Fatigue assessment in Camp Mirage CC130 Aircrew:

Recommendations for pharmacologic intervention

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Abstract

An *acute fatigue* issue with serious flight safety implications was uncovered during a recent deployment among aircrews conducting tactical airlift between Camp Mirage (CM) and Kabul. This acute fatigue issue is due to jet-lag-induced sleep deprivation. The relief aircrews arriving in CM have been deployed across 9 time zones, but are pressed into the tactical airlift schedule after only 2 nights of sleep at CM. Thus, they undertake their first mission with an acute sleep deficit. In spite of the fact that the arriving relief crew (Crew A) spent an average of 7.75 hours in bed the night before their first mission, they slept only an average of 3.4 hours. This was due to circadian desynchronosis: their body clocks were significantly retarded relative to local time. The next day, a sister crew (Crew B) which had been in theatre for a month (and thus was no longer jet-lagged) flew a mission into Kabul. This crew had a similar time in bed (7.5 hours) but slept for an average of 6.3 hours. The very low sleep-efficiency (47%) in Crew A the night before their first mission was a serious flight safety concern, especially because they were flying over hostile territory in a demanding tactical environment over a 14-hour crew day. Using the USAF performance modelling software, objective sleep data and actual crew duty day data, we estimated crewmember cognitive effectiveness during duty days for the two crews mentioned, above. We also estimated crewmember cognitive effectiveness for Crews C and D flying a night-time schedule several months earlier. RESULTS. The model estimates indicated the following: a) Crew A which commenced operations on their 3rd day in theatre, were operating at dangerously low levels of cognitive performance on their first mission, b) their cognitive performance deficits improved over time and were no longer evident after 9 days in theatre, c) Crew B, having been in theatre for a month, were no longer jet-lagged and had acceptable cognitive performance, and d) because a significant portion of the missions in the preceding months were flown at night, the model indicated that the crewmembers' (Crews C and D) cognitive performance would be impacted dramatically by fatigue. RECOMMENDATIONS. In the event that CM aircrew are again called upon to fly significant portions of these missions at night, we recommend that they be provided more rest opportunity between missions to improve their cognitive performance, and that they practice the planned, tactical employment of caffeine for critical mission elements that occur during the unavoidable nadir in crewmember performance. To preclude jet-lag-induced performance impact on crews arriving in theatre, we offer a pharmacologic countermeasure to advance their circadian rhythms using a 5-day protocol (5 doses) commencing at home. To optimize this intervention, we need to verify its efficacy via objective actigraphic monitoring. The CF Central Medical Board has recommended new aeromedical policy for the short-term flight-surgeon-supervised use of selected pharmaceutical agents (melatonin, zopiclone and zaleplon) to facilitate sleep in aircrew during missions that are known to impact on aircrew sleep. However, because melatonin is not yet available in Canada, we would first have to obtain regulatory approval for its operational use from Health Canada via the Special Access Program (SAP). While we are waiting for SAP approval for the use of melatonin, we recommend that aircrew arriving in theatre be given pharmacologic sleep support with either zopiclone or zaleplon under the direct supervision of the CM flight surgeon for the first few nights in theatre.

Résumé

Au cours d’un récent déploiement devant servir à examiner la question de la fatigue chronique parmi nos équipages d’aéronefs appelés à effectuer du transport aérien tactique entre le camp Mirage (CM) et Kaboul, le premier auteur de ce document (MP) a observé un problème de fatigue aiguë ayant de graves répercussions en matière de sécurité aérienne. La fatigue aiguë est une séquelle du décalage horaire causé par une avance de phase circadienne de neuf heures, inhérente à ce déplacement transméridien. Les équipages de relève sont affectés par roulement au transport aérien tactique après deux nuits de sommeil inadéquat au CM. La difficulté à dormir est due au désynchronisme circadien découlant de vols transméridiens d’une telle durée. Au cours de leur deuxième nuit de sommeil au CM (c’est-à-dire de la nuit précédant leur première mission), les membres de l’équipage nouvellement arrivé ont dormi en moyenne 3,4 heures, ce qui donne une efficacité de sommeil de 46,8 %. Par contre, le lendemain, l’autre équipage qui était dans ce théâtre d’opérations depuis un mois et n’éprouvait plus de décalage horaire a effectué une mission aérienne après avoir beaucoup mieux dormi (6,3 heures en moyenne pour l’équipage, avec une efficacité de sommeil normale de 82,2 %) la nuit précédant le départ. La période de sommeil limitée et l’efficacité très réduite du sommeil parmi l’équipage nouvellement déployé représente un sérieux problème de sécurité aérienne, étant donné qu’il survole un territoire hostile dans un contexte tactique exigeant, pendant une durée de service de 14 heures. Nous proposons une solution pharmaceutique visant à améliorer la sécurité aérienne en avançant les rythmes circadiens au moyen d’un protocole de cinq jours (cinq doses). L’application de ce protocole commencerait au Canada avec la prise d’une dose à 16 h, à chacun des deux jours précédant le déploiement, suivie d’une autre dose à 16 h (heure de Trenton) dans l’avion, en route vers le CM, puis des deux dernières doses, à l’heure du coucher locale du CM, soit une à chacun des deux premiers jours sur place; le protocole se terminerait la veille du début des opérations de transport aérien tactique. Il faut vérifier l’efficacité de cette intervention à l’aide d’un actigraphe porté au poignet. La Commission centrale de médecine des FC a recommandé une nouvelle politique visant l'utilisation à court terme et surveillée par le médecin de l'air d'agents pharmacologiques choisis (mélatonine, zopiclone et zaleplon) pour faciliter le sommeil de l'équipage durant les missions qui sont reconnues avoir de l'influence sur le sommeil de ce dernier. Cependant, comme la mélatonine n’est pas encore disponible au Canada, il nous faudrait d’abord obtenir l’autorisation de l’utiliser de Santé Canada, dans le cadre du Programme d’accès spécial (PAS). En attendant d’obtenir l’autorisation du SAP, nous recommandons de fournir aux équipages qui arrivent dans un théâtre d’opérations des produits pharmaceutiques susceptibles de les aider à dormir, soit de la zopiclone ou du zaleplon, sous la supervision directe du médecin de l’air du CM et ce, pendant les premières nuits passées dans ce théâtre.

Executive summary

An *acute fatigue* issue with serious flight safety implications was uncovered during a recent deployment to address possible *chronic fatigue* in our aircrews conducting tactical airlift between Camp Mirage (CM) and Kabul. This acute fatigue issue is due to jet-lag-induced sleep deprivation. The relief aircrews arriving in CM have been deployed across 9 time zones, but are pressed into the tactical airlift schedule after only 2 nights of sleep at CM. Thus, they undertake their first mission with an acute sleep deficit. In spite of the fact that the arriving relief crew spent an average of 7.75 hours in bed the night before their first mission, they slept only an average of 3.4 hours. This was due circadian desynchronosis: their body clocks were significantly retarded relative to local time. The next day, a sister crew that had been in theatre for a month (and thus was no longer jet-lagged) flew a mission into Kabul. This crew had a similar time in bed (7.5 hours) but slept for an average of 6.3 hours. The very low sleep-efficiency in the arriving crew (47%), the night before their first mission was a serious flight safety concern, especially because they were flying over hostile territory in a demanding tactical environment over a 14-hour crew day. Using the USAF performance modelling software FAST™ (Fatigue Avoidance Scheduling Tool), objective sleep data collected by the first author and actual crew duty day data, we estimated crewmember cognitive effectiveness during duty days for the two crews mentioned, above. We also estimated crewmember cognitive effectiveness for crews flying a night-time schedule several months earlier. RESULTS. The model estimates indicated the following: a) Crew A which commenced Tactical Airlift Operations on their 3rd day in theatre, were operating at dangerously low levels of cognitive performance on their first mission, b) the low cognitive performance levels for Crew A improved over time and were no longer evident after 9 days in theatre, c) Crew B, having been in theatre for a month were no longer jet-lagged and had acceptable cognitive performance, and d) because a significant portion of the missions in the preceding months were flown at night, the model indicated that the crewmembers' (Crews C and D) cognitive performance would be impacted dramatically by fatigue. RECOMMENDATIONS. In the event that CM aircrew are again called upon to fly significant portions of these missions at night, we recommend that they be provided more rest opportunity between missions to improve their cognitive performance, and that they practice the planned, tactical employment of caffeine for critical mission elements that occur during the unavoidable nadir in crewmember performance. The potential for caffeine-induced diuresis and subsequent dehydration is easily manageable. To preclude jet-lag-induced performance impact on crews arriving in theatre, we offer a pharmacologic countermeasure to advance their circadian rhythms using a 5-day protocol (5 doses) commencing at home with a single dose, taken at 1600 hours, each of 2 days prior to deployment, another dose at 1600 hours (Trenton time) on the aircraft en route to CM, and the final 2 doses at local bedtime in CM for each of the first 2 days in theatre, ending the night before they commence tactical airlift operations. To optimize

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this intervention, we need to verify its efficacy via objective actigraphic monitoring. After acquiring some preliminary data, especially from the night prior the first mission for each freshly arrived relief crew, we may need to adjust the melatonin formulation/dose. The CF Central Medical Board has recommended new aeromedical policy for the short-term flight-surgeon-supervised use of selected pharmaceutical agents (melatonin, zopiclone and zaleplon) to facilitate sleep in aircrew during missions that are known to impact on aircrew sleep. However, because melatonin is not yet available in Canada we would first have to obtain regulatory approval for its operational use from Health Canada via the Special Access Program (SAP). While we are waiting for SAP approval for the use of melatonin, we recommend that aircrew arriving in theatre be given pharmacologic sleep support with either zopiclone or zaleplon under the direct supervision of the CM flight surgeon for the first few nights in theatre.

Sommaire

Au cours d'un récent déploiement devant servir à examiner la question de la *fatigue chronique* parmi nos équipages appelés à effectuer du transport aérien tactique entre le camp Mirage (CM) et Kaboul, le premier auteur de ce document (MP) a observé un problème de *fatigue aiguë* ayant de graves répercussions en matière de sécurité aérienne. Ce problème de fatigue aiguë est causé par un manque de sommeil associé au décalage horaire. Les équipages de relève qui arrivent au CM ont franchi neuf fuseaux horaires et souffrent d'un décalage horaire sévère à leur arrivée. Lorsqu'ils ont à s'engager dans leur première mission de transport aérien tactique entre le CM et Kaboul, après avoir dormi deux nuits au CM, ils souffrent d'un manque de sommeil aigu. Malgré que les membres de l'équipage de relève en cause aient passé 7,75 heures au lit la nuit précédant leur première mission, cette « fenêtre de sommeil » n'a donné qu'une durée de sommeil moyenne de 3,4 heures et une efficacité de sommeil de 46,8 %. Ceci est attribuable au désynchronisme circadien, en ce sens qu'à l'heure normale du coucher au CM, l'horloge interne des nouveaux arrivants accusait un sérieux retard par rapport à l'heure locale. Le lendemain, l'autre équipage qui se trouvait dans le théâtre d'opérations depuis un mois et ne ressentait donc plus les effets d'un décalage horaire s'est envolé en mission vers Kaboul. Ses membres sont demeurés couchés environ le même nombre d'heures (7,5 h), mais ils ont dormi en moyenne 6,3 heures, ce qui donne une efficacité de sommeil de 82,2 %. La période de sommeil limitée et l'efficacité très réduite du sommeil parmi l'équipage nouvellement déployé représentent un sérieux problème de sécurité aérienne, particulièrement en raison du fait qu'il survole un territoire hostile dans un contexte tactique exigeant, pendant une durée de service de 14 heures. Nous proposons une solution pharmaceutique visant à avancer les rythmes circadiens au moyen d'un protocole de cinq jours (cinq doses), dont l'application commence au Canada par la prise d'une dose à 16 h, à chacun des deux jours précédant le déploiement, suivie d'une autre dose à 16 h (heure de Trenton) à bord de l'avion, en route vers le CM, puis des deux dernières doses, à l'heure du coucher locale du CM, soit une à chacun des deux premiers jours sur place; le protocole se terminerait donc la veille du début des opérations de transport aérien tactique. Pour optimiser cette intervention, nous devons vérifier son efficacité à l'aide d'un actigraphe porté au poignet. Après avoir recueilli des données actigraphiques préliminaires sur le sommeil de chacun des membres de l'équipage nouvellement arrivé, en particulier au cours de la nuit précédant la première mission, nous déterminons s'il est nécessaire d'ajuster la formulation de mélatonine/dose. La Commission centrale de médecine des FC a recommandé une nouvelle politique visant l'utilisation à court terme et surveillée par le médecin de l'air d'agents pharmacologiques choisis (mélatonine, zopiclione et zaleplon) pour faciliter le sommeil de l'équipage durant les missions qui sont reconnues avoir de l'influence sur le sommeil de ce dernier. Cependant, comme la mélatonine n'est pas encore disponible au Canada, il nous faudrait d'abord obtenir

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l'autorisation de l'utiliser de Santé Canada, dans le cadre du Programme d'accès spécial (PAS). En attendant d'obtenir l'autorisation du SAP, nous recommandons de fournir aux équipages qui arrivent dans un théâtre d'opérations des produits pharmaceutiques susceptibles de les aider à dormir, soit de la zopiclone ou du zaleplon, sous la supervision directe du médecin de l'air du CM, et ce, pendant les premières nuits dans ce théâtre.

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Background/problem definition

During a recent deployment to address *chronic fatigue* issues in support of our aircrews conducting tactical airlift between Camp Mirage (CM) and Kabul, the first author (MP) of this document became aware of an *acute fatigue* problem with serious flight safety implications.

He was initially deployed to assess aircrew sleep hygiene (via wrist actigraph[1]) with a view to determining whether the crews were obtaining sufficient sleep, and to use the obtained actigraphic sleep data along with crew duty day data, as input to a performance prediction software system (FAST^{TM}, or Fatigue Avoidance Scheduling Tool; Appendix D). The FAST^{TM} software models theoretical cognitive performance (as a percentage of very good performance), the output of which is performance effectiveness. In this manner it was hoped that it would be possible to determine to what extent the operational cadence impacted performance of our CM-based aircrews over time.

However, during the course of this deployment, another worrisome sleep-related flight safety issue was uncovered. Essentially, aircrews are of necessity pressed into service on their third day after arrival in theatre. At this stage in their recovery from a 9-hour transmeridian deployment, these crews are still very jet-lagged. The first author (MP) of this document arrived in theatre on the same Airbus as Crew A and accompanied it on its first mission 2 days after arrival at CM. Just before departure on this mission, MP interviewed all members of the crew to obtain subjective estimates of their time in bed and their actual sleep time. The next day, just before they conducted a mission, MP interviewed Crew B who had been in theatre for a month. Table I illustrates the subjective sleep behaviour for the night before a mission for each of the recently arrived Crew A, and for Crew B (which had been in theatre for a month). Both crews had similar time in bed on the night before their missions. However, the average sleep hours for Crews A and B were 3.4 and 6.3 hours, respectively. The sleep efficiency (percent of the sleep opportunity actually spent asleep) for Crews A and B were 46.8% and 82.2% respectively.

Using an artillery firing task, Belenky et al. (3) demonstrated that less than 6 hours of sleep results in impaired performance in continuous operations. More recently, Paul et al. (15) demonstrated a fatigue-induced impact on the ability to learn a computer-based flying task after about 6.5 hours of sleep. However, the notion of flying a demanding tactical airlift mission over unfamiliar and potentially hostile territory after an average crew sleep time of 3.4 hours is most worrisome, especially when the aircraft commander and co-pilot obtained only 2 and 1 hour of sleep respectively the night before the mission. The reason Crew A experienced such difficulty in obtaining sleep is jet-lag. Even the accompanying scientist (MP who had the same jet-lag stress) obtained only 4 hours of sleep for 8 hours in bed, and he had taken a dose of a sleeping medication (zaleplon).

[1] A small accelerometer, worn on the wrist like a wristwatch, that records whole-body activity for the purpose of differentiating sleep periods from wake periods across many days and nights.

Table I. Sleep efficiency disparity between incoming crew and crew half-way through rotation

CREW A (2 DAYS IN THEATRE)			
Crew position	Hours in bed	Hours asleep	Sleep efficiency
A/C	8	2	25%
F/O	8	1	12.5%
F/E	6	4.5	75%
Nav	8	4	50%
LM1	8	6	75%
LM2	7	3	43%
Average	7.5	3.4	46.8%

CREW B (4 WEEKS IN THEATRE)			
Crew position	Hours in bed	Hours asleep	Sleep efficiency
A/C	8	6	75%
F/O	8	6	75%
F/E	6	6	100%
Nav	7.5	6.75	90%
LM1	8.5	7	82%
LM2	8.5	6	71%
Average	7.75	6.3	82.2%

To quantify the impact of the jet-lag-induced acute fatigue on our TAL (tactical airlift) aircrews as they arrive in theatre and to determine to what extent the CM Flight Operational Tempo might result in attrition of performance over the deployment cycle, the crew duty day data along with sleep data were used as input for the FAST™ program. The execution and analysis of that effort is provided by the co-author of this report (JM) as follows.

FAST™ Analysis of Canadian CC-130 Operations from Camp Mirage (CM)

FAST™ Modelling Program

A description of the FAST™ (Fatigue Avoidance Scheduling Tool) is provided in Appendix D. FAST™ graphs are shown in Appendix A for Crew A, Appendix B for Crew B and Appendix C for Crews C and D. Some details regarding these graphs are as follows:

- The vertical axis on the left side of the FAST™ graphs represents human performance effectiveness and is demonstrated by the oscillating line in the diagram representing group average performance as determined by time of day, biological rhythms, time spent awake, and amount of sleep.

- The green band represents performance effectiveness for skilled workers, the lower limit of which (90%) is an indication of when it is time to sleep.

- The yellow performance band (from 60% to 90% cognitive effectiveness) indicates caution. Personnel engaged in skilled performance activities such as aviation should not be functioning in this performance band.

- The area from the dotted line to the pink area represents cognitive effectiveness during the circadian nadir and during a 2nd day without sleep.

- The pink performance band (below 60%) represents performance effectiveness after 2 days and a night of sleep deprivation. Under these conditions, no one can be expected to function well on any task.

- The red line represents acrophase (see immediately below for definition)

- The abscissa illustrates periods of work (red bars), sleep (blue bars), and time of day in hours

Modelling Methods

For the purposes of this analysis, 'acrophase' is the time of day at which peak cognitive effectiveness occurs; normally, in the late afternoon or early evening. Acrophase is easily disturbed by night work, shift rotation (shift lag) and time zone changes (jet-lag). For Crew A, the crewmember acrophase was offset 9 hours earlier in FAST™, to Trenton time, at three days prior to the 14 days displayed here in FAST™ graphs (Appendices A and B). Then, one night of total sleep deprivation was allotted for the third night prior to the periods shown in the FAST™ graphs. This deprivation occurred during the 17-hour deployment period to CM. Subsequently, the crew was assumed to sleep well for 8 hours (2200-0600) for one night at CM, and then moderately well for 8 hours (2200-0600) the next night at CM.

Two methods were used to estimate crewmembers' levels of cognitive effectiveness during crew duty days. First, Crew A's subjective sleep length estimates for the night immediately preceding its first mission were used to predict cognitive effectiveness during its first mission from CM to Kabul and return (graphs in Appendix A). Table II defines four 30-minute periods of the first mission for Crew A. Nominal take-off and landing times of 0800, 1230, 1330 and 1800 hours were used to determine cognitive effectiveness for 'take-off-and-departure' and 'approach-and-landing' for each crewmember. This method was applied to all 6 members of Crew A.

In the second method, the work period quantified was the last 30 miutes of each crew day (graphs in Appendix B). The amount of sleep entered into FAST™ for each major sleep period after the subjective estimate used in the first method was the number of minutes of sleep reported by the wrist activity monitor (WAM). This method was applied to the 5 members of Crew A and 2 members of Crew B who wore the WAM.

The sleep start time in FAST™ was delayed from the WAM-reported sleep start time by the amount of the WAM-reported sleep latency (the number of minutes it took to fall asleep). The sleep end time in FAST™ was the sum of the delayed sleep start time and the WAM-reported number of minutes of sleep generated. Thus, the sleep start and end times in FAST^{TM} were not those used to describe the classic time in bed (TIB) period, and the sleep end time ignored wake after sleep onset (WASO). However, WASO was taken into account as sleep efficiency: when the WAM-reported sleep efficiency was less than 90%, then sleep quality in FAST^{TM} was entered as only "moderate" instead of "excellent." Moderate sleep quality filled the sleep reservoir in FAST^{TM} more slowly than excellent sleep quality.

Modelling Results

In the FAST^{TM} graphs shown in Appendices A and B (Methods 1 and 2, respectively), cognitive effectiveness (50 to 100%) is displayed on the y-axis. Local CM time is displayed on the x-axis. Blue bars are sleep times in CM. Red bars are the last 30 minutes of reported Crew Day.

Method 1

For Mission 1 of Crew A, note the very low 65.5 % cognitive effectiveness at the critical approach and landing phase just before the end of the crew day (Table II).

Table II. *Summary of cognitive effectiveness for Crew A during its first mission.*

DAY	DATE	START TIME	DURATION	***COGNITIVE EFFECTIVENESS (%)***							
				A/C	**F/O**	**NAV**	**F/E**	**LM1**	**LM2**	**MEAN**	***SD***
Sun	12/14/2003	0800 hours	30 minutes	78.3	74.0	86.8	86.8	93.1	80.5	*83.3*	*6.9*
Sun	12/14/2003	1200 hours	30 minutes	82.1	77.9	90.2	90.1	96.2	84.1	*86.8*	*6.6*
Sun	12/14/2003	1330 hours	30 minutes	79.6	75.5	87.8	87.8	93.9	81.7	*84.4*	*6.7*
Sun	12/14/2003	1730 hours	30 minutes	60.4	55.8	69.2	69.2	75.8	62.6	*65.5*	*7.3*

Method 2

In Table III, note the 4 cells highlighted in yellow under the MEAN column demonstrating the gradual increase in cognitive efficiency as the crew slowly adapts to local CM time (i.e. decreasing jet-lag stress is accommodating a gradual increase in peformance).

Table III. Summary of cognitive effectiveness for Crew A for last 30 minutes of Crew Day.

DAY	DATE	START TIME	DURATION	*COGNITIVE EFFECTIVENESS (%)*						
				F/O	**NAV**	**F/E**	**LM1**	**LM2**	***MEAN***	***SD***
Sun	12/14/2003	1630 hours	30 minutes	51.8	66.0	65.9	81.0	71.9	*67.3*	*10.6*
Mon	12/15/2003	1910 hours	30 minutes	77.1	75.3	78.3	74.4	72.5	*75.5*	*2.3*
Wed	12/17/2003	1915 hours	30 minutes	86.0	84.0	85.3	79.2	77.2	*82.3*	*3.9*
Thu	12/18/2003	2030 hours	30 minutes	84.7	80.6	83.2	80.6	79.1	*81.7*	*2.3*
Sat	12/20/2003	1850 hours	30 minutes	98.1	96.9	96.9	95.5	96.2	*96.7*	*1.0*
Mon	12/22/2003	1930 hours	30 minutes	98.6	98.4	96.5	95.3	98.1	*97.4*	*1.4*
Tue	12/23/2003	1730 hours	30 minutes	103.0	97.6	98.6	93.9	99.4	*98.5*	*3.3*
Wed	12/24/2003	1730 hours	30 minutes	99.1	95.3	92.0	97.2	93.5	*95.4*	*2.8*
Fri	12/26/2003	2034 hours	30 minutes	97.0	93.7	91.4	94.7	93.4	*94.0*	*2.1*

For Crew B, the mean effectiveness for seven periods was 97.6 +/- 2.3% and 98.3 +/- 2.4%, respectively, for the two crew members who wore the WAM (Table IV).

Table IV. Summary of cognitive effectiveness for Crew B for last 30 minutes of Crew Day.

DAY	DATE	START TIME	DURATION	A/C	LM1
Wed	12/17/2003	1700 hours	30 minutes	93.0	96.6
Fri	12/19/2003	1815 hours	30 minutes	99.9	99.6
Sat	12/20/2003	1350 hours	30 minutes	97.8	95.1
Sun	12/21/2003	1830 hours	30 minutes	99.8	101.9
Tue	12/23/2003	1715 hours	30 minutes	96.7	100.3
Thu	12/25/2003	1800 hours	30 minutes	97.5	98.4
Sat	12/27/2003	2000 hours	30 minutes	98.4	96.3
Mean				97.6	98.3
SD				2.3	2.4

Discussion

For Mission 1 of Crew A, the mean cognitive effectiveness for the 4 mission periods, ranges from 86.8% to 65.5%, with the lowest value (65.5%) occurring just before the end of the crew day (Table II). These data suggest that this crew was probably quite impaired[2] by acute and cumulative fatigue plus jet-lag during their first mission. The model estimated that the two pilots would have been operating at approximately 60 % and 56% cognitive effectiveness, respectively, during the termination approach and landing at Camp Mirage. These numbers should be viewed as quite disturbing: the time for normal sleep occurs at about 90% cognitive effectiveness in the model. This is a situation in which one's brain is saying, "It's time for sleep," and not "It's time to begin work." Generally, it is best to keep workers with safety-sensitive jobs (aviators, drivers, command and control personnel, etc.) at 90% cognitive effectiveness or better while at work. This practice minimizes the risk that fatigue-induced, life-threatening errors will be made on the job.

For Crew A, the model illustrated in Appendix B and Table III also suggested that the crew probably continued to be impaired by acute and cumulative fatigue plus jet-lag

[2] Predicted cognitive effectiveness < 90%.

at the end of each of its first four crew days (7 days after deployment). In addition, there may have been some impairment at the ends of the termination sorties on each of those days. However, subsequent to the reasonably adequate acclimatization of acrophase to the new time zone (about day 7 on the actigrams or day 9 since deployment), the model suggested that this crew was probably not impaired by fatigue at the end of the crew day. Nor did there appear to be any time during these latter missions when the crew's cognitive effectiveness would have declined below 90%.

For Crew B, the model suggested that this crew was probably not impaired by acute or cumulative fatigue by the end of the crew day (Table IV). Nor did there appear to be any time during these missions when the crew's cognitive effectiveness would have declined below 90%.

However, there is one possible caveat to this latter observation: a crewmember may begin to experience "chronic fatigue" after several weeks of continuous operations. In addition to the acute fatigue, cumulative fatigue and circadian effects modeled in SAFTE and FAST™, we often observe a phenomenon that should be called "chronic fatigue." (The USAF Safety Center calls it "motivational exhaustion," and they use the name "chronic fatigue" to refer to cumulative fatigue. However, motivational exhaustion, or apathy, is only one symptom of chronic fatigue.) Chronic fatigue is mutually exclusive with chronic fatigue syndrome (CFS), though there are several overlapping symptoms.

Chronic fatigue may be specified when an individual displays, concurrently, four or more of the following symptoms: the desire to sleep, apathy, substantial impairment in short-term memory or concentration; muscle pain; multi-joint pain without swelling or redness; headaches of a new type, pattern or severity; unrefreshing sleep; and post-exertional malaise lasting for more than 24 hours. The symptoms must have persisted or recurred for at least one month, but less than six months, and should have one or more known sources such as boredom, unhappiness, disappointment, lack of sleep, and/or hard work.

The crew duty day times included in the analyses above, occurred primarily during daylight hours. The average crew day start and end times for the missions reported here (December 2003) for Crews A and B were 0544 hours and 1848 hours respectively. Previously, operations from CM were flown primarily at night, changing the estimated fatigue picture dramatically. The corresponding crew day start and end times for the CM missions as flown in September/October of 2003 were 0220 hours and 1541 hours respectively. The crew day durations were similar during both periods of operations. Appendix C discusses the cognitive effectiveness in Crews C and D during missions that took place in September/October time frame. The significant night flying component of this Fall 2003 schedule resulted in attrition of crew performance over time (see Crews C and D in Appendix C), whereas the December 2003 schedule flown by Crews A and B did not deteriorate, at least not after the crewmembers' acrophases acclimatized to the new time zone.

The quantitative assessment of fatigue patterns mediates risk management and begs for its use in safety-sensitive operations such as flight in a combat theatre. Even Napoleon recognized the need for fatigue management in combat when he admonished his commanders that they “must not needlessly fatigue the troops” (1796). However, Napoleon did not have the quantitative prediction and assessment tools that are available today. Nor, of course, did he have troops operating in the aerial environment. Given such quantitative, predictive tools, the failure of a commander to estimate and manage risk in safety-sensitive occupations is the ethical equivalent of condoning driving under the influence of alcohol and other impairing substances.

We know that military operations are likely to induce fatigue: we deploy rapidly across time zones, inducing jet-lag in our troops, and we operate with very long duty days and often at night. The human body and brain are not designed to deal adequately with these stresses. Thus, it is incumbent on commanders to estimate the potential impact of a specific operation on crew effectiveness and to provide risk management strategies to minimize the likelihood that fatigue-induced mishaps will occur, compromising the operation and needlessly increasing risk for the troops.

Recommended pharmacologic countermeasures

In the event that CM aircrew are again called upon to fly significant portions of these missions at night, we recommend that they be provided more rest opportunity between missions to improve their cognitive performance. However, should this extra rest opportunity demand day-time-only sleep with flight operations during the pre-dawn circadian nadir, we recommend planned, tactical employment of caffeine for these periods to enhance cognitive performance (2, 6). This employment would require limited chronic caffeine use (i.e., < 200 mg per day) and then carefully planned use for critical mission elements, such as operations around Kabul and termination approach and landing, that occur during the unavoidable nadir in crewmember performance. The potential for caffeine-induced diuresis and subsequent dehydration is easily manageable (2). Alternatively, caffeine may be presented in the form of chewing gum (8).

To preclude jet-lag-induced performance impact on crews arriving in theatre, we offer a pharmacologic countermeasure to advance their circadian rhythms using a 5-day protocol (5 doses) commencing at home with a single dose, taken at 1600 hours, each of 2 days prior to deployment, another dose at 1600 hours (Trenton time) on the aircraft en route to CM, and the final 2 doses at local bedtime in CM for each of the first 2 days in theatre, ending the night before they commence tactical airlift operations. Melatonin is a naturally occurring hormone synthesized by the pineal gland from the precursor amino acid tryptophan (4). In pharmacologic doses, melatonin has a large margin of safety (4), producing a mild soporific effect with minimal side-effects.

Over the last 15 years, considerable work has been done demonstrating that properly timed doses of melatonin can attenuate the effects of jet-lag (1, 5, 7, 9, 16-21) by either advancing circadian rhythms for westward travel or by retarding circadian rhythms for eastward travel. Typically, circadian rhythms are advanced by late afternoon doses of melatonin (to advance the arrival of ‘physiologic night’) and are retarded by morning ingestion of melatonin (to extend ‘physiologic night’ and thus delay circadian rhythms. The melatonin doses used to effect these changes in circadian rhythms have ranged from 1.5 mg of surge-sustained release melatonin (18) to 10 mg of regular release melatonin (7). Based on DRDC-Toronto sleep facilitation research in support of Air Transport Aircrews (10-12, 14), the Canadian Forces (CF) Central Medical Board (CMB) has drafted new recommendations (13) for short-term flight-surgeon-supervised use of selected pharmaceutical agents (melatonin, zaleplon, and zopiclone) to facilitate sleep in aircrew during missions which are known to impact on crew sleep (Appendix E).

Given the very significant flight safety risk inherent in the existing practice of rotating freshly deployed crews (2 days after arrival in theatre) into the flow of Tactical Airlift missions, and fact that the CF has policy in place to allow the use of melatonin in support of our Air Transport aircrews, we recommend that as soon as possible, all aircrew deploying from 8 Wing to CM be provided 5 doses (over 5 days) of Circadin ® (a sustained release formulation of melatonin) to pharmacologically advance their circadian rhythms in order to improve their sleep efficiency prior to their first mission after deployment to CM. These 4 mg Circadin ® doses would first be taken at home at 1600 hours for each of 2 days prior to deployment, with a third dose taken at 1600 hrs (Trenton time) on the aircraft on the day of travel, and the last 2 doses would be taken the first two days in theatre at local bedtime. About a week prior to deployment, each of the participating aircrew would be given a trial of this 4 mg Circadin ® dose in order to rule out any idiosyncratic reactions before committing to the entire melatonin-induced circadian advancement protocol. To date, of the 219-aircrew from 8 Wing who have participated in an operational evaluation of melatonin and zopiclone during air transport operations to Bosnia, no one has had an idiosyncratic reaction to these medications, and all have reported improved sleep.

The notion of using melatonin to pharmacologically advance circadian rhythms in our aircrew presents an opportunity to objectively document to what extent such an intervention is efficacious. In this case, the arbiter of efficacy will be wrist actigraphy. If the actigraphic data demonstrates that our melatonin formulation/dose raises sleep efficiency from the 47% reported in Crew A to a more normal 82% reported by Crew B, then we will have succeeded. If the actigraphic data shows an improvement, but the improvement is not as good as we require (say significantly less than 80% sleep efficiency), then we will know that our formulation/dose regimen needs to be further optimized. In order to advance our state of knowledge with respect to phase shifting circadian rhythms, we need CF stakeholder endorsement of this approach as well as funding support.

Because melatonin is not yet approved for general use in Canada, it is recommended that the CF pharmacy specialists apply to the Special Access Program of Health Canada for regulatory approval to use melatonin.

While we are awaiting regulatory approval from Health Canada for operational use of melatonin via the Special Access Program, we recommend that aircrew arriving in theatre be given pharmacologic sleep support with either zopiclone or zaleplon while under the direct supervision of the CM flight surgeon for the first few nights in theatre.

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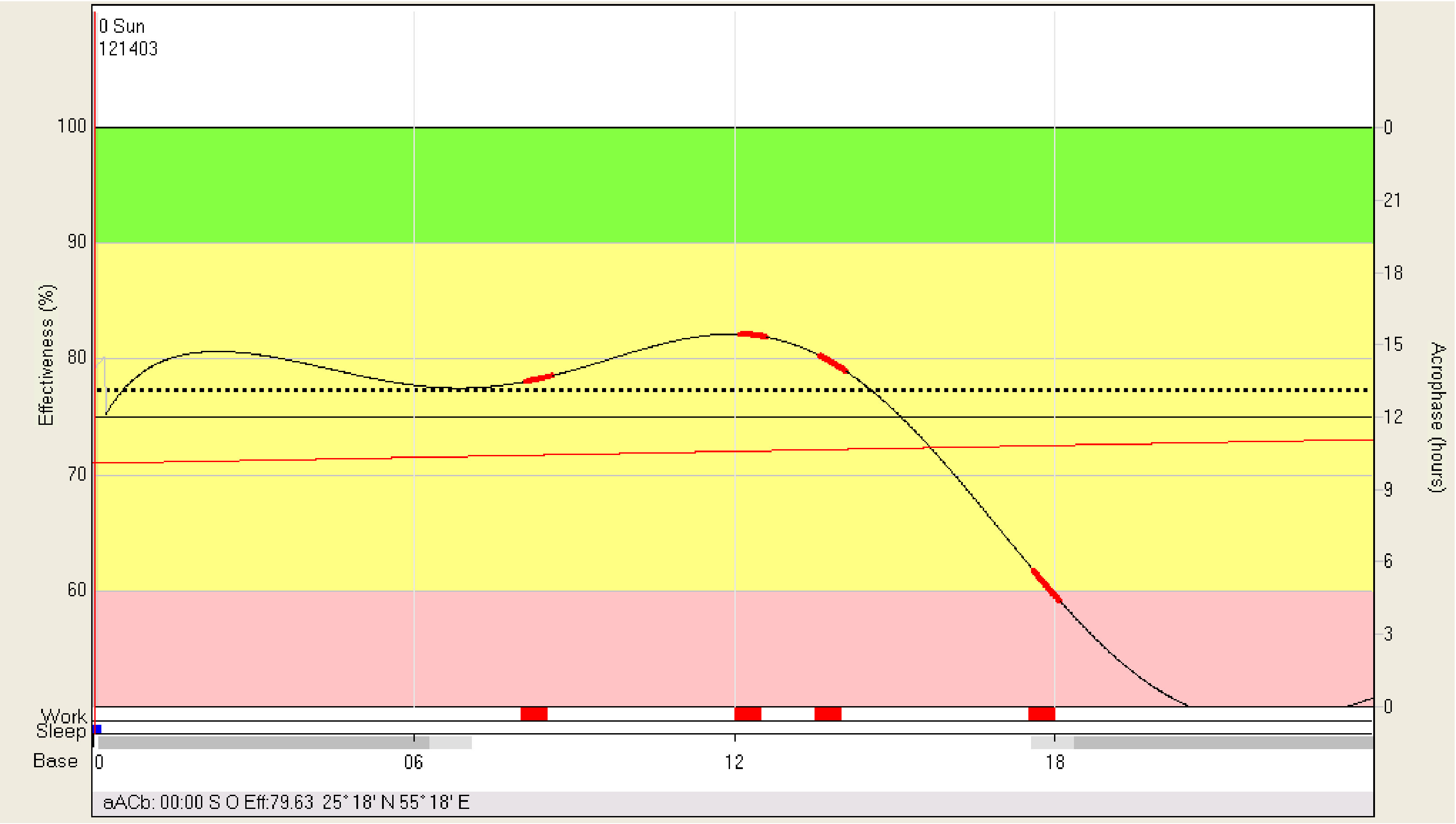
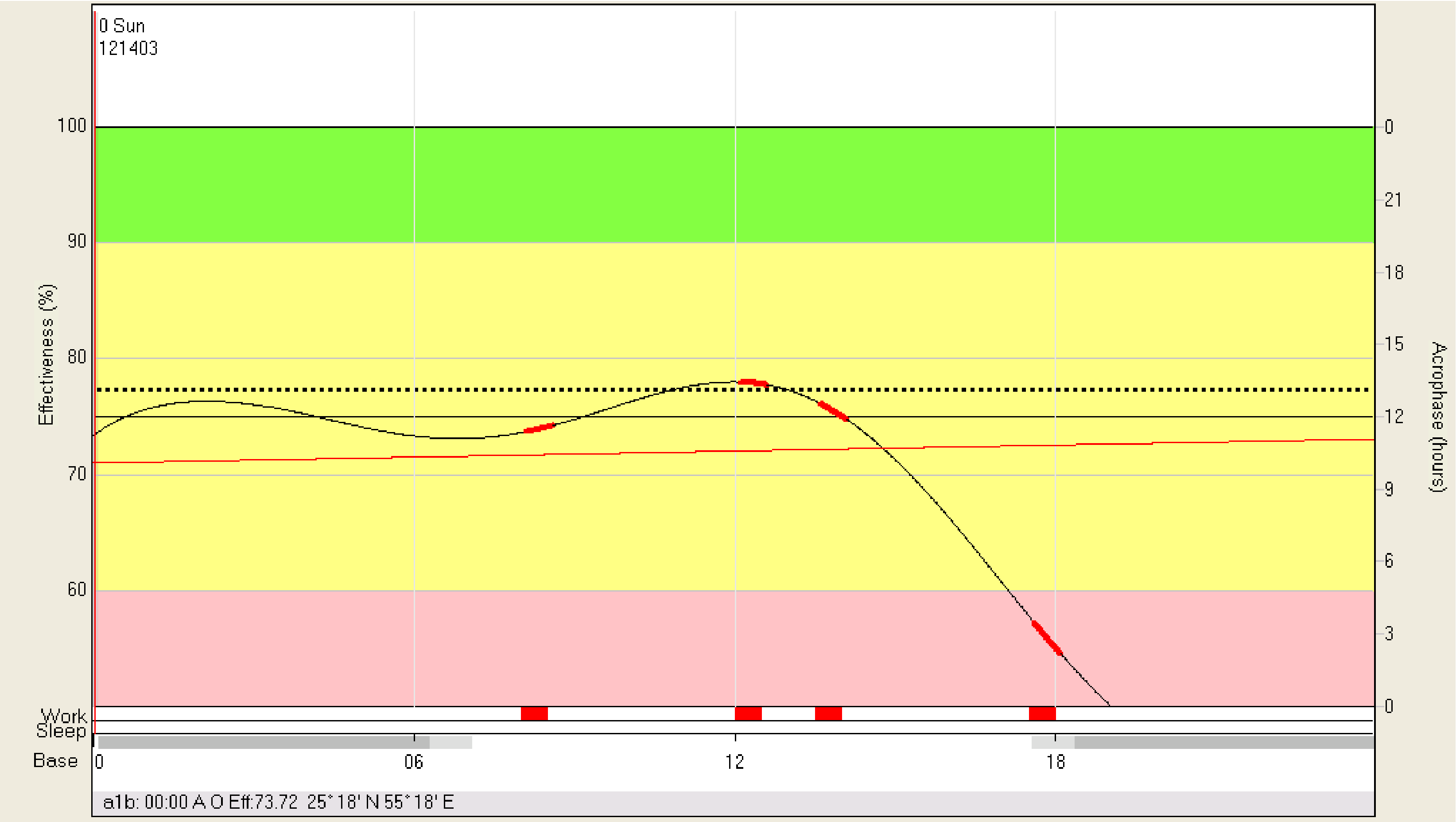
Appendix A: FAST™ Graphs for Individual Crewmembers (Method 1)

Crew A, A/C:

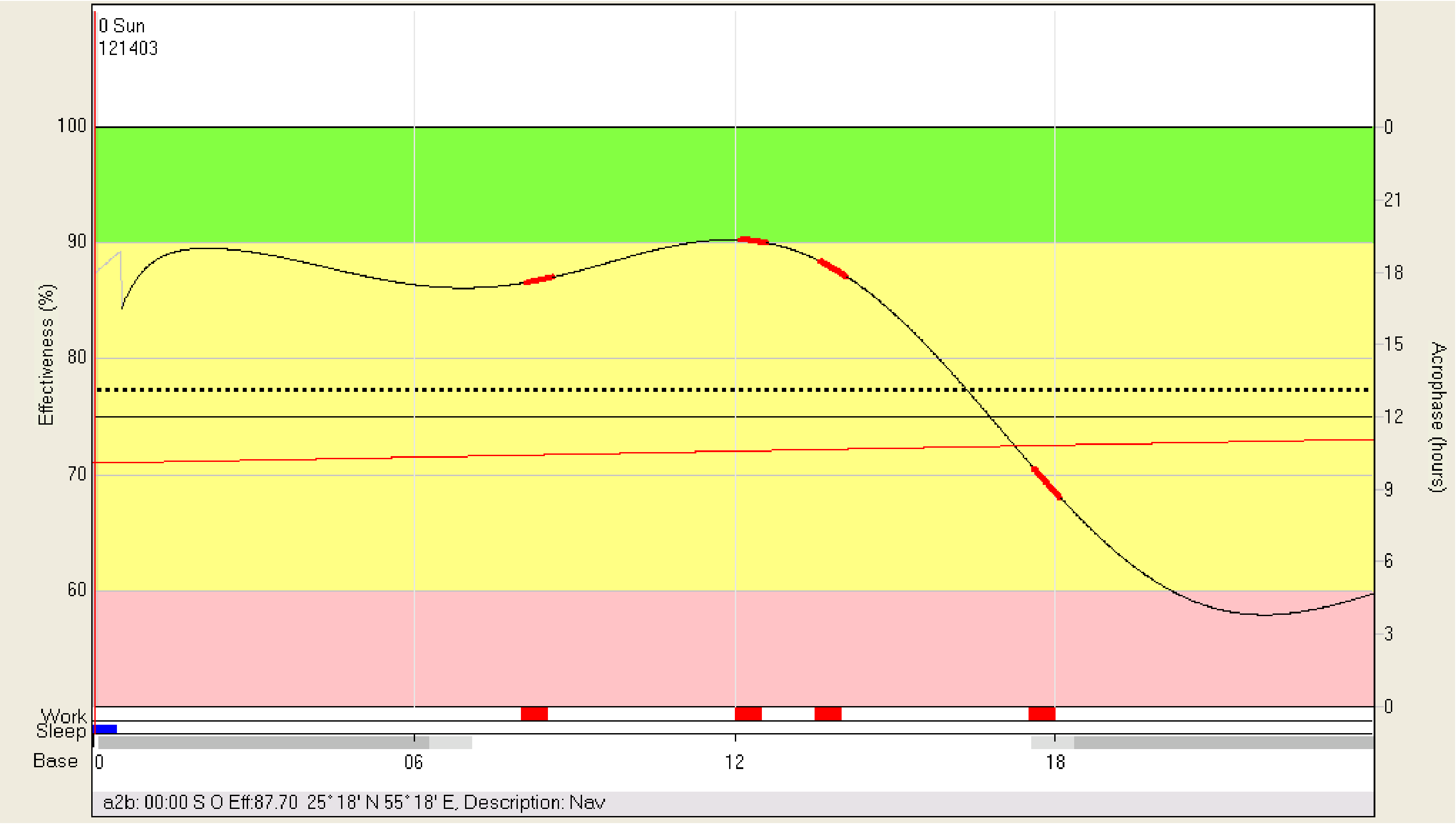


Crew A, F/O:



0 Sun
121403
100
90
80
70
60
Effectiveness (%)
Work
Sleep
Base
0
06
12
18
0
21
18
15
12
9
6
3
0
Acrophase (hours)
a1b: 00:00 A O Eff:73.72 25° 18' N 55° 18' E

Crew A, NAV:



0 Sun
121403
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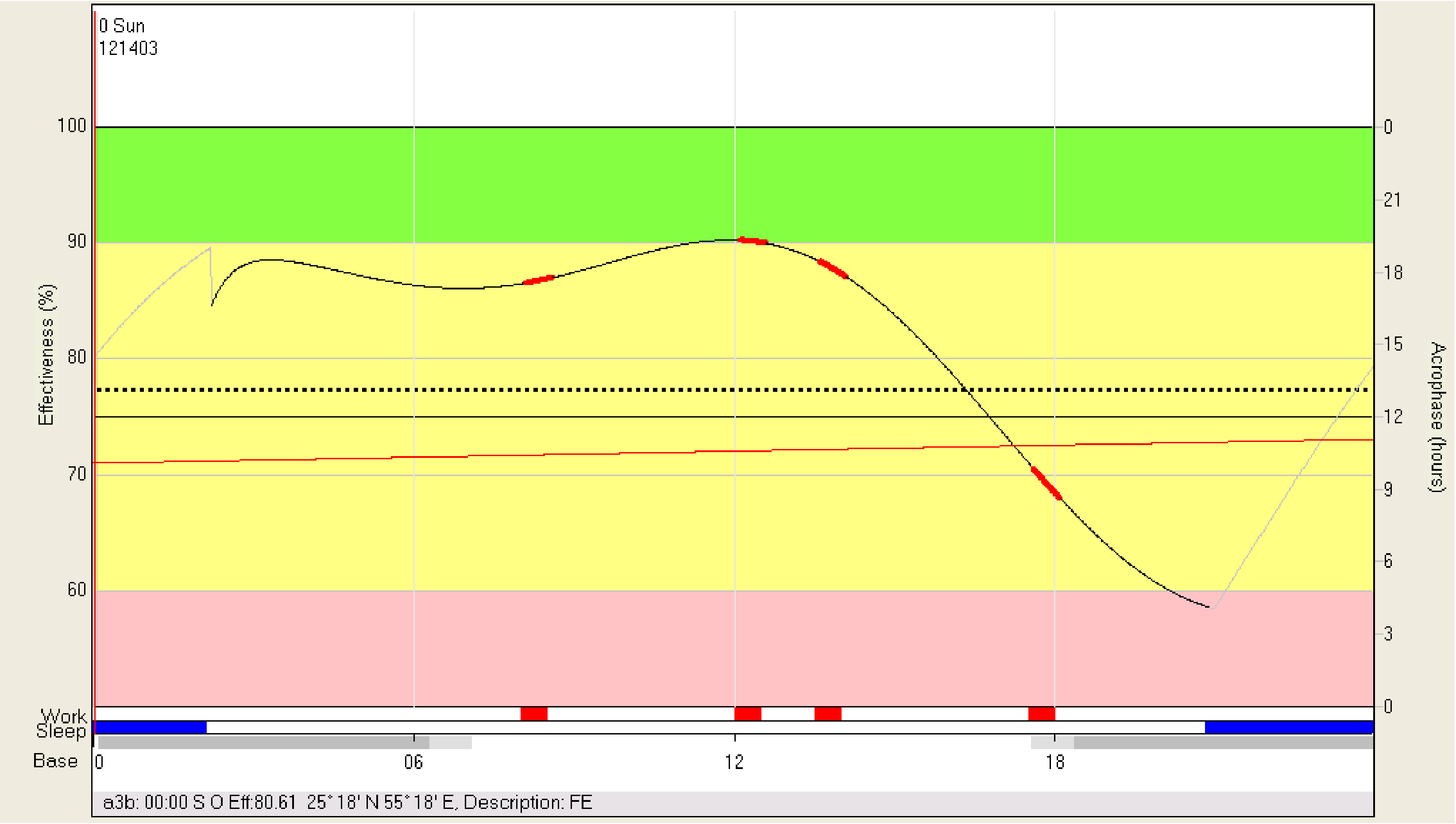
90
80
70
60
Effectiveness (%)
Work
Sleep
Base
0
06
12
18
0
21
18
15
12
9
6
3
0
Acrophase (hours)
a2b: 00:00 S O Eff:87.70 25° 18' N 55° 18' E, Description: Nav

Crew A, F/E:


0 Sun
121403
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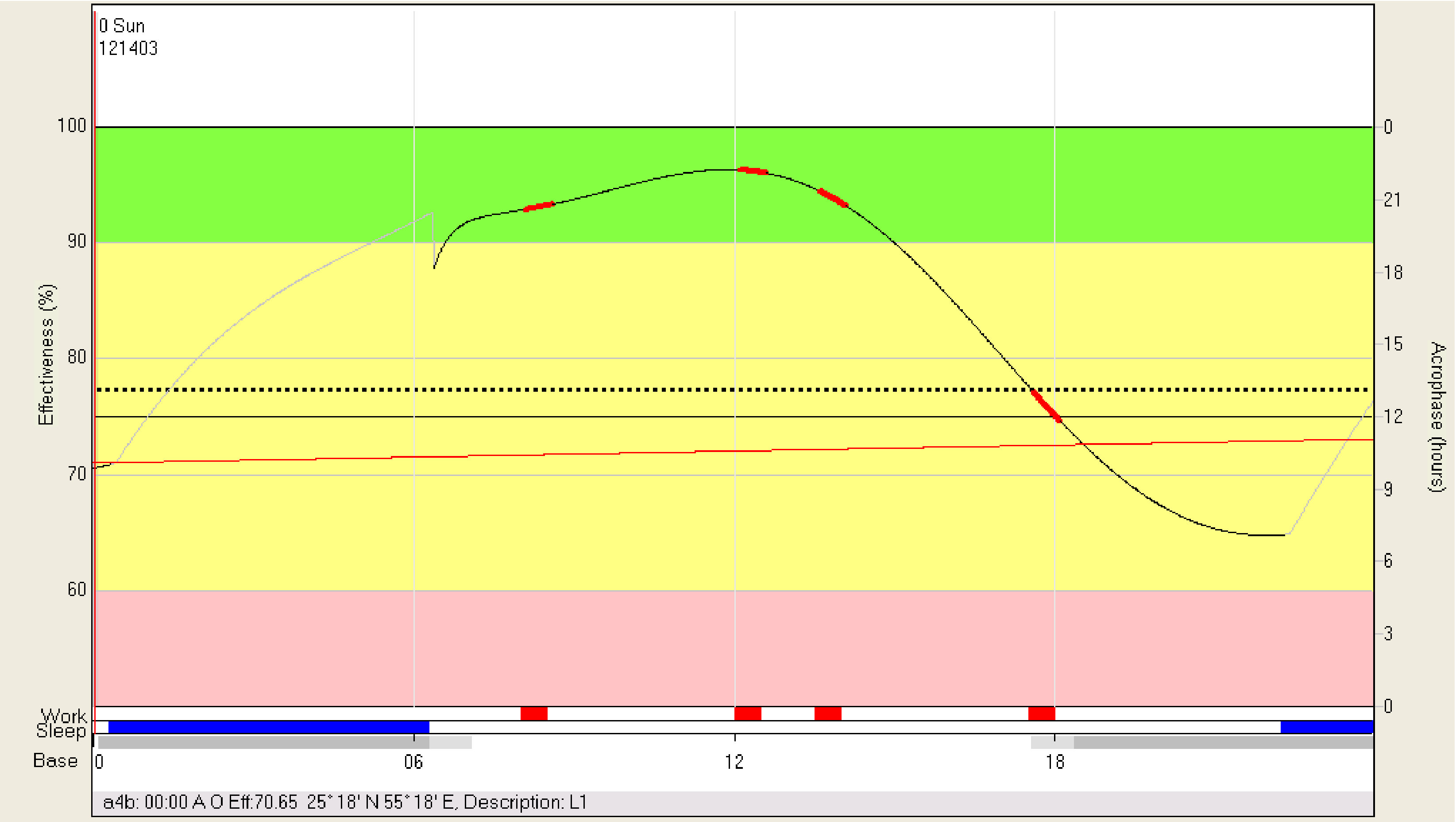
90
80
70
60
Effectiveness (%)
Work
Sleep
Base
0
06
12
18
0
21
18
15
12
9
6
3
0
Acrophase (hours)
a3b: 00:00 S O Eff:80.61 25° 18' N 55° 18' E, Description: FE

CREW A, LM1:


0 Sun
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Effectiveness (%)
Work
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Base
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06
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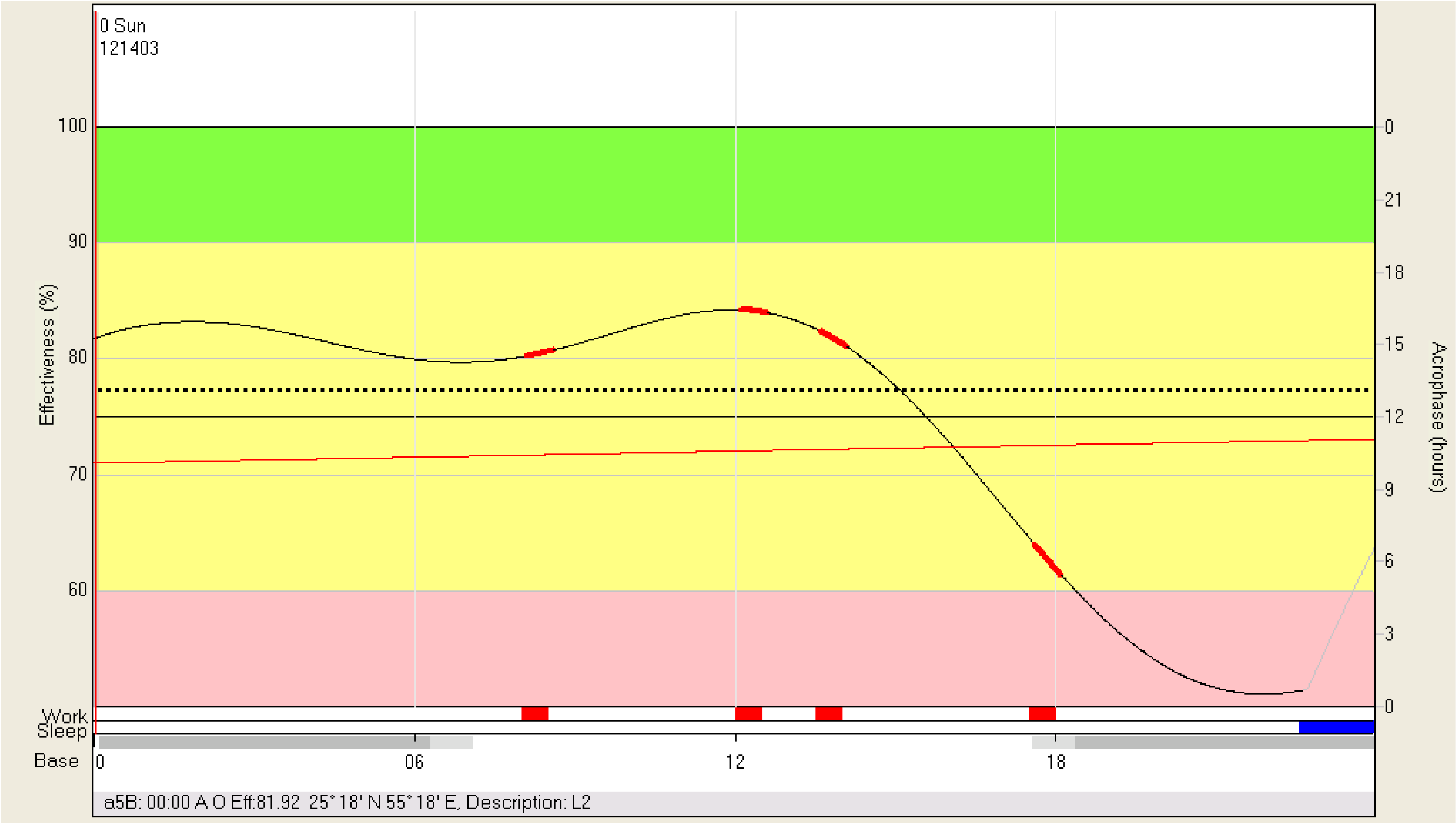
18
15
12
9
6
3
0
Acrophase (hours)
a4b: 00:00 A O Eff:70.65 25° 18' N 55° 18' E, Description: L1

Crew A, LM2:



0 Sun
121403
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70
60
Effectiveness (%)
Work
Sleep
Base
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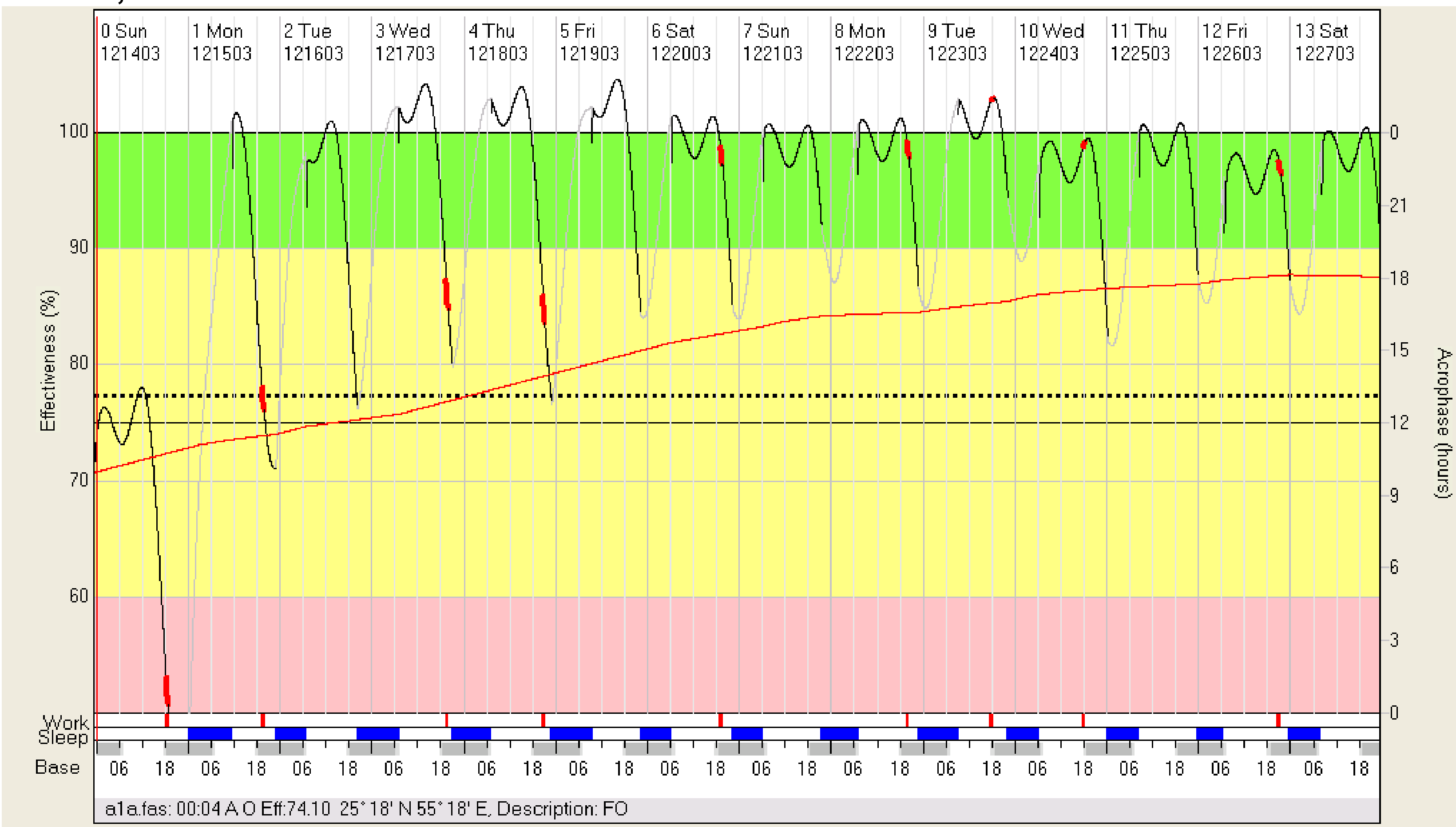
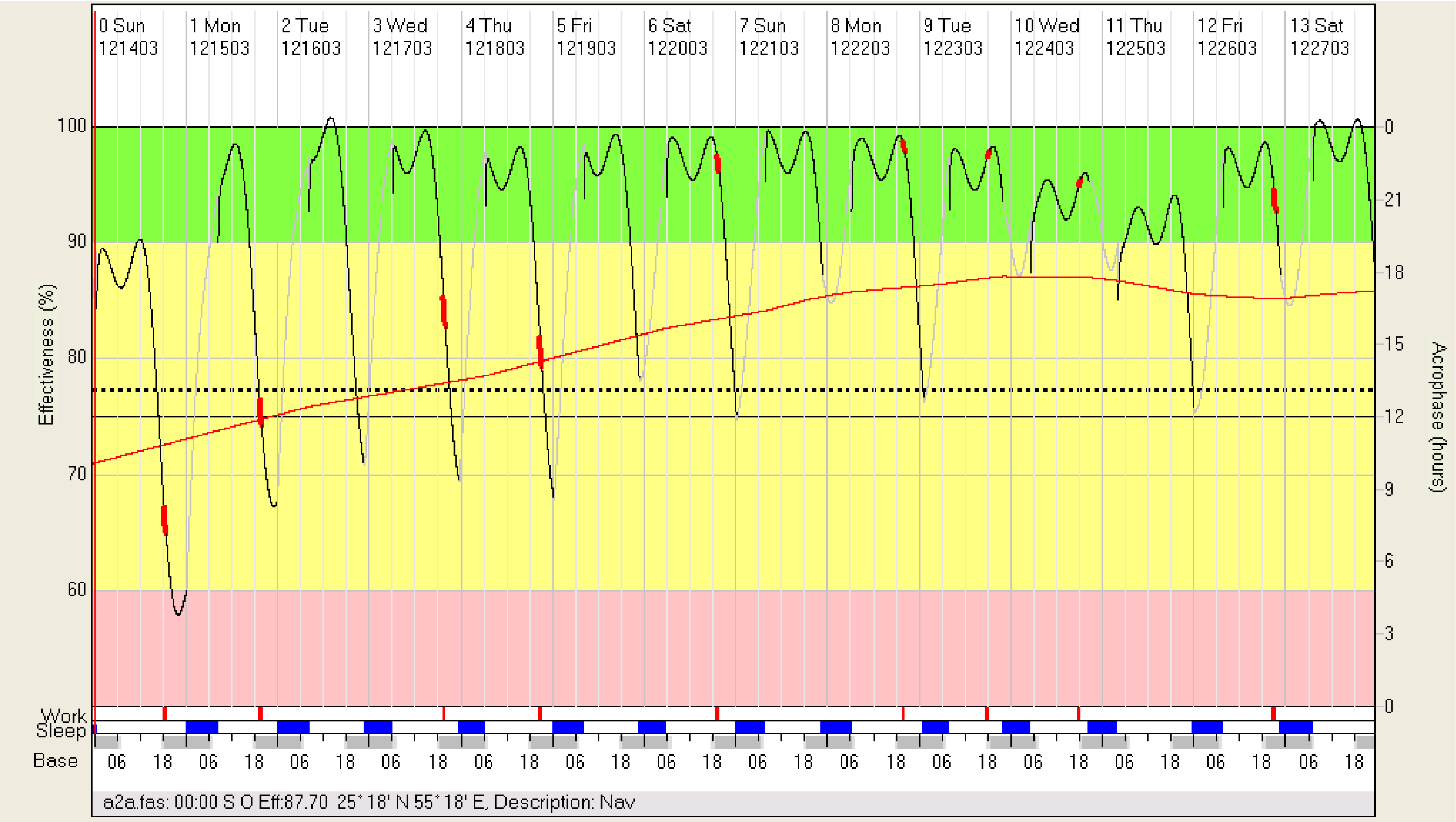
06
12
18
0
21
18
15
12
9
6
3
0
Acrophase (hours)
a5B: 00:00 A O Eff:81.92 25° 18' N 55° 18' E, Description: L2

Appendix B: FAST™ Graphs for Individual Crewmembers (Method 2)

Crew A, F/O:

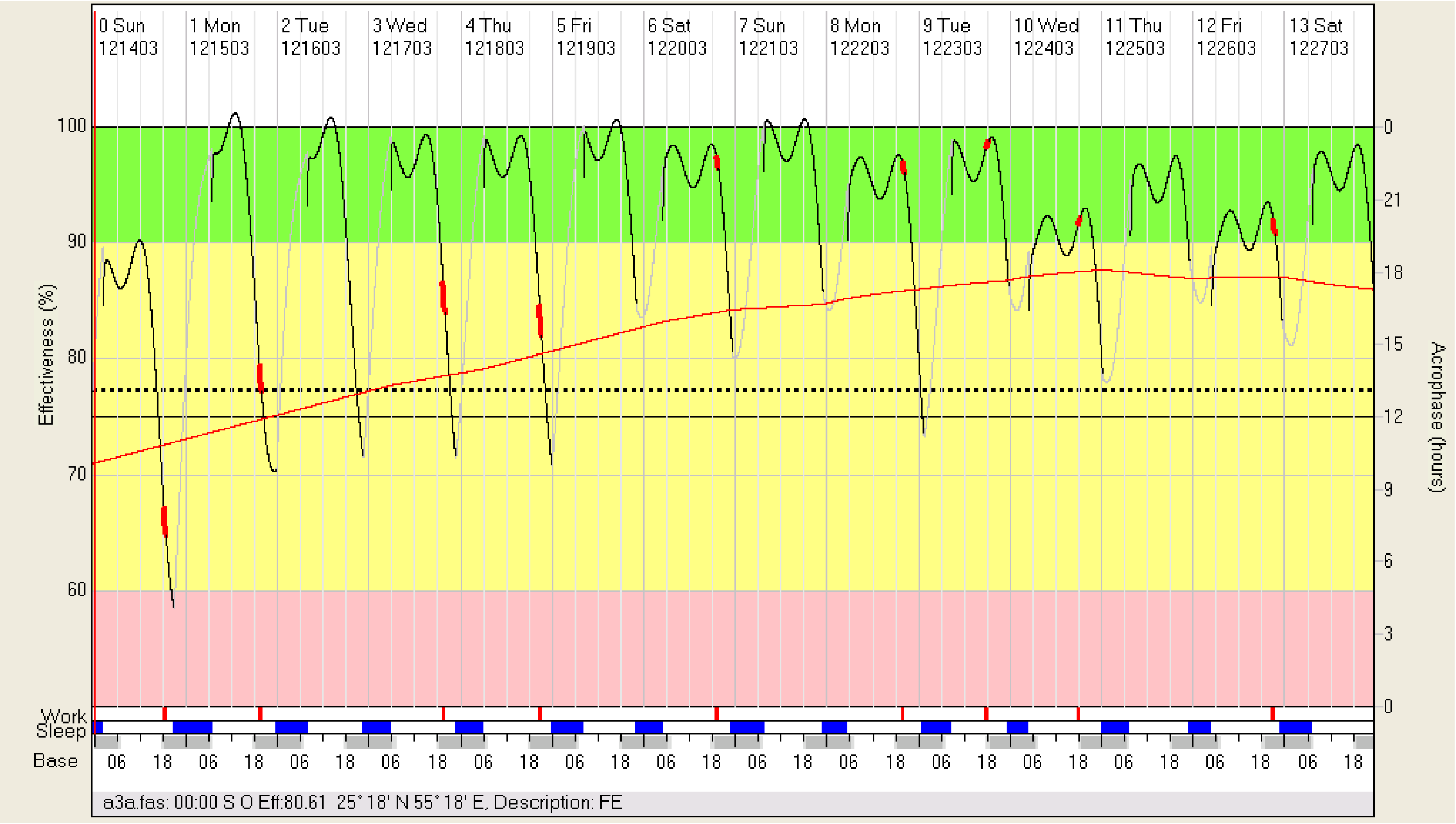


Crew A, Nav:



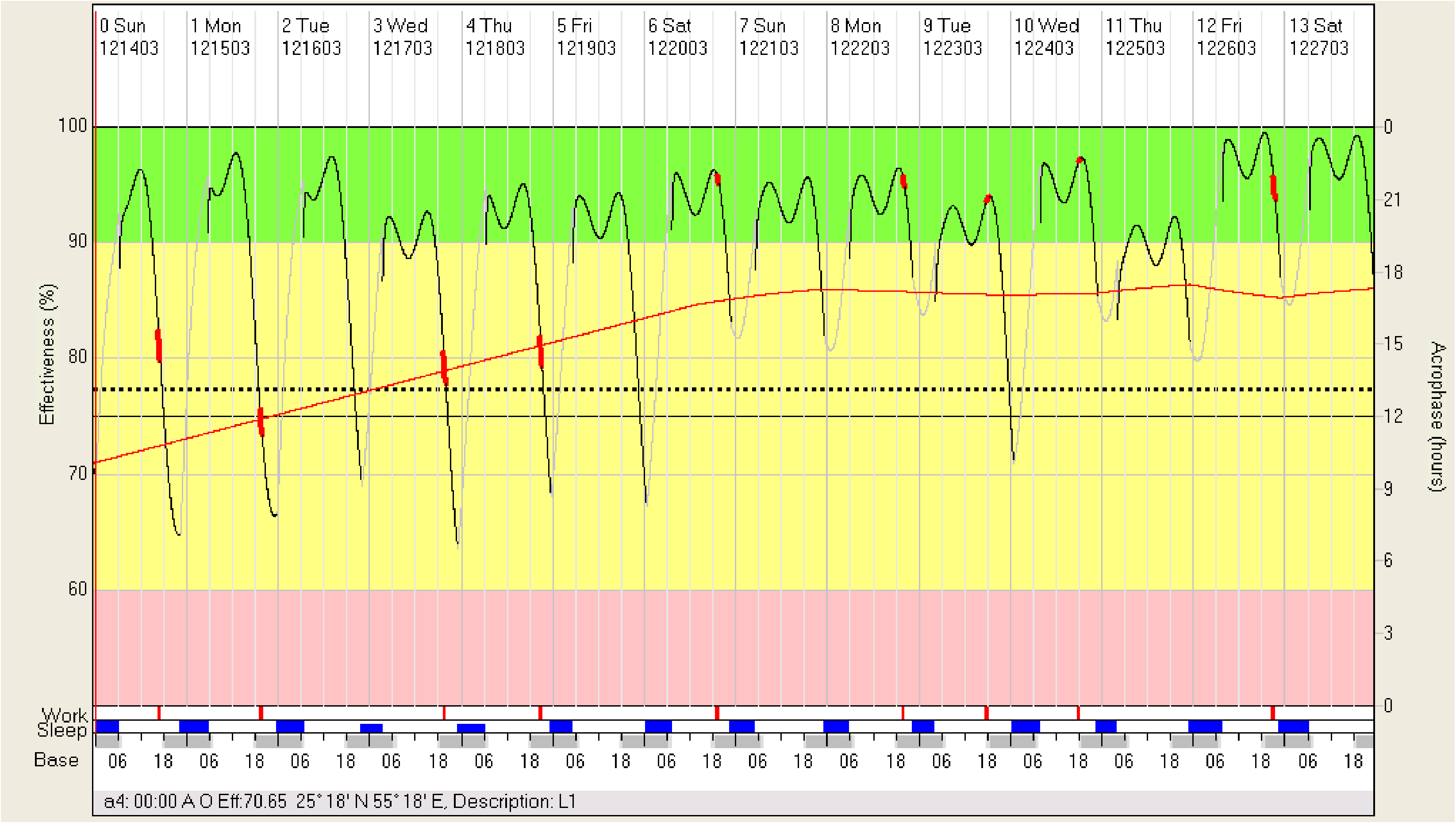
0 Sun 121403
1 Mon 121503
2 Tue 121603
3 Wed 121703
4 Thu 121803
5 Fri 121903
6 Sat 122003
7 Sun 122103
8 Mon 122203
9 Tue 122303
10 Wed 122403
11 Thu 122503
12 Fri 122603
13 Sat 122703
Effectiveness (%)
100
90
80
70
60
Acrophase (hours)
0
21
18
15
12
9
6
3
0
Work
Sleep
Base
06 18 06 18 06 18 06 18 06 18 06 18 06 18 06 18 06 18 06 18 06 18 06 18 06 18 06 18
a2a.fas: 00:00 S O Eff:87.70 25° 18' N 55° 18' E, Description: Nav

Crew A, F/E:



0 Sun 121403
1 Mon 121503
2 Tue 121603
3 Wed 121703
4 Thu 121803
5 Fri 121903
6 Sat 122003
7 Sun 122103
8 Mon 122203
9 Tue 122303
10 Wed 122403
11 Thu 122503
12 Fri 122603
13 Sat 122703
Effectiveness (%)
100
90
80
70
60
Acrophase (hours)
0
21
18
15
12
9
6
3
0
Work
Sleep
Base
06 18 06 18 06 18 06 18 06 18 06 18 06 18 06 18 06 18 06 18 06 18 06 18 06 18 06 18
a3a.fas: 00:00 S O Eff:80.61 25° 18' N 55° 18' E, Description: FE

Crew A, LM1:



0 Sun 121403
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2 Tue 121603
3 Wed 121703
4 Thu 121803
5 Fri 121903
6 Sat 122003
7 Sun 122103
8 Mon 122203
9 Tue 122303
10 Wed 122403
11 Thu 122503
12 Fri 122603
13 Sat 122703
100
90
80
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60
Effectiveness (%)
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21
18
15
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3
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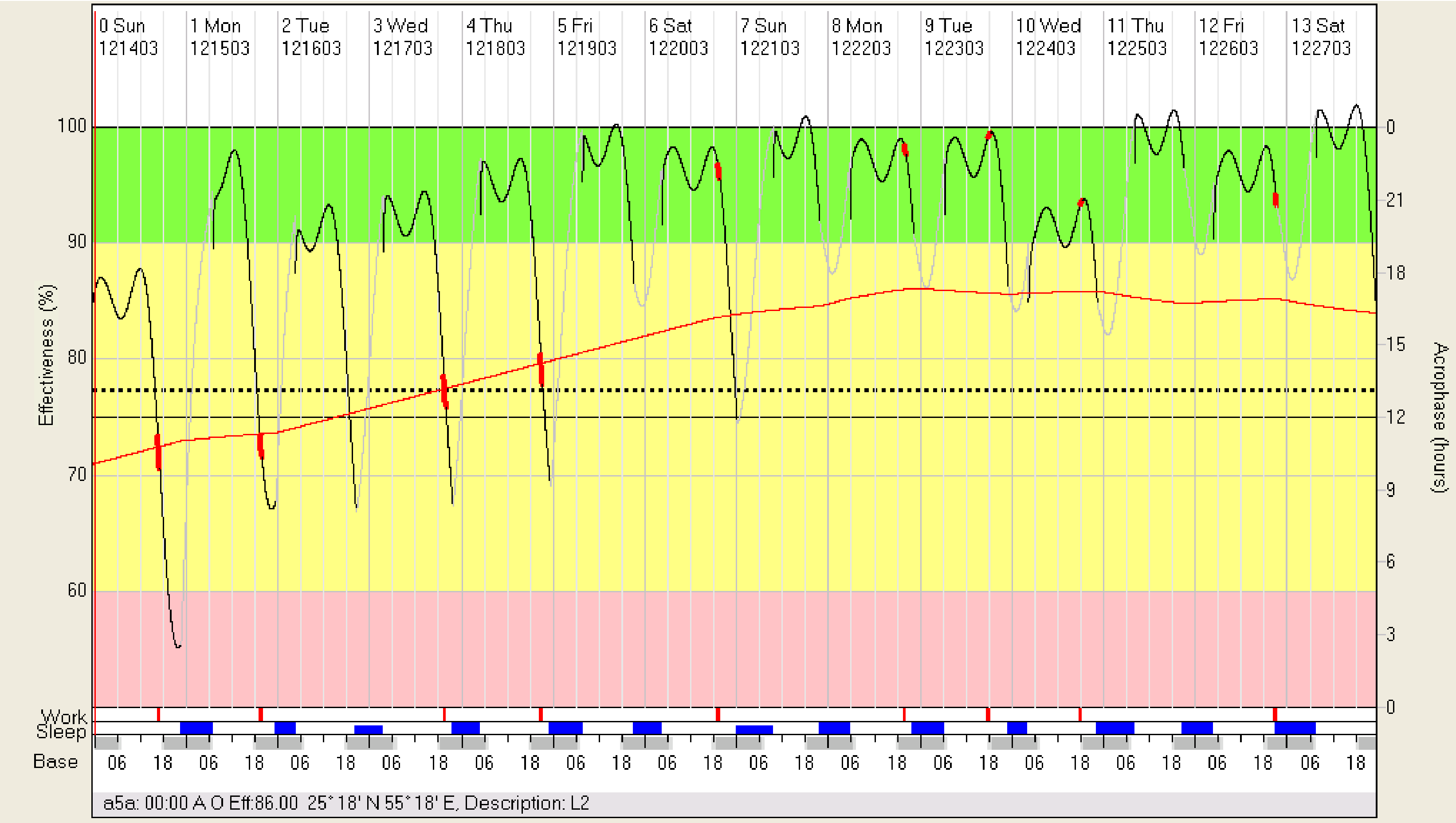
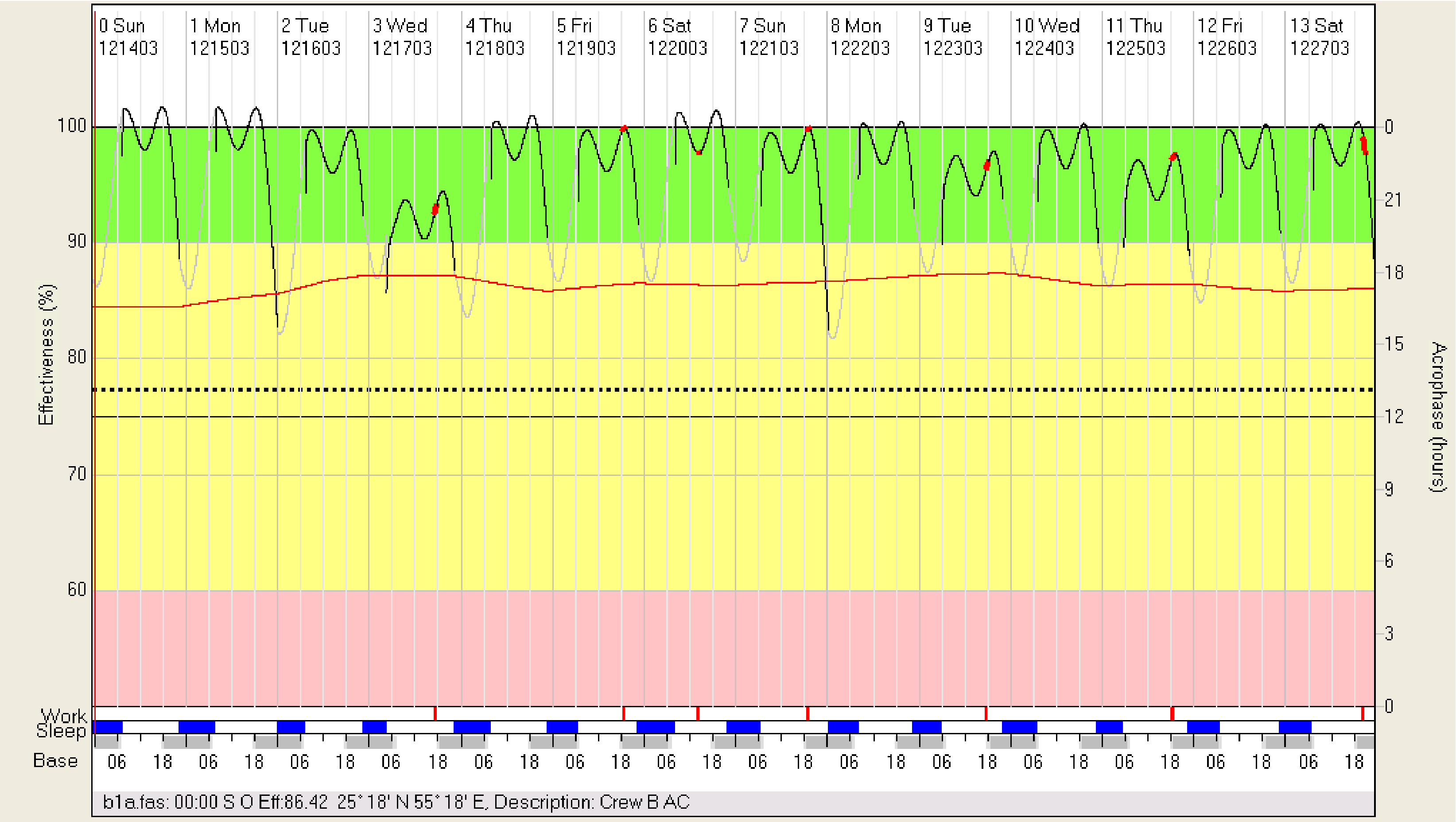
Acrophase (hours)
Work
Sleep
Base
06 18 06 18 06 18 06 18 06 18 06 18 06 18 06 18 06 18 06 18 06 18 06 18 06 18 06 18
a4: 00:00 A O Eff:70.65 25° 18' N 55° 18' E, Description: L1

Crew A, LM2:



NOTE: last work period of A5 overlaps subsequent sleep period.

Crew B, A/C:



0 Sun 121403
1 Mon 121503
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3 Wed 121703
4 Thu 121803
5 Fri 121903
6 Sat 122003
7 Sun 122103
8 Mon 122203
9 Tue 122303
10 Wed 122403
11 Thu 122503
12 Fri 122603
13 Sat 122703
Effectiveness (%)
100
90
80
70
60
Acrophase (hours)
0
21
18
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6
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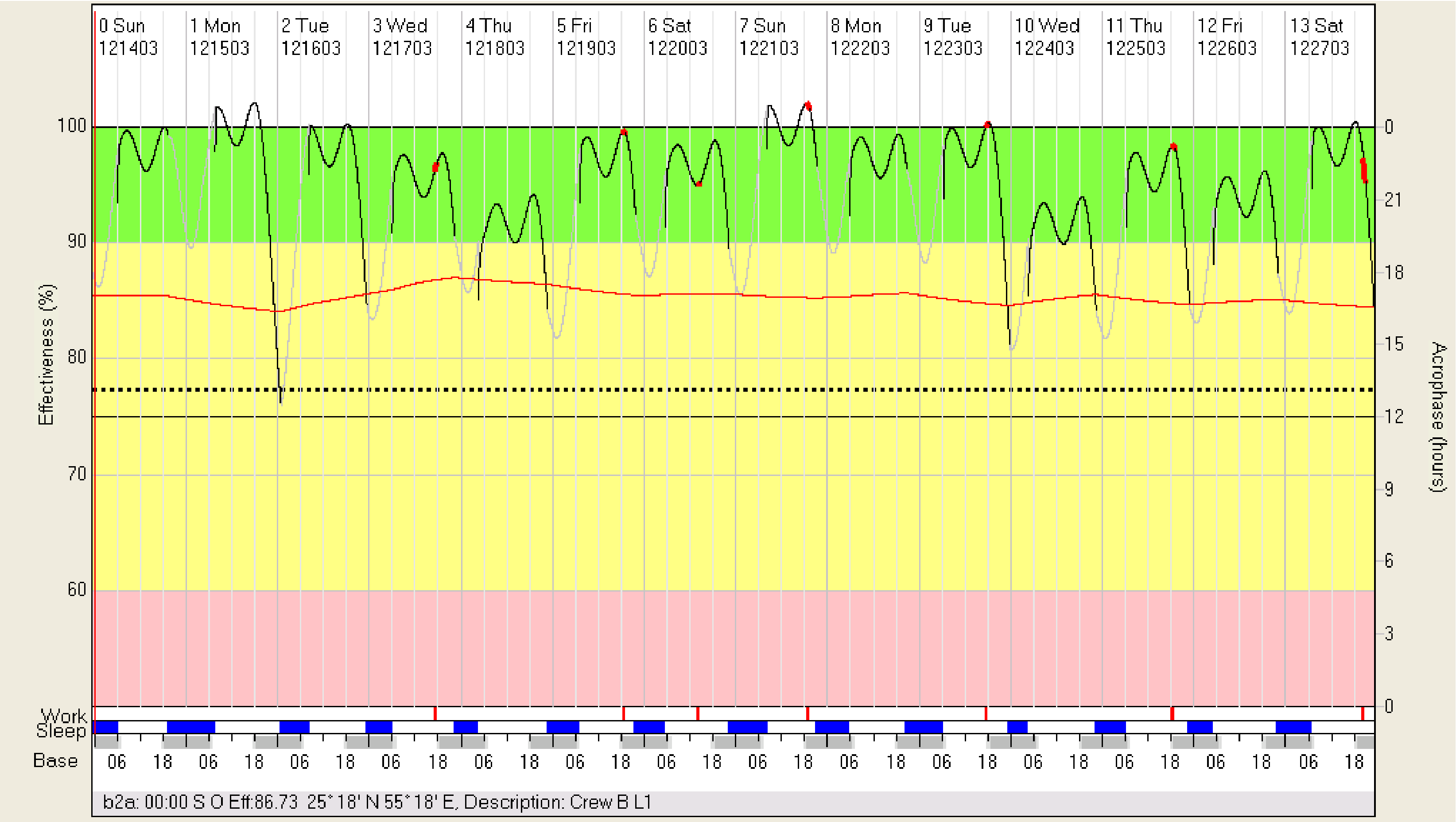
Work
Sleep
Base
06 18 06 18 06 18 06 18 06 18 06 18 06 18 06 18 06 18 06 18 06 18 06 18 06 18 06 18
b1a.fas: 00:00 S O Eff:86.42 25° 18' N 55° 18' E, Description: Crew B AC

Crew B, LM1:



0 Sun 121403
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4 Thu 121803
5 Fri 121903
6 Sat 122003
7 Sun 122103
8 Mon 122203
9 Tue 122303
10 Wed 122403
11 Thu 122503
12 Fri 122603
13 Sat 122703
Effectiveness (%)
100
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Acrophase (hours)
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Work
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Base
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b2a: 00:00 S O Eff:86.73 25° 18' N 55° 18' E, Description: Crew B L1

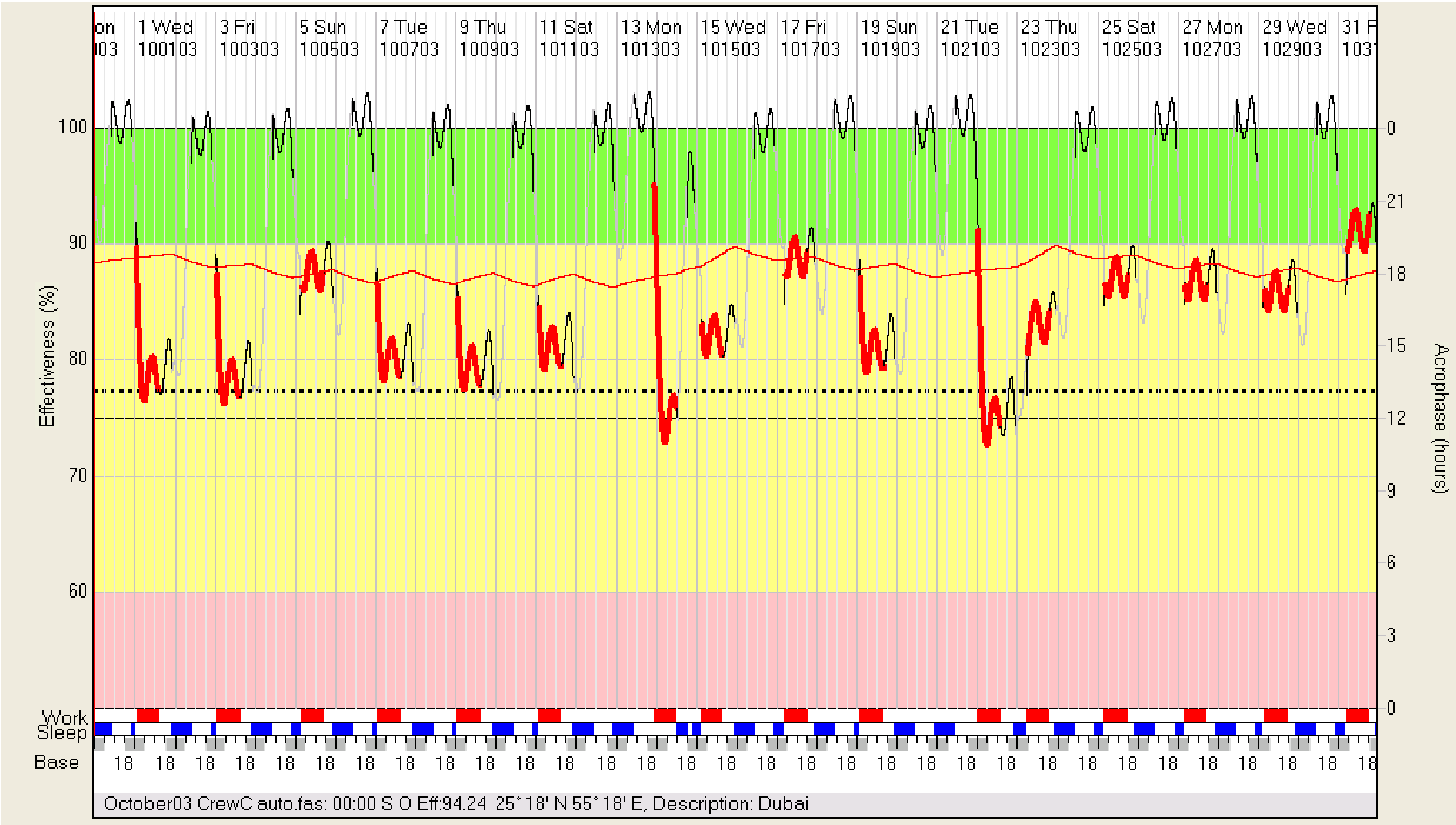
Appendix C: Fatigue assessment for the Fall 2003 flying schedule from Camp Mirage

The daily, 2-crew, CC-130 duty-day schedule for tactical airlift operations from CM from about October 2003 (nominal period) was entered into FAST^{TM}. Crew C flew on odd days, and Crew D flew on even days. Next, a sleep prediction function (AutoSleep) was executed within FAST^{TM}. It's parameter values included: maximum sleep period of 12 hours, minimum sleep period of 60 minutes, normal bedtime at 2200 hrs, a 1-hour "commute" between sleep and operations, and a "forbidden zone" for sleep during 1800-2200 hours. Finally, the FAST^{TM} prediction of percent cognitive effectiveness for each of the missions was tabulated and averaged.

Figure C-1 shows the FAST^{TM} prediction of sleep and effectiveness for Crew C, and Figure C-2 shows the FAST^{TM} prediction of sleep and effectiveness for Crew D. Table C-I shows the predicted cognitive effectiveness for each mission of Crew C. The mean predicted cognitive effectiveness across duty days was about 83%. Table C-II shows the predicted cognitive effectiveness for each mission of Crew D. The mean predicted cognitive effectiveness across duty days was, again, about 83%.

Generally, predicted cognitive effectiveness for the crews was unacceptable, i.e., less than 90%, for all duty days.

FAST[TM] prediction of sleep and effectiveness for Crew C.



FAST[TM] prediction of sleep and effectiveness for Crew D.

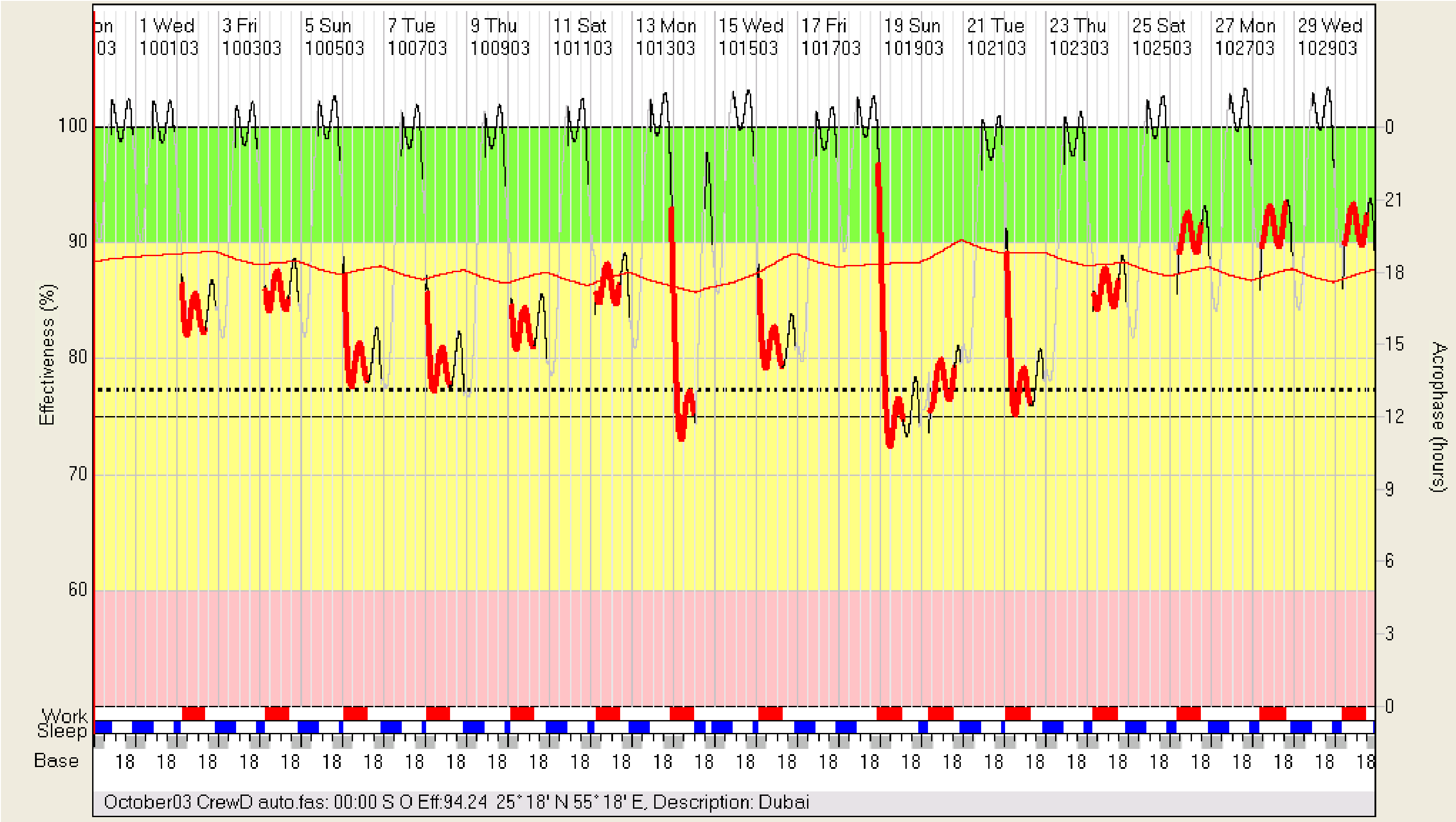


Table C-I. Predicted cognitive effectiveness for each mission of Crew C

START			**END**			**STATS**	
Day	***Date***	***Time***	***Day***	***Date***	***Time***	***Duration(min)***	***Efficiency(%)***
Wed	10/1/2003	1:00	Wed	10/1/2003	13:59	780	79.6
Fri	10/3/2003	1:00	Fri	10/3/2003	14:59	840	78.8
Sun	10/5/2003	3:40	Sun	10/5/2003	16:39	780	87.4
Tue	10/7/2003	1:00	Tue	10/7/2003	14:19	800	80.4
Thu	10/9/2003	1:00	Thu	10/9/2003	14:09	790	79.7
Sat	10/11/2003	1:30	Sat	10/11/2003	14:29	780	81.1
Mon	10/13/2003	22:30	Tue	10/14/2003	11:29	780	78.3
Wed	10/15/2003	3:00	Wed	10/15/2003	14:59	720	82.0
Fri	10/17/2003	4:30	Fri	10/17/2003	17:39	790	88.6
Sun	10/19/2003	1:30	Sun	10/19/2003	15:29	840	81.0
Tue	10/21/2003	23:30	Wed	10/22/2003	12:59	810	76.9
Thu	10/23/2003	5:30	Thu	10/23/2003	18:29	780	83.1
Sat	10/25/2003	4:00	Sat	10/25/2003	17:29	810	86.9
Mon	10/27/2003	3:30	Mon	10/27/2003	16:44	795	86.6
Wed	10/29/2003	3:00	Wed	10/29/2003	16:59	840	85.7
Fri	10/31/2003	4:30	Fri	10/31/2003	17:59	810	91.1
mean						796.6	83.0

Table C-II. Predicted cognitive effectiveness for each mission of Crew D.

START			END			STATS	
Day	***Date***	***Time***	***Day***	***Date***	***Time***	***Duration(min)***	***Efficiency (%)***
Thu	10/2/2003	3:00	Thu	10/2/2003	15:59	780	83.8
Sat	10/4/2003	3:20	Sat	10/4/2003	16:29	790	85.6
Mon	10/6/2003	1:00	Mon	10/6/2003	13:59	780	80.0
Wed	10/8/2003	1:00	Wed	10/8/2003	13:59	780	79.5
Fri	10/10/2003	2:00	Fri	10/10/2003	14:49	770	82.5
Sun	10/12/2003	3:00	Sun	10/12/2003	16:29	810	86.2
Mon	10/13/2003	22:30	Tue	10/14/2003	11:29	780	77.7
Thu	10/16/2003	1:30	Thu	10/16/2003	14:29	780	81.3
Sat	10/18/2003	22:30	Sun	10/19/2003	12:29	840	78.3
Mon	10/20/2003	4:30	Mon	10/20/2003	18:29	840	77.8
Wed	10/22/2003	1:00	Wed	10/22/2003	14:29	810	78.4
Fri	10/24/2003	3:30	Fri	10/24/2003	17:29	840	85.8
Sun	10/26/2003	4:30	Sun	10/26/2003	17:29	780	90.7
Tue	10/28/2003	4:30	Tue	10/28/2003	18:44	855	91.4
Thu	10/30/2003	4:30	Thu	10/30/2003	17:29	780	91.4
mean						801.0	83.4

Appendix D: Sleep, Activity, Fatigue and Task Effectiveness (SAFTE) Model

Fatigue Avoidance Scheduling Tool (*FAST*™)

The Sleep, Activity, Fatigue and Task Effectiveness (SAFTE) model integrates quantitative information about (1) circadian rhythms in metabolic rate, (2) cognitive performance recovery rates associated with sleep, and cognitive performance decay rates associated with wakefulness, and (3) cognitive performance effects associated with sleep inertia to produce a 3-process model of human cognitive effectiveness.

- The SAFTE model has been under development by Dr. Steven Hursh for more than a decade. Dr. Hursh, formerly a research scientist with the Army, is employed by SAIC (Science Applications International Corporation) and Johns Hopkins University and is currently under contract to the WFC (Warfighter Fatigue Countermeasures) R&D Group and NTI, Inc. to modify and expand the model.
- The general architecture of the SAFTE model is shown in Figure 1. A circadian process influences both cognitive effectiveness and sleep regulation. Sleep regulation is dependent upon hours of sleep, hours of wakefulness, current sleep debt, the circadian process and sleep fragmentation (awakenings during a sleep period). Cognitive effectiveness is dependent upon the current balance of the sleep regulation process, the circadian process, and sleep inertia.

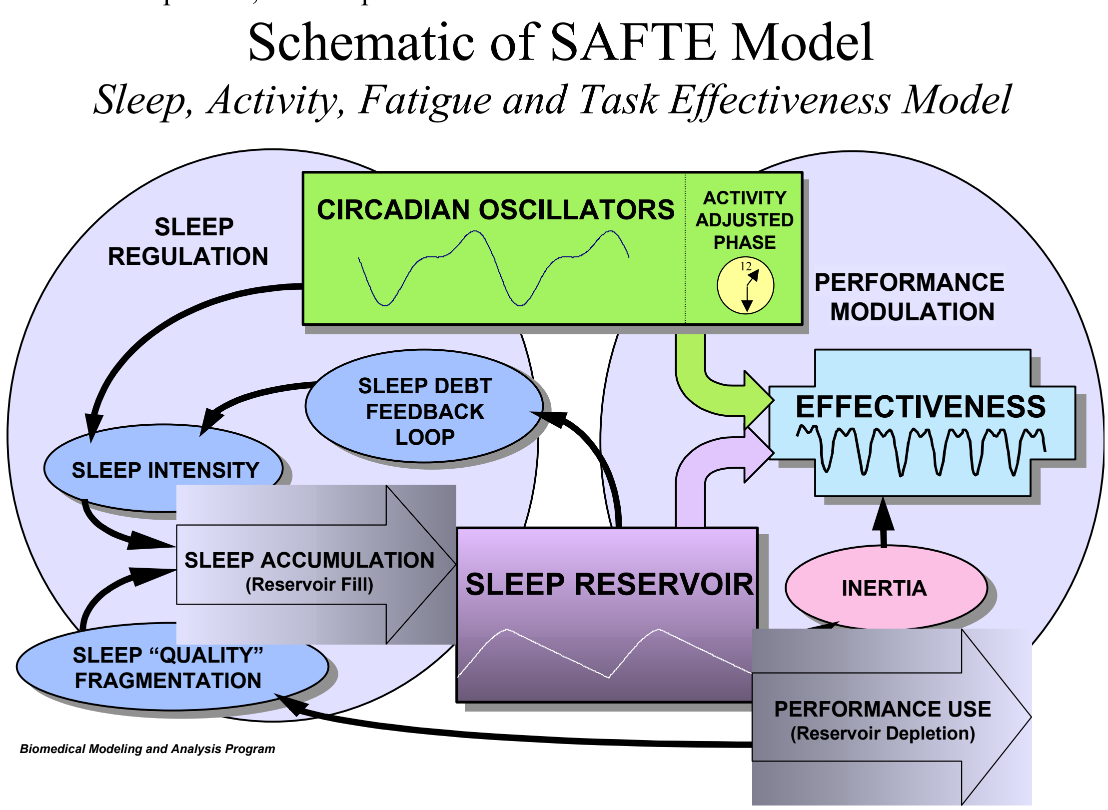


Figure 1. *Schematic of SAFTE Model*

- SAFTE has been validated against group mean data from a Canadian laboratory that were not used in the model's development (Hursh et al., in review). Additional laboratory and field validation studies are underway and the model has begun the USAF Verification, Validation and Accreditation (VV&A) process.

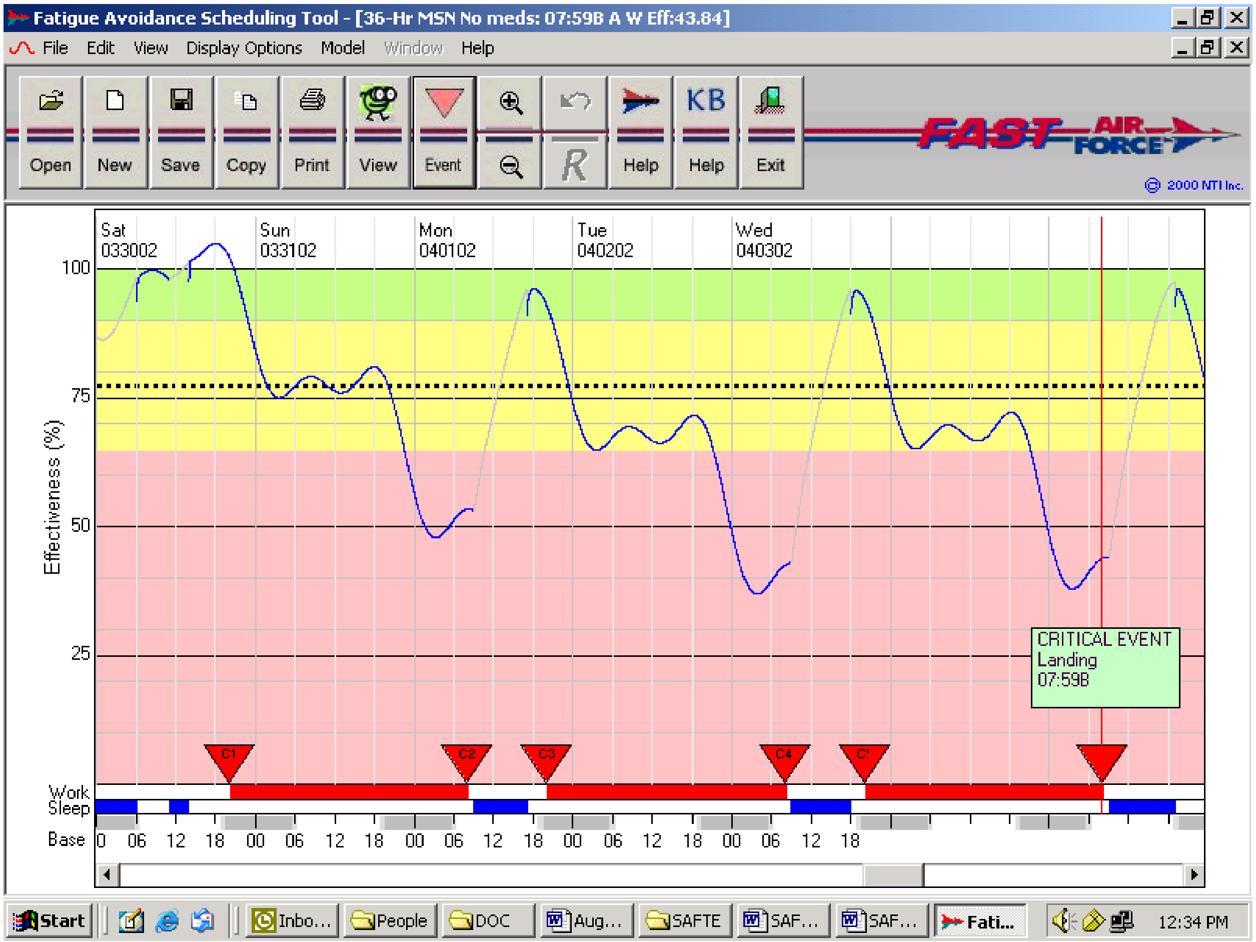
- The model does not incorporate the effects of pharmacological alertness aids; chronic fatigue (motivational exhaustion); chronic fatigue syndrome; fatiguing physiological factors such as exercise, hypoxia or acceleration; sleep disorders; or the fatiguing effects of infection.

The SAFTE Model has a number of essential features that distinguish it from other attempts to model sleep and fatigue (Table 1). Together, these features of the model allow it to make very accurate predictions of performance under a variety of work schedules and levels of sleep deprivation.

Table D-I. SAFTE model essential features.

KEY FEATURES	ADVANTAGES
Model is homeostatic. Gradual decreases in sleep debt decrease sleep intensity. Progressive increases in sleep debt produced by extended periods of less than optimal levels of sleep lead to increased sleep intensity.	Predicts the normal decline in sleep intensity during the sleep period. Predicts the normal equilibrium of performance under less than optimal schedules of sleep.
Model delays sleep accumulation at the start of each sleep period.	Predicts the detrimental effects of sleep fragmentation and multiple interruptions in sleep.
Model incorporates a multi-oscillator circadian process.	Predicts the asymmetrical cycle of performance around the clock.
Circadian process and Sleep-Wake Cycle are additive to predict variations in performance.	Predicts the mid-afternoon dip in performance, as well as the more predominant nadir in performance that occurs in the early morning.
Model modulates the intensity of sleep according to the time of day.	Predicts circadian variations in sleep quality. Predicts limits on performance under schedules that arrange daytime sleep.
Model includes a factor to account for the initial lag in performance upon awakening.	Predicts sleep inertia that is proportional to sleep debt.
Model incorporates adjustment to new time zones or shift schedules	Predicts temporary "jet-lag" effects and adjustment to shift work

The Fatigue Avoidance Scheduling Tool (*FAST*™) is based upon the SAFTE model. *FAST*™, developed by NTI, Inc. as an AF SBIR (Air Force, Small Business Innovative Research) product, is a Windows® program that allows planners and schedulers to estimate the average effects of various schedules on human performance. It allows work and sleep data entry in graphic and text formats. A work schedule comprised of three 36-hr missions each separated by 12 hours is shown as red bands on the time line across the bottom of the graphic presentation format in Figure 2. Average performance effectiveness for work periods may be extracted and printed as shown in the table below the figure.



AWAKE			WORK		
Start Day - Hr	Duration (Minutes)	Mean Effectiveness	Start Day - Hr	Duration (Minutes)	Mean Effectiveness
0 - 06:00	300	98.97	0 - 20:00	1079	81.14
0 - 14:00	2580	76.42	1 - 14:00	1080	63.97
2 - 17:00	2400	64.78	2 - 20:00	1079	71.23
4 - 18:00	2340	64.58	3 - 14:00	1080	54.51
6 - 19:00	1741	72.23	4 - 20:00	1079	72.00
			5 - 14:00	1080	54.92

Figure 2: *Sample FAST^{tm} display. The triangles represent waypoint changes that control the amount of light available at awakening and during various phases of the circadian rhythm. The table shows the mission split into two work intervals, first half and second half.*

- Sleep periods are shown as blue bands across the time line, below the red bands.
- The vertical axis of the diagram represents composite human performance on a number of associated cognitive tasks. The axis is scaled from zero to 100%. The oscillating line in the diagram represents expected group average performance on these tasks as determined by time of day, biological rhythms, time spent awake, and amount of sleep. We would expect the predicted performance of half of the people in a group to fall below this line.
- The green area on the chart ends at the time for normal sleep, ~90% effectiveness.
- The yellow indicates caution.
- The area from the dotted line to the red area represents performance level during the nadir and during a 2nd day without sleep.
- The red area represents performance effectiveness after 2 days and a night of sleep deprivation.

The expected level of performance effectiveness is based upon the detailed analysis of data from participants engaged in the performance of cognitive tasks during several sleep deprivation studies conducted by the Army, Air Force and Canadian researchers. The algorithm that creates the predictions has been under development for two decades and represents the most advanced information available at this time.

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Appendix E: Central Medical Board recommendations for the use of medications to facilitate sleep in aircrew

These recommendations are based on the laboratory and operational field trials reported in this Technical Document, and are for short-term support (5 days consecutive maximum) of aircrew during Operations that can impact on aircrew sleep hygiene. Such pharmaceutical support must be directly under the supervision of a flight surgeon. Prior to any operational use, all aircrew are required to have home trials of any medication listed below in order to preclude any idiosyncratic reactions.

1. To facilitate sleep when there is a minimum of eight (8) hours before the next duty period, the use of zopiclone (Imovane) 5 or 7.5 mg is recommended.

2. If the recall to duty may occur in less than eight hours, but is greater than three hours, zaleplon (Starnoc) 10 mg may be used to facilitate sleep. Starnoc may also be used for longer sleep opportunity windows if preferred by individual aircrew, but because of its shorter action, it is less likely to produce sustained sleep.

3. Athough melatonin shows promise as a sleep aid, it is not yet approved for use at present in Canada without special approval from Health Canada. CMB recommends that DPharmS seek approval from the Health Protection Branch for limited use of melatonin (Circadin 2mg) for use by aircrew during layovers to facilitate sleep.

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14. ABSTRACT

(U) An acute fatigue issue with serious flight safety implications was uncovered during a recent deployment among aircrews conducting tactical airlift between Camp Mirage (CM) and Kabul. This acute fatigue issue is due to jet lag-induced sleep deprivation. The relief aircrews arriving in CM have been deployed across 9 time zones, but are pressed into the tactical airlift schedule after only 2 nights of sleep at CM. Thus, they undertake their first mission with an acute sleep deficit. In spite of the fact that the arriving relief crew spent an average of 7.75 hours in bed the night before their first mission, they slept only an average of 3.4 hrs. This was due circadian desynchronosis: their body clocks were significantly retarded relative to local time. The very low sleep-efficiency in the arriving crew (44%), the night before their first mission was a serious flight safety concern, especially because they were flying over hostile territory in a demanding tactical environment over a 14-hour crew day. Using the USAF performance modelling software, objective sleep data and actual crew duty day data, we estimated crewmember cognitive effectiveness during duty days for the two crews mentioned, above. We also estimated crewmember cognitive effectiveness for crews flying a nighttime schedule several months earlier. RESULTS. The model estimates indicated the following: a) the crew which commenced operations on their 3rd day in theatre, were operating at dangerously low levels of cognitive performance on their first mission, b) their cognitive performance deficits improved over time and were no longer evident after 9 days in theatre, c) another crew, having been in theatre for a month were no longer jet-lagged and had acceptable cognitive performance, and d) because a significant portion of the missions in the preceding months were flown at night, the model indicated that the crewmembers' cognitive performance would be impacted dramatically by fatigue. RECOMMENDATIONS. In the event that CM aircrew are again called upon to fly significant portions of these missions at night, we recommend that they be provided more rest opportunity between missions to improve their cognitive performance, and that they practice the planned, tactical employment of caffeine for critical mission elements that occur during the unavoidable nadir in crewmember performance. To preclude jet-lag-induced performance impact on crews arriving in theatre, we offer a pharmacologic countermeasure to advance their circadian rhythms using a 5-day protocol (5 doses) commencing at home. To optimize this intervention, we need to verify its efficacy via objective actigraphic monitoring. The CF has new aeromedical policy for the short-term flight-surgeon-supervised use of selected pharmaceutical agents (melatonin, zopiclone and zaleplon) to facilitate sleep in aircrew during missions that are known to impact on aircrew sleep. However, because melatonin is not yet available in Canada we would first have to obtain regulatory approval for its operational use from Health Canada via the Special Access Program (SAP). While we are waiting for SAP approval for the use of melatonin, we recommend that aircrew arriving in theatre be given pharmacologic sleep support with either zopiclone or zaleplon under the direct supervision of the CM flight surgeon for the first few nights in theatre.

(U) Au cours d'un récent déploiement devant servir à examiner la question de la fatigue chronique parmi nos équipages d'aéronefs appelés à effectuer du transport aérien tactique entre le camp Mirage (CM) et Kaboul, le premier auteur de ce document (MP) a observé un problème de fatigue aiguë ayant de graves répercussions en matière de sécurité aérienne. La fatigue aiguë est une séquelle du décalage horaire causé par une avance de phase circadienne de neuf heures, inhérente à ce déplacement transméridien. Les équipages de relève sont affectés par roulement au transport aérien tactique après deux nuits de sommeil inadéquat au CM. La difficulté à dormir est due au désynchronisme circadien découlant de vols transméridiens d'une telle durée. Au cours de leur deuxième nuit de sommeil au CM (c'est-à-dire de la nuit précédant leur première mission), les membres de l'équipage nouvellement arrivé ont dormi en moyenne 3,4 heures, ce qui donne une efficacité de sommeil de 46,8 %. Par contre, le lendemain, l'autre équipage qui était dans ce théâtre d'opérations depuis un mois et n'éprouvait plus de décalage horaire a effectué une mission aérienne après avoir beaucoup mieux dormi (6,3 heures en moyenne pour l'équipage, avec une efficacité de sommeil normale de 82,2 %) la nuit précédant le départ. La période de sommeil limitée et l'efficacité très réduite du sommeil parmi l'équipage nouvellement déployé représente un sérieux problème de sécurité aérienne, étant donné qu'il survole un territoire hostile dans un contexte tactique exigeant, pendant une durée de service de 14 heures. Nous proposons une solution pharmaceutique visant à améliorer la sécurité aérienne en avançant les rythmes circadiens au moyen d'un protocole de cinq jours (cinq doses). L'application de ce protocole commencerait au Canada avec la prise d'une dose à 16 h, à chacun des deux jours précédant le déploiement, suivie d'une autre dose à 16 h (heure de Trenton) dans l'avion, en route vers le CM, puis des deux dernières doses, à l'heure du coucher

locale du CM, soit une à chacun des deux premiers jours sur place; le protocole se terminerait la veille du début des opérations de transport aérien tactique. Il faut vérifier l'efficacité de cette intervention à l'aide d'un actigraphe porté au poignet. Les FC sont dotées d'une nouvelle politique aéromédicale sur l'usage à court terme, sous la supervision d'un médecin de l'air, de certains agents pharmaceutiques (mélatonine, zoplicone et zaleplon) susceptibles de favoriser le sommeil parmi les membres d'équipages au cours de missions qui sont de nature à perturber le sommeil. Cependant, comme la mélatonine n'est pas encore disponible au Canada, il nous faudrait d'abord obtenir l'autorisation de l'utiliser de Santé Canada, dans le cadre du Programme d'accès spécial (PAS). En attendant d'obtenir l'autorisation du SAP, nous recommandons de fournir aux équipages qui arrivent dans un théâtre d'opérations des produits pharmaceutiques susceptibles de les aider à dormir, soit de la zopiclone ou du zaleplon, sous la supervision directe du médecin de l'air du CM et ce, pendant les premières nuits passées dans ce théâtre.

15. KEYWORDS, DESCRIPTORS or IDENTIFIERS

(U) aircrew fatigue;jet lag; pharmacologic intervention