DRAFT

Railroad Train Dispatcher Workload, Stress, and Fatigue
Phase II Report: Pilot Field Test

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Prepared for
Dr. Thomas J. Raslear

U.S. Department of Transportation
Federal Railroad Administration
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07 - Human Factors

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PREFACE

This report presents the results of Phase II of a research study to evaluate the impact of workload, stress and fatigue on train dispatcher health and well-being. Phase II involved conducting a pilot field test and, based on the results of that pilot test, developing plans for a full-scale field study. The work was performed under Contract DTFR53-95-C-00049 with guidance from Dr. Thomas Raslear of the Office of Research and Development, Federal Railroad Administration. Dr. Theodore Baker of Shiftwork Resources, Inc., was responsible for performing the salivary cortisol analysis for the pilot test. The Foster-Miller study team expresses its thanks to the management of Amtrak, Conrail, and Metra for allowing us to collect pilot data at their dispatching centers, and to the American Train Dispatchers Department of the BLE for encouraging their members to be a part of this important research.

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1. INTRODUCTION

1.1 Problem Background

The train dispatcher is responsible for the safe and expedient movement of trains across a given territory. While primary consideration is given to collision avoidance, attention must also be paid to the economic realities of a free market system, where late running trains result in increased costs to employers, manufacturers, retailers, and ultimately to the railroads themselves.

In addition, to controlling train movements, the dispatcher is also responsible for coordinating maintenance of way (MOW) activities, communicating with train crews and with dispatchers on adjacent territories, responding to emergency events, and keeping a log of the days' events. The elements of the dispatcher's job require him or her to remain vigilant over prolonged periods of time; cope with sustained high workloads and surges in workload; monitor multiple visual and auditory channels of information; and rapidly make decisions and solve problems based on such information. These activities often take place in a dark, noisy environment without the benefit of any regularly scheduled breaks, including a lunch break. Add to this scenario the fatigue of newer employees working nights and rotating shifts, and it becomes clear that the train dispatcher's job is a highly demanding one.

Continued technological advances, together with operational consolidations and changes in operating rules and procedures, introduce the potential for increasing dispatcher workload, stress, and fatigue further, and highlight the importance of adequately understanding their effects, so as not to exceed the operators' physical and cognitive limits. A related concern involves the capabilities of new recruits, as more and more employees are coming to dispatching from non-railroad backgrounds, and therefore lack the conceptual framework of railroad and train operations as a knowledge base to build upon.

In two audits of the train dispatcher's job (1,2), the Federal Railroad Administration (FRA) tried, but was not fully successful in their efforts, to establish a model of dispatcher workload, stress, and fatigue. For example, while the FRA was able to identify particular job stressors (e.g., ambiguous rules, time-sharing between train and maintenance crews), it lacked the expertise to quantify and evaluate their impact. In addition, while the FRA teams were able to identify important aspects of workload (e.g., number of trains handled per unit time), they were not able to synthesize all of the disparate elements of workload into a coherent picture, which accurately characterizes the variability and complexity of the dispatcher's work. Specifically, while it is important to quantify communications, controls, monitoring units, and paperwork, in order to successfully characterize operator workload, it is crucial to provide an assessment of the level of mental effort associated with the different types of cognitive processes that are performed, as well as with the changing demands of the task: Changes in traffic, maintenance requirements, and the occurrence of unexpected and emergency events.

A primary focus of the FRA's interest in train dispatcher workload, stress, and fatigue concerns the impact of these factors on operator health and well-being. Among other health problems, stress has been linked to heart disease, hypertension, various psychological disorders, and substance abuse (3). In addition, the fatigue produced by work overload, night work, and shift rotation can have ill effects on sleep patterns, mood, and mental processes (4). In order to maximize employee physical and psychological health, it is critical to identify and evaluate the features of the job, workplace, and organization which may serve to erode the dispatcher's resources for meeting the demands of a task which places a great burden on attention, memory, and decision making capabilities.

1.2 Purpose of Study

The purpose of this project is to identify the sources of workload, stress, and fatigue associated with the train dispatcher's job and working life. In order to accomplish this task, the following issues will be examined: The characteristics and requirements of the task; environmental and ergonomic features of the workplace; organizational policies and procedures; and the shift work system. Since occupational stress and other sources of stress are frequently interdependent, consideration will also be given to stressors associated with the dispatcher's social, family, and personal life.

Issues will be explored and variables quantified via subjective and physiological measures. Once stressors and other important features of the dispatcher's job have been identified, an attempt will be made to specify the ways in which these factors may serve to compromise dispatcher health, both physical and psychological. This will be accomplished by reviewing the occupational stress, health, and shiftwork literature in the railroad industry and related transportation industries. Finally, interventions to combat the ill effects of overload, stress, and fatigue will be proposed. Such interventions will include organization-based, as well as operator-centered strategies.

1.3 Scope and Objectives of Phases I, II, and III

1.3.1 Phase I: Selection of Measures

In Phase I, candidate methods for measuring train dispatcher workload, stress, and fatigue were identified. A pilot study was then designed, the purpose of which was to test and evaluate the selected measures. The participation of three railroads was also secured during Phase I of the project: Amtrak (Boston), Conrail (Selkirk, NY), and Metra (Chicago).

1.3.2 Phase II: Pilot Test

Phase II consisted of three tasks: 1) data collection at the three participating sites; 2) data analysis; and 3) planning the full field study. The objective of Phase II was to conduct the pilot study in the dispatcher's workplace, to ensure that the selected measures were appropriate to that environment, easy to use or administer, and unobtrusive in terms of interfering with the dispatcher's work.

1.3.3 Phase III: Field Study

The field study, conducted in accordance with a detailed study design, will occur in Phase III. The study design will describe the measures to be used, the experimental variables of interest, data collection procedures, and the statistical tests to be performed on the data.

1.4 Organization of Phase II Report

The Phase II Report is organized according to the following sections: Section 2 provides a detailed description of the train dispatcher's task, with an emphasis on the features of the job associated with high workload, stress, and fatigue. The technical approach to the pilot test is described in Section 3. This section includes a description of the selected measures and the procedures employed at the three participating test sites. The results and conclusions from the three sites are presented in Section 4. The plan for the Phase III field study is described in Section 5. References are listed in Section 6.

2. THE JOB OF A TRAIN DISPATCHER

2.1 The Train Dispatcher's Tasks

The primary responsibility of the train dispatcher is the safe, efficient, and economical movement of trains across an assigned territory, according to specific operating rules and procedures. The dispatcher operates signals and switches; communicates with train crews, maintenance crews, and other dispatchers; schedules maintenance of way (MOW) work; responds to unplanned and emergency events; and performs administrative duties and paperwork, such as completing the train sheet.

The first thing that dispatchers do at the beginning of the workshift is to construct a basic strategy for successfully moving trains through their territories for the duration of the shift. The strategy takes into account current traffic, expected traffic, the physical characteristics of the territory, train priorities (passenger versus freight), track and signal maintenance requirements, characteristics of train and crew performance, the presence of hazardous materials (hazmat), and information garnered from MOW crews, yard personnel, and dispatchers on adjoining territories.

Once the basic plan is in place, dispatchers spend the remainder of the shift trying to keep the trains running on schedule, despite the inevitable occurrence of delays and unforeseen events. For even a short delay, the entire plan for the shift may have to be reformulated. Indeed, the plan may have to be reformulated a number of times during the course of the shift as unplanned events transpire. The dispatcher is also responsible for keeping track of train crew hours to ensure compliance with the Federal Hours of Service Act. Finally, the dispatcher must also assume responsibility for railroad and non-railroad problems that are phoned in by rail personnel, as well as the general public, and must be knowledgeable about the proper procedures for notifying the authorities in the event of an emergency, such as a hazmat spill.

2.2 Sources and Consequences of Dispatcher Workload

Workload may be defined as the interaction between the demands of a given task and the ability of the operator to meet those demands. It is a multidimensional concept, which may include elements of time pressure, pace of work, task difficulty and complexity, perceived control over work, and the level of effort and frustration associated with task performance.

2.2.1 Workload and Performance

Workload can affect performance in a number of ways. First, high workload can degrade performance when the demands of the task exceed the resources that the operator is able to devote to it. Examples where this might happen include jobs that involve multiple simultaneous tasks, and tasks that involve rapid decision making and problem solving. Somewhat counterintuitively, low workload can also have ill effects on task performance. In this case, a task may be so simple or repetitive that the operator's attention is not fully engaged, and therefore performance suffers. Examples may include sorting tasks and routine paperwork. Finally, performance suffers the most as a result of surges in workload, rapid transitions in workload level that may be predictable or not. A predictable surge may include rush hour traffic. An unpredictable one could refer to an accident or other emergency situation.

2.2.2 Contributors to Dispatcher Workload

While the preceding description gives some indication of the demanding nature of the dispatcher's job, it is also instructive to consider the following specific features of the operation, which serve as additional contributors to workload.

- Number of trains handled.
- Number of train movements executed.
- Number of authorities issued.
- Number of control points/interlockings in a territory.
- Number and quality of communications.
- Geography of territory.
- Total track miles in the territory.
- Administrative duties and paperwork.
- Maintenance of Way requests.
- Emergency and unplanned events.

In addition to the objective elements of operator workload, above, a full description of a task's workload requires subjective reports made by the operator in order to link the workload demands of the task to the operator's cognitive resources.

2.3 Sources and Consequences of Dispatcher Stress

Like workload, stress is a complex construct with many causes and manifestations. Subjectively, the experience of stress may include feelings of anxiety, anger, fear, helplessness, frustration, irritability, and depression. These feelings arise from the way an individual perceives and interprets events in his or her environment. This is a very idiosyncratic process, since events may be experienced as stressful for one person but routine for another. Stress occurs, at least occasionally, in our personal lives, as well as in our professional lives. Job stress itself can be categorized according to the source of stress. First, the actual demands of the task may make an individual feel stressed. This illustrates the relationship between stress and workload. Second, environmental features of the workplace can cause stress, features such as lighting, air quality, and temperature. Finally, organizational issues such as work climate, work scheduling, conflict, change, and pressure may cause the individual a considerable amount of stress.

The FRA audit (2) of train dispatchers identified the following as sources of operator stress:

- Work overload and surges in workload.
- Juggling maintenance and traffic requirements.
- Ambiguous operating rules and procedures.
- Inconsistent application of rules between areas.
- Safety responsibilities.
- Threat of relocation.
- Radio frequency interference.
- Training concerns.
- Changing technology.

As was the case with the workload issues, FRA expressed reservations concerning the audit's ability to adequately inventory and describe sources of dispatcher job stress.

2.3.1 Stress and Performance

Stress is associated with performance degradation and error production on the job. It causes a narrowing of attention, such that an operator may become fixated on one aspect of a problem and ignore other sources of information. Stress may also fragment attention, causing operators to search for information and solutions in a disorganized, unsystematic way. Becoming distracted as a result of stress may lead to procedural errors such as performing the wrong response or failing to respond to an important event. Other effects on cognitive functioning include poor decision making and problem solving ability, disorganization, forgetfulness, and distractibility.

2.3.2 Stress and Health

In addition to degrading performance, exposure to unremitting stress in the workplace can have a negative impact on employee health and well-being. Indeed, chronic work stress can lead to burnout, a condition in which the operator becomes so physically and psychologically exhausted that he or she is no longer able to function effectively on the job (5). Although direct causal relationships often cannot be definitively proven, occupational stress has been linked to the following physiological and psychological effects (3,4,6).

Psychosomatic Disorders

- Heart disease.
- Hypertension.
- Skin problems.
- Gastrointestinal problems.
- Sleep disorders/circadian desynchronization.
- Asthma.
- Immune system suppression (infections, cancer, autoimmune diseases).
- Musculoskeletal pain/discomfort.
- Headaches.

Mood-State Changes

- Anxiety.
- Depression (sadness, helplessness, loss of hope).
- Excessive worry.
- Anger/hostility.
- Irritability.
- Loss of motivation.
- Burnout (physical, mental, emotional exhaustion).

Psychosocial Effects

- Alienation from family, friends.
- Alcohol and drug abuse.
- Workplace violence.
- Domestic violence.

2.3.3 Stress of Dispatching

There is little research dealing with the effects of stress on train dispatcher health, however, the research which does exist suggests that occupational stress is a likely risk factor for ill health and decreased longevity among the dispatcher population. Most of the existing data have been compiled by the American Train Dispatchers Association (ATDA) and published in the Devoe Report (7). Those studies are briefly described here, along with a more recent investigation.

A 10 month study conducted in 1929-30 showed an abnormally high rate of heart, blood, kidney, and anxiety problems among 165 train dispatchers. The average age of dispatcher death was, at the time, 50 years, with a very high proportion due to cardiovascular disease.

Research dating from the 1940s and 1950s shows similar trends. McCord (8) found that the average lifespan of a dispatcher was 50.1 years, as compared to 65.9 years for age matched white males. Of the dispatchers studied, 81 percent had diseased hearts and blood vessels. A study from the 1950s showed that 50 percent of dispatcher deaths were due to heart disease and another 20 percent involved diseases of the blood vessels (7).

In a five year study of railroad personnel conducted in the 1970s, researchers noted an exceptional number of smokers among train dispatchers, as well as a very high rate of death due to coronary heart disease (7). This finding indicates that smoking behavior may serve as a moderator variable in the relationship between train dispatcher stress and subsequent illness.

More recently, Menotti and Seccareccia (9) conducted a five year mortality study of nearly 100,000 Italian railroad workers, aged 40 to 59 years. Workers were classified according to the level of physical activity (low, moderate, high) and responsibility (low, moderate, high) involved in their positions. Responsibility referred to the degree to which employees were accountable for loss of life, injury, and economic losses. The researchers found that railroad workers with low activity/ high responsibility jobs were at greater risk than other groups for myocardial infarction. Although subjects were not classified by job title in this study, the dispatcher's job clearly fits the description of one that is both sedentary and high in responsibility.

Finally, it is worth mentioning that cardiac problems are also associated with shiftwork, in general, particularly for those performing nightwork and those working a rotating shift system. Other problems associated with shiftwork include sleep disorders and attendant fatigue, gastrointestinal problems, alcohol and drug abuse, social isolation, and disorders of mood (4).

2.4 Sources and Consequences of Dispatcher Fatigue

Mental and physical fatigue may also interfere with the train dispatcher's work. Although the job does not require hard physical labor, it is important to keep in mind that shiftwork and sleep deprivation can cause physical fatigue, and that this in turn is likely to affect the dispatcher's level of mental fatigue and alertness. Mental fatigue can also build up as a result of time on task, large work volumes, rapid information processing and decision making, and responding to problems, such as emergency events.

2.4.1 Mental Fatigue and Performance

The symptoms of mental fatigue involve loss of alertness, feelings of sleepiness, lack of energy, weariness, and exhaustion. The effects of fatigue on performance include slower reactions, poor concentration and forgetfulness, complacency, and an increasing reluctance to expend any effort in task performance. Fatigue is also associated with on-the-job microsleep (3). When an individual is microsleeping, he or she appears to be awake (sitting upright, eyes open), but an electroencephalogram (EEG) would indicate that the person is actually in a light sleep.

2.4.2 Fatigue and Shiftwork

There are two major contributors to fatigue among train dispatchers. First, staffing shortages result in overwork. A shortage of relief employees results in the dispatcher having to work on normal rest days.

A second source of fatigue involves the shiftwork system. This is of particular concern for nightworkers and those who work rotating shifts. Rotating schedules have adverse effects because the body's circadian rhythms do not have time to adjust to any single schedule. Even when one works third shift consistently, there is a long period of adaptation required for re-entraining physiological functions (6). In fact there is some question as to whether complete adaptation to night work is even possible. The degree of adaptation depends on both the individual and the length of time spent on the shift. One longitudinal study, however, shows incomplete adaptation even after three years working the night shift (10). Thus, at the very least, it is likely that night shift employees will experience long periods of fatigue and loss of alertness while adapting to the night shift schedule.

In addition to the fact that daytime noise will often interfere with a night shift employee's sleep, the nightworker may also lose sleep because of family and personal obligations that must be attended to during the day. The conflict between the need to sleep and the desire to spend time with family and friends can also become a significant source of stress in the dispatcher's life (4).

3. PILOT TEST TECHNICAL APPROACH

The background research of Phase I allowed Foster-Miller to identify candidate instruments for measuring dispatcher workload, stress and fatigue in the Phase II pilot test. This section describes each of those instruments along with the procedures and materials developed for pilot testing the instruments at three different dispatching centers.

3.1 Selected Instruments

The instruments described below and summarized in Table 1, were selected for inclusion in the pilot field test. They were chosen based upon their utility, as well as their acceptance by the dispatcher test population. Foster-Miller believes that this battery of tests provides an excellent overall picture of dispatcher workload, stress, and fatigue.

3.1.1 Background Survey

Foster-Miller developed a background questionnaire, which focuses on sources of dispatcher workload, job stress, and fatigue, as well as information regarding employee health, work scheduling, sleep habits, quality of life issues, demographic data, job satisfaction, and work climate. This is a one time only questionnaire that was completed by participants at the beginning of the study period.

The purpose of this survey was to use the findings to form an overall stress profile of the train dispatcher's job. As noted above, stress that is associated with task performance on the job

Table 1. Measurement instruments for pilot test

Type of Data	Measurement Instruments
Background Information	Survey
Workload	NIMS data collector mTAWL observation Dispatcher records Subjective ratings
Stress	Cortisol measurement Subjective rating
Fatigue	Sleep logs Actigraphy Subjective rating

is not the only source of stress in an individual's life, and stress from different sources will tend to interact in a synergistic manner. For example, other job-related stressors involve various organizational problems — poor relationships with colleagues or supervisors, issues related to shift work and work scheduling, and stress that occurs in response to organizational or technological changes. Stress that is related to personal, family, social, and financial matters will likely contribute to stress on the job, as well. Thus, the goal of the background survey was to discover: 1) what other factors in addition to job demands are creating stress in the lives of dispatchers; and 2) what, if any, stress related health symptoms are currently being manifested.

3.1.2 NIMS Data Collector

Objective workload refers to an assessment of a task's load independent of the human operator. The NIMS data collector, developed at the Volpe Transportation Center for a Federal Aviation Administration project, was identified for possible use in the current study. Foster-Miller reviewed the program and proposed a set of modifications to the interface and data collection parameters. These modifications reflected the unique features of the dispatching environment.

The NIMS program required a trained research associate to observe the train dispatcher at work and make computer inputs corresponding to specific dispatcher tasks. The program was designed to yield a running record of all of the dispatcher's activities during a work shift. The dispatcher's job was broken down into distinct tasks which were represented on the computer's interface – dispatcher initiated communications, record keeping, control system entries, and so forth. The observer watched a particular dispatcher and made entries into the computer system that corresponded to the start and stop times of specific tasks. Output from the program consists of the duration, sequencing, and frequency of task performance.

The set of activities to be monitored went through several iterations, based on the Devoe Report (7), input from a subject matter expert (SME) with dispatching experience, and several visits to the South Station dispatching center in Boston. The resulting 13 dispatcher activities (see Table 2), were validated during a final visit to South Station to ensure that no activities were missing and that the activities included were representative of the dispatcher's workload.

3.1.3 Subjective Reports of Workload, Stress, and Fatigue

Subjective workload refers to the interaction between task and operator, and is frequently assessed using self-report rating scales, which are administered to operators to complete during or immediately following task performance. Often, they are administered several times during a work period in order to document changes in perceptions of workload over time. There are several popular subjective workload techniques available, both unidimensional and multidimensional. Scales are defined as unidimensional if the operator is required to rate the *overall* workload of a task only. Multidimensional techniques are more diagnostic in the sense that operators are asked to rate different elements of the task, such as time pressure and cognitive demand.

Table 2. Dispatcher activities

1.	Record keeping and record review.
2.	Report writing.
3.	CTC entry.
4.	Issue/annul Form Ds and verbal train movement authorities.
5.	Issue MOW protection/roadway worker protection.
6.	Communicate with other dispatchers and Chief dispatcher.
7.	Dispatcher-initiated communications.
8.	Externally-initiated communications.
9.	Respond to unplanned and emergency events.
10.	Experience communication problems.
11.	Other administrative duties.
12.	Non-operational absence.
13.	Transferring responsibility to or from a desk.

The Overall Workload (OW) scale is a unidimensional bipolar scale ranging from 0 to 100 (11). Operators are typically asked to place an X on the part of the scale corresponding to their perceived level of workload. The NASA Task Load Index (TLX), on the other hand, is a multidimensional scale (11). Operators rate six sources of workload — mental physical, and temporal demand, performance, effort, and frustration on a scale ranging from 0 to 100. Choosing the greater contributor to workload in pairwise comparisons produces a weight for each source of workload. Ultimately, this process yields a weighted rating for each of the six workload dimensions, as well as an overall, global workload rating.

Foster-Miller determined that the best subjective workload technique to use in this particular operational setting is the OW in conjunction with the three NASA-TLX subscales that are most appropriate to dispatcher workload: Mental Demand, Temporal Demand, and Effort (see Figure 1). These three subscales simply required a single rating between 0 and 100. The NASA weighting process was not utilized.

The workload scales were administered every 2 hr over the course of the dispatcher's shift. Two additional, similarly constructed stress and fatigue rating scales were included on this questionnaire, as well. Participants were also asked to report the number of trains and other track users on their territories and to describe any stressful, unforeseen or emergency event that they encountered during the preceding 2 hr work period. This questionnaire was acceptable to both dispatchers and management, as it demanded a minimal amount of time to interpret and complete.

3.1.4 Salivary Cortisol

Extensive review of the literature on salivary cortisol analysis, including studies of air traffic controllers, indicated that cortisol is a reliable stress marker which can be collected quickly and

SUBJECTIVE RATING SCALES

Please complete these rating scales 5 times daily -- at the very start of your shift and every two hours after that. Remember that your job comes first. If you are too busy to complete the scales at the appointed hour, wait until you have time.

ID Number ____________________ **Date** ____________________

The time is now ______________ **AM or PM (circle one)**

Mental Demand

0 Very Low — 100 Very High

Temporal Demand

0 Very Low — 100 Very High

Your Level of Effort

0 Very Low — 100 Very High

Overall Workload

0 Very Low — 100 Very High

Fatigue

0 Not Fatigued — 100 Very Fatigued

Stress Level

0 Low Stress — 100 High Stress

Number of Trains: ________ **Number of other Track Users:** _______

Unusual or emergency events this period: ______________________________________

436-FRA-97120-5

Figure 1. Workload, stress and fatigue scales

unobtrusively in a high workload field setting (12, 13-19). At the beginning of the shift, and every 2 hr thereafter, volunteers were required to chew on a small cotton roll until it was soaked, approximately 30 to 60 sec. They then deposited the cotton in a test tube and stored it in a small cooling apparatus located at their workstations. A research assistant brought all necessary equipment every morning, and returned to retrieve the samples every afternoon.

3.1.5 Actigraphy and Sleep Logs

Actigraphs are activity recorders. They are approximately the size and shape of a normal wristwatch and respond to movements of the hand and arm. In studies of fatigue, actigraphs are worn continuously day and night, in order to monitor the subject's sleep/wake cycles. The data are downloaded into a software program that provides summary statistics and actigrams of sleep/ wake periods. These data make it possible to discern the amount of sleep that each dispatcher is getting per 24 hr period, and when sleep periods are taking place. An actigraph is illustrated in Figure 2.

The Sleep Log depicted in Figure 3 was used in conjunction with the actigraph data to assess the duration and quality of volunteers' sleep. This sleep log is based, in part, on similar instruments used by the United States Coast Guard (USCG) and DOT in studies of watchstander and locomotive engineer fatigue, respectively. Participants were asked to complete the sleep log each day, shortly after awakening.

3.1.6 Debriefing Questionnaire

At the conclusion of the pilot study, participants were asked to complete one final, follow-up survey. This survey solicited volunteers' opinions and suggestions concerning the methods that were used to collect information for the study. The survey also asked for opinions regarding desired improvements to the job/workplace.

3.1.7 Modified Task-Analytic Workload (mTAWL)

Assessing the workload of dispatchers is difficult for three reasons. First, many of the tasks involve cognitive activity that is not directly observable. Second, the timeframe of task performance is often unpredictable due to

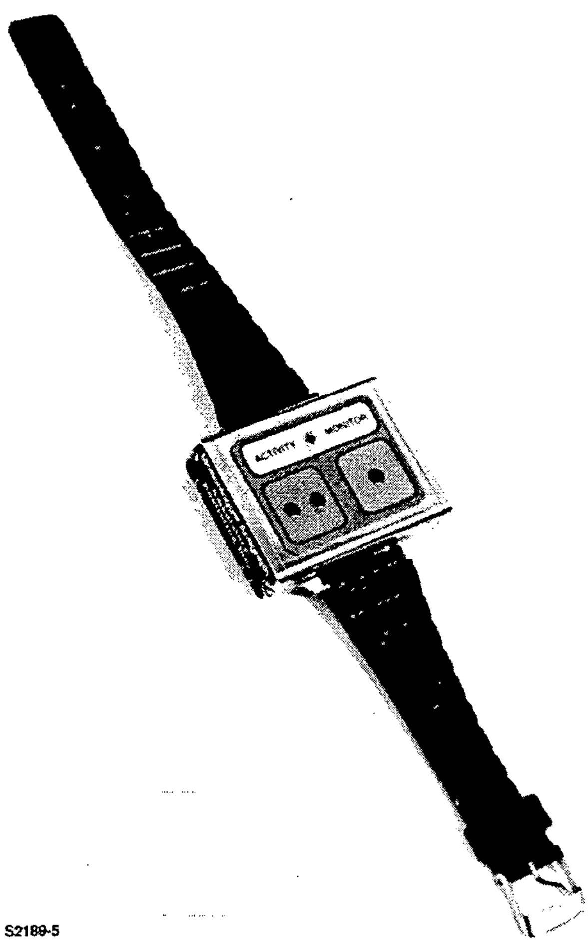

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Figure 2. Actigraph

SLEEP LOG

Please fill out this sleep log every day at home, before you go to work. Make sure you are wearing your Actigraph!

ID Number ____________________ **Date** ____________________

The time is now __________ **AM or PM (circle one)**

What time did you go to bed? ________ AM or PM

About how long did it take you to fall asleep? ____ hrs. ____ min.

What time did you wake up? ________ AM or PM

What time did you get out of bed? ________ AM or PM

How many hours did you sleep? ________ hrs.

Number of awakenings: ______

Did you take any **sleep aids**? Please provide details on type, quantity, and frequency. Include prescription and over-the-counter medication, alcohol, melatonin, herbal remedies, & others:____________________

____

Rate Your Sleep

Ease of falling asleep:

Very Easy	Fairly Easy	Fairly difficult	Very Difficult
1	2	3	4

Ease of getting up:

Very Easy	Fairly Easy	Fairly difficult	Very Difficult
1	2	3	4

Length of sleep:

More than Sufficient	Sufficient	Insufficient	Wholly Insufficient
1	2	3	4

Quality of sleep:

Very Good	Good	Fair	Poor	Very Poor
1	2	3	4	5

Overall, I feel:

Very Rested	Fairly Rested	Somewhat Fatigued	Very Fatigued
1	2	3	4

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Figure 3. Sleep log

the delays that may exist between event onset and the initiation of a response. Finally, assessment is aggravated by the fact that multiple simultaneous tasks are often performed during a given time period. In response to these problems, an observational methodology and analytical technique was derived from an approach originally intended for the assessment of the workload of military helicopter flight crews, Task Analysis/Workload (TAWL; 20).

The starting point for adapting the TAWL for use with train dispatchers was based on the list of dispatcher responsibilities outlined by Devoe (7):

1. Prepare documentation.
2. Conduct preliminary planning.
3. Monitor/coordinate train movements.
4. Initiate/stop train movements.
5. Respond to unplanned events.
6. Respond to emergencies.

Items 5 and 6 in the list represent subcategories that are largely made up of events rather than tasks. The implication is that certain events trigger some action or response on the part of the dispatcher. In this respect, tasks can be seen as beginning when events reveal the need for action, and ending when the events are resolved. Thus, it becomes possible to consider specific behaviors, such as activating CTC controls or making radio calls, as integral elements of a time-framed task, rather than as brief, discrete, unrelated activities. An additional benefit of this perspective is that cognitive processes, such as evaluation and planning for action, while not directly observable, can be seen taking place within the defined task timeframe.

An issue that Devoe's research failed to address was that the dispatcher's work consists primarily of multiple, *simultaneous* tasks. The TAWL is intended to deal with overlapping tasks, and its assumptions are especially appropriate for use in the dispatching environment. The TAWL approach and the model of operator workload that it generates represents a rigorous approach to the definition and observation of task load.

In modifying the TAWL (mTAWL) for use in the dispatching environment, a subject matter expert (SME) identified the triggering events and concluding actions that marked the beginning and end points of each task. Then, each task was scored according to its contribution to workload in four information-processing channels: auditory, visual, cognitive and psychomotor, on a scale from zero to seven. The mTAWL ultimately yields a graphical means of identifying peak workload in one or more of the information-processing channels, when it occurs, and which tasks are contributing to the dispatcher's workload.

When the workload score (summed across tasks) for a given information-processing channel exceeds the highest possible level of seven, an overload condition is considered to exist. In flight scenarios, these periods are understood to be occasions in which catastrophic errors are likely to occur. This is likely to be the case in other high-risk professions as well, including dispatching.

3.2 Purpose of Pilot Test

The purpose of the pilot field test was to examine the feasibility of using the measures in the dispatchers' operating environment, and to evaluate their usefulness in preparation for the final field study. The pilot test was also conducted to identify the potential problems that can occur in a field study of this nature. For example, it allowed the study team to:

- Determine the soundness of the actigraphs in terms of breakage and malfunction.
- Assess the compliance of participants in maintaining their sleep logs.
- Discover whether the cortisol collection procedure is too intrusive.
- Obtain feedback from the participants on the various measures used.
- Determine the feasibility of using the NIMS and mTAWL methods to collect workload data.

The data gathered during the pilot test were not analyzed for the purpose of drawing conclusions about dispatcher workload, stress, and fatigue, since the sample size was very small.

3.3 Materials for Pilot Test

In preparation for the pilot field test, Foster-Miller designed an instruction and survey booklet for subjects, drafted an informed consent statement, and obtained two actigraphs to pre-test on Foster-Miller personnel.

3.3.1 Survey Booklets

The survey booklets included the following documents:

- An introduction to the study.
- Working definitions of workload, stress, and fatigue.
- Instructions for completing each type of survey.
- A set of surveys for each day of the study's duration.
- A debriefing survey.

Each day's set of surveys included one sleep log and five sets of subjective workload, stress, and fatigue scales. Extra sleep logs were included so that participants could keep track of their sleep on non-workdays.

3.3.2 Informed Consent

An Informed Consent Statement for volunteers was prepared for use in the pilot study. The Statement outlined in detail the conditions of the study, as well as participants' rights and responsibilities. These are reviewed, below.

It was emphasized that participation was completely voluntary, and that participants could withdraw consent at any time without incurring penalties or loss of benefits. However, volunteers received financial remuneration for participating in the pilot test, and payment was contingent upon completion of the study. Participants were also informed that all data from questionnaires, physiological measurements, and observations would remain strictly confidential. Participants were assigned an identification number that was known only to them and the principal investigator from Foster-Miller. Volunteers' names were not recorded anywhere, except on the consent form and the receipt for the participation fee. Foster-Miller has also kept these records strictly confidential.

Finally, it was emphasized that the volunteers' primary functions of dispatching and safety were to take precedence over any study activities, and that if any conflict should arise, they should complete their primary job duties first, and address the study tasks at a convenient time later.

3.4 Pilot Test Sites and Procedures

Conrail in Selkirk, NY, Amtrak at South Station in Boston, MA and Metra in Chicago, IL, served as sites for the pilot test. The pilot study took place the week of 20 October at Conrail and the week of 17 November 1997 at Amtrak. The mTAWL was piloted at Metra in November and December 1997.

3.4.1 Conrail

Conrail is a freight operation. Its dispatching center in Selkirk, NY is a large office space, where the dispatchers are arrayed along two of the four walls. The instruments tested at Conrail included the background questionnaire, subjective ratings, and NIMS data collector. For their participation, two volunteers were paid $35.00 each.

Problems using the NIMS data collector were apparent at the outset of the pilot test. These problems are specified below in the Results section. As a consequence, the investigator who was making the observations experimented with collecting frequencies of various activities by hand, as an alternative to the PC system (e.g., number of incoming versus outgoing calls, number of Form D's completed, etc.). Frequency counts are not sensitive to time, since they can be recorded after the fact, and they provide almost as much information as that which would be yielded by the PC system. Based on the experience at Conrail, it was decided to collect frequency count information during the pilot study at Amtrak as a measure of objective workload.

3.4.2 Amtrak

Amtrak is an intercity passenger railroad. The dispatching center at Boston's South Station is a dimly lit, amphitheater style center. This center controls Amtrak trains between Boston and New Haven, CT, as well as MBTA commuter operations from South Station. The entire battery of tests was piloted on five Amtrak volunteers for a seven day period of time. Volunteers were compensated in the amount of $100.00 each. Only first shift dispatchers were asked to participate in order to simplify data collection procedures. While volunteers had days off within this seven day timeframe, it was still possible to gather at least four or five days of data on each subject. In addition, since volunteers wore the actigraphs even on off-days and weekends, those data and the sleep log data were available for the entire seven day period.

Amtrak management solicited participants. Once the volunteers were selected, Foster-Miller staff went to the dispatching center at South Station to distribute background questionnaires, informed consent statements, survey booklets, and actigraphs to participants. The subject identification number was also provided to volunteers at that time. During a second visit to South Station, logistical decisions about the placement of cooling devices to hold the saliva samples were made, and the saliva collection procedure was explained to each participant individually.

Frequency count information was collected during the pilot study at Amtrak as a measure of objective workload (e.g., number of incoming versus outgoing calls, number of Form D's completed, etc.). Each of the five participants was observed for one day. Volunteers provided a saliva sample five times daily. At the conclusion of the shift, personnel from SRI collected the samples and delivered them to a local lab for analysis. At the end of the study period, actigraphs and surveys were collected from volunteers, who were then paid for their participation. The actigraphs were sent back to Ambulatory Monitoring, where the data were downloaded and analyzed.

Additional data were obtained from Amtrak's paper records, such as number of Form D's and foul time permits issued by each participating dispatcher during the testing period.

3.4.3 Metra

Metra provides commuter rail service to six counties in the Chicago area. Its modern dispatching center in Chicago has four desks, and uses state of the art dispatching technology. Metra was used to evaluate the modified TAWL (mTAWL).

Together with Metra personnel, the B-12/Southwest Service desk was selected for observation during evening rush hour. This desk was considered appropriate for observation since it had a very high level of traffic and involved both passenger and unscheduled freight movements. The first observations were made with a floor supervisor present to answer questions, and assist in the creation of task definitions and resource channel loads for the tasks. A total of three observations of 2 to 3 hr duration were conducted before task definitions and channel loadings were determined.

3.4.3.1 Task Definitions

Task definitions were determined following the initial observations. Tasks fell into four conceptual areas, which were characterized as:

- *Background tasks* are either continuous (monitoring) or voluntary, such as doing required paperwork at a time chosen by the dispatcher.

- *Foreground tasks* are unanticipated, and are unrelated to current or previously anticipated train or work crew moves. Such tasks require an immediate response.

- *Anticipatory tasks* are preparatory actions and plans for dealing with trains or work crews whose approximate arrival time in the dispatcher's territory is known. The timeframe for this type of task begins when the track occupant first becomes apparent, or in the case of a scheduled train, when the receiving section of track is cleared to receive it. The anticipatory period concludes when the expected track occupant actually enters the dispatcher's control or is no longer expected to arrive. Each anticipated occupant constitutes a separate event.

- *Track management tasks* are those actions taken to control trains and protect work crews present on the dispatcher's territory. The timeframe of this type of task begins when the track occupant first enters the territory. It ends when the track occupant leaves the dispatcher's territory. Each occupant constitutes a separate event.

3.4.3.2 Channel Loadings

Preliminary observations indicated that the channel loads associated with the performance of any given task did not fluctuate over time in any predictable way. Thus average channel loadings were computed for each task. Table 3 presents the subcategories and average channel loadings for each type of task.

3.4.3.3 Observation and Evaluation Techniques

During a single observation period, the dispatcher at Metra handled 118 track occupants, with a majority of these occupants present during the 2 hr evening rush. This level of activity makes it impossible to simultaneously observe, record, and classify the dispatcher's behavior. With multiple events occurring in a1 min period, it was deemed appropriate to observe and record the events as they occurred, and later classify them as a post-processing activity. Train sheets proved to be especially useful in the categorization process to verify track occupancy times and locations.

Observed events were entered into a time-sequenced spreadsheet that also included a graphical representation of train movements and track occupancy. Columns in the spreadsheet were used to represent tracks. The track columns were arranged to represent spatial relationships so that conflicts in movement and occupancy would be readily apparent. This spreadsheet reveals the dispatcher's responses to triggering events and how track occupancy conflicts were resolved. A sample spreadsheet is provided in Figure 4.

Table 3. Task types and channel loadings

Task Area	Task Description	Channel Loading: Audio	Visual	Cognitive	Psycho-motor
Background	• *Auditory monitoring* - listening for unanticipated radio or telephone calls.	1	0	0	0
	• *Visual monitoring* - watching for unanticipated events on the informational displays.	0	1	0	0
	• *Background "phone"* - telephone or radio calls made during the course of work at times chosen by the dispatcher and not directly related to the anticipated or actual control of a specific train or work crew.	3	1	2	1
	• *Background "computer"* - computer or paper entries required during the shift which could be performed at times chosen by the dispatcher.	0	2	2	6
Foreground	• *Foreground "phone"* – telephone or radio calls made or received during the course of work which required an immediate response and which were not directly related to previously anticipated actions or the current control of a specific train or work crew.	3	1	2	1
	• *Foreground "computer"* – computer or paper entries required during the shift which were not directly related to previously anticipated actions or the current control of a specific train or work crew.	0	2	2	6
Anticipatory	• *Anticipated unopposed* – the anticipated arrival of a track occupant whose progress to the dispatcher's territory is expected to be unimpeded.	1	1	1	0
	• *Anticipated opposed* – the anticipated arrival of a track occupant whose progress to the dispatcher's territory was expected to be opposed by another track occupant or occupants.	1	1	2	0
Track Management	• *Track occupant unopposed* - a period of time during which a specific track occupant under the dispatcher's control is unimpeded.	1	1	1	1
	• *Track occupant opposed* – a period of time during which a specific track occupant under the dispatcher's control is opposed by another track occupant or occupants.	1	1	2	1

11-Dec-98				
TIME	TRAIN	TRACK	DIR	EVENT
1559				Phone; gets mark up WC T049
1559				Enters trains into computer stack (FC)
1601				Radio; sets up CP1399
1603				
1605				Radio; calls CP So Side to advise move
1606	*CP So Side*	***3 to NPB***	*West*	***Enters circuit***
1607	***MW 2223***	***1 to 1***	*West*	***Enters circuit***
1608				Phone; calls dispatcher to set up time for WCCXFFLD at 1655
1608				Radio; calls MW2223 for location; no answer
1609	***MW2242***	***2 to 2***	*East*	***Enters circuit***
1610	*CP So Side*	***3 to NPB***	*West*	***Leaves circuit***
1613				Makes entry to late reports (BC)
1614				OS report (BC)
1616	***WCT 049***	*WC to CPL*	*West*	***Enters circuit***
1616				Phone; line up
1617	***MW 2223***	***1 to 1***	*West*	***Leaves circuit***
1617				OS report (BC)
1617				Hand sets part of a route
1619	***MW2242***	***2 to 2***	*East*	***Leaves circuit***
1619				OS report (BC)
1619				Hand sets part of a route
1620				Computer drops stacked routes for unknown reason; resets. (FC)
1620				Radio: lineup for WCCXFFLD; revised.
1621				Radio to NC112 for location
1623	*WCCXFFLD*	*WFL to WC*	*East*	***Enters circuit***
1623				Radio to WC T049; on move? (switching)
1626				Radio to CP1399; tells them to watch for signal
1628	*WCCXFFLD*	*WFL to WC*	*East*	***Leaves circuit***
1628	***CP1399***	*3 to NPB*	*West*	***Enters circuit***
1629	***NC112***	*CTC to 2*	*East*	***Enters circuit***
1630	***WCT 049***	*WC to CPL*	*West*	***Leaves circuit***
1631				Attempts to phone in OS times; busy (BR)
1632				Phone; line up
1634				Radio; calls for time on MW2244 (late)
1634				SWS11 is on approach (au)
1635				MW2244 on approach
1635				Reports MW2244 late
1637				Partially lines route for SWS11 (short window)
1637	***NC112***	*CTC to 2*	*East*	***Leaves circuit***

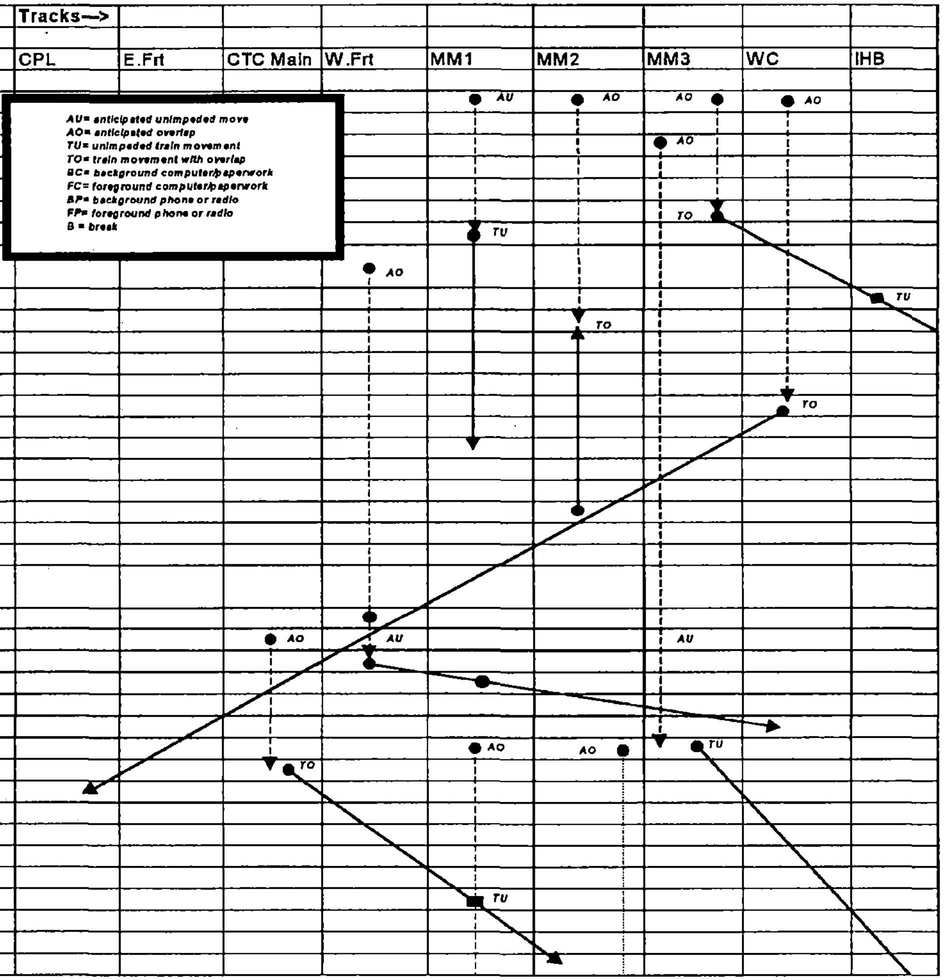

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Figure 4. Sample mTAWL spreadsheet

4. RESULTS AND CONCLUSIONS

Different measures were tested at each of the three locations used for the pilot study. The background survey, NIMS data collector, and subjective ratings were tested at Conrail; all of the workload, stress, and fatigue measures were piloted at Amtrak; and the mTAWL was tested at Metra. The results for each measure at each location are discussed in this section.

4.1 Conrail

The NIMS data collector proved very difficult and inefficient to use for the following reasons:

1. Individuals, including the train dispatcher under observation, attempt to engage the observer in conversation, making it difficult to make accurate recordings.

2. The dynamic nature of the dispatcher's work makes it difficult to determine when activities begin and end. Calls are put on hold/standby and dispatchers switch back and forth between activities (e.g., from recording something in their train sheet, to changing a switch/signal on their CTC, to returning to the train sheet to complete their entry, etc.).

3. It often takes several moments to determine what activity is taking place, and recording time is lost in the process. For example, it takes time to determine if a call or radio communication is incoming or outgoing. Furthermore, the conversations can be very brief. As a result, it is easy to lose recording time, as well as to miss entire events.

Other dispatcher activities may also be short duration, high frequency and highly repetitive, making it that much more difficult to accurately capture all of the activities taking place. For all of these reasons, the PC data collection system was abandoned and frequency information was collected instead, as described above (e.g., number of incoming versus outgoing calls, number of Form D's completed, etc.). While data collection efforts at Conrail indicated that frequency information is relatively easy to collect and a valid reflection of workload, the data were not analyzed since only very limited data were collected over the course of the two days. It was also anticipated that we would be able to correlate the dispatcher subjective ratings with the NIMS data. However, because of the difficulties and challenges in using the NIMS software in the dispatching environment, and because limited frequency information was collected, we were unable to correlate subjective ratings with either measure of objective workload. Data from the two background surveys were insufficient to reveal any meaningful pattern of responding.

4.2 Amtrak

4.2.1 Background Survey

Data from the background surveys were examined. Among the more interesting findings are the following: 1) Several of the dispatchers have experienced or are currently experiencing health symptoms related to stress, for example, back and neck pain, intestinal upsets, anxiety, and headaches. 2) In terms of work scheduling, all of the dispatchers complained that they were too busy to take breaks and that it was difficult to get another dispatcher to cover for them, even in emergencies. In addition, most complained about the lack of a regular lunch break and the attendant necessity of having to eat hurriedly at their workstations. 3) Four out of the five dispatchers at South Station reported at least one symptom of insomnia and experienced daytime sleepiness as a consequence. 4) Most of the respondents rated the visual demands of their work as high or very high, and also reported symptoms of eyestrain. 5) Lack of control over features of their work and working environment were reported as important sources of occupational stress. 6) The occasional loss of temper on the job was nearly universal among surveyed volunteers, and many also confided that they tend to take their work stress home with them at the end of the day.

4.2.2 Objective Workload

Objective workload assessment was based on simple frequency counts of trains and other track users, mandatory directives (track usage authorities) issued by dispatchers, and incoming and outgoing phone calls. The data were collapsed across participants and days, and are illustrated in Figures 5 through 7. Figure 5 shows that train traffic peaked early in the shift, then decreased after morning rush hour.

There was a corresponding increase in other track usage in mid-morning, as maintenance crews made track repairs and inspections during periods of light train traffic. This pattern is also reflected in increases in track usage authorities (Figure 6) and phone calls (Figure 7) following rush hour.

Inspection of the dispatchers' records indicated that they are a viable source of workload information. There is one problem with the written records from South Station, however. Dispatchers are required by law only to report when foul time permits — a type of track usage authority — are voided. Dispatchers are not required to report when the permits were issued, information which would be of interest in terms of assessing overall dispatcher workload. Other railroads may have different reporting requirements.

4.2.3 Subjective Ratings

Figure 8 shows that, collapsed across all five volunteers, fatigue gradually increased throughout the day while workload and stress rose to a peak at the height of morning rush hour and then steadily declined. The three workload subscales followed the same pattern as overall workload. Temporal Demand was the lowest rated subscale. Each volunteer's overall workload ratings were correlated with the number of track users (trains and others) on his territory at five

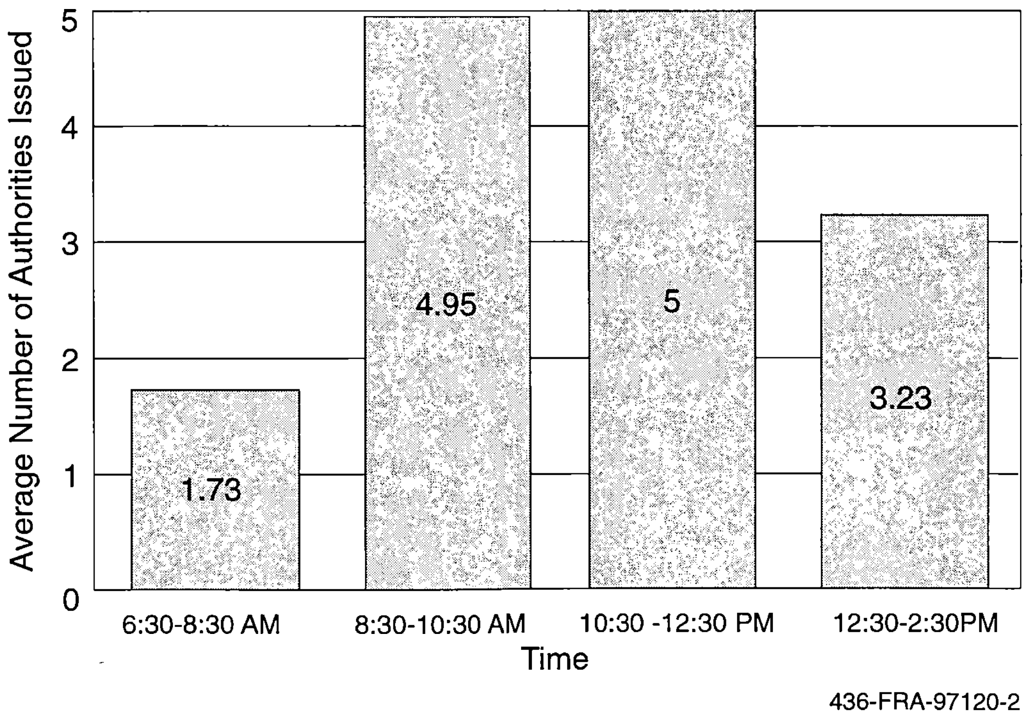

Figure 6. Track usage authorities

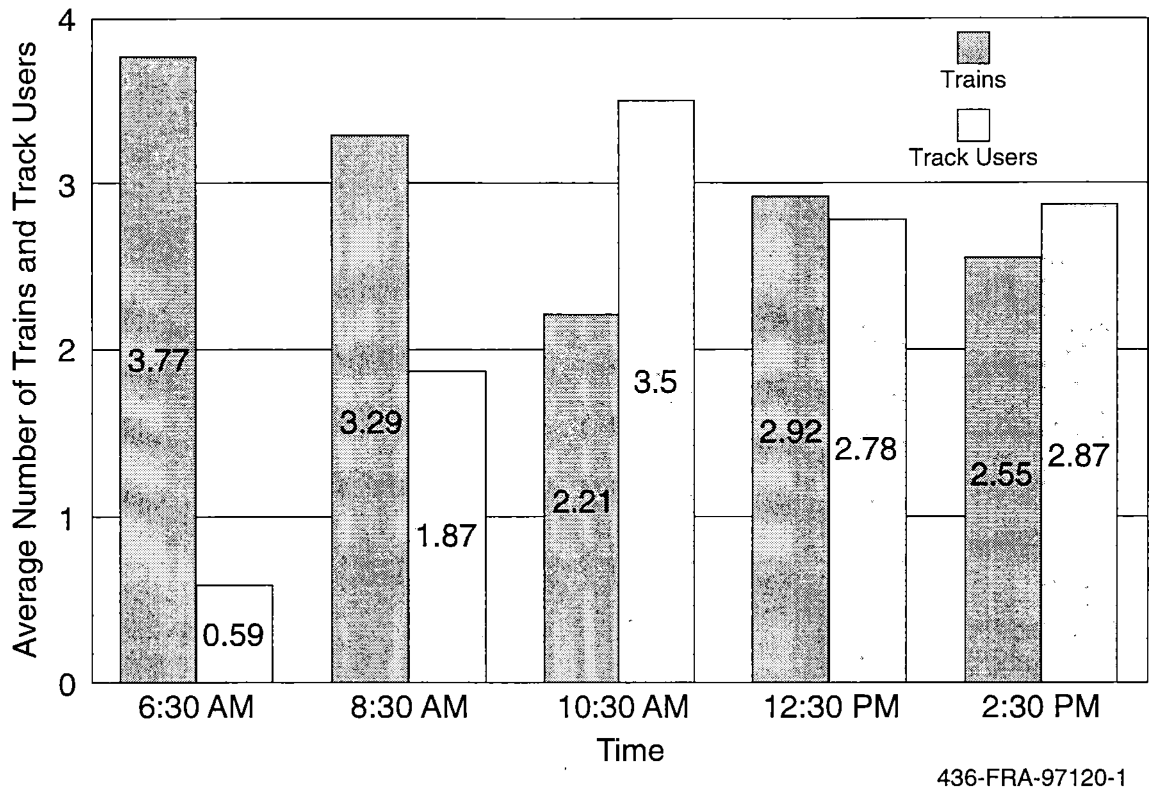

Figure 5. Traffic volume

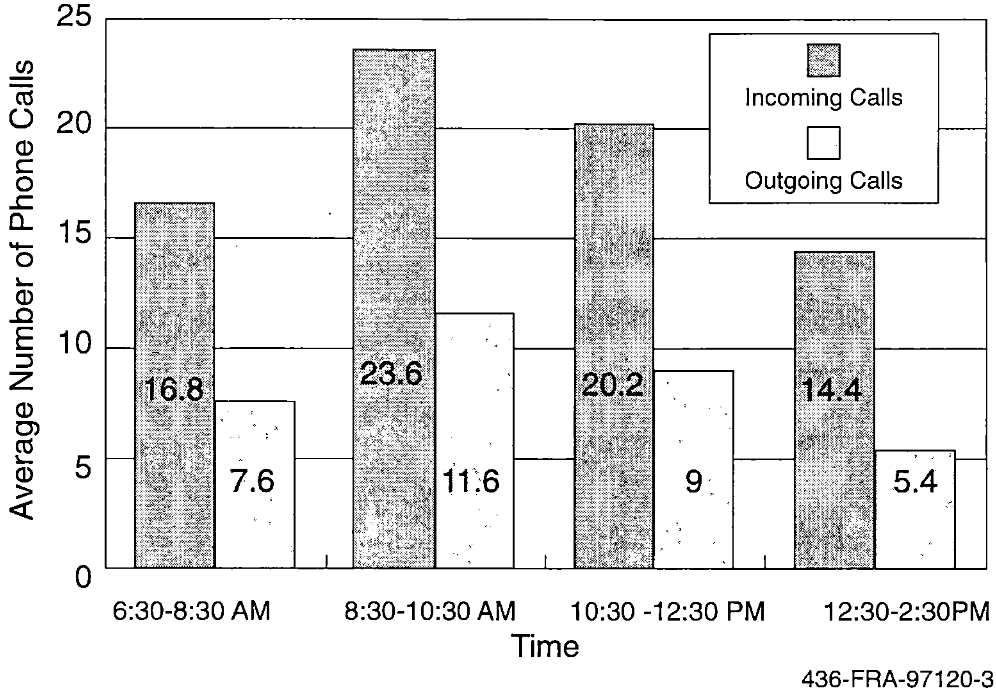

Figure 7. Phone calls

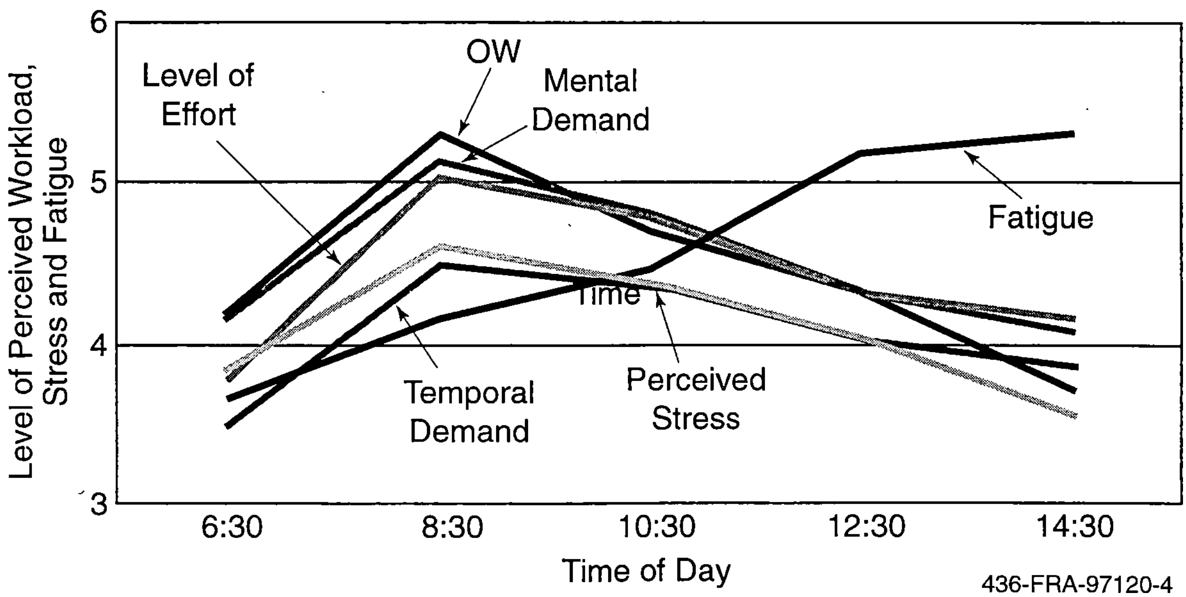

Figure 8. Subjective ratings

intervals during the day for each day of study participation. The Pearson correlations for each of the volunteers were positive and strong, ranging from 0.62 to 0.83. The strong association with the objective workload measure suggests that the dispatchers' ratings are an accurate reflection of task demands, an important issue in establishing the validity of self-report instruments.

4.2.4 Cortisol Measurement

The saliva sampling procedures, as well as the assays, were highly successful. The volunteers were compliant and only one sample was not analyzable due to insufficient sample quantity. Such findings indicate that the cortisol measure is appropriate and feasible for workplace studies of stress. While conclusions about the relationship between workload and stress cannot be based on such a small sample, an interesting trend emerged in the data. Cortisol levels for the two volunteers working at the busiest desks peaked late in the day. These desks are considered to be high workload by the dispatching staff and chief. On the other hand, the cortisol output of the remaining participants, who worked at lower workload desks, was consistent with the normal diurnal release pattern: A morning peak followed by a slow, steady decline across the day. This relationship is illustrated in Figure 9, where Subject A demonstrates an atypical release pattern indicative of stress and Subject B reveals the normal release pattern. The data are collapsed across five days for each dispatcher.

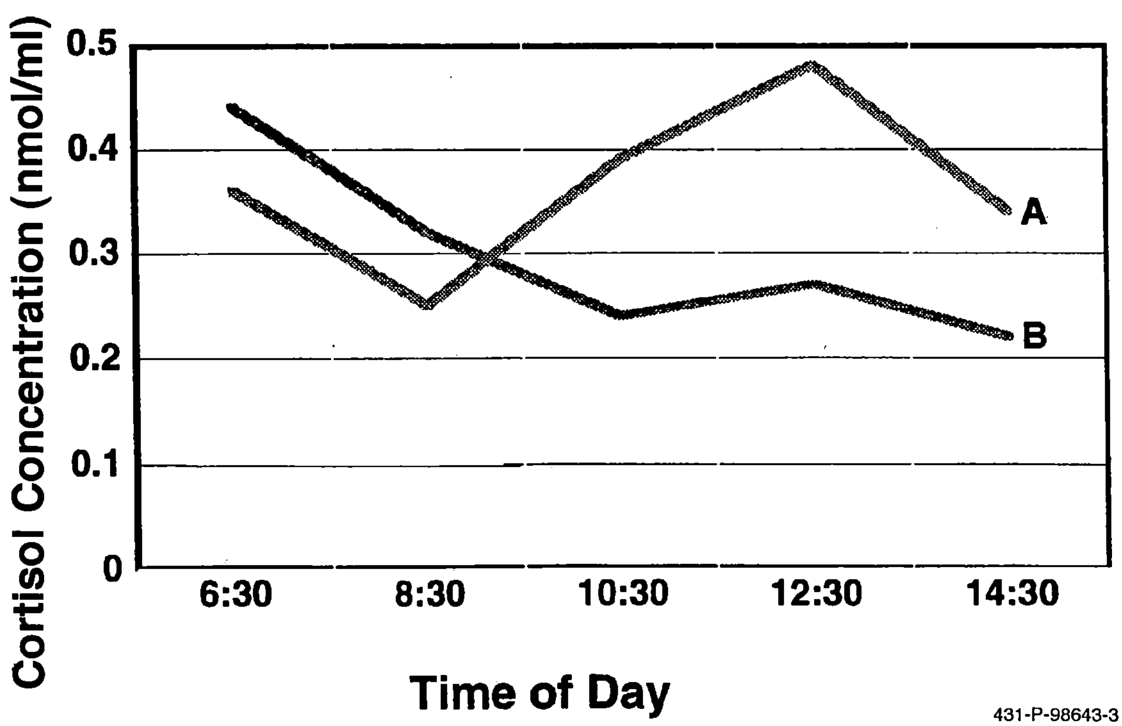

Figure 9. Cortisol levels for two subjects

4.2.5 Actigraphy and Sleep Logs

Inspection of the participants' sleep logs indicated that most were sleeping between 6 and 7 hr per night, although it was not uncommon for some dispatchers to occasionally get only 4 to 5 hr of sleep per night. Subjective reports of sleep duration were generally consistent with the results of the actigraphy. In a few cases, however, the actigraphs either overestimated or underestimated the participants' sleep duration. With respect to overestimation of sleep, the actigraph will likely score a still but wakeful subject as being asleep. In terms of underestimating sleep length, a volunteer may be tossing and turning in Stage I (light) sleep and the actigraph readings will indicate that he is awake.

Only in the case of one subject were the subjective reports and actigraph conclusions profoundly dissociated. This subject was an extremely restless sleeper, who regularly reported getting a lot more sleep than was indicated by his actigraph recordings. He also indicated that he uses beer as a relaxant and sleep aid. This presents a number of problems. First, frequent awakenings to go to the bathroom are likely. Second, alcohol tends to diminish Stages III and IV (deep) sleep, making sleep less restful and restorative. Finally, alcohol has a tendency to affect perceptions, making the individual less accurate at estimating or recalling his previous night's sleep. In this pilot test, as in many cases of dissociation, it is difficult to tell whether the actigraph recordings or subjective reports are more accurate.

All of the dispatchers but one reported waking up an average of one to three times per night, but some awoke as frequently as five to six times per night. Four out of five volunteers reported no use of sleep aids, while the fifth dispatcher admitted to using beer as a sleep aid. Ease of falling asleep and ease of getting up ranged generally from very easy to fairly difficult, with a few reports of "very difficult." Ratings of sleep sufficiency were split fairly evenly between sufficient and insufficient, with only one report each of wholly insufficient and more than sufficient. Assessments of overall sleep quality ranged from fair to poor for four out of the five participants. The fifth participant consistently rated his sleep quality as good to very good. Reports of overall fatigue generally ranged from somewhat fatigued to fairly rested, with few reports of being either very fatigued or very rested.

4.2.6 Debriefing Survey

Volunteers had complaints and suggestions concerning several of the methods: 1) In terms of the saliva collection procedure, participants expressed a reluctance to restrict their food intake and smoking prior to providing a saliva sample. Since this is necessary in order to get an accurate reading, when the full field test is planned, information regarding these restrictions will be supplied to potential volunteers beforehand. That way, they will be better prepared to deal with them and can opt not to participate in the study if the restrictions are too inconvenient. Only one dispatcher commented that chewing on the cotton swab interfered slightly with his communications, and one also felt that the pressure to produce the sample could increase workload. One dispatcher noted that the timing of the saliva collection was sometimes inconsistent with high workload periods. A better understanding of the train schedules at the railroads that participate in the final study should help to alleviate this problem. 2) Taking the

time to complete the surveys was not a problem for the dispatchers, however, it was noted that the survey booklets were large and unwieldy. Other comments indicated that the surveys could increase workload when the dispatcher is busy, and that it is sometimes difficult to evaluate one's own stress level on the spot. Finally, one participant felt that recording the number and types of trains and other track users on their territories every 2 hr was time consuming.
3) Several respondents felt that the actigraphs were too large, the watchband too flimsy, and the devices uncomfortable overall, however, all expressed a willingness to wear one again in a similar study of longer duration, with appropriate financial remuneration.

4.3 Metra

The task load totals for each channel were used to generate Figure 10, where the four lines represent Auditory, Visual, Cognitive, and Psychomotor loads. The duration of the observation was 146 min. Time progresses from left to right on the abscissa. The height of the lines represents resource channel loads. When a line exceeds the value of 7 on the vertical scale, it implies an overload for that channel.

The mTAWL concept of maximum channel load (value of 7) implies that an operator's ability to perform a task may be compromised if a channel is loaded beyond that point. Figure 10 shows a number of overload periods. The most significant of these occurs between the 41st and 51st min. During this period, all channels are in overload. An investigation of the written record shows that six trains were present during this time period and considerable effort was expended in successfully moving them, particularly since many of the movements were potentially opposed.

During the first 20 min of the session, observed overload primarily involved the cognitive channel. The written record shows that a long, slow moving freight train unexpectedly appeared and had to be moved across the high-speed passenger main lines. The move was accomplished without delay or incident, but the overload of the cognitive channel implies a high level of planning and mental effort.

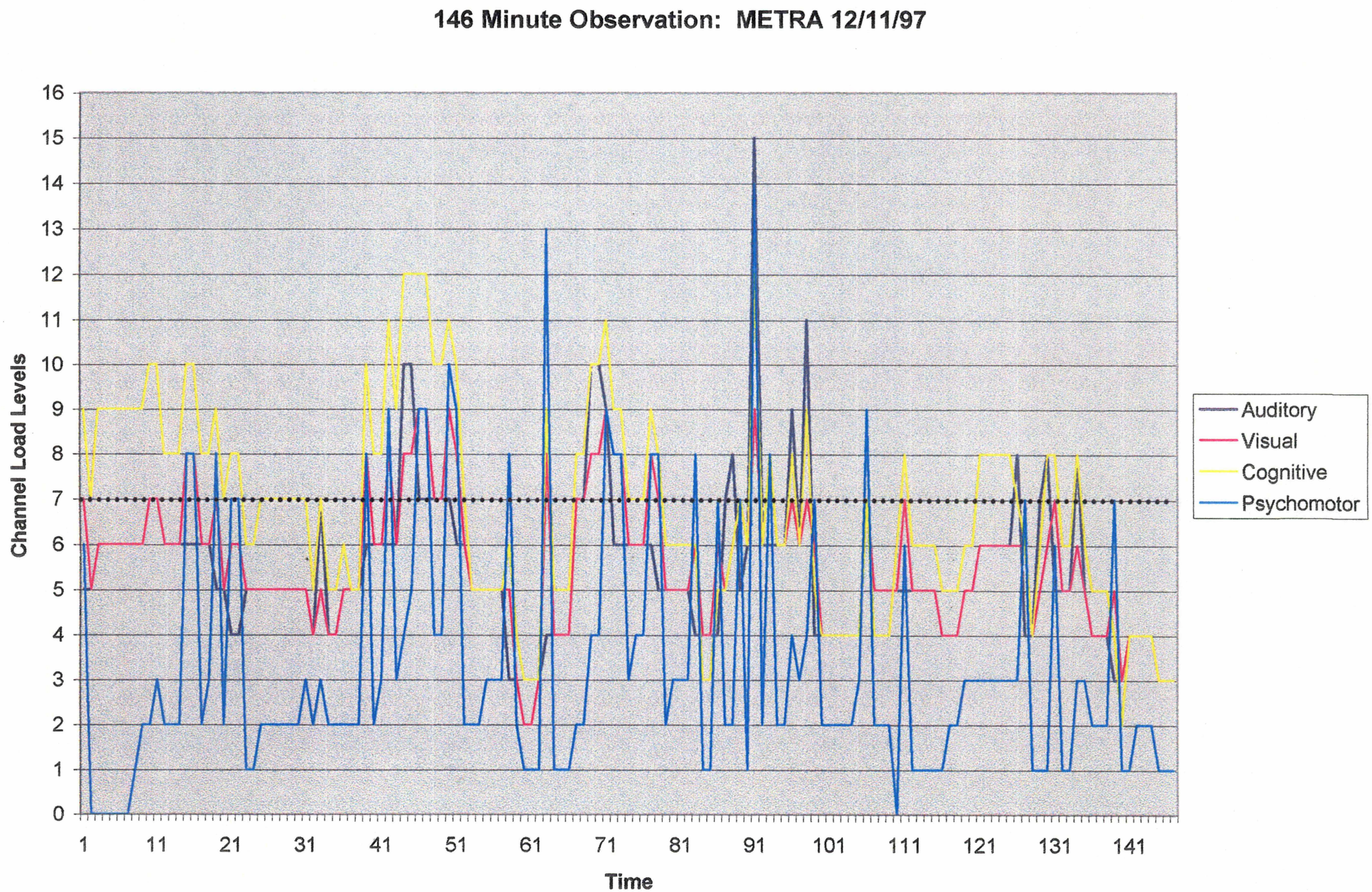

Figure 10. Sample mTAWL output

5. PLAN FOR FIELD STUDY

A number of factors had to be considered in formulating plans for the Phase III field study. Since there are differences in the dispatching environments for passenger and freight operations, Foster-Miller recommends collecting data in each type of environment. One passenger railroad and one freight railroad have already agreed to be test sites for the full field study. Two weeks of data collection in each environment will ensure that adequate data is available to explore workload, stress and fatigue. Also, within the two week time period data will be collected for a full, uninterrupted work cycle for each subject.

The dispatcher's workload is heaviest when track work and maintenance activities are being done. Particularly in northern climates, maintenance of way projects are done in the spring through early November. Since it is desirable to collect data during periods when the dispatcher must handle frequent requests for track authority, the Phase III field study must take place during this time period. This section describes the plan for the Phase III field study, which is based on these considerations as well as the results and conclusions of the pilot test described in Section 4.

5.1 Sites and Participants

The sites for the field study will be Conrail, Selkirk, NY and Amtrak, 40th Street Station, Philadelphia. Two weeks (14 days) of data collection will be done at each location. Conrail's Selkirk dispatching center has 10 desks and Amtrak has 8. It is difficult to predict the number of dispatchers that will volunteer for the study, however, Foster-Miller estimates that there will be a total of 50 to 70 subjects.

Arrangements must be finalized with management at each site. The availability of workload data from each center's computer system must be determined and procedures for obtaining it must be agreed upon with the railroad. Project staff will make a preliminary visit to each site to develop an understanding of the operation, to resolve any issues related to the workload data and to solicit subjects.

Foster-Miller will work with railroad management and the dispatcher's union to solicit subjects. Foster-Miller will prepare a letter for distribution to all dispatchers at each site. The letter will explain the purpose of the study, what will be expected of each subject, compensation for participation and how to volunteer to participate. A sign-up form will accompany the letter. With the railroad's concurrence, the sign-up forms will be returned to a designated individual at the dispatching center. The sign-up form will include a request for information about the subject's work schedule during the data collection period. Using this information, a schedule will be developed for the mTAWL observation. Two observers will be employed at each location.

5.2 Use of Human Research Participants

Department of Transportation regulations dictate than an Internal Review Board (IRB) must evaluate and approve the design, protocol, and materials used in this project. An IRB is composed of individuals who are not part of the project team but have expertise in related areas of human subject research. The purpose of the IRB is to ensure that the study's procedures do not pose any risk of harm to the volunteers. Foster-Miller will employ the services of an outside organization for this function. Dunlap and Associates, an organization regularly used by the Volpe Center for this purpose, will review the study design, protocol, and materials.

5.3 Materials and Procedures

Based on the experience of the pilot test of Phase II, a few minor modifications will be made in some of the data collection procedures for the field study. No changes are anticipated in the content of the background survey. In terms of objective workload measurement, data can be collected from dispatcher records efficiently and unobtrusively at the conclusion of the study. The specific workload variables to be investigated, as well as the method of data collection, will depend on the types of dispatcher data routinely collected at the study site, as well as the type of dispatching technology in use (e.g., computer-generated data versus paper records).

Traffic volume information will be collected through dispatchers' self-reports if records are not available. In that case, dispatchers will be asked to record separately the number of trains and the number of other track users that have traversed their territory during 2 hr blocks of time. Such information can be provided on the subjective report questionnaires. The subjective rating scales themselves will not be modified. However, since this will be a two week study, it will be preferable to collect all surveys daily, rather than compiling them in booklet form and collecting them all at the end of the study. Daily collection will increase the likelihood of volunteers completing their surveys on time. Since some volunteers were surprised by the food and smoking restrictions required by the saliva collection procedure, we will provide that information prior to soliciting volunteers. Finally, an alternative actigraph model will be used for the field study. This model is lighter, smaller, and sturdier than the model used in the pilot test. The research team believes that these new actigraphs will be more acceptable and comfortable to volunteers.

Prior to the start of data collection, each subject must sign the informed consent statement and return it to Foster-Miller. Each subject will also be given a background data survey to complete and return to Foster-Miller. Since all responses must be treated with confidentiality, the Principal Investigator will assign a unique identification number to each volunteer. These numbers will be used on all data sheets in place of participants' names.

A Foster-Miller representative will be on site at the initiation of data collection to gather the consent forms and background surveys, to distribute the actigraphs, and to instruct the subjects on how to fill out the daily data sheets. The procedure for collecting the saliva samples will also be explained. Each dispatcher will be given a packet of data sheets for recording subjective ratings every 2 hr during the workday and a separate set of sleep logs to be completed each day upon awakening. The volunteers will be asked to turn in both the data sheets and sleep logs every day. Since it is unlikely that all of the dispatchers will be at work on the first day of data collection, arrangements will be made to assure that those who will not be working on the first day will be able to begin keeping their sleep logs.

The daily data collection procedure will be similar to that of the pilot study. Participants will supply daily baseline subjective ratings upon reporting to work. They will then provide ratings at 2 hr intervals until the end of the shift. Saliva samples will be provided at the same intervals. A member of the study team will collect the saliva samples, ratings, and sleep logs at the end of the shift. In addition, a trained observer will monitor each dispatcher for two 1 hr periods to gather data for the mTAWL workload analysis. Upon completion of the study, the volunteers will complete the debriefing survey, return their actigraphs, and receive compensation for their participation.

5.4 Implications of the mTAWL for the Field Study

Preliminary observation of the desks to be evaluated and consultation with qualified personnel familiar with those desks are necessary in deriving appropriate task definitions. Task definitions for one setting, such as the one used for this report, should not be blindly applied to new settings without appropriate review. The constructs of triggering events and anticipatory states should be used, however.

Due to the subjective nature of assigning channel loads to tasks, it is especially important that qualified personnel make these judgments. Familiarity with the desks and the observational methodology are necessary, thus Foster-Miller will ask the chief dispatcher to act as a subject matter expert at each location. The chief will be paid for the time devoted to this task.

When the mTAWL methodology is used in a full-scale study, its output should be compared to other workload data. Such a comparison would provide an index of congruent validity.

5.5 Variables

The goal of this project is to explore the effects of the following independent variables on dispatcher workload, stress, and fatigue:

- Time of day.
- Work schedule (shift and rotation).
- Years of dispatching experience (experts versus novices).
- Traffic volume.

Since Foster-Miller has secured the cooperation of two railroads, it will also be possible to compare levels of workload, stress, and fatigue between sites.

Descriptive statistics and graphical representations of the data will be generated. Depending upon sample size, it may also be possible to perform some parametric statistical procedures on the data in order to explore the relationship between variables.

6. REFERENCES

1. Federal Railroad Administration, Office of Safety (1990). *National Train Dispatcher Safety Assessment*, Washington, DC.
2. Federal Railroad Administration, Office of Safety (1995). *National Train Dispatcher's Follow-up Review*, Washington, DC.
3. Weiten, W. (1992). *Psychology Themes and Variations (2nd ed.).* Pacific Grove, CA: Brooks/Cole.
4. Moore-Ede, M.C. and Richardson, G.S. (1985). Medical Implications of Shiftwork. *Annual Review of Medicine, 36*, 607-617.
5. Dell'Erba, G., Venturi, P., Rizzo, F., Porcu, S., and Pancheri, P. (1994). Burnout and Health Status in Italian Air Traffic Controllers. *Aviation, Space, and Environmental Medicine, 65*, 315-322.
6. Knauth, P. and Rutenfranz, J. (1987). Shiftwork. In J.M. Harrington (Ed.), *Recent Advances in Occupational Health*, (pp. 263-281). Edinburgh: Churchill Livingstone.
7. Devoe, D.B. (1974). *An Analysis of the Job of Railroad Train Dispatcher*. Technical Report, FRA-ORD&D-74-37. National Technical Information Service, Springfield, VA.
8. McCord, C.P. (1948). Life and Death by the Minute. *Industrial Medicine*, Oct., 377-382.
9. Menotti, A. and Seccareccia, F. (1985). Physical Activity at Work and Job Responsibility as Risk Factors for Fatal Coronary Heart Disease and Other Causes of Death. *Journal of Epidemiology and Community Health, 39*, 325-329.
10. Dahlgren, K. (1981). Long-term Adjustment of Circadian Rhythms to a Rotating Shiftwork Schedule. *Scandinavian Journal of Work, Environment, and Health, 7*, 141-151.
11. Hart, S.G., and Staveland, L.E. (1988). Development of the NASA-TLX (Task Load Index): Results of Experimental and Theoretical Research. In P.A. Hancock and N. Meshkati (Eds.), *Human Mental Workload* (pp. 139-183). Amsterdam: North Holland.
12. Zeier, H. (1994). Workload and Psychophysiological Stress Reactions in Air Traffic Controllers. *Ergonomics, 37*, 525-539.
13. Fibiger, W., Evans, O., and Singer, G. (1986). Hormonal Responses to a Graded Mental Workload. *European Journal of Applied Physiology, 55*, 339-343.
14. Vickers, R.R., Hervig, L.K., Wallick, M.T., Poland, R.E., and Rubin, R.T. (1987). *Psychological Correlates of Cortisol Excretion in Normal Individuals under Stress*. Naval Health Research Center Report 87-1, San Diego, CA.
15. Henningsen, G.M., Hurrell, J.J., Baker, F., Douglas, C., MacKenzie, B.A., Robertson, S.K., and Phipps, F.C. (1992). Measurement of Salivary Immunoglobulin A as an Immunologic Biomarker of Job Stress. *Scandinavian Journal of Work, Environment, and Health, 18*, 133-136.
16. Motohashi, Y. (1992). Alteration of Circadian Rhythm in Shift-working Ambulance Personnel: Monitoring of Salivary Cortisol Rhythm. *Ergonomics, 35*, 1331-1340.

17. French, J., Bisson, R.U., Neville, K.J., Mitcha, J., and Storm, W.F. (1994). Crew Fatigue during Simulated Long Duration B-1B Bomber Missions. *Aviation, Space, and Environmental Medicine, 65 (Supplement)*, A1-A6.
18. Van Eck, M., Berkhof, H., Nicolson, N., and Sulon, J. (1996). The Effects of Perceived Stress, Traits, Mood States, and Stressful Daily Events on Salivary Cortisol. *Psychosomatic Medicine, 58*, 447-458.
19. Obminski, Z., Golec, L., Stupnicki, R., and Hackney, A.C. (1997). Effects of Hypobaric-Hypoxia on the Salivary Cortisol Levels of Aircraft Pilots. *Aviation, Space, and Environmental Medicine, 68,* 183-186.
20. Bierbaum, C.R., Fulford, L.A., and Hamilton, D.B. (1990). *Task Analysis/Workload (TAWL) User's Guide.* Version 3.0 (Research Product 90-15) Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD S221 865).

Railroad Train Dispatcher Workload, Stress, and Fatigue. Phase II Report: Pilot Field Test (Draft), 1998, Gertler, Becker, Reinach (Foster-Miller, Inc.), Kuehn, 07-Human Factors