date/time)
        CE1 (date/time)
        AR3 (lat/lon, date/time)
        TD (lat/lon, date/time).
    END LEG1
    LEG 2
        T/O (lat/lon, date/time)
        AR1 (lat/lon, date/time)
        CE1 (date/time)
        AR3 (lat/lon, date/time)
        TD (lat/lon, date/time).
    END LEG2
END MISSION "XYZ"
```

Figure 2. Schematic of AMC Mission Legs (Segments).

The following were discussion points for developing requirements.

- We are using the term leg here generally, since bomber crews flying long-range missions, or fighters doing multiple mission elements may want the term "leg" defined generally, and not specifically as a T/O or TD flight segment. Future discussion point: The group talked about specifying the air platform on the initial data entry screen. If we could use that information to define the terminology, we could implement this suggestion. That is, the platform or airframe would define the meaning of "leg."
- Allow for crew changeover and re-computation when augmented crews are used, etc. Future discussion point: It might be better to have an easy way to port the mission components from one schedule to another and then add the sleep histories of the augmented crew to the new schedule and continue from there when augmented crews are used.
- Need to make provision for "Crew Standby Duty"
- The implied "protected times" before the T/O and after TD should be user-defined as a part of the initial entry since time is needed for mission planning, review, preflight, etc, and a multitude of post-landing tasks. A scheduler should be able to input and save standard pre-and post-flight periods, but be able to modify them easily if needed, perhaps with a mouse-over and then "right click" for a sub-menu. For example, after entering the platform/mission-type, the software might present the scheduler with the defaults for the platform/mission-type selected. These could be modified then or later as desired.

3. The scheduler needs the capability to label/edit the key events in a flight leg, such as T/O, AR's, CE, and TD at first- and second-order levels. First, during the master schedule development as "Take off" with airport Symbol, etc.; then, the user may add details to a

sub-screen associated with that object in terms of remarks with mouse-over. For example, select the Takeoff Icon on the screen, and then perhaps a right click to add or see additional details ("T/O from XXX at 0400 at a blacked-out field with SAM threats in the area).

- After all of the legs and critical events in the master schedule are entered, the user should be able to look at a first-cut fatigue analysis to see what the average effectiveness is per defined leg or a whole mission. In addition, an analysis for key subsets of a mission by highlighting the area on the graphic user interface (GUI), and clicking to get the effectiveness between, for example, "waypoints." Also, the lowest area of effectiveness in the leg and mission that is computed should be called to the user's attention if it is below a certain level. This value may be defined by the user at the master level, or selected and changed to evaluate different scenarios.

4. With the basic mission attributes in place, the performance charts generated, the key waypoints and CEs labeled appropriately—there is a need to evaluate "what if" scenarios. This should be as easy for the scheduler as possible.

5. The key attribute of the GUI should be "drag-and-drop" editing of all objects.
    - The objects defined above (Legs T/O, AR, CE, TD) should be movable in time by an object-oriented drag-and-drop editor. The tool should then re-compute performance effectiveness and display new charts. (Furthermore, when an object is grabbed, dragged and dropped, it should be possible to access the original table values with one or two clicks. Thereafter, the user should be asked if they want the changes made permanent based upon the new scenario. An alternative would be to save the edited schedule as Scenario 2. In any case, it should be possible to save the edited schedule as Scenario 2.
        - There are some constraints to be considered here. 1. The model takes several seconds to compute the new values even for a short schedule. Therefore, we may want to be able to make several changes and then click a re-compute button (you can do this in Excel for large spreadsheets). 2. Saving a modified schedule is always an option, but we don't want it to be done automatically. Huge amounts of data would be saved and the user may not want 95% of it. With current FAST™, a user can save the schedule at any time, can rename a modified schedule, and can save it, etc. That forces the user to decide what he wants to save each time it is done by assigning it a new file name. The undo command should be capable of storing up to three changes. That would give a user enough memory depth for correcting mistakes or trying something and then returning to the original when it didn't work.
    - The tools should be able to evaluate at least five different mission scenarios based on the original baseline mission values. The alternate scenarios need basic name change labels/reminder boxes one can edit. This is so that they can be reminders of the potential changes to the baseline mission structure.
        - File names and descriptions accomplish this purpose in FAST™.
    - The fields on the GUI that contain sleep and work should be editable (shortened or extended) without leaving the main display. Performance effectiveness values should be computed after a move is made. (Note: It should be remembered that only

changes to sleep or waypoints require a re-compute using the SAFTE model. Changing work intervals or critical points have no effect on the model of the human simulation.)

- The details of an object should display when the mouse pointer rests over them.
- Generally, a right click should allow modification of an object's attributes or times (with modification possible).
- If the schedule is for multi-crewed aircraft, then need the capability to assess Crewmember 1, 2, Loadmaster, etc.
- The time should be displayed in the format of hours + minutes. Also, allow for 15 min increments for the drag and drop functions on the main GUI display with the ability for one-minute resolution for direct or right click pop-up inputs.
- Use color/shape coding for different types of events: T/O, AR, CE, TD, and pre- and post-flight activities.
- Eventually: Click and drag curve to improve performance and suggest fatigue risk mitigation (crew rest/naps, task reduction, and medical countermeasures). Request decision-aid maximizes performance for a particular time point. This would have to be limited to making changes constrained to within a variable number of hours of the particular time.
- Display mission goal criterion line and actual performance effectiveness line for the work schedule (include color coding)
- Remind personnel that if mean effectiveness values are poor, then additional crew rest and/or changing mission parameters need consideration as part of an Operational Risk Management (ORM) approach. (Narrative reports regarding parts of a schedule falling below criteria could be used for this purpose.)

6. Performance effectiveness displays and reminders are needed for crews while they are flying. Performance effectiveness score summaries need to be presented for the whole mission, and/or just the mission "legs" as desired.
   - At the very beginning, the ability to go backwards in time "X days" will be needed to better assess the fatigued state of the pilot before the mission begins as an additional option.
   - Calculate and display color-coded mean effectiveness curves/values for the overall mission and critical events
   - Display goal criterion line and actual criterion line for mean work schedule effectiveness
   - Eventually be able to modify the mission values during the mission on board an aircraft easily to change parameters to reflect the real world events to see how the effectiveness values change (by taking an extra nap, or encountering worse than expected headwinds, for example).
   - Clean, user-defined summary report output to aircrew/scheduler/ aircraft pilots
     - Include Graph/Tables/Text all on one page
     - User defined reports using a checklist similar to the existing FAST™ timeline report.
     - Command Post (execution phase access to file for modification and new FAST™ assessment if needed)
     - Some files-- Read only

7. Additional details
    - User should have the option of entering an airport symbol, or coordinates, as the need dictates. Or, making changes to an airport/location "on the fly" simply by highlighting the location and right clicking to pull up a box with coordinates/symbols in it.
    - The Autosleep/Autonap features need to work for transmeridian flights.
    - The ability to insert easily a nap during a work schedule is important to see its effect on performance. A minimum nap of 15 min. is probably ok, but longer ones need to be more specific than 15, 30, or 45 minutes.
    - Need ICAO identifiers in database for more ease of calling up locations.
    - Need to consider "BRAVO standby." This disastrous mechanism leads directly to pilots flying fatigued. We need to give this some thought.
    - Need display choices for information capture: All data, 1 level de-clutter (key events only), and another level de-clutter for basic information.

The major recommendations coming from the usability analysis follow. These are general comments on the FAST™ interface, Version 1.0.3, by the schedulers after learning it and using it for about one hour.

1. Fine technical tool, but too hard to use in practice without specialized training.
2. Graphical User Interface needs major overhaul for improved ease-of-use for schedulers, planners, and other risk-assessment personnel as aircraft missions are planned.
3. Current interface in general takes too much time for mission input, and it is difficult to use if changes or "what-if" scenarios need to be examined.
4. Ideally, need to be able to take data that comes to schedulers and planners, input it with little modification into FAST™, and get out preliminary result of fatigue-related computations.
5. An "object-oriented" approach to the interface needs to be developed directly off of the main FAST™ GUI screen, with the ability to get into the details of the program if needed by calling up sub-screens.
6. Much easier evaluation and changing of Mission Legs and "what if" scenarios directly from the FAST™ Output GUI should be developed.

A caveat for the AMC TA results and suggestions for improving FAST™: there are differences in AMC between the regular AF and AFRC. Although these differences are not minor, we believe that the guidance and recommendations we received from our Reservist schedulers was exactly what was needed to make the F-PAS product more useful to both. If anything, Reservists have more freedom to plan missions and make changes that may impact fatigue and, therefore, performance. With the additional freedom, they require more decision-aid capabilities to edit schedules, play "what-if" scenarios, and creatively attempt to maximize performance and minimize fatigue in their AFRC missions. The TA development team recognizes that AFRC and AMC might have different needs, but believe that we should use AMC to establish common ground regarding FAST™ implementation, and then identify exceptions for AFRC mission planners.

From other sources. As FAST™ was developed, it was made available to those who wanted it, in return for their feedback and suggestions for improving it. In addition to the TA and usability analysis conducted with the AMC schedulers, commercial users and other AF users have provided suggestions to improve the tool. Suggestions that duplicate AMC recommendations or that have already been addressed in the current version of FAST™ are not reported here.

A Major from 3 AS/DOIP (AMC), Dover AFB, had used an earlier version of FAST™ for about six months and gave us the following excellent feedback in September, 2004. A USAF Captain gave similar recommendations. Many of their suggestions parallel those of the AMC schedulers coming out of the TA. The following is taken from a series of emails between the users and Dr. Eddy. Occasionally items are clarified or potential solutions are proposed for further elaboration.

1. I would like to be able to select multiple events and move or shift them one way or another and see the effect as I move them (such as moving a 3-hour nap forward or backward, or delaying a mission for several hours).

   I would suggest that this change be made, since the tool is otherwise quite useless to AMC, since our missions slip in time so often, and we have to play what if's with our naps. Bottom Line, I need to be able to generate an entire profile including all data entry in 30 Seconds. Otherwise, our schedulers will not use it.

2. Does the model predict sleep pressure (the circadian force compelling one to sleep)? It needs to be plotted, since this tells us when we need to have more conversation or more pilots in the cockpit, and when just one would likely to be safe. In addition, it needs to tell us how easy it is to fall asleep and get good rest at a given time.

   I prefer to see visually where sleep pressure maximizes and where ambient light is at a minimum to decide when a nap is possible, optimal, and when extra vigilance is called for.

   Developers comment: We could provide a narrative report to indicate the best times to get rest if time is available. The software could either print a paragraph providing advice by day for specific times or place a short phrase at the appropriate time on a timeline similar to that available in FAST™.

3. I would like to have multiple times across the bottom (sic. of the graph): Zulu, Elapsed Mission time, and base time.

   Comment: He sent a picture of what he wanted; we have been unable to print it. His comments about it follow.

   Here's a sketch of what I wanted for C2 software, I'd like something similar. You can see that I have the amount of daylight fading in and out in the background across the screen, and then the local times within that color scheme. Underneath it, in Black and white, I would have Zulu time. You could display the elapsed mission time or elapsed alert time directly on the Gantt chart of the mission.

4. Can you add a caffeine event?

   Few pilots use anything but Caffeine (or want to); concentrate your energies there. Even a disclaimer with approximate data would be useful.

5. Remember that for AMC, your tool needs to provide very quick answers to make key decisions:
   - Is this mission safe as scheduled?
   - Does this mission provide a minimum level of alertness assuredness at a critical event?
   - Would it be safer if I shifted a ground time or naptime? (I want to be able to do this graphically by dragging with my mouse)
   - When is it optimal to plan my work-rest periods (when do I order the copilot to go back and sleep)?
   - Such decision-making is routine, and takes place very quickly. Schedulers and controllers are task saturated, and they have no time to spend 10-20 minutes building in events that cannot be easily shifted. There need to be drop down menus for standard sequence of events and ground times.

   In order to build such a tool, a user interface that allows rapid entry and easy changes is needed; here is a suggested interface that mirrors GDSS, our C^2 Tool:

ICAO (with smart-fill)	Depart Time	Initial sleep: Drop downs for (hours, quality, end at: alert, normal wakeup time for zone, specific time)
ICAO	Arrive Time	(Specify hard time or approximate flight time)
	Depart Time	(Hard time or In sequence with drop down for standard ground times)
Add ICAO…		

   From this, the software calculates ground and flight times, populates normal SOP ground and flight events (relative to takeoff times), and then displays a Gantt chart against the calculated periods of light and darkness. It calculates the performance and sleep pressure curves based upon the single sleep period, and now offers the following:

6. Add Event Marker (Time from a given event and/or Lat/Long, hard time or in sequence)

7. Add Sleep Event with point and click (default relative to takeoff or landing, option for hard time, length, quality)

   Then, any event that is not a hard time can be slid left or right with the mouse to create a recalculation.

8. Grid view: the box that opens at the end of an interval should be displaced to the right one box so it does not overlap the interval. The date on the left should be highlighted somehow for the row that is currently being worked on. (I) Would like to have a Save button when creating a long schedule. This would avoid the wait while the schedule is graphed.

9. Tabular view: would like to have a column with Lapse Index values.

10. Graphical View: It would be nice to be able to "unlock" the cursor position across graph windows in some cases. This is particularly true of two schedules that have different start dates but overlap in time. There is no way manually to position the cursor at the same time in the two schedules.

These two AF officers have provided excellent details for creating an AMC interface for FAST™ and F-PAS. Other than the editing capabilities that were described, many of the other ideas were included in the <u>final</u> Phase 2 FAST™ product (Eddy & Hursh, 2006b).

AMC Pilots

As mentioned in the methods section, a task analysis was not conducted; no task or job appeared to exist regarding the pilots active involvement in mission planning. Furthermore, the pilots felt that the tool would not be used if it didn't make a difference in the schedules they were flying. They stated that they are given their mission plan via TACC's Global Decision Support System-2 (GDSS-2) and they follow it. They believed that if a mission needed changing and they had used our fatigue assessment tool to justify their schedule recommendations, TACC would not accept the change based on a tool with which they were not familiar. That is, TACC would discount the analysis and recommendation. The pilots said they needed the tool and would use it if TACC used it too.

The pilots further stated that if TACC used the model in their mission scheduling, they would prefer a Personal Data Assistant (PDA) version of the product. However, they stated that they would use a PC version too. Therefore, the discussion turned to several related topics that helped the development team clearly understand how AMC creates and executes schedules, and how the schedules affect aircrews. The scheduling process is described below followed by notes from the development team.

<u>Normal Sequence of an AMC Mission</u>

1. A multi-sortie, multi-day mission is created by mission planners at TACC. The start date and departure time of the mission are specified. Regulations governing crew duty and crew rest periods are considered, as are restrictions for the planned airfields, customer needs, and other relevant information. Presumably, GDSS-2 is used for mission planning. There may be a bias in mission planning toward using the minimum ground times that are consistent with regulatory crew rest minima.

2. The mission plan is assigned to an airlift wing and then to a squadron. The wing or squadron may notice an error or problem in the plan and negotiate a change with the

TACC mission planners. The wing or squadron assigns a crew and an aircraft to the mission.

3. During the preflight planning period prior to the first sortie of the mission, between show time and takeoff time, the assigned aircrew acquires the mission plan in the form of GDSS-2 files that include timely weather and NOTAM information for the first sortie. If there are multiple sorties in one crew duty period, then the crew still only receives the files for the first sortie. Thus, after the first sortie they must get the flight plan for the next sortie before progressing to their eventual crew-rest layover. The flight plan is filed automatically at this time by TACC with the FAA or ICAO, probably using a GDSS-2 function. The mission is now under the control of a mission-execution group at TACC, not the original mission planners.

4. The takeoff and landing times for the first sortie are acquired automatically through L-Band Satcom, or alternatively, through an AMC Command Post and forwarded to TACC. Otherwise, reporting may fall to UHF phone patch, HF radio, or telephone after landing.

5. After landing, the crew debriefs and then enters crew rest.

6. Steps 3 through 5 are repeated for subsequent sorties in the mission. The GDSS-2 files now include a brief mission history of previous sorties.

<u>Mission Changes</u>

If there are no maintenance-, weather- or customer-generated changes to the planned mission schedule, the mission proceeds as planned. However, there will usually be a change to the planned schedule at some point during mission execution. The crew may learn of the change during a post-sortie debrief, immediately before a show time, during a preflight planning period, or while in flight. If the change takes the form of a delayed takeoff and occurs during the preflight planning period, a new GDSS sortie plan is not provided to the crew unless the delay exceeds about four hours. Given that there is a change, it is now up to the mission commander to negotiate schedule changes with the mission execution group at TACC. If the crew is notified between the end of crew rest and takeoff time of a significant delay in takeoff time, they may re-start a new crew rest period.

Often, revised mission schedules are poorly devised by TACC because those doing the revising do not have all the necessary information that the original schedulers had. Therefore, the aircrew is often required to review and correct the new schedule based on their knowledge of airport access time, ground support hours, etc. The new information can sometimes lead to additional mission delay.

In theory, the aircraft commander may declare unscheduled crew rest if the crew is too fatigued to fly safely. This determination is made through a highly-subjective Operational Risk Management (ORM) process that may be wing-specific and is negotiated with TACC. In fact, an individual mission commander may exercise this option only rarely (perhaps once a year) without the threat of being "re-educated" by the wing or squadron. Therefore, fatigue must be extremely severe for unscheduled crew rest to be declared by the commander.

One opportunity for input that pilots do have is the ORM worksheet completed during Step 3 above. Up to now, they have had opportunities to input at least subjective measures of fatigue into this worksheet. However, there seems to be a strong culture of "pencil-whipping" these sheets to make the flight "safe." This culture has probably arisen due to the entirely, up to now, subjective nature of judging fatigue levels, especially future fatigue levels. In the past, pilots have been unwilling to admit they are too fatigued to fly because of social pressure to not appear vulnerable to fatigue.

The GDSS-processed flight plan includes a great deal of information that is "nice to have," but that may not really affect the actions of the crew. The pilots indicated that even the vast majority of weather information is generally disregarded unless it is a severe weather situation. The team did detect that the aircrew would be generally interested in receiving a FAST™ like plot along with the GDSS-2 flight plan to be referred to and used as each crewmember saw fit.

Our four pilots pointed out that attending to and actively managing crew fatigue would be a major change in AMC operations and certainly not something they saw occurring presently. They strongly indicated that the culture flies by its regulations and after 17-18 hours of ground time and some crew rest, no matter what the status of the crew and whether or not adequate recuperative sleep was attained, the crew will be required through cultural pressure to carry on. This also describes what members of our task analysis team have personally experienced when flying AMC missions off and on over the past 30 years.

Our pilots expressed some interest in a tool for pilots to use on their own (perhaps PDA based) to analyze their own fatigue and perhaps make better ORM judgments. However, it was noted that unless there is buy-in from the command structure overseeing the ORM process, these "more objective" ORM analyses are likely to be ignored.

There was some interest in a pilot tool for helping to plan their personal schedules and adjust to jet lag and phase shifting. It was expressed that these data need to be kept anonymous. It was suggested that our FAST™-like tool should really calculate the schedule's impact on performance based on the overall crew and assume that the cognitive performance rating of the individual is really an average for the entire crew.

There was some indication that pilots might be willing to wear wrist activity monitors for keeping track of their own sleep/wake data. However, the upload system would have to be simple. It was expressed that PDAs are really the only technology that people are likely to use on a regular basis, as most are unlikely to pull out a laptop to evaluate the impact of their sleep schedule. The pilots indicated that the PDA is the only format that an aircraft commander would in reality have the time, and take the time, to actually update a FAST™-like schedule as a mission progressed from point to point.

It was suggested that the schedule information might be best recorded in an Excel format as it can be viewed on a PDA and is easily transferable via a thumb drive and one can simply click through cells with one of the directional buttons to determine cognitive effectiveness at any given point along the schedule. (PDAs now accept thumb drives.)

A display format was suggested that superimposed a performance effectiveness curve on a mission laid out horizontally across the screen. Each part of the mission was labeled such as pre-mission, KSKF-KSUN, ground time (with sleep time), etc. It was not clear how this improved on a FAST™ graph with labels for the intervals. However, it was clear that the pilots preferred a timeline display where they could clearly see trends in the performance effectiveness curve as the mission proceeded. One of our team members suggested that our mission timeline be modified to highlight flight time versus ground time instead of highlighting every other four-hour block of time.

The 433 OG/CCM possessed electronic files of the flight plans actually flown by the wing over several months. Evaluation of these schedules with our model and ordering them with respect to their fatigue impact on the aircrew would be supportive of AMC/CC's intention to begin evaluating and doing something about excessively fatiguing AMC missions. If change is in the wind at AMC, it may be that a FAST™-like tool could contribute to it as we attempt, perhaps, to integrate it with GDSS 2.

Potential Counter-Fatigue Intervention Recommendations

First, the SAFTE™ model may be used by GDSS-2 during mission planning to optimize the mission schedule to minimize fatigue. The model would need to be provided with acceptable maxima and minima for takeoff and landing times (per individual airfield restrictions), expected sortie lengths, and lat/lon data. If AMC chooses not to integrate the SAFTE™ model with GDSS-2, the local Wing schedulers could still use a FAST™-like tool for generating local mission flight plans.

Second, the SAFTE™ model may be used passively by GDSS-2 during mission planning to calculate and report critical in-flight fatigue periods in an ORM context and recommend timely and useful fatigue countermeasures (Miller & Eddy, 2009). The GDSS-2 generated package acquired by the aircrew at step 3, above would include this output. Problem: if there is a several-hour delay in takeoff time and no new GDSS-2 files and fatigue countermeasures recommendations are generated, then the original countermeasure recommendations may no longer be appropriate.

Third, a personal version of F-PAS may be used by a mission commander to track his/her own fatigue level during a mission. The GDSS-planned mission schedule could be downloaded to the personal device before the first sortie. A wrist activity monitor could be used by aircrew enroute to download actual sleep times to the personal device/s. Sleep times could also be input from activity logs maintained by individual aircrew. The output of this "personal system" could feed quantitatively into the ORM process such that it aids the mission commander's crew rest negotiations with TACC. Anonymity of the data from aircrew would be required if results were transmitted to TACC. The record of events and work interrupting adequate sleep could also be used to support the commander's decisions during the "re-education" process that might follow.

The pilots provided information regarding how mission schedules are received by the aircrew. This is accomplished via a flight-planning computer. Apparently, the flight-planning computer is a stand-alone machine. Assuming F-PAS is running in a stand-alone mode, it could receive the schedule data from the download of the route-of-flight attachment or from the flight-planning computer. The format of the data coming from either place would have to be standard and the F-PAS software would have be able to read it for the information it would need, flight times, waypoints, etc.

With the above information and the morning session ending, we decided we should not impose on the pilots for additional time. Therefore, a full TA was not completed; we did not run through a scenario on how they would use the product or where it would fit into their mission planning, execution, or re-planning. We discussed general concepts that indicated they would need to have extensive schedule editing capability, and be able to answer “what-if” questions comparing alternative schedules. With these concepts in mind, we presented some design specifications for a PDA version of F-PAS in the final report of the contract (Eddy, Miller & Moise, 2008).

Flight Surgeons

Through the discussion with the FS, we learned whom the FS envisioned as the primary users of the fatigue countermeasures interface. They believed that the pharmaceutical fatigue countermeasures option in the tool should be available to all aircrew members. They did not want to be in a position of pushing Go and No-Go pills on the aircrew for fatiguing missions, viewing such a practice as being both unethical and in opposition to AF regulations. They wanted the aircrew to use the modeling tool to see for themselves the impact of fatigue on their predicted performance, experiment with the Go-No Go pill options, see the possible benefits to their performance, and then go to their FS for advice on administration. As the FS saw it, the FS could then prescribe the appropriate medication and medication schedule for the aircrew based on the mission schedule, time of day, and post mission activities. Together, the FS and aircrew would use F-PAS as a decision aid to help them determine the best countermeasure with the fewest side effects. Through the ensuing discussion, the FS provided answers to the following questions.

Who would the product users be, who should be included and who should be excluded?
The FS insisted that the users would be aircrew and commanders, as well as FS, and that the interface should be designed to accommodate aircrew scheduling goals and tasks, not those of the FS. Therefore, in answer to the question of who the users might be, it was concluded that no special interface was needed for FS to access the model and obtain performance predictions. We concluded that we should follow the user requirements for pilots and aircrew.

Generally, what knowledge, skills and abilities did users need to use pharmaceutical fatigue countermeasures options?
Since the interface would be used by aircrew, standard computer use skills would be needed along with an understanding of flight scheduling events and times. Since most aircrew are computer literate and intimately familiar with crew scheduling practices, their general knowledge and skills should be adequate to navigate the browser-based interface for access to the tool.

What special skills/abilities do users need to use pharmaceutical fatigue countermeasures options?

Some context sensitive help would be needed to present how Go-No Go pills worked, their time course, interactions with other substances, and side effects. This information could be created by the RAMs for final inclusion in the browser-based interface for projecting the effects of pharmaceutical fatigue countermeasures.

Other comments by the FS helped to reinforce our existing interface ideas developed with the schedulers and emphasized the importance and priority of specific interface features. The FS ideas included:

- A graphic display similar to FAST™ with normal (un-medicated) performance and medicated performance on the same graph.
- A sleep propensity graph comparing the two conditions.
- How FS received the flight schedule. They listed:
    - Attending squadron meetings
    - Aircrew walk-in
- How the flight schedule was formatted when FS received it:
    - Mission print out
    - Pilot Flight Planning System (PFPS) printout
    - Sometimes the safety officer or an aerospace physiologist brings them a FAST™ graph with concern for fatigue risk.
- One RAM with extensive operational experience indicated that we should explore the PFPS, the tool that aircrews use to plan their training missions, especially in AFSOC. If our product could read the mission information from PFPS, it would reduce the data entry time for the fatigue analysis and reduce data entry errors. They believed that we could learn about PFPS with navigator training squadrons that fly the T-43 aircraft. We may be able to attend a monthly PFPS class there.
- Have web-based, fatigue management training. Although this was not within the statement of work of our existing contract, this would be an excellent task to add.
- F-PAS should have templates (they didn't say what kind) that were aircraft-type specific. That way the aircraft type, elicited from an initial question, could determine some of the follow-on questions and even determine the format for data entry. The most specific aircraft type information includes show time (the number of hours before take-off that must be scheduled) and the Go/No-Go pill regulations.
- Create a kneepad version of the output for pilots.
- Have links to MAJCOM policy letters on the use of Go and No-Go pills in AF aviation.
- On the use of caffeine as a fatigue countermeasure, the FS were concerned about making predictions for caffeine dependent aircrew. From our discussion, we decided that it would be important to know the caffeine dependency of the subjects used in the Walter Reed caffeine study, upon which the cognitive performance predictions were modeled. In answer to this question the following quote was taken from the publication documenting the study: "All subjects selected for participation reported …daily caffeine consumption of <400 mg" (Wesensten, Killgore, & Balkin, 2005). Four hundred mg of caffeine is approximately 3-5 cups of coffee (http://coffeefaq.com/caffaq.html).
- For educational purposes, include aircraft-type-specific intervention examples in a PowerPoint format.
- Make each drug an event that can be used in any of the F-PAS interfaces, as an educational tool.

- By contract, create a USAF login at a website outside of the military website (.MIL). That way, any aircrew can log in from any location in the world. If the tool is only on the AF website, crew and FS could only log in from a .MIL computer.

WALK-THROUGH

FAST™ was originally designed for mission planning and flight schedule evaluation. As such, the requirements for the Mission Interface were essentially the same for the mission interface as for FAST™. With the extensive data gleaned through a usability evaluation of FAST™ conducted with the AMC schedulers, a walk-through evaluation was deemed unnecessary. The excellent comments from the SMEs regarding FAST™ displays, data entry, and editing approach was judged sufficient for designing a new interface built on SME advice and web programming constraints. Once a rudimentary Mission Interface was complete, a group of potential SMEs was assembled for an inspection evaluation.

INSPECTION EVALUATION

A Travis-to-Ramstein scenario (Appendix C) was used for an inspection evaluation, which occurred in the computer laboratory of the altitude training group of the USAF School of Aerospace Medicine (USAFSAM/ATA), Brooks City-Base, Texas, on the afternoon of 25 September 2008. The SMEs were three flight surgeons from the USAFSAM Residency in Aerospace Medicine (RAM) program, a program that teaches fatigue management. All three were Majors with 7, 8, and 14 years of active duty. One had used FAST™ for mishap analysis, one had been exposed to FAST™, and one was completely unfamiliar with FAST™. One pair of SMEs walked through the scenario, and then a single SME walked through the scenario, with one observer taking notes. The session with the single SME produced a representative elapsed time for data entry and analysis of the scenario for a novice user: 33 minutes.

No significant errors and only two minor reversals occurred during data entry and display for any of the SMEs. Twelve assists were logged on the data form (Appendix B) across the three SME sessions.

Comments from Assists

- Two of the SMEs were confused by the right-hand placement of the window for city and base location data entry on the Edit Properties page. They expected a drop-down list to occur within the window in which they were working. One SME also missed the "Use This" button.
- One SME noted the absence on the Edit Schedule page of instructions to select the Edit Schedule option after executing the Edit Properties option. Later, the absence on the same page was noted for an instruction to use the Effectiveness Graph option after using the Edit Properties and Edit Schedule options. The expected sequence of use of the options should be described on the Edit Schedule page.

- Two of the SMEs needed assistance to click within the calendar to obtain the pop-up window that initiates the entry of work and sleep periods and events. A where-to-click instruction near the calendar is needed.
- One SME needed assistance to use the up-down arrow functions for adjusting date and time for sleep and work periods and events.
- All of the SMEs needed assistance when trying to enter the first event. They had been instructed to enter work periods before events. Intuitively, they clicked on existing work periods in the schedule for the entry of an event associated with the work period. In fact, they needed to click on empty space in the schedule to initiate data entry. Two suggestions followed. First, put an instruction on the page. It should be located with the instruction suggested in the preceding paragraph. Second, default the work period indicator to a narrower column in the calendar so that white space is available next to it.
- One SME failed to see the event type field.
- One SME requested an explanation of why different events have different heights when displayed in the calendar, and why an event occupies 30 minutes in the calendar display when it actually occupies only a moment in time. An event should be defaulted to one minute.
- One SME was confused by event color-coding. Perhaps an explanation in the help file would suffice.

Reversals

Two SMEs experienced a software problem. One SME had committed a minor error in data entry: he entered a sleep-period end-time earlier than the start time (he failed to change the date on an over-midnight period). A debugger error message occurred, from which recovery ensued by using the browser "back" function. However, that sleep period had acquired the start and end times of the preceding work period. The two periods appeared next to each other in the calendar, both labeled "Work," with one colored orange and one colored blue. The same display anomaly occurred for the other SME, but whatever error he had committed was too obscure to recall. The software problem caused minor reversals for the SMEs.

Additional Comments

- Reduce the empty space on the Main Menu page to prevent the need to scroll vertically.
- Change the cursor shape when hovering over a hot link on the Main Menu page.
- There was confusion about the Save and Exit button on the Edit Properties and Visual Schedule Editor pages. What was saved? Where? How did this function differ from the Save File function on the Edit Schedule page?
- The default location for a given event should echo the most recent location known in the schedule.
- To edit a sleep period, work period or event, a right mouse click would be preferable to a double-left click.
- When a sleep or work period is being entered, the default length should be greater than 30 minutes. (Three hours might be useful.)
- The relationship between "Location" and "Location Select" fields needs better functional grouping.

- The nature of the Description field (i.e., a non-required comments field) was unclear.
- When events were entered during a work period after midnight, and the work period extended over midnight, the work period filled the whole calendar column before midnight and only half the column after midnight. This was a bit confusing in terms of continuity across midnight.
- As an alternative to clicking within the calendar, place Sleep, Work and Event buttons above the top left of the calendar.
- The hover window over an event should not indicate that the event is 30 minutes long.
- The 6-hour and 1-minute resolutions on the graph may not be useful. Two- and 3-hour resolutions may be useful.
- The sleep and work period indicators along the x-axis of the graph should be on separate lines. This would allow overlap to be visible.
- Need cut-and-paste tabular reports, as used in FAST.
- The items in the Dashboard need better functional grouping, such that numeric data are related to flags more clearly.
- Do not allow users to change the boundaries of the green and yellow areas on the graph. Changing the level of the criterion line is good.
- During file saving operations, instruct the user to avoid adding a filename extension.
- The sequence of operations on the file saving screen was not intuitive.
- Overall, the windows used are too tall for use on Department of Defense visual displays. All DoD computers have a security function that places a blue-colored status bar across the top of the screen. It is about the height of the Windows menu bar at the bottom of the screen.

Questionnaire Responses

The following three questions were evaluated by the SMEs with subjective ratings, using the following scale:

- Very acceptable (1)
- Acceptable (2)
- Borderline (3)
- Unacceptable (4)
- Very unacceptable (5)

Please rate the ease of application of the interface to the intended task: the simplicity with which the interface can be employed to determine whether fatigue was a factor in a mishap. In an ideal world, the interface would be totally natural and predictable in behavior. Nothing should obstruct your progress in completing this task.

- The ratings of all three SMEs were “Acceptable (2).”

Rate the performance of the interface: the speed with which the interface responds to requests.
Rate the support information for the interface: the information available to acquire, use and support the interface. Encompasses initial instructions, user guides, tutorials, integrated assistance, context sensitive help.

- The rating of one SME was “Very acceptable (1)” and the other two were “Acceptable (2).”

Rate the interface's function: the overall capabilities of the interface.

- The ratings of all three SMEs were "Acceptable (2)."

The following open-ended questions generated several comments from the SMEs.

What were your objectives as you tested this interface?

- "[Assess] usability for a novice [user]" (one response)

Was the scope of the usability testing that you did adequate to meet your objectives?

- "Yes" (one response)

Can you suggest another method of raw data entry that would reduce time, prevent entry errors, and provide greater awareness of data conflicts/errors?

- "More point and click and pop-ups"
- "Use the [calendar] grid with right click capability [for changes] and 15-minute intervals"
- "[The] sleep interval default time should be set to 8 hours, not 30 minutes"
- "Allow click on work [period] to [enter] events"

Can you suggest other data editing methods that would work on a web page and would be more powerful for making changes?

- "Right click with pull-down [menu]"
- "Pop-up locations should start with last known location, i.e., take-off location should [default to] last land location"

Could the interface graph be formatted differently to better assist you in completing your mishap investigation and report?

- "Separate work and sleep bars on the bottom [on the x axis]"

What other improvements should be made to the interface?

- "More leading questions"
- "More click and point"

SUMMARY OF BETA INTERFACE

After signing into the F-PAS website with user identification and a password, the user may select from the Mission Scheduler options to create a new schedule, open an existing schedule, or import a schedule from FAST™. If a new or previous schedule is selected, the user may enter or edit schedule data. Starting with the schedule properties the user names the schedule, may enter a short description, gives it a starting location, specifies the time (Zulu or local), and then saves all entries and exits the Properties window. Upon return to the Edit Schedule (high level) window, the user may enter their schedule. In the Visual Schedule Editor, the user enters objects (elements) such as sleep, work, and events (takeoff, landing, etc.). These entries are all created using a calendar like display with the days across and the hours down the page. Figure 3 shows the data entry screen for a week's worth of days. A user can easily move between different days, months, or years editing sleep intervals, work intervals, and events. Figure 3 also shows how a user can switch between local and Zulu time bases for data entry or editing as needed.

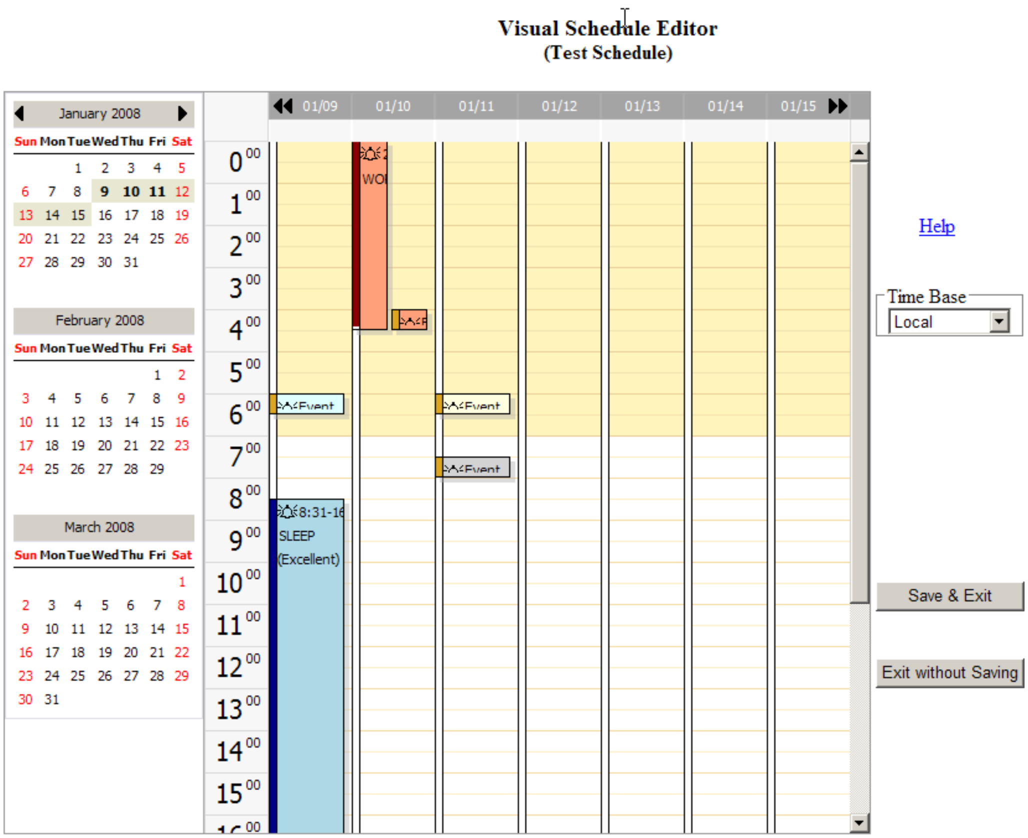

Figure 3. Mission interface calendar-layout, data-entry screen.

Once an object is entered it can be moved, lengthened, or shortened by click and drag. A pop-up window, activated by clicking on the interval or event, allows editing to the minute. There are preprogrammed events such as take-off, landing, drug events, etc. Each may be given a location by selecting the nearest city, base, or inserting lat/lon. Events with lat/lon coordinates allow F-PAS to track the light conditions on the earth. Returning to the Edit Schedule (high level) menu the user may generate a graph of performance effectiveness shown in Figure 4 by clicking on Effectiveness Graph. The graph can be zoomed to several resolutions ranging from 1 minute to 1 day. Figure 4 shows a graph at 6-hour resolution on a Zulu time base. The information in the graph may be customized to change the color zone limits, criterion line level, and right axis scales. The green zone on the graph (default 100% to 90%) is the range of performance during a normal daytime duty day following an eight-hour period of excellent sleep at night. The yellow zone (default 90% to 65%) is the range of performance during the 24 hr period after missing one night of sleep. The criterion line divides the Yellow Zone in the middle (default 77.5%) and is a guide for using countermeasures to enhance performance. Performance in the yellow zone below the criterion line (BCL) represents the performance of a person during the day following loss of an entire night's sleep. The red zone (default below 65%) indicates performance that is below the level that is acceptable for operations. The red zone represents performance following sleep deprivation of two full days and a night. Reaction time in the Red Zone is more than 50% longer than that of a well-rested person.

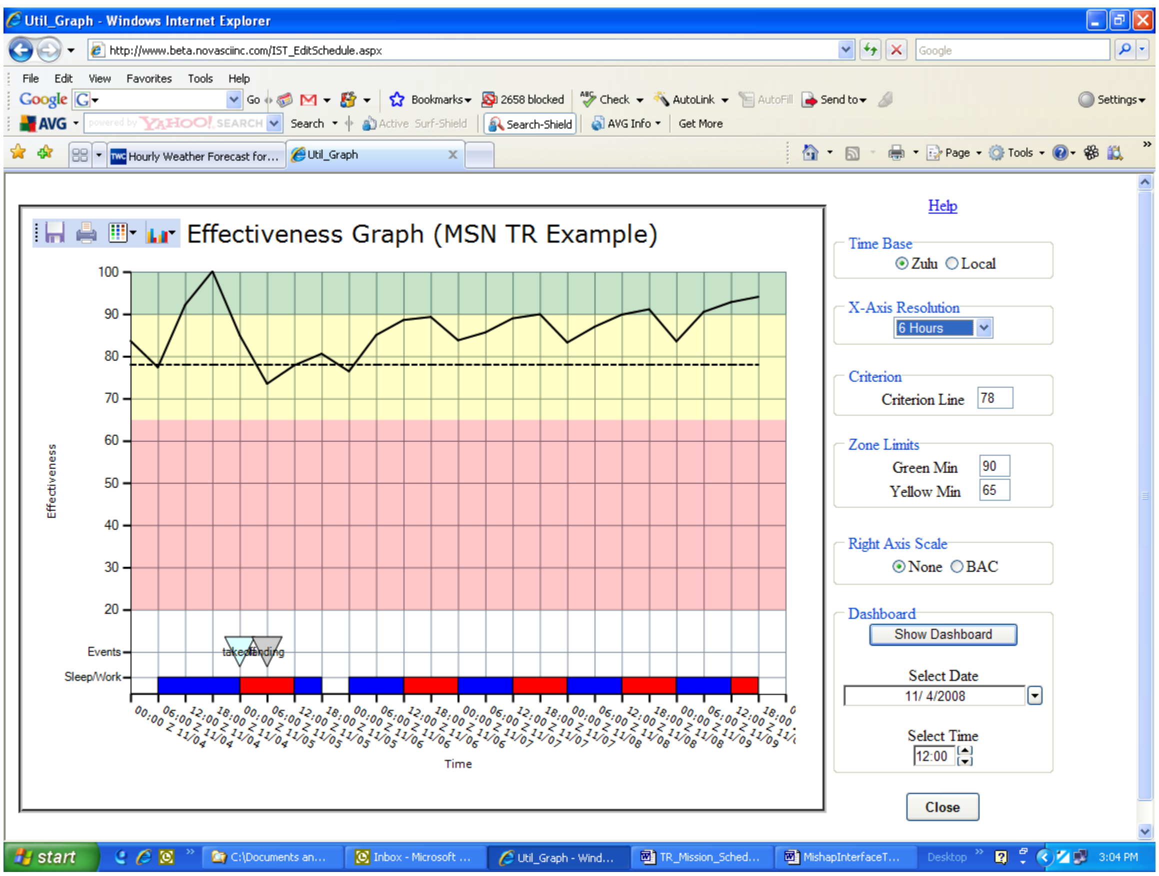

Figure 4. This image was taken from the F-PAS graphical output screen. The graph shows performance at a 6-hour resolution on a Zulu time base.

Summary tables of average performance effectiveness for each awake, work, and sleep period, and each event may be seen by clicking on Summary Data Tables at the top of the main screen. The tables also include in the bottom row, average effectiveness and the percent of time BCL.

The user may save the schedule to the server at any time. Using the Managing Files button on the main menu, files may be transferred to a local computer.

Managing Files. From the Main Menu, a user may select Manage Files to perform file management functions. The user may move files from the server to a local computer or vice versa, rename files, or delete files. The user selects the function, then selects the file/s and then presses the button to make it happen. The mission and mishap files are listed in one column with the shift work files in another. Mission and mishap schedules may be viewed, edited, or displayed using either of the two interfaces. The shift-work schedule files are only available using the shift work interface. Files left on the server are secure since each user has their own password-protected space and all files are encrypted.

Planned Software Changes

Some of the features planned for the mission interface were not available for testing during inspection evaluation. These features are briefly described here along with other changes noted during the evaluation. The planned additions are followed by a list of possible future additions.

Planned additions

- Pharmaceutical fatigue countermeasures – This important feature for AF aviation involves inserting pharmaceutical event into the schedule and observing its effect of performance along side unassisted performance. It also involves a plot showing the effect of the drug on sleep compared without the drug.
- Transmeridian Autosleep – This tool will allow a scheduler to insert sleep automatically into the schedule based on work times. It does this using a model of when people sleep given their work schedule and goals. The model is based on whether the individual is a tourist or wants to stay on their point of origin schedule. Aircrew fall between the two extremes and rules are included for such objectives.
- ORM Report – This will be a narrative report that rates the overall schedule, the work interval, and the events with respect to fatigue ORM. It will identify fatigue points in a schedule and recommend remediation.
- Mission timeline – Similar to the mission timeline option in FAST™, a temporally organized table showing in 30 minute or 1 hour blocks the progress of a mission including a column for performance effectiveness, illumination, scheduled events, and times to nap.
- Copy and paste – The addition of copy and paste to the clipboard of all screens, tables, and pop-ups.
- Simultaneous display of schedule and graph.
- Grouping of schedule elements for simultaneous moves and copying.

Potential future additions

- Assessment of fatigue for multiple crewmembers (different sleep history) on the same mission (minor variation is schedules).
- Use of shape coding for different types of events: T/O, AR, CE, TD, and pre- and post-flight activities.
- A function that maximizes performance for a particular time point.
- Stand alone and PDA versions of F-PAS.
- Both Zulu and local time changing with location on the x-axis simultaneously.

DISCUSSION

AMC has been flying more and longer missions with fewer pilots and fatigue has become a safety issue. A fatigue assessment and management tool built on a scientifically based model of sleep and cognitive performance can be helpful in managing the fatigue problem. By the summer of 2006, the aerospace physiologists of the B-2 community had used FAST™ successfully to plan more than 2,000 hours of long-duration missions (personal communication, 2006). The general plan for designing the Fatigue-Performance Assessment System (F-PAS) interfaces was to use two main conceptual pathways for scheduling: regular schedules and irregular schedules. Regular schedules for shift workers would use the sequential, prescriptive approach documented in Miller (2006). The Shiftwork Scheduling Interface described in Miller, Eddy, Smith, & Moise (2009) supports this approach. Schedulers creating and evaluating irregular schedules for long-aviation or sustained operations missions would use an interface similar to existing FAST™ methods. This "descriptive" approach allows the user to generate a schedule without any constraints and the model evaluates it for fatigue effects. After collecting requirements from several AF user groups, two interfaces for irregular schedules were designed, one for mishap investigation and one for mission planning that would be used by schedulers, aircrew, and flight surgeons. The task analysis and usability assessments described in the results section were the basis for designing the Mission Scheduler Interface. The Mishap Investigator Interface is described in Eddy, Miller, & Smith (2009).

From the schedulers' TA and remarks, the interface required quick data entry if schedules could not be electronically imported from some other source. A graphical depiction of the schedule that conveys the big picture was required to maintain situation awareness of the mission goals and objectives. Graphical output was needed to support quick comprehension of the schedule impacts on fatigue and performance. Schedule editing was needed to support moving sleep, work, and event objects quickly and easily in the mission schedule. Ease of editing was deemed necessary for both original schedule planning and for re-planning by aircrew in the field to achieve optimal performance and productivity while maintaining safety of flight and operation. The tool was to support the grouping of sleep, work, and event objects to maintain situation awareness and speed of answering "what-if" type questions related to fatigue. In short, an enhanced interface that better supported FAST™ functionality was required for AMC mission schedulers and aircrews. The AMC pilots indicated that they would be comfortable with a similar interface and would use the fatigue modeling tool if TACC also used it. Their most preferred format would be for the tool to run on a PDA.

In our requirements assessment meeting with FS, we learned that they did not want a special interface for themselves. They wanted the aircrew to have the option of trying various stimulant and sleep aid alternatives with our fatigue analysis tool when they could not acquire sufficient sleep prior to a mission to perform it without excessive fatigue. The FS did not want to be in the position of pushing these medications on the aircrew; they wanted the aircrews initiating a request for the prescription. This approach would allow the FS an opportunity to discuss pros and cons, alternatives, side effects, dose timing, etc. with the aircrew. The FS did want to review the fatigue countermeasures interface to insure that it presented the alternatives accurately and that we provided sufficient information on the side effects of the medications, such as stimulants preventing sleep, etc.

Even though the first meeting was short, did not include a TA of FS tasks in making decisions on Go-No Go pill administration, and we had several digressions, we learned much about what FS needed and did not need in our tool. The information in the Results section, above, defines the requirements for the fatigue countermeasures interface adequately. The big take-away message from the session was that the fatigue countermeasures interface should be designed for the aircrew to allow them to explore options for fatigue management during long-duration and nighttime missions. Further, that the interface be so easy to use that "even a caveman can do it." With that said, once aircrew determined that opportunities for adequate sleep could not be used to minimize fatigue, they could work jointly with FS on the best countermeasures to use and the best time before or during the mission to use them. Although the pharmaceutical fatigue countermeasures interface was not complete at the time of usability testing, we believe the interface will meet FS requirements and expectations. Once it is available, we will attempt to recruit them to evaluate the interface and the accompanying information on fatigue countermeasures medications.

It is the investigators' opinion that the web-based F-PAS will eventually replace FAST™. It has three unique interfaces for shift work scheduling, mishap investigation, and mission planning whereas FAST™ has but one interface with options for data entry. The F-PAS interfaces are based on TA of the various AF user groups. Currently, F-PAS can be run on a stand-alone computer by configuring it as a server, but with addition programming effort F-PAS could be converted to a standard Windows application. Further, it could also be configured to run on a PDA, but would also require redesign of the displays for the small screen. These various topics and others are discussed in the contract final report (Eddy, Miller, & Moise, 2008).

CONCLUSIONS

The F-PAS mission scheduler's interface should provide a mechanism that allows schedulers, aircrew, and FS to make informed decisions with respect to the impact of the mission schedules on fatigue and the likelihood of performance errors. It can also make “what-if” comparisons across various alternative schedules. Using the SAFTE™ model in F-PAS, a user can compare critical events (take-off, aerial refueling, landing) within two or more different, fatiguing schedules. The model may identify, for example, the likelihood that an individual beginning a flight leg has not fully recovered from previous flight legs and is, therefore, at an elevated risk of causing a fatigue-induced mishap during take-off or departure. The interface can suggest countermeasures to use when mishap risk is higher than normal. Aircrew and FS should use the tool's prediction of performance to determine the best course of action regarding possible Go-No Go pill administration.

In usability testing, the input component was found to be both time efficient and provide extensive optional guidance with respect to avoiding or minimizing fatigue. The output component of the interface was shown to identify clearly the “fatigue points” in the proposed schedule, based upon SAFTE™ calculations. The output, once extended, will allow side-by-side comparison of several candidate schedules. When schedule changes or alternative options for sleep have been tried and found insufficient for fatigue risk management, pharmaceutical countermeasures can be investigated within the modeling tool. These should be understood easily by aircrew who are not physicians. F-PAS has the potential to replace the research-oriented FAST™

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APPENDIX A: F/PAS MISSION SCHEDULER INTERFACE USABILITY QUESTIONNAIRE NTI, Inc., September 2008

Years of active duty: ____ FAST user? Yes No (circle one)

Please rate the ease of application of the interface to the intended task: the simplicity with which the interface can be employed to determine whether fatigue was a factor in a mishap. In an ideal world, the interface would be totally natural and predictable in behavior. Nothing should obstruct your progress in completing this task.

- Very acceptable (1)
- Acceptable (2)
- Borderline (3)
- Unacceptable (4)
- Very unacceptable (5)

Rate the performance of the interface: the speed with which the interface responds to requests.

- Very acceptable (1)
- Acceptable (2)
- Borderline (3)
- Unacceptable (4)
- Very unacceptable (5)

Rate the support information for the interface: the information available to acquire, use and support the interface. Encompasses initial instructions, user guides, tutorials, integrated assistance, context sensitive help.

- Very acceptable (1)
- Acceptable (2)
- Borderline (3)
- Unacceptable (4)
- Very unacceptable (5)

Rate the interface s function: the overall capabilities of the interface.

- Very acceptable (1)
- Acceptable (2)
- Borderline (3)
- Unacceptable (4)
- Very unacceptable (5)

Please discuss with the observer:

- What were your objectives as you tested this interface?
- Was the scope of the usability testing that you did adequate to meet your objectives?
- Can you suggest another method of raw data entry that would reduce time, prevent entry errors, and provide greater awareness of data conflicts/errors?
- Can you suggest other data editing methods that would work on a web page and would be more powerful for making changes?
- Could the interface graph be formatted differently to better assist you in completing your mishap investigation and report?
- What other improvements should be made to the interface?

APPENDIX B: NTI F-PAS MISSION SCHEDULER TOOL USABILITY DATA COLLECTION FORM

Data:

On a separate page, keep orderly, transcribable notes of the **pathways** the participants take, **problems** participants have and what participants **say** as they work. Definitions for the table, below:

- *Number of subtask **assists**:* When the participant cannot proceed on a subtask, the observer gives direct procedural help to allow the test to proceed.
- *Number of subtask **errors**:* Instances where test participant had to attempt portions of the task more than once.
- *Number of subtask **reversals**:* Number of times participant had to "back up" to find something on a previous page that they needed on the current page.
- *Subtask **completion** (Y/N):* **Yes** = complete and correct achievement of subtask goal.
- *Problem **severity** (0/1/2):* **0** = no problem; **1** =minor (users are annoyed, but this does not keep them from completing the scenario); **2** = show stopper (if we don't fix this, users will not be able to complete the scenario; and/or many users will be frustrated, and they may give up).

Subtask	# Assists	# Errors	# Reversals	Severity	Completion
1. Start time at Main Menu:					
2. Choose "Mission Scheduler—New Schedule." Success = appearance of "Edit schedule" screen.				0 1 2	Yes No
3. Choose "Edit Properties." Success = appearance "Edit Properties" pop-up window.				0 1 2	Yes No
4. Enter schedule name, starting date, and starting time (calendar), and choose Zulu time (Zulu).				0 1 2	Yes No
5. Enter Starting location (Travis) without DST. Success = proper starting location displayed on "Edit Properties" pop-up.				0 1 2	Yes No
6. Click "Save and Exit." Success = appearance of "Edit Schedule" screen.				0 1 2	Yes No
7. Choose "Edit Schedule." Success = appearance "Visual Schedule Editor" pop-up window. **PROBLEM**: The instruction here is to choose "Edit Properties." Needs second paragraph cueing the selection of schedule editor after properties have been entered.				0 1 2	Yes No
8. Enter first work period, Travis (via Randolph) to Pope. **PROBLEM**: No instruction given on the screen to double-click at the desired time in the calendar to enter a work period. Success = appearance of proper work period on calendar on "Visual Schedule Editor" pop-up window. **NOTE**: Visual Schedule Editor page needs a save-without-exit option. **NOTE**: Hover window over work period shows time in 12-h clock when time base is Zulu				0 1 2	Yes No

Subtask	# Assists	# Errors	# Reversals	Severity	Completion
and 24-h clock should be shown.					
9. Enter second work period, Pope to Lajes. Success = appearance of proper work period on calendar on “Visual Schedule Editor” pop-up window.				0 1 2	Yes No
10. Enter third work period, Lajes to Ramstein. Success = appearance of proper work period on calendar on “Visual Schedule Editor” pop-up window. **NOTE**: To this point, incredibly slow response times from novasciinc.com.				0 1 2	Yes No
11. Enter first Event, take-off from Travis. Success = appearance of proper event on calendar on “Visual Schedule Editor” pop-up window. **PROBLEM**: Again, no cue to double-click in calendar. **SHOW-STOPPER**: First work period's start time has mysteriously reverted to midnight of first day! The edit function failed to fix the problem. **PROBLEM**: No instruction on page about how to edit a work period. **PROBLEM**: Must clcik on empty, non-work space in calendar to insert an event, even if the event occurs during a work period. **PROBLEM**: Pop-up window for selection of Work, Sleep or Event is displayed during Event save.				0 1 2	Yes No
12. Enter second Event, Landing at Randolph. Success = appearance of proper event on calendar on “Visual Schedule Editor” pop-up window. CHANGE: In the add-an-event window, place the “Start Time” filed above the “Event Type” field for better sequencing of user inputs.				0 1 2	Yes No
13. Enter third Event, take-off from Randolph. Success = appearance of proper event on calendar on “Visual Schedule Editor” pop-up window.				0 1 2	Yes No
14. Enter fourth Event, landing at Pope. Success = appearance of proper event on calendar on “Visual Schedule Editor” pop-up window.				0 1 2	Yes No
15. Enter fifth Event, take-off from Pope. Success = appearance of proper event on calendar on “Visual Schedule Editor” pop-up window.				0 1 2	Yes No
16. Enter sixth Event, landing at Lajes. Success = appearance of proper event on calendar on “Visual Schedule Editor” pop-up window.				0 1 2	Yes No
17. Enter seventh Event, take-off from Lajes. Success = appearance of proper event on calendar on “Visual Schedule Editor” pop-up window.				0 1 2	Yes No
18. Enter eighth Event, landing at Ramstein. Success = appearance of proper event on calendar on “Visual Schedule Editor” pop-up window.				0 1 2	Yes No
19. Enter first crew rest sleep period at Pope. Success = appearance of proper sleep period on				0 1 2	Yes No

Subtask	# Assists	# Errors	# Reversals	Severity	Completion
calendar on “Visual Schedule Editor” pop-up window. **PROBLEM**: What was sleep before the schedule started?					
20. Enter second crew rest sleep period at Lajes. Success = appearance of proper sleep period on calendar on “Visual Schedule Editor” pop-up window.				0 1 2	Yes No
21. Save and exit “Visual Schedule Editor” pop-up window. Success = appearance of “Edit Schedule” screen.				0 1 2	Yes No
22. Save the schedule. Success = message confirming saving of schedule.				0 1 2	Yes No
23. Display the effectiveness graph. Success = appearance of graph. **RECOMMENDATION**: Use 1-hour resolution as default; easier to get the big picture with 1-hour than with 15-min res.				0 1 2	Yes No
24. Switch to 1-hour resolution. Success = re-display of graph.				0 1 2	Yes No
25. **End time for data entry**:					
26. **Start time for fatigue countermeasure applications**:					
27.				0 1 2	Yes No
28.				0 1 2	Yes No
29.				0 1 2	Yes No
30.				0 1 2	Yes No
31.				0 1 2	Yes No
32.				0 1 2	Yes No
33.				0 1 2	Yes No
34.				0 1 2	Yes No
35.				0 1 2	Yes No
36.				0 1 2	Yes No
37.				0 1 2	Yes No
38.				0 1 2	Yes No
39.				0 1 2	Yes No

Subtask	# Assists	# Errors	# Reversals	Severity	Completion
40.				0 1 2	Yes No
41.				0 1 2	Yes No
42.				0 1 2	Yes No
43.				0 1 2	Yes No
44.				0 1 2	Yes No
45.					
46.					
47.				0 1 2	Yes No
48.				0 1 2	Yes No
49.	NA	NA	NA	NA	NA
50.	NA	NA	NA	NA	NA
51.				0 1 2	Yes No
52.				0 1 2	Yes No
53.				0 1 2	Yes No
54.				0 1 2	Yes No
55.				0 1 2	Yes No
56.				0 1 2	Yes No
57.				0 1 2	Yes No
58.				0 1 2	Yes No
59.					
60.				0 1 2	Yes No
61.				0 1 2	Yes No
62.				0 1 2	Yes No
63.				0 1 2	Yes No

Subtask	# Assists	# Errors	# Reversals	Severity	Completion
64.				0 1 2	Yes No
65.				0 1 2	Yes No
66.				0 1 2	Yes No
67.				0 1 2	Yes No
68.					
69.					
70.					
71. **End time**:	NA	NA	NA	NA	NA

Comments:

APPENDIX C: MISSION SCHEDULER SCENARIO

Usability Test, 25 Sep 2008

DATA

Mobility Mission no. 456
Travis AFB, CA, to Ramstein AB, Germany
Show time: Take-off minus 3 hrs
Call sign: **Mickey21**
Home base, **Travis AFB**, CA

Pre-mission sleep: predicted sleep period 0600Z-1200Z, predicted sleep quality "excellent"

1st Work Period (13.5 hrs)

11. Show time, Travis AFB: 23APR1348Z
12. Take-off, Travis AFB: 23APR1648Z
13. Landing Randolph AFB, TX: 23APR2000Z (3.2 hrs enroute)

9. Take-off, Randolph AFB, TX: 23APR2350Z
10. Landing, Pope AFB, NC: 24APR0320Z (3.5 hrs enroute)
11. Debrief, Pope AFB, NC: 1 hour

Crew rest: 18 hrs, predicted sleep period 0830Z-1330Z, predicted sleep quality "fair"

2nd Work Period (9 hrs)

- Show time, Pope AFB, NC: 24APR2115Z
- Take-off, Pope AFB, NC: 25APR0015Z
- Landing, Lajes AB, Azores: 25APR0520Z (5 hrs enroute)
- Debrief, Lajes AB, Azores: 1 hour

Crew rest: 13 hrs, predicted sleep period 0700Z-1300Z, predicted sleep quality "fair"

3rd Work Period (9.5 hrs)

- Show time, Lajes AB, Azores: 25APR1830Z
- Take-off, Lajes AB, Azores: 25APR2130Z
- Landing, Ramstein AB, Germany: 26APR0300Z (5.5 hrs enroute)
- Debrief, Ramstein AB, Germany: 1 hour

Mission Scheduler Scenario

Usability Test, 25 Sep 2008

Test Instructions (Simulated Help File)

Data Entry:

- From the Main menu, choose “Mission Scheduler—New Schedule” and then “Edit Properties.”
- Referring to the test scenario, enter the schedule properties as instructed. Use Zulu time and do not use Daylight Savings Time for this whole test.
- Return to the “Edit Schedule” screen. Choose “Edit Schedule.”
- Referring to the test scenario, enter each of the three work periods, from show time through the end of the mission debrief.
- Referring to the test scenario, enter the four pairs of take-offs and landing as events, being sure to enter the location.
- Referring to the test scenario, enter the three predicted sleep periods (automated prediction is not yet available in the software); assign the correct sleep quality to each one.
- Save and exit the “Visual Schedule Editor” pop-up window.
- Save the schedule.
- Display the graph, and change to 1-hour resolution.
- Add pharmacological manipulations for future testing.