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Workstation and Workplace Ergonomics at Federal Aviation Administration Operations Control Centers: Phase 1- Evaluation of Ergonomic Issues

Vicki Ahlstrom, Human Factors Team – Atlantic City, ATO-P
Randy Sollenberger, Ph.D., Human Factors Team – Atlantic City, ATO-P
Anton Koros, Northrop Grumman Information Technology
Henry Dorsey, Northrop Grumman Information Technology

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16. Abstract

The purpose of this study was to collect data on current workplace ergonomic conditions at Federal Aviation Administration Operations Control Centers. Ergonomic issues and associated work-related musculoskeletal disorders can arise due to a combination of factors including environmental conditions, workstation design, frequency and duration of tasks, and psychosocial considerations. In order to create a comprehensive picture of Operational Control Center ergonomics, researchers collected a range of data. Researchers collected data on the workplace environment, including temperature, lighting, and noise. They collected workstation data, measuring the dimensions and features of the desks and chairs and comparing them to standards. Researchers observed and recorded the frequency and duration of user activities during periods of typical work. Finally, they collected data through a questionnaire, which allowed the participants to provide feedback and ratings on their current level of discomfort and on various aspects of their work environment. The research team identified instances where measurements of the current workplace did not meet recommended standards, including temperature, lighting, and workstation adjustability. These deficiencies could result in increased ergonomic risk to the users, a concern that was reflected in the questionnaire results. Questionnaire responses also identified potential ergonomic issues beyond the physical workstation, including psychosocial and organizational factors. These issues and some potential solutions are discussed in detail in this report.

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Executive Summary

Operations Control Centers (OCCs) serve a vital function in the Federal Aviation Administration (FAA). From three geographically separated locations, specialists at the OCCs manage and report status of the National Airspace System, perform remote maintenance, communicate vital information, and coordinate maintenance actions. Specialists who work at these OCCs perform the majority of their functions by interfacing through a computer system or by telephone. As with many other knowledge workers and modern technical specialists, the specialists at the OCCs spend the majority of their workday (up to 10 hours) seated at a computer workstation.

According to some sources (Bernard, 1995), work-related musculoskeletal disorders are increasing in the United States, accounting for more than 60% of all occupational illnesses. The increase in the prevalence of work-related musculoskeletal disorders associated with video display terminal work, such as the work done at the OCCs, is well-documented. A poorly-designed work environment can pose an ergonomic hazard, exposing the users to risk of work-related musculoskeletal disorders. With the amount of time that the specialists spend at the computer workstations, it is important that the workstations are well-designed to support the users in their tasks.

The past few years have resulted in a number of complaints from OCC specialists related to the workstation and workplace environment. In response to these complaints, the Technical Operations organization requested the help of human factors specialists from the Human Factors Team-Atlantic City to collect information on ergonomic issues associated with the current OCC work environment. The research team collected four categories of data; environmental measurements, workstation measurements, observational data and work activity sampling, and ergonomics questionnaire data.

For the environmental data collection, the researchers used the work area layout as a map to record data collection locations for temperature, lighting, and noise measurements as well as to identify functional arrangements. Researchers used a photometer to collect light measurements, a sound pressure level meter to collect sound measurements, and a digital thermometer to measure temperatures. Data and measurement locations were carefully recorded on the data sheets. Environmental data were supplemented with subjective user data solicited on the questionnaire.

Researchers used standard measurement tools such as measuring tapes and yardsticks to measure the workstation. The researchers took measurements of the workstation dimensions including desktop height, keying surface height, and knee space. They measured from the front edge of the work surface to the telephone, reference materials, monitors, keyboards, and mouse (mice). They noted the makes and models of chairs used by the specialists. Researchers measured and photographed the chairs and workstations.

To obtain observational data, the researchers used a simple checklist to identify ergonomics aspects of the workstation such as whether the chair adjusts, whether there was observable glare on the screen, etc. Researchers also noted whether users adopted awkward or potentially risky positions while working such as arms abducted from the body, neck held in a bent position, or arms resting on a hard edge. To collect the activity sampling data, the researchers used a customized data collection tool in conjunction with a handheld device. Researchers observed volunteers at each site for almost 30 minutes, capturing the actions of the specialists while they performed normal activities. The data collection tool captured the patterns, paths, frequencies, and durations of specialist activities.

The questionnaire allowed researchers to collect qualitative data from the users. Data categories on the questionnaire included both self reports of pain and ratings of various aspects of the work environment. Researchers asked the volunteers to rate various aspects of their work environment (such as temperature, lighting, and workstation) on the questionnaire using a Likert scale. Other questions asked volunteers to rate and provide feedback on general work structure topics such as the work schedule and break schedule. The purpose of the questionnaire was to allow participants to rate various aspects of their workplace including the environment, workstation, and other contributing factors and to identify pain experienced at the workplace by the specialists including the severity and frequency of the pain.

The research team compared the data collected from the measurement of the environment against existing human factors standards. A comparison of the noise level data against the standards found that noise levels at one OCC exceeded the recommended noise levels for frequent telephone use. The lighting levels at both OCCs were below the recommended lighting levels for general office work. All of the temperature measurements at one OCC and more than half of the measurements at the other exceeded the recommended summer comfort zone.

The research team compared the workstation data to existing human factors standards. The desk height and the knee space met the minimum standards for a workstation, however, the keying surface and the depth at the toe did not meet the recommended standards. The research team also noted that the specialists did not have the ability to adjust the keying and mousing surface to accommodate different sized users. The research team also compared the chairs to existing standards. The chairs complied with existing standards.

The researchers analyzed the activity sampling data. For the eight specialists observed over a course of nearly 4 hours, the researchers recorded 787 actions. The most frequent action involved using the mouse with the right hand, followed by using the keyboard with the right hand, then by using the keyboard with the left hand. The action with the longest average duration was using the mouse with the right hand, followed by resting the left hand on the table and using the keyboard with the left hand. The high number of actions a high duration of time spent on mousing action with the right hand indicates that the OCCs are a very mouse-intensive work environment.

Analysis of the questionnaire data revealed that many specialists reported having pain at the workplace. Keep in mind that this finding does not necessarily imply a causal relationship between the workplace and the pain experience by the users. Out of the 20 people surveyed, however, 10 individuals reported feeling discomfort every day while working. Six of these people rated the pain as unbearable at its worst. Even without knowing the original cause of the reported pain, the researchers hoped that with proper ergonomics interventions, it may be possible to reduce the number of people who reported feeling discomfort on a daily basis. Users rated the physical aspects of the environment including the lighting, temperature, noise, workstations, and chairs, the keyboards, mouse, monitors and phones, and the psychosocial aspects of the environment including the workload, amount of ergonomics training, stress levels, and breaks. Out of the physical aspects of the environment, the two items that received the worst user ratings were the workstations and the chairs. All of the four mentioned psychosocial aspects received negative ratings from 45% or more of the respondents.

The study identified shortcomings in the workplace environment, workstation, and psychosocial and organizational factors. These shortcomings are detailed in the body of this report. Many employees report suffering from significant pain during the workday. The ergonomic shortcomings identified in this report could be costing the OCCs significantly in lost productivity, increased errors, employee injury and absenteeism. In addition to physical shortcomings in the environment, the questionnaire results led the researchers to believe there were many psychosocial and organizational shortcomings in the workplace. Psychosocial and organizational factors can have a significant impact on workplace discomfort. Fixing the physical aspects of a work environment without addressing psychosocial factors can leave a work place still at risk.

Participants also reported a lack of ergonomics training. Proper ergonomics training could help inform the users of the impact of impact of improper ergonomics and the benefits of proper posture, the variety of activities, and the frequent changes of position. Ergonomics education could also teach them how to adjust the workstation so that it is more comfortable.

To ameliorate the potential risks associated with the shortcomings identified in this study, we recommend the following changes:

- To the extent possible, we recommend that the users be given more control over their workspace, possibly including the ability to adjust lighting, temperature, and chair and keyboard/mouse height.

- We recommend that the specialists be provided with task lighting.

- We recommend that management work with engineers at the facilities to adjust air handlers so that they work more quietly and efficiently, reducing noise and improving temperature levels.

- We recommend evaluating alternative pointing devices for potential use at the OCCs.

- We recommend providing ergonomic training to the specialists. This training should also teach the specialists how to adjust their workstations, chairs, lighting, and workspace to meet their needs.

- We recommend providing specialists with adjustable keyboard and mouse trays to improve the keying and mousing height. Pullout, adjustable keyboard trays could also increase the available leg space, allowing the users to comfortably shift body position.

- We recommend providing the specialists with new ergonomic chairs. Although the chairs at the OCCs had many of the desired ergonomic features, the specialists expressed great dissatisfaction with the chairs.

- We recommend that the work be examined to find ways to reduce the psychosocial stress, such as allowing specialists more control of their work, making sure that specialists are able to make full use of their skills, involving specialists in decisions, ensuring good communication, reducing monotonous tasks, and encouraging users to take breaks.

- Finally, we were concerned with the user reported lack of breaks. Although we did not verify the self reports of breaks, the specialists indicated that they were not taking breaks. Instead, it is likely that they are maintaining prolonged static postures to the detriment of their performance and physical well being. We believe that through education and management support, these negative habits and associated risks can be reduced.

We recommend testing potential ergonomic solutions on a small scale in the operational environment to ensure that the solutions are viable in the intended operational environment.

This document can not only provide information for targeting ergonomic interventions to maximize their effectiveness, but can also serve as a baseline against which to evaluate the success of future ergonomic interventions.

1. INTRODUCTION

In an effort to streamline and modernize maintenance operations, the Federal Aviation Administration (FAA) created three regional Operations Control Centers (OCCs). The OCCs play a critical role in the maintenance and management of the National Airspace System. They are responsible for management of the National Airspace System, the coordination of maintenance actions, remote monitoring and control of maintenance systems, response prioritization, and documentation of maintenance activities (FAA, 2005). As most of these tasks are accomplished electronically or by telephone, the specialists spend the majority of their time seated at computer workstations.

In the past few years, there have been numerous complaints from the specialists who work at the OCCs about ergonomics issues (B. Clark, personal communication). In 2001, the Technical Operations organization at FAA headquarters created a database to capture human factors issues identified at the OCCs. Some of the issues in the database included insufficient lighting at workstations; high sound levels; workstation surfaces that are too high and not adjustable, leaving shorter people without foot support (FAA, 2001). These complaints have been addressed in a "piecemeal" fashion. Facilities purchased desk lamps for additional lighting and footrests for individuals of shorter stature, yet complaints about user discomfort due to ergonomics at the OCCs have continued.

In 2005, a representative from the FAA's Safety and Operations Support Office returned from a trip to the Mid-states Operations Control Center (MOCC) in Olathe, Kansas. She reported the following issues:

- "They must raise the chair to reach the desk comfortably, causing feet to dangle."
- "Many specialists commented that they have shoulder pain caused by reaching for the phones."
- "Wrist pain is becoming the norm for many of the personnel."
- "Although ergonomic keyboards had been offered as an alternative in the past, and most said no, there is much more interest in having them available at this time." – Excerpts retrieved from Trip Report dated February 22-24, 2005.

To address this continuing problem, the FAA Technical Operations organization asked the Human Factors Team-Atlantic City to systematically evaluate the ergonomic issues related to the OCCs. At the time this study was initiated, the researchers were told to focus any recommendations on ways of adapting the existing workstations rather than suggesting new workstations.

1.1 Background

According to a study conducted by the Institute of Medicine in 1999, nearly 1 million people took time away from work to treat and recover from work-related musculoskeletal pain (Institute of Medicine, 2001). The same study asserts that musculoskeletal pain can be reduced through ergonomic workplace redesign, administrative changes, and individual factors. The body of research on this topic justifies the introduction of ergonomic interventions to reduce the risk of musculoskeletal disorders.

There are many different factors that can have a negative impact on the workplace. These factors could be broadly categorized as environmental issues, workstation factors, and psychosocial/organizational factors. There are specific risk factors in each of these categories.

The ambient noise, temperature, and lighting levels can have an impact of the workers. A report by the General Services Administration states that environmental improvements such as in thermal comfort, lighting, acoustics, and indoor air quality can increase worker productivity by 5% to 15% – and can reduce employee absenteeism by 8% to 45% (General Services Administration, 1999). DeMarco and Lister (as cited in General Services Administration, 1999) found a direct correlation between noise in the workspace and performance, with people in workspaces with fewer acoustic disruptions performed 2.6 times better than those with less acoustic control.

The OCCs workstations are arranged in an "open-plan office" environment, where multiple individuals work in the same room without walls or dividers to separate them. There are several sources of noise in modern open-plan offices. The noise produced by equipment and the heating, ventilation and air conditioning equipment, the regular click of keyboards or the buzz of printers, movement sounds such as the sounds of footsteps, telephones, and conversations of coworkers all contribute to the ambient noise. The predominant effects of too much noise in offices are interference with speech, distraction, disturbance of intellectual activities, and annoyance (Grandjean, 1992).

Ambient temperature can also have an impact on performance. The General Services Administration (1999) reported that, when typing, people performed significantly more work at a temperature of 68 degrees Fahrenheit (68 °F) than at a temperature of 75 degrees Fahrenheit (75 °F). Cold temperatures have been identified as potential risk factors for work-related musculoskeletal disorders.

The most frequent subject of ergonomics evaluations is the workstation, perhaps because so much research has linked improper workstations to work related musculoskeletal disorders (Bernard, 1997). Work surfaces that are too high or too low can lead to awkward postures such as extending the arms to reach the mouse, elbows held away from the body, and elevated shoulders, resulting in neck, arm, shoulder, and back pain (Grandjean, 1992). Repeated or continuous contact with hard surfaces, called contact stress, can create pressure that can inhibit nerve function and blood flow. There are several potential contributors to contact stress in a typical office environment. Locating the keyboard on the desktop surface could lead to contact stress. Contact stress can also be caused if the legs press against a hard surface on a chair or elbows rest on a hard armrest.

In addition to work surface height, leg space is an important consideration for minimizing ergonomic risk. It is important when users spend long periods of time at a workstation to allow plenty of space for leg movement. It is advantageous if the legs can be crossed without difficulty and if there is room for the user to stretch the legs under the desk. Limited space under the desk can constrain leg positions, causing the user to adopt awkward leg positions or sit too far away from the desk, leading to reaching (Grandjean, 1992).

Although all three of the OCCs use the same software, each has different system configurations. At the time this report was written, the MOCC used three monitors connected to a single keyboard and a mouse through an electronic switching system. This was a new development for the MOCC, which up until recently had three keyboards and three mice; one keyboard and mouse for each of the three computers (see Figure 1). At that time users had to switch between input devices, depending on the computer that was used. The Atlantic OCC (AOCC) had a slightly different configuration, with two keyboards and two mice connecting to two different monitors.

Figure 1. The workstation configuration (with three monitor and three mice previously used at some Operations Control Centers).

In addition to physical aspects of the workplace, psychosocial factors and organizational factors can also have a significant impact on workplace comfort or discomfort. According to Health and Safety Executive (Health and Safety Executive, 1999), some undesirable features that can lead to psychosocial risks include

- workers having too little control over work and work methods;
- workers not being able to make full use of their skills;
- workers not involved in decisions that affect them;
- tasks that are perceived as repetitive, or monotonous;
- workplace where workers are encouraged to work without breaks;
- work demands perceived as excessive;
- high levels of effort not balanced by sufficient reward; and
- limited opportunity for social interaction.

These psychosocial and organizational factors can affect work-related musculoskeletal disorders and productivity both directly and indirectly (Carayon et al, 1999).

Failure to address ergonomic issues in the workplace can lead to the presence of or increase of musculoskeletal pain, lost man-hours due to injury, increased errors, and reduced productivity (Institute of Medicine, 2001). The consequences of musculoskeletal disorders – and the evidence that these disorders can to some degree be prevented or lessened – justify a concerted effort to develop and implement ergonomic interventions. These interventions should be evaluated periodically for success and modified as appropriate to meet the needs of the user.

1.2 Purpose and scope

The purpose of this study was to collect data on current ergonomic conditions at a target OCC. To accomplish this purpose within the limitations of this project's time and budget, the scope was limited initially to a single OCC. This initial target facility was the MOCC located in Olathe, Kansas. The Technical Operations organization chose this location based on the expression of need and the willingness of the facility to participate in the project. Following the initial data collection at the MOCC, the scope was expanded to include a second OCC, based on reports of ergonomic issues that were being experienced at that OCC. The second OCC was the AOCC in Atlanta, Georgia.

In addition to the primary purpose of this study, which was to collect information on ergonomic issues associated with the current OCC work environment, a secondary goal of this effort was to identify potential interventions that could work within the context of the existing workstations. Therefore, an assessment of several factors was required, including, but not limited to, the following;

- whether the users had any training on proper ergonomics, including ways to avoid repetitive stress injury;
- the extent to which the current workplace and workstation complies with ergonomics guidelines and standards;
- the subjective reports on ergonomic aspects of the workplace and workstation;
- the specialist actions, including frequencies, transitions, and durations;
- the extent to which specialists are currently experiencing body discomfort that could be related to their work environment; and
- the extent to which specific changes or enhancements could improve the ergonomics of the workplace.

2. METHOD

The basic goal of ergonomic workplace design is to ensure that the user can perform the necessary tasks safely, comfortably, and efficiently. There are many factors that can impact the goal of good ergonomics, including ambient environment, physical aspects of workstation design, workspace layout, location of tools, and the organization of tasks. To address the range of factors that can impact workplace ergonomics, researchers used a range of methods to collect data. These methods are described in further detail in the following sections of this report.

2.1 Materials

The research team used the following equipment for data collection at the OCC sites:

- One digital camera to verify layout and the position of equipment
- Small stickers for use as measurement reference points
- One sound pressure level meter
- One photometer
- One tape measure
- One digital thermometer
- Two yardsticks
- One laptop computer for data collection and storage
- Two handheld Personal Data Assistant (PDA)-type computers with custom software installed for data collection
- A data collection sheet and ergonomics questionnaire

2.2 Procedures

The research team collected four categories of data; environmental measurements, including lighting, sound, and temperature; workstation measurements; observational data and work activity sampling; and ergonomics questionnaire data. Prior to field site visits, the research team conducted dry runs to validate the data collection equipment and recording processes at a location in the FAA William J. Hughes Technical Center.

Data collection occurred at the OCC in Olathe, Kansas during June of 2007 and at the OCC in Atlanta, Georgia during August of 2007. The researchers coordinated all activities at the sites with management to ensure that they did not adversely impact operations. All efforts were coordinated in advance with facility management and FAA headquarters.

Upon arrival at a facility, the researchers briefed management and participants on the nature of the study and the data collection methods used in the study. The researcher team collected measurement data at times when it was deemed least disruptive to ongoing operations, based on the judgment of facility management. All participants were given a written statement of informed consent and were reminded that participation was voluntary and that they may withdraw from the study at any time. Although the researchers collected demographic data, names of the participants were not recorded on the data sheets. Participants received a coded participant number so that researchers could match the data with any follow-up data collection efforts. Participants included both male and female federal employees.

2.2.1 Environmental Measurement Data

The research team documented the general layout of the facility. They photographed the work area, then drew and labeled the work area on a grid – including all relevant furniture and equipment, entryways, large screens, printers, workstations and operator positions. The researchers used the work area layout as a map to record data collection locations for temperature, lighting, and noise measurements as well as to identify functional arrangements of equipment and furniture. Figure 2 shows an example of such a layout. The digital camera was used, as necessary, to capture layout and equipment data, but mainly served as a backup for researcher notes.

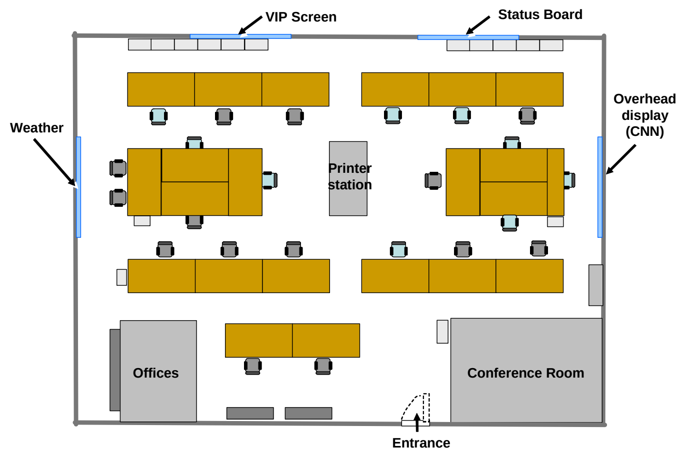

Figure 2. Example of a layout.

The research team collected environmental data at each site, including temperature, lighting, and noise. Details of each of these measurements are provided in the following sections.

2.2.1.1 Temperature Measurements

Using a standard digital thermometer, the researchers took temperature measurements in three different locations, carefully recording the locations on the map. If there were differences in temperature greater than 5 degrees Fahrenheit (> 5 °F), a researcher took additional temperature measurements. In addition to this base set of measurements, the researchers asked the personnel to point out areas that were unusually (or uncomfortably) hot or cold. If there were locations that were unusually hot or cold, a researcher would record these locations on the map and measure the temperature at those locations.

2.2.1.2 Lighting Measurements

Researchers collected light measurements using an International Light Radiometer/Photometer (Model IL 1400A). According to manufacturer specifications, this tool presents a variability of +/- 5%. The researchers calibrated the tool prior to the measurements being taken. Researchers took measurements at the center of the work area and at three workstations throughout the work area. Data were recorded from each workstation by holding the sensor upon a console surface (or desktop). A researcher marked the measurement locations on the map and indicated on the data sheet both the results of the measurements and whether task lighting was on or off at the time the measurement was taken. Researchers observed the work area and identified whether there were any spots that were particularly bright or particularly dark. These spots were indicated on the map, measured, and recorded on the data sheet.

2.2.1.3 Noise Measurements

Researchers used a Sound Pressure Level (SPL) meter to measure the noise SPL of the ambient environment. Noise measurements were taken in four different locations; the center of the work area and three different workstations. Each of the measurement locations were identified on the map. Measurement locations, data, and time were recorded on a data sheet – along with a subjective rating of the current workload as high, medium, or low. (The researchers were interested in knowing the workload in case the noise level fluctuated in tandem with the workload.) The researchers identified any equipment in the work area that significantly contributed to the noise level, including the equipment type, location, and any other relevant information. Researchers also asked the staff whether there were any particularly noisy locations, times of day, or pieces of equipment. If the staff answered affirmative, the researchers noted the areas on the data sheet and map and made every effort to measure the noise levels during those conditions.

2.2.2 Workstation Data

Members of the research team photographed the workstation area. The researchers placed small, red, circular stickers on critical pieces of equipment, such as the telephone, monitor, keyboard, and mouse. These stickers were used as reference points to ensure consistency of measurements. The researchers photographed, drew, and labeled the workstation area using a grid on a data collection form. The drawing included the desk, chair, monitor, keyboard, printer, and all other relevant materials.

The researchers took measurements from the front edge of the work surface to the telephone, reference materials, monitors, keyboards, and mouse (mice). They measured the desk height, depth, and width, keyboard height, knee space, and depth at the toe. They noted the makes and models of chairs used by the specialists. Researchers photographed the chairs and workstations.

2.2.3 Observational Data and Activity Sampling

2.2.3.1 Checklist

Researchers used a simple checklist to evaluate general ergonomic aspects of the OCCs. A researcher sat in an unused workstation and filled out the checklist, identifying such aspects as whether the chair adjusts easily; whether the work surface is adjustable; whether there is observable glare or reflections, and so forth. The complete checklist is provided in the Appendix. In addition to the items on the checklist, researchers took notes on their own observations of potential relevance for the study. Examples of these observations include observations of users in awkward positions; any observed adaptations of the workstation or workspace, and use of any existing ergonomic intervention/tools.

2.2.3.2 Activity Sampling

Examining static aspects of the workstation in isolation is not sufficient as repetition, load, and duration of activities are also important risk factors (Bernard, 1995). In order to fully understand the ergonomic issues of the OCC, the researchers observed volunteers who were in the process of performing their work. Researchers observed four volunteers at each site for 27 minutes each. The researchers used handheld computers in conjunction with a custom data collection program to code user activities (such as using the telephone, the keyboard, and the mouse, as well as taking notes or talking person-to-person) and whether the activity was performed with the right or left hand (see Figure 3). This data collection program used these inputs to capture the patterns, paths, and durations of specialist activities.

Figure 3. Handheld device with custom program used to code user activities.

2.2.4 Questionnaire

The researchers asked volunteers at each site to complete a questionnaire. The questionnaire contained 40 items and included questions related to user demographics, ratings of current pain/discomfort, workstation satisfaction ratings, and psychosocial/organizational ratings. An example of the questionnaire is contained in the Appendix.

2.2.4.1 Questionnaire Participants

Researchers collected participant demographic information to define the target population. Demographic data can contribute to the development of appropriate ergonomic solutions as some ergonomic issues are thought to be related to the demographics of the user (Sizer, et al, 2004). The demographic data collected were limited to information that may impact workplace or workstation ergonomics. The types of data included:

- Age
- Male or Female
- Typing proficiency
- Height
- Number of years at current job
- Handedness
- Whether the person wears glasses and type of glasses
- Whether the person smokes or not

2.2.4.2 Questionnaire Ergonomic Evaluation

Researchers asked the volunteers to rate the adequacy of various aspects of their work environment (such as temperature, lighting, and workstation) on the questionnaire using a Likert scale. The questionnaire included topics such as the amount of ergonomics training received and current ergonomic aids (such as a footrest or document holder). Other questions covered general work structure topics such as the work schedule, stress level, work load, and break schedule. The questionnaire also asked the volunteers to identify the location of and rate the severity of any current symptoms of discomfort or pain. As discomfort is one of the first outward signs of an ergonomic problem, an analysis of user symptoms can help identify ergonomic deficiencies in the workplace. The full questionnaire is contained in the Appendix.

3. RESULTS

3.1 Environment

The following sections address the environmental factors of temperature, light, and sound/noise. Researchers compared measurements collected at the field sites to standards set to optimize worker comfort and well-being. These sections summarize the results of the environmental data collection and highlight any measurements that did not meet current standards.

3.1.1 Temperature

At the MOCC, the research team took temperature measurements at 5 different locations. As a result of user comments, the researchers then took additional measurements at a sixth location over a period of 4 hours to see how the temperature changed with time. At the AOCC, the researchers took five different measurements at various locations. The results of these measurements are presented in Table 1.

Table 1. Temperature Measured at the Mid-states OCC and Atlantic OCCs

MOCC		**AOCC**	
Location	Temp. (°F)	Location	Temp. (°F)
1	75.2	1	75.9
2	75.4	2	76.6
3	77.0	3	74.3
4	77.5	4	76.3
5	75.9	5	70.3
6	75.2-75.7		

The Human Factors Design Standard (Ahlstrom & Longo, 2003), recommends a summer comfort zone range of 65.8 - 75.0 °F. Temperatures measured at the OCCs are shown in Table 1. All of the temperature measurements taken at the MOCC and more than half of the temperature measurements taken at the AOCC exceeded the recommended summer comfort zone.

3.1.2 Lighting

Researchers took lighting measurements at 14 different locations at the MOCC and 18 different locations at the AOCC (see Table 2). Most of the measurements were taken at the employee workstations. The measurements with the * indicate measurements that were taken *between* workstations. The researchers compared the measurements taken at the field sites to exiting human factors standards.

Table 2. Lighting Measurements Taken at the Mid-states OCC and Atlantic OCCs

MOCC				AOCC			
Location	**fc**	**Location**	**fc**	**Location**	**fc**	**Location**	**fc**
1	16.5	10*	13.2	1	15	10	5
2	18.2	11	11.9	2*	8	11	7
3	17.2	12	15.7	3	9	12	7
4	9.4	13	10.1	4	27	13	11
5*	14.6	14	15.9	5	30	14	.4
6*	16.0			6*	20	15	.5
7*	11.6	-	-	7*	12	16	6
8*	17.0	-	-	8	13	17	34
9	18.5	-	-	9	24	18	3

Note. An asterisk (*) indicates measurements that were taken between workstations.

The recommended lighting levels for general office work and reading notes is 50 fc to 70 fc (Ahlstrom & Longo, 2003). This is an appropriate recommendation for the OCC environment because OCC specialists interact frequently with their computer and often take and subsequently read handwritten notes. All of the measured lighting levels at both the AOCC and MOCC were below recommended minimum lighting levels for general office work and reading notes.

The recommended lighting level for passageways and corridors is 10 to 20 fc. Areas between workstations should be at least this bright to prevent tripping hazards. One of the measurements between the workstations at the AOCC was below this recommended minimum level for passageways.

3.1.3 Sound and Noise

The Human Factors Design Standard (HFDS) recommends that ambient noise values not exceed 55 dBA for frequent telephone use (Ahlstrom & Longo, 2003). Exceeding these values could make it difficult for specialists to hear information transmitted on the telephone.

The researchers measured the noise levels at 8 different locations at the MOCC and 13 different locations at the AOCC. The results of the measurements are presented in Table 3. All but one of the measurements at the MOCC was within recommended limits for frequent telephone use and occasional speech conversation. All of the measurements at the AOCC exceeded the recommended limits for frequent telephone use and occasional speech conversation.

Table 3. Noise Measurements Taken at the Mid-states OCC and Atlantic OCCs

MOCC		AOCC			
Location	**dB(A)**	**Location**	**dB(A)**	**Location**	**dB(A)**
1	52.8	1	65.0	9	62.0
2	38.2	2	65.9	10	60.3
3	52.1	3	67.0	11	62.5
4	57.2	4	64.0	12	64.0
5	53.7	5	70.0	13	72.6
6	50.1	6	61.0		
7	53.7	7	61.4		
8	51.3	8	61.6		

3.2 Workstation

The MOCC and AOCC had different workstation configurations. At the time the researchers gathered the data, the AOCC workstation had two different configurations: (a) the old configuration that consisted of two computers, keyboards, monitors, and mice, and (b) the new configuration that consisted of two monitors, but only one keyboard and one mouse (see Figure 4). Each MOCC workstation had three monitors, one mouse, and one keyboard (see Figure 5). This was a new relatively new configuration. The MOCC configuration was possible due to a switching tool that allowed them to go from 3 keyboards and 3 mice to a single keyboard and mouse. According to the participants' surveyed, response to this change was overwhelmingly positive with comments such as, "Big improvement" and "One of the best changes I've seen."

Figure 4. The old workstation configuration (left) and new workstation configuration (right) at the Atlantic Operations Control Centers.

Figure 5. Workstation configuration at the Mid-states Operations Control Center.

The researchers used small red circular stickers as reference points and measured the distance from the front of the work surface to each of the workstation items (see Figures 6 and 7). The items on the desk were movable so that users could move tools closer as desired. The HFDS recommends a monitor viewing distance of 20-40 inches (Ahlstrom & Longo, 2003). One of the monitors at the AOCC was placed 41" away from the edge of the desk. All of the other monitors complied with the monitor distance recommendations. The HFDS recommends that tools that are used frequently be placed within easy reach of the user. The functional reach for a 5th percentile female user is 25.9 inches. Applying this to the OCC work surface measurements, all of the tools with the exception of the second keyboard at the AOCC would be within easy reach of even the 5th percentile female user. According to the United States Occupational Safety and Health Administration (OSHA) workstation recommendations, workstations should avoid hard leading edges because of a risk for contact stress (OSHA, 2007). Both OCC workstations did have hard leading edges.

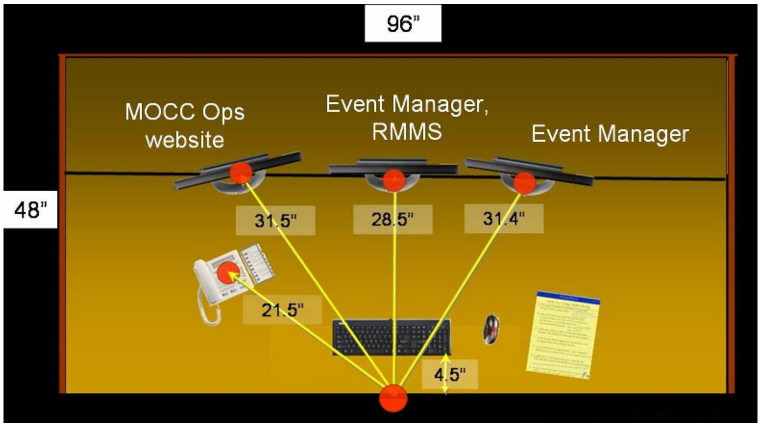

Figure 6. Workstation configuration measurements at the Mid-states OCC.

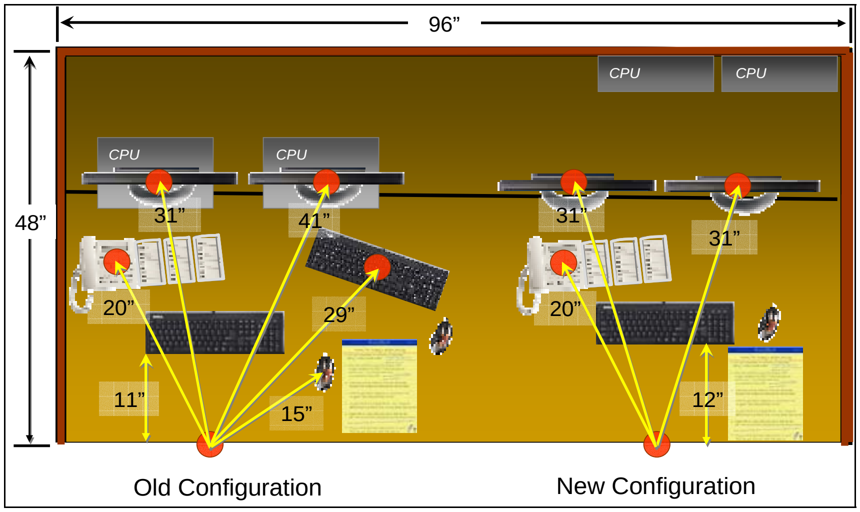

Figure 7. Workstation configuration measurements at the Atlantic OCC.

The research team also measured the furniture, including desk height, keyboard height, knee space, and depth at the toe. The measurements were the same for both of the OCCs. The desk height was within the recommended range; however, the keyboard height (i.e., keyboard placed on the desktop) was higher than the recommended range and was not adjustable (see Table 4).

Table 4. Workstation Measurements and Recommendations.

	Measured	**Recommended**
Desk height	30″	29-31″ (HFDS, 2003)
Keyboard height	31″	23-28″ (ANSI 100, 1988)
Knee space	21.5″	18″ minimum (HFDS, 2003)
Depth at toe	21.5″	23.6″ minimum (BSR/HFES 100, 2002)

A number of footrests were available to the specialists. However, specialists reported that the footrests were not widely used because prior to the new workstation configuration, (a) the specialists moved around too much and (b) the footrests were not stable and often wobbled due to the heel catch built into the workstation (see Figure 8).

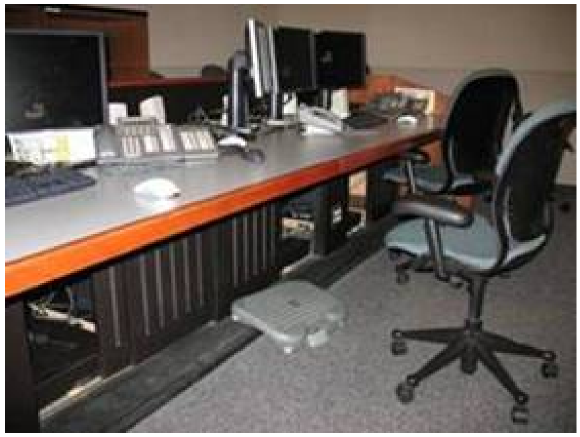

Figure 8. The workstation with a footrest.

3.2.1 Chairs

There were two different chairs available to the specialists at the MOCC, the Equa 2 and the Aeron chairs. These chairs had a number of features that complied with recommendations from current standards (Ahlstrom & Longo, 2003). The chair features included rolling casters, adjustable armrests, adjustable seat height, undercut armrests, and waterfall seat pan front edges. According to the manufacturer's specifications, these chairs come in three sizes. The researchers were unable to determine how many of each size were available. The specialists interviewed did not indicate any realization that different chair sizes were available.

3.3 Observational Data

Researchers observed many awkward positions adopted by specialists working at the OCCs. Observed positions included elbows held away from the body, shoulders lifted, and specialists resting their arms on the hard edge of the work surface (contact stress). Researchers observed specialists leaning on the arms of chairs or on the hard surface of tables. Researchers also observed that some specialists attempted to adapt the workstation to increase the leg space by opening the maintenance access doors that are located at the bottom of the workstation (see Figure 9). Although some of the OCC specialists reported being left-handed, the researchers did not observe any specialists using the mouse on the left side.

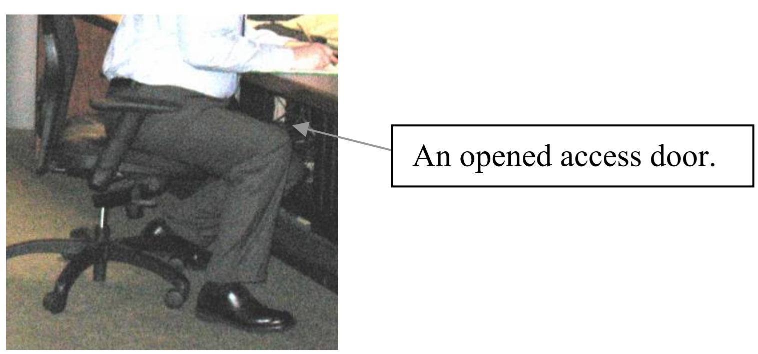

Figure 9. Specialists opened access doors to allow additional room for their knees.

3.4 Activity Sampling

The researchers observed and recorded user activities, such as using the keyboard, using the mouse, and dialing the telephone. Based on researcher input, the program recorded the duration of the activity, the frequency of repetition, and the sequence of activities. The researchers observed 8 specialists for a total of 3 hours and 43 minutes, and a total of 787 actions. The most frequent action recorded was using the mouse with the right hand. Figure 10 illustrates the frequency of specialists' actions. The researchers also recorded the duration of specialists' actions (see Figure 11). The action with the longest total duration was identified as u*sing the mouse with the right hand*.

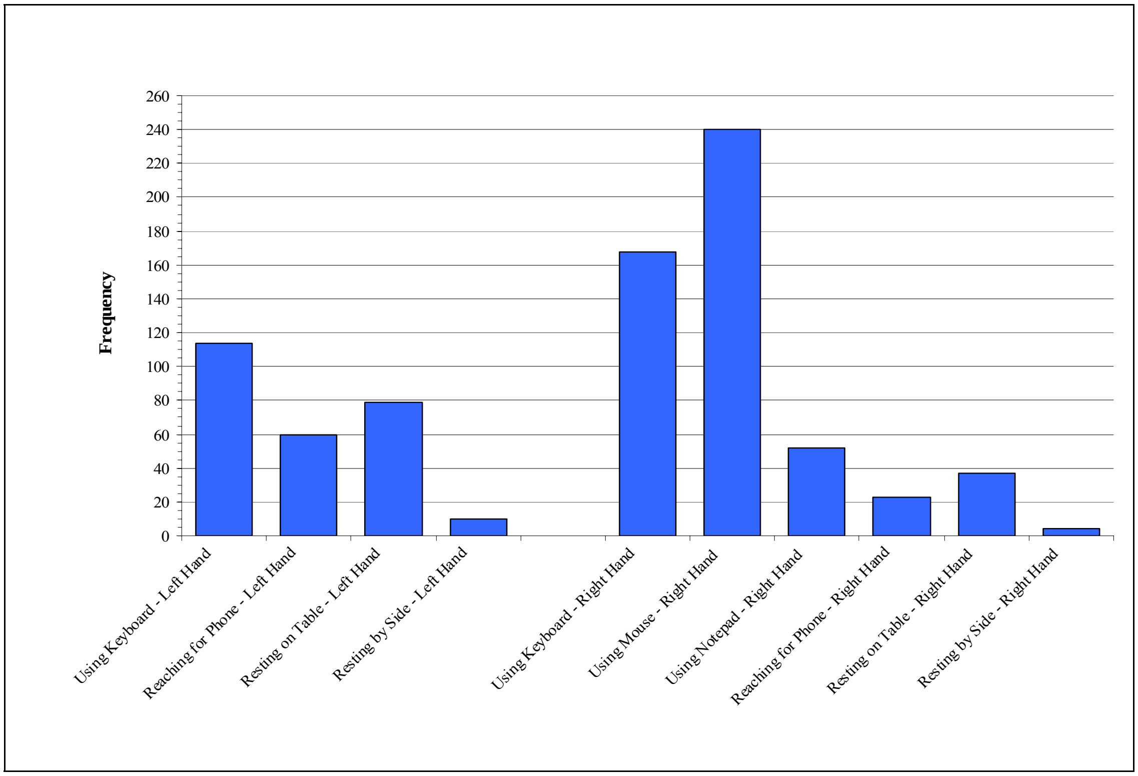

Figure 10. Frequency of specialists' actions.

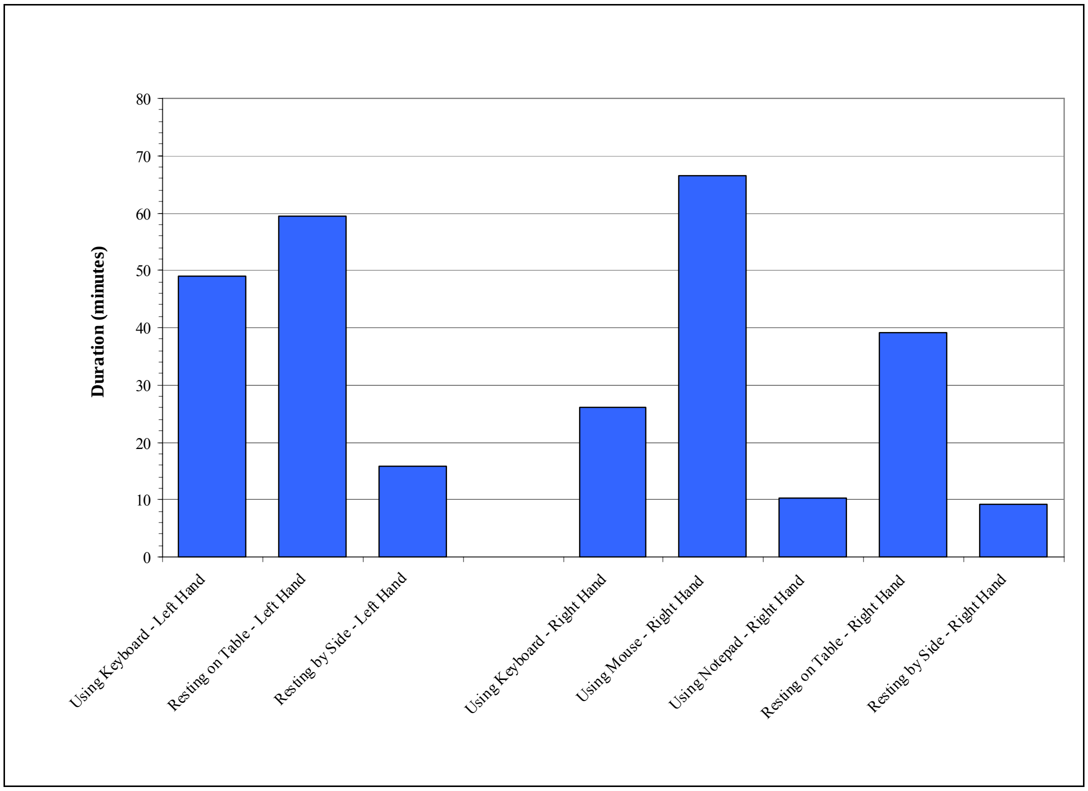

Figure 11. Duration of specialists' actions.

3.5 Questionnaire Responses

3.5.1 User Demographics

The following section summarizes the results from the questionnaire. Table 5 shows the demographics of the participants who filled out the user questionnaire.

Table 5. User Demographics

	MOCC	AOCC
Age	40-59 (mean 48)	35-58 (mean 44)
Male/Female	19 male, 4 female	10 male, 0 female
Typing ability	16 not touch typists 7 touch typists	5 not touch typists 5 touch typists
Handedness	21 right-handed 2 left-handed	10 right-handed 0 left-handed
Smokers	2 smokers	0 smokers
Glasses	4 wear glasses 11 wear bifocals 1 wears trifocals	2 wear glasses 2 wear contacts
Height	65-77 in.	67-75 in.

3.5.2 User Discomfort

The questionnaire asked the participants to identify areas of pain, to rate the discomfort, and to identify the frequency of which they experience this discomfort at work. Out of 33 participants surveyed, 29 reported pain, some in more than one area of the body. At the MOCC, out of 23 people, 4 reported never experiencing physical discomfort at work, 12 participants (52% of those surveyed) reported experiencing discomfort every day or almost every day. Of the participants surveyed at the MOCC, 9 rated the pain as unbearable or almost unbearable at its worst. At the AOCC, 7 out of 10 participants who completed the questionnaire, (70%) reported experiencing pain every day or nearly every day. Seven of the 10 participants surveyed at the AOCC (70 %) rated the pain as unbearable at its worst.

Figure 12 shows the location of pain as reported by the individuals filling out the questionnaire. Thirty-nine percent of people reporting pain reported it in the wrists. Out of individuals reporting upper-body pain, 65% reported the pain specifically on the right side of the body. Many specialists reported leg pain and buttock pain. Some of the participants who reported leg pain specifically mentioned the hard front surface of the chair as a contributing factor.

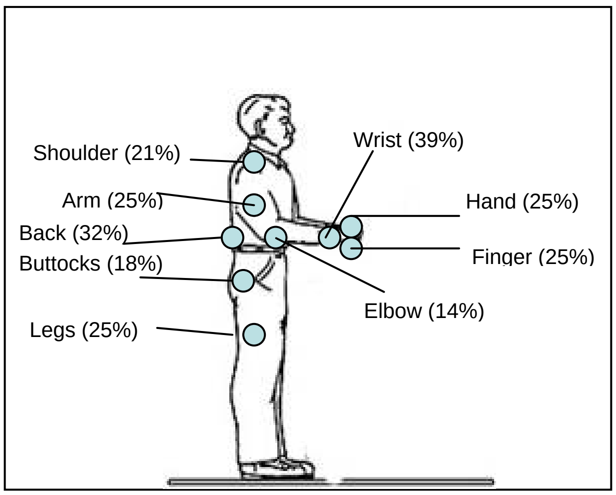

Figure 12. Location of self-reported body pain of users surveyed (multiple answers were possible).

3.5.3 Environmental Factors

The study participants were asked to rate their perception of the lighting at the OCC. The participants rated the lighting on a 7-point scale that ranged from 1 (*too dark*) to 7 (*too bright*). Although many of the lighting measurements were below recommended levels in the standards, only 2 of the 20 MOCC participants rated the lighting as *too dark*, and 1 participant rated the lighting as *too bright*; however, 3 participants commented that the lighting ranged from either too dim or too bright.

At the AOCC, the people filling out the questionnaire were split on their ratings. Out of 10 participants, 4 rated the lighting as too dark, and 4 rated the lighting as too bright. The AOCC questionnaire responses indicated that there was task lighting available, but it was not used because the task light gets too hot.

The researchers asked the participants to rate the noise levels at the OCC. The participants rated the noise on a 7-point scale that ranged from 1 (*too quiet*) to 7 (*too loud*). Of the 29 participants (at both OCCs) who responded to this question, no participants rated the noise level as *too quiet*. Ten participants (6 at the AOCC, and 4 at the MOCC) rated the noise levels as *too loud* (34%). At the MOCC, 5 participants commented that loud talking coworkers and the air conditioning system were the greatest contributors caused noise levels that were distracting.

Researchers asked the participants to rate the temperature at the OCC where they worked. Subjective participant responses indicated that temperatures were often not comfortable, ranging from too hot to too cold. At the MOCC, 16 participants rated the temperature. One individual rated the temperature as too hot and one rated the temperature as too cold. Thirteen of the participants commented that the temperature ranged from either too hot or too cold and was not maintained at a comfortable level. At the AOCC, there was a 6 degrees Fahrenheit (6 °F) difference between the warmest measured location and the coldest measured location. Ten participants from the AOCC rated the temperature: 2 of the 10 participants rated the temperature as too hot, and 2 of the 10 participants rated the temperature as too cold.

3.5.4 Workstation Factors

Out of 20 people surveyed at the two OCCs, 8 people rated the desks as completely unacceptable with 5 people specifically commenting that the desks are too high and not adjustable. Although the chairs conformed to the minimum recommended standards, participants reported that the chairs were worn, uncomfortable, and "completely unacceptable." Out of thirty-one specialists who provided ratings on the chairs, 20 (65%) gave the chairs a 1 or 2 rating, indicating *completely unacceptable*. Although only 4 females responded to the questionnaire, all 4 of the female participants gave the chair the lowest possible rating. Three specialists rated the chairs as *completely acceptable*. Some of the specialists reported using broken chairs. Broken chairs could present a safety hazard to the users or could compromise user comfort. With the amount of time that the specialists spend in the chairs, it is important to replace or repair chairs that are broken. Based on the specialist comments, however, the specialists were dissatisfied with the chairs that were not broken as well.

When asked about the keyboards, mouse, monitors and phones, 8 out of 20 people rated the current keyboards as completely acceptable with none of the people rating the keyboards as completely unacceptable. Out of 20 people surveyed, 13 rated the monitors as completely acceptable with only one person rating the monitors as completely unacceptable. Five out of twenty people rated the mouse as completely unacceptable. They commented that they prefer the trackball instead of the mouse. Six out of twenty people rated the phones as completely acceptable, and two rated the phones as completely unacceptable.

3.5.5 Psychosocial and Organizational Factors

The following sections address other factors that can contribute to optimal workplace ergonomics. These other factors include the psychosocial aspects of workload, stress, rest breaks, and training. It should be noted that neck and upper-limb pain is associated with not only physical factors but also psychosocial factors in the work environment. Even if the physical factors of the workplace are consistent with recommended standards, it is possible for psychosocial aspects of the workplace to have a negative impact on the user's well being. Thus, these are issues that may require attention.

Organizational factors, such as perceived workload, stress, and rest breaks, can influence worker well being (Carayon et al, 1999). Not every participant who completed the questionnaire answered every question; therefore, the number of responses is different for each question. For the rating of workload, 29 participants responded. None of the 26 participants rated the workload as *too low*, whereas 73% of the participants rated the workload as *too high*. Nineteen of the 33 participants (58%) rated the stress level as completely unacceptable. Five of the participants who rated stress as *high* attributed the high stress to high workloads and coworkers. One third of the respondents rated the variety of tasks as completely unacceptable. Fifteen of the participants (45%) rated the satisfaction with their jobs as completely unsatisfactory. Seventeen of the participants (52%) rated job satisfaction as completely unacceptable.

Prolonged static postures are considered a contributing factor to a negative ergonomic environment (Fagarasanu & Kumar, 2003). One way of mitigating this risk factor is to take frequent breaks and move around. Eighteen of the 29 participants who completed the rating on the acceptability of current breaks at the OCCs (62%) rated the breaks as completely unacceptable, and 3 participants (10%) rated the breaks as completely acceptable. Eleven of the participants completing the questionnaire commented that there were too few breaks and no official policy on breaks.

One of the questions on the questionnaire asked the specialists how often they take breaks at work. Thirty-one participants answered this question. Two of the respondents answered that they worked a 10-hour shift and took zero minutes of break from their workstation (even eating lunch at their workstation), only leaving the workstation when they needed to go to the bathroom. Eight other individuals reported taking one break (from 2 to 20 minutes) in a 10-hour shift. If the self-reported data are accurate, more than 30% of the workers could be working 5 hours without breaks. Ahlstrom and Kudrick (2004a, 2004b) recommends a 3 minute break after every hour of typing, or a 5 minute break after every hour of non-keyboard interaction device use.

The researchers asked the participants to rate the amount of ergonomics training they received. Twenty-six of the 30 participants (87%) who completed the questionnaire rated the amount of ergonomics training as *too little*. Most of the participants surveyed claimed that they had received no ergonomics training at all.

4. DISCUSSION

Out of 23 people surveyed at the OCCs, 19 (approximately 83%) reported experiencing pain, with some reporting pain in multiple body parts. Many of these specialists rated their pain as unbearable at its worst. Work-related musculoskeletal pain can cause significant losses in workplace productivity. Although work-related musculoskeletal pain can have a significant impact in the workplace, it can be reduced through ergonomic workplace redesign, administrative changes, and individual factors (Institute of Medicine, 2001).

After the researchers completed the initial study, they were informed that many of the participants who currently worked in the OCCs came to the OCCs with preexisting injuries. The researchers did not have access to this data and have no way to determine the extent to which preexisting injuries influenced self-reports of incidents of pain and severity of pain. It is our opinion, however, that even if the original source of the pain is from a preexisting condition, it is all the more necessary to provide an ergonomically sound workplace to prevent the aggravation or exacerbation of these injuries.

Analysis of the data from the two OCCs revealed specific problems related to the environment, organizational factors and workstation factors that could have a negative impact on ergonomics. This study found several instances where the existing OCC workplace did not meet current standards or received unacceptable subjective user ratings. Through systematic measurement of the ambient environment, workstation, and psychosocial factors, we not only identified areas where the OCCs can make improvements for those who work there, but was also established a baseline against which future efforts can be measured. In the following sections, we will discuss the findings from this effort and identify some potential mitigation strategies for the risks identified in this report.

4.1 Environmental Considerations

Some of the measurements of the environmental conditions at the work area did not meet recommended standards in temperature, lighting, and noise. Subjective ratings by the specialists indicated reported that the temperature was not comfortable. The measured lighting was not sufficient to allow specialists to read their handwritten notes. Another major concern was the noise and distraction from coworkers' conversations.

4.1.1 Temperature

The first step in addressing concerns about the temperature should be to adjust the ventilation system such that it meets the recommended temperature. This alone may not be sufficient, however. User perception of temperature and satisfaction can be subjective and can depend not only on the temperature, but also on the air velocity, the user's physical activity, and the resistance of their clothing (ISO 7730, 2005). This means that even if the thermostat is adjusted so that the overall temperature is within the limits recommended by the standards, if someone is sitting where there is a cold draft, or if someone is sitting by a window directly in the summer sun, he or she is not likely to be comfortable. Different individuals tend to vary in their perception of heat as well. What may be comfortable for one person in the office may not be comfortable for another person. Ideally, individuals should be able to control the environment around them. Although individualized thermostat control is often not a possibility in office settings, there are other ways to allow individuals to modify their temperature. Some possibilities include providing small fans for those individuals who are too warm, and identifying and addressing sources of heat or drafts.

4.1.2 Lighting

The measured lighting levels at both the AOCC and the MOCC were lower than what is recommended for typical office environments and for reading notes. As a result of questionnaire responses, we found that the AOCC specialists had task lighting available to them, but that they did not use it because it got too hot.

4.1.3 Noise

Like many other open plan offices, the OCCs reported that noise was a problem. In addition to ratings and subjective reports on the survey, sound pressure level measurements at the AOCC exceeded those recommended by standards for frequent telephone use. On the survey, when specialists were prompted to identify the source of the disturbing noise, the number one answer was conversation of coworkers. This finding is consistent with Nemecek and Grandjean (as cited in Grandjean, 1992) who found that talk or conversation among other people was the most disturbing noise source in an office environment. Nemecek and Grandjean (as cited in Grandjean, 1992) surveyed 519 office employees and found that almost 70% of the workers claimed that noise disturbed their concentration at work. These findings are consistent with the subjective reports of the specialists at the MOCC. It is obvious that the perception of noise goes beyond sound pressure level measurements. Even though the majority of the measurements taken at the MOCC were within the recommended limits, the specialists still stated that noise interfered with their tasks. In addition to the noise from conversation, specialists also cited a noisy air handler as a source of noise.

The contribution of the noisy air handler to the noise levels could be solved through mechanical adjustments. The solution to the noise of other conversations is not as simple to resolve. Some offices try to remedy noise problems through the installation of machines that mask speech noises through the transmission of white noise. White noise can also have a negative impact, however, adding to the overall noise level. Overall, it is not clear whether the use of white noise is effective or not (Keighley & Parkin, as cited in Grandjean, 1992). Other solutions commonly used for reducing the noise problem include the addition of sound absorbing materials on the ceilings, walls, and floors, and the addition of sound dampening, cubical- style partitions (Bradley, 2003).

4.2 Workstation Considerations

4.2.1 Arrangement and Location of Tools

There is strong evidence in the ergonomic literature associating prolonged static postures and musculoskeletal disorders (Bernard, 1995). The OCCs are a very phone-intensive work environment. As such, if the specialists at the OCCs hold the phone up to their ear continuously instead of using headsets, the arm is held in a bend position for a long period of time. Maintaining a prolonged static position (such as when holding a phone to the ear or leaning on the elbow for prolonged periods) could put stress on the nerve, and could lead to pain, weakness, numbness and tingling (Bernard, 1995). The OCCs introduced telephone headsets to help alleviate such problems. Although the specialists have telephone headsets, subjective reports and observation indicated that not all of the specialists use the headsets that are available. It is likely that the specialists are unaware of this risk. It would be beneficial to inform the specialists of this potential risk and to encourage them to use headsets, when possible, to reduce the risk.

4.2.2 Desk

The current workstations do not have the ability to adjust the keying surface to accommodate different sized users. The keyboard and mousing height did not meet the minimum recommendations contained in human factors standards. Researchers noted that many specialists were unable to maintain neutral body posture due to the height of the keying and mouse surface on the current workstations. They observed specialists working with their forearms resting on the edge of the table and holding their elbows away from their body. In addition to the inability to adjust the keying surface and a keying/mousing surface that was too high, the current workstations did not meet minimum recommendations for the depth at the toe. The researchers observed that the specialists compensated for lack of leg space by opening maintenance access doors and using that space for their knees.

4.2.3 Chairs

Although the chairs met the minimum criteria from the existing standards, many of the specialists rated them as completely unacceptable. There are several other possible explanations for the low ratings. First, the chairs were several years old and could have lost some elasticity or cushioning. The researchers were unable to find information concerning the effective wear-out period for a chair(e.g., whether there is a time limit on how long an ergonomic chair can be used before it loses some of the ergonomic benefits, such as cushioning or flexibility). Second, it is possible that the chair sizes that were available did not match up with the sizes of the users or that the users did not properly adjust the chairs. A "c" sized Aeron chair has a larger seat pan. A person of short stature but higher weight may choose this chair because the seat pan is wider, not realizing that the seat pan for this chair is also deeper. The deeper seat pan of the "c" sized chair would be too long for specialists with shorter legs to sit with their back comfortably against the backrest without causing pressure on the back of the knee. Third, it is possible that the current standards for chairs are inadequate for work environments where most of the day is spent sitting and that there is some additional factor not currently captured that is the reason behind the user dissatisfaction. Finally, it is possible that the discomfort ratings reflect the way that the specialists use the chairs (e.g., sitting for long periods without shifting position) as much as factors about the chair itself. If so, changing the chair without changing the user's behavior will not have a significant impact for the user. It is possible that the low ratings stem from a combination of factors.

4.3 Observation and Work Activity Sampling

It is insufficient to look only at the static aspects of the work environment. To get a clear picture of the workplace issues, it is important to not only examine the physical aspects of the environment, but also the dynamic aspects of the environment. The work activity sampling provided insight on the frequency and durations of common user tasks. Observations conducted by the researchers during typical operations supplemented the information obtained through the work activity sampling.

The work activity sampling showed that a high amount of the user's was time spent using the mouse. Even though some of the specialists reported being left-handed, the researchers consistently observed the mouse to be on the right side of the work surface. Activity analysis of observed actions corroborated this observation, showing a high frequency and duration of using the mouse on the right-hand side. Several of the specialists rated the mouse as completely unacceptable. The high frequency and duration of mousing was a concern to the researchers, particularly as the mouse was located on the desktop. Cole et al (2006) found increased mousing time to be associated with increases in work disability. The height of the desktop and location of the mouse on the desktop could exacerbate this problem by leading to users adopting awkward positions. Researchers also observed contact stress with the hard front surface of the desk when the mouse was located on the desktop.

We were very concerned about the high incidence of pain in the right-hand wrist and arm area and the associated observation of high incidence of mouse use. We are concerned that the pain experienced by the specialists may be exacerbated by the intensive mouse use. There are many alternatives to a traditional mouse that allow the user to maintain a more neutral wrist posture. Alternatives to a traditional mouse may be a way to help the users maintain a more neutral writs posture when mousing.

Researchers observed specialists leaning on the arms of chairs or on the hard surface of tables. Leaning on hard surfaces causes contact stress which is a risk factor for ergonomic discomfort, particularly arm and elbow pain. Many people also reported arm and elbow pain.

4.4 Psychosocial and Organizational Factors

No matter how good your current workstation or working posture is, sustaining the same posture for prolonged periods of time can lead to musculoskeletal discomfort. Specialists who completed the questionnaire indicated that they were working for long periods without taking any breaks. Some studies have shown that taking 3-5 minute pauses every hour can reduce worker fatigue and improve concentration (Grandjean, 1988). Frequent, short breaks to stand up, stretch, or walk around are desirable for promoting worker health. These pauses give the muscles and tendons time to recover and increase the blood flow. These pauses could also reduce user discomfort, as the risk for discomfort increases after 1 hour of continuous typing. Some research has also found an 80% increase in errors when workers type for 2 hours without a break (Grandjean, 1988). The research team did not have access to data that would be able to correlate rest breaks with sick time or errors, but the lack of rest breaks in the self-reported data are sufficient to identify rest breaks as an area of concern.

The questionnaire data and researcher observations suggest that specialists are not taking sufficient breaks, even when given the opportunity. Instead, it is likely that they are maintaining prolonged static postures to the detriment of their performance and physical well being. The OCC management reported that the specialists were free to take breaks as needed and were not required to eat lunch at their workstation. Grandjean (1988), however, reports that if breaks are optional, workers tend to work continuously, opting not to take breaks at the times when it would be beneficial to do so. This appears to be the case at the OCCs, as the researchers did not observe many specialists taking breaks and observed specialists eating lunch at their desks. We believe that through education and management support, these negative habits and associated risks can be reduced.

Psychosocial risk factors also include issues such as perceived workload and stress level. Specialists rated the workload as too high and the stress level as completely unacceptable. Providing users with increased control over their work and work methods, making sure that specialists are able to make full use of their skills, involving workers in decisions that affect them, reducing the number of monotonous, repetitive tasks, ensuring good communication and reporting of problems, and encouraging users to take breaks are ways that can reduce the psychosocial risks of the workplace.

4.4.1 Lack of Awareness of Proper Ergonomics

There was a general lack of awareness in the OCCs of proper ergonomics. Most of the participants surveyed claimed that they had received no ergonomics training. Specialists who have not had specific ergonomics training may not realize the benefit of taking breaks on their health and productivity. Lack of ergonomics knowledge can also lead to users adopting other habits which can exacerbate ergonomic issues, such as leaning on hard surfaces, or maintaining prolonged static postures without changing position or stretching. We recommend providing the specialists with ergonomics training. This ergonomics training should inform the users of the impact of improper ergonomics and the benefits of proper posture, the variety of activities, and the frequent changes of position. Ergonomics education should also teach them how to adjust the workstation so that it is more comfortable.

5. RECOMMENDATIONS

The following section presents recommendations for addressing the issues found at the OCCs. The scope of the study was to identify potential ergonomic interventions to help address ergonomics risks within the context of the existing workstations. It was not within the scope of the study to evaluate entirely new replacement workstations.

As mentioned earlier in this report, the OCCs have been the subject of piecemeal ergonomic interventions in the past. The majority of these interventions have been met with minimal success. Occasionally, some devices may appear to be plausible ergonomic solutions but do not work well in the operational context. The footrest is one such example that is currently available to specialists. However, it is not always used because of incompatibility with existing furniture and work methods. Therefore, we recommend purchasing a limited number of ergonomic devices and setting up a test bed at the OCCs. This ergonomic test bed will allow the users to try the alternatives within the context of operational use and evaluate their effectiveness before a large scale implementation is conducted.

5.1 Environment

To improve the ambient workplace environment, we recommend:

- To the extent possible, that the users be given control over their workspace, including the ability to adjust lighting, temperature, and chair and workstation height.

- That management work with engineers at the facilities to adjust air handlers so that they work more quietly and efficiently, reducing noise and improving temperature levels.

- That the specialists be provided with task lighting. This task lighting should be evaluated to ensure that it does not get too hot and does not cause glare on neighboring workstations. Specialists frequently write notes as they are working on a problem. Insufficient lighting can make it difficult to read the notes, which can lead to errors.

- Because specialists cited overheard conversations as a major source of distraction, some attention should be paid to ways to reduce the noise level, with special focus on increasing speech privacy (reducing the transmission of conversation to adjacent specialists). The OCCs may want to investigate using sound deadening partitions between specialists as one way to reduce the noise.

5.2 Workstation

To address ergonomic risks of the workstation, we recommend

- Providing specialists with adjustable keyboard and mouse trays with an area for a mouse and trackball to improve the keying and mousing height. These trays should allow the user to adjust the keying and mouse surface to accommodate their individual body size and shape. Pullout, adjustable keyboard trays can also increase the available leg space, allowing the users to comfortably shift body position. Keyboard trays must be easy to adjust, must be stable when in a locked position, and must not compromise knee or leg space. Without the keyboard and mouse trays, users are forced to adopt awkward positions, which can have a negative ergonomic impact. We feel that providing the adjustable surface for keying and mousing is the first priority for addressing the ergonomic issues at the OCCs.

- Providing new footrests that work with the existing furniture.

- Allowing users to evaluate alternatives to the mouse that may help promote neutral wrist position. As not every device works for every person, we suggest providing several alternatives for the specialists to try.

- Providing the specialists with new ergonomic chairs. As the specialists spend the majority of their time seated at their computer workstations, proper chair support is essential for a pain-free work experience. An effective chair will provide the user with lumbar support, will have a stable base with rolling coasters, will have adjustable armrests, will minimize pressure points, and will allow the user the ability to move and shift positions throughout the workday. We recommend that any new chair purchase be accompanied by an effort to inform the users on the chair features and how to best use the chairs to meet their body size and needs. In addition, an effort should be made to identify whether there is information lacking in the current guidelines that would help in identifying the most effective chairs for users who spend the majority of their time in chairs.

5.3 Psychosocial and Organizational Factors

To improve the psychosocial and organizational factors at the OCCs, we recommend:

- Providing educational materials to teach specialists how to improve their working ergonomics. These materials should identify proper working positions and should identify habits to be avoided, such as long periods of static posture and pressure points. This training should also teach the specialists how to adjust their workstations, chairs, lighting, and workspace to meet their needs.

- Talking with the specialists and explaining the risks associated with not taking breaks. We recommend that specialists be asked for input on ways to increase the number of microbreaks and avoid prolonged work without breaks.

- That the work is examined to find ways to reduce the psychosocial stress, such as allowing specialists more control of their work and increasing recognition for a job well done. We recommend asking the OCC specialists for their input on how to achieve this goal.

In this report we have evaluated the OCC workplace ergonomics and identified multiple issues. We identified some ways to address the ergonomic issues. The ergonomic interventions that we have identified need not be expensive and, if effective, can end up saving the OCCs money that may have otherwise been lost due to injury, reduced productivity, and errors. In addition to identifying opportunities for improving the OCCs, we hope that this document will be useful as a baseline against which future ergonomic interventions can be measured. Periodic collection of ergonomic data can allow the Technical Operations organization to quantify their achievements toward improving the OCC environment.

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Acronyms

AOCC	Atlantic Operations Control Center
FAA	Federal Aviation Administration
HFDS	Human Factors Design Standard
MOCC	Mid-states Operations Control Center
NAS	National Airspace System
NOCC	National Operations Control Center
OCC	Operations Control Center
PDA	Personal Data Assistant
SPL	Sound Pressure Level

Appendix

Data Collection Forms

PART I: ENVIRONMENTAL SURVEY

Instructions

Part I of this form documents the ambient environmental conditions at the field site. This form collects information on temperature, noise levels, and lighting levels. Gather the following equipment:

Equipment

- Ruler or tape measure
- Digital camera
- Thermometer
- Photometer
- Sound level meter

Background Information

Site: ___________________________________

Date: ___________________________________ Time: ___________________________________

Data collector(s): ____

Notes:____

a) Document the Work Area.

i. Photograph the work area.

ii. Draw and label the work area. *Include locations of personnel and all relevant furniture and equipment (e.g., windows, entry ways, aisles, cubicles, desks, chairs, file cabinets, copier, printers, and bookcases).*

Scale: ______________

GENERAL WORKPLACE SURVEY

b) Equipment – General information

i. Number of workstations__________
ii. Number of people per workstation ❑1 ❑2 ❑3 ❑Other__________
iii. Does the same person/people always use the same workstation? ❑No ❑Yes Explain:_______________
iv. Functional positions:
   a. ______________________________
   b. ______________________________
   c. ______________________________
   d. ______________________________
   e. ______________________________
v. Primary communications by letters:
   a. Communicates mainly with ______________________________
   b. Communicates mainly with ______________________________
   c. Communicates mainly with ______________________________
   d. Communicates mainly with ______________________________
   e. Communicates mainly with ______________________________

vi. Make/model of workstations ______________________________

   a. Is the work surface height adjustable? ❑No ❑Yes
   b. Is there a keyboard tray? ❑No ❑Yes

vii. Make/model of chair 1 ______________________________
(*take front, back & side picture next to yardstick*)
   a. adjust easily? ❑No ❑Yes
   b. have a padded seat with a rounded front? ❑No ❑Yes
   c. have an adjustable backrest? ❑No ❑Yes
   d. provide lumbar support? ❑No ❑Yes
   e. have cushioned armrests? ❑No ❑Yes
   f. have casters? ❑No ❑Yes

viii. Make/model of chair 2 ______________________________
(*take front, back & side picture next to yardstick*)
   a. adjust easily? ❑No ❑Yes
   b. have a padded seat with a rounded front? ❑No ❑Yes
   c. have an adjustable backrest? ❑No ❑Yes
   d. provide lumbar support? ❑No ❑Yes
   e. have cushioned armrests? ❑No ❑Yes
   f. have casters? ❑No ❑Yes

ix. Make/model of chair 3 ______________________________
(*take front, back & side picture next to yardstick*)
   a. adjust easily? ❑No ❑Yes
   b. have a padded seat with a rounded front? ❑No ❑Yes
   c. have an adjustable backrest? ❑No ❑Yes
   d. provide lumbar support? ❑No ❑Yes
   e. have cushioned armrests? ❑No ❑Yes
   f. have casters? ❑No ❑Yes

x. Ergonomic interventions – *Note and describe any "ergonomic" interventions already in place. These devices may include special keyboards, trackballs, etc. Also note how many of the workstations have the item.*

a. Wrist rests:____

b. Document Holders:____

c. Footrests:____

d. Ergonomic keyboards:____

e. Ergonomic mouse/TB:____

f. Phone Headsets:____

g. Other:____

xi. Personal Adaptive Devices- Note and describe any adaptive devices used. These devices may be things they bring from home to make the work area more comfortable.

a. Cushions:____

b. Other:____

ENVIRONMENTAL DATA

c) Temperature

xii. Ask the staff if there are areas that get unusually hot or cold. If so, mark the areas on the map and measure the temperature at these locations.
If yes, where: ____

xiii. Take temperature at two workstations plus at least one other location (mark the location on the map):

Workstation W1. Location: _________________________ Temperature: _____º F Humidity: ______
Workstation W2. Location: _________________________ Temperature: _____º F Humidity: ______
Other T1. Location: _________________________ Temperature: _____º F Humidity: ______
Other T2. Location: _________________________ Temperature: _____º F Humidity: ______

xiv. If there are large differences in temperature (i.e., > 5º F) take additional measurements:

T4.______º F T5.______º F T6.______º F T7.______º F T8.______º F

Notes: ____

d) Noise

i. Make the following noise measurements. *Mark the measurement locations on the map* (N1-N6).

N1. Location: Center of work area Time:________ SPL1: _____dBA SPL2: _____dBA Workload: L/N/H**
N2. Location: Workstation 1* ______Time:________ SPL1: _____dBA SPL2: _____dBA Workload: L/N/H
N3. Location: Workstation 2* ______Time:________ SPL1: _____dBA SPL2: _____dBA Workload: L/N/H
N4. Location: Workstation 3* ______Time:________ SPL1: _____dBA SPL2: _____dBA Workload: L/N/H
N5. Location:__________________Time:________ SPL1: _____dBA SPL2: _____dBA Workload: L/N/H
N6. Location:__________________ Time:________ SPL1: _____dBA SPL2: _____dBA Workload: L/N/H

* Take measurement at employee's approximate ear location
**Light, Normal, Heavy

____

____

____

____

ii. Is there any equipment etc. in the area that is a significant source of noise? *If yes, note the location, type of equipment, and other relevant information and mark the location on the map.*

____

____

iii. Ask the staff if there are any particularly noisy locations, times during the day, etc. *If yes, note the areas and measure noise levels during these conditions*.

____

____

iv. Take additional measurements if warranted due to equipment cycling, noisier areas, noisier time of day etc.)

____

____

____

____

Notes: ____

____

____

____

____

c) Lighting

i. Make the following light measurements. *Mark the measurement locations on the map* (L1-L4).

L1. Location: Center of work area . . . . ______fc

L2. Location: Workstation 1* Task lighting **off** ______fc Task lighting **on** ______fc

L3. Location: Workstation 2* Task lighting **off** ______fc Task lighting **on** ______fc

L4. Location: Workstation 3* Task lighting **off** ______fc Task lighting **on** ______fc

* Take measurement at approximate location where reference material is used

ii. Are there noticeable “hotspots” or “dark areas” in the work area? If so, mark them on the map and document the lighting levels with the photometer.

L5.______fc **L6**.______fc **L7**.______fc **L8**.______fc **L9**.______fc

iii. Is task lighting available at all workstations?

a. ❑ Yes.

b. ❑ No. *How many workstations do not have task lighting?* ______________________

iv. Number of ceiling light fixtures____

v. Type of ceiling light fixtures____

vi. Type of light control (single switch, multiple switch, dimmer) __________________________

(Take picture of light controls if possible)

vii. Number and location of windows *(note on map)*______________________________________

Notes: ____

PART II: WORKSTATION SURVEY

Instructions

This section documents workstation factors and includes 3 sections:

a) Individual Workstation Survey
b) Employee Survey

You should complete these survey items for a minimum of **3** different employee workstation locations.

a) Individual Workstation Survey

Workstation *(circle one)*: 1 2 3 4 5

Date: ____________________________________ Time: ______________________________

Data collector(s): ____

i. Photograph the workstation area.

ii. Draw and label the workstation area.
Include all relevant equipment (e.g., phone, monitor, keyboard, mouse, reference manuals).

Scale: ______________

iii. Measure the distance from the **worker to**:

1. Front edge of the worksurface: _________inches
2. Phone1: ___________________________inches
3. Phone 2 :__________________________inches
4. Reference materials: _________________inches

5.	Monitor 1: ________inches	Monitor 2: _________inches	Monitor 3: __________inches
6.	Keyboard 1: _______inches	Keyboard 2: ________inches	Keyboard 3: _________inches
7.	Mouse/TB 1:_______inches	Mouse/TB 2: _______inches	Mouse/TB 3: ________inches

iv. Measure the distance from the **floor to**:

1. Top of seat pan: __________________inches
2. Bottom of work surface: ___________inches
3. Top of monitor: __________________inches (Monitor directly in front of them)
4. Worker eye level: ________________inches

v. Measure the knee space from the front underside of the worksurface to the first obstruction_________inches

Notes:

Workstation *(circle one)*: 1 2 3 4 5

vi. Complete the following. Observe the employee while they are working.

1. Does the user adjust the workstation when beginning work?	❑No ❑Yes
2. Is the head/neck upright and in line with the torso? (head not bent up or back)	❑No ❑Yes
3. Do the head, neck, and trunk face forward (not twisted)?	❑No ❑Yes
4. Is the trunk perpendicular to the floor (may lean backward but not forward)?	❑No ❑Yes
5. Are the shoulders and upper arms in line with the torso, generally perpendicular to the floor and relaxes (not elevated or stretched forward)?	❑No ❑Yes
6. Are the upper arms and elbows close to the body (not extended outward)?	❑No ❑Yes
7. Are the forearms at about 90 degrees from upper arm?	❑No ❑Yes
8. Are the wrists and hands straight (not bent up/down/sideways)?	❑No ❑Yes
9. Do the wrists, arms, or hands rest on a hard surface?	❑No ❑Yes
10. Can the input device be used without reaching?	❑No ❑Yes
11. Are the thighs parallel to the floor and lower legs perpendicular to the floor?	❑No ❑Yes
12. Are the feet flat on the floor or supported by a stable footrest?	❑No ❑Yes
13. Are glare and reflections present on the monitor?	❑No ❑Yes
14. Does the monitor have brightness and contrast controls?	❑No ❑Yes
15. Is there sufficient space between the top of the user thighs and the bottom of the work surface so that the user can move the legs freely without scraping them on the work surface?	❑No ❑Yes
16. Is there sufficient space under the work surface for knees and feet with the user in a normal working position?	❑No ❑Yes
17. Can the workstation be used for either right- or left-handed activity?	❑No ❑Yes
18. Is the head upright (not bent) and shoulders relaxed (not elevated) when using the phone?	❑No ❑Yes
19. Do the users stretch, stand, or move while taking microbreaks?	❑No ❑Yes

Notes:

b) Employee Survey

Date: ____________ Time: __________ Workstation *(circle one)*: 1 2 3 4 5

Background

1. What is your job title?	________________________________
2. How long have you been employed at your current job?	_______ years ______ months
3. On average how many hours per day do you type while **at work**?	_______ hours
4. On average how many hours per day do you type while **at home**?	_______ hours
5. On average, how many hours per day do you talk on the phone at work?	_______ hours
6. At work, how often do you take breaks?	____ mins per _______ hours worked
7. Are you a touch typist?	❑ No ❑ Yes
8. What is your dominant hand?	❑ Left ❑ Right
9. What is your sex?	❑ Female ❑ Male
10. What is your age?	_______ years
11. How tall are you?	_______ feet ______ inches
12. Do you smoke?	❑ No ❑ Yes
13. Do you wear any of the following?	❑ Contact lenses ❑ Single Rx glasses ❑ Bifocals ❑ Trifocals

14. While at work do you use:

a. a footrest? ❑No ❑Yes	b. armrests? ❑No ❑Yes	c. back support? ❑No ❑Yes	d. a document holder? ❑No ❑Yes

15. Have you received training or brochures on ergonomics (chair adjustments, monitor placement, taking breaks, etc.)?	❑ No ❑ Yes

16. Are you experiencing any of the following? ❑ No

❑ Yes. *Check all that apply. Write down the affected area(e.g., left wrist)*

❑ Aching ______________________	❑ Swelling ______________________
❑ Burning ______________________	❑ Stiffness ______________________
❑ Cramping ______________________	❑ Tingling ______________________
❑ Numbness ______________________	❑ Weakness ______________________
❑ Pain ______________________	❑ Other ______________________

If you answered Yes:

a. What area bothers you the **MOST**? ________________________________

b. How much discomfort are you are experiencing **now:**	None	① ② ③ ④ ⑤ ⑥ ⑦	Unbearable
c. How much discomfort do experience when it is **at its worst:**	None	① ② ③ ④ ⑤ ⑥ ⑦	Unbearable

Comments:

Workstation

Rate the following: *Mark the circle to indicate your rating.*

17. Office temperature	Too cold	①②③④⑤⑥⑦	Too hot
Comments:			
18. Lighting	Too dark	①②③④⑤⑥⑦	Too bright
Comments:			
19. Noise levels	Too quiet	①②③④⑤⑥⑦	Too noisy
Comments:			
20. Workstation furniture (desk)	Completely unacceptable	①②③④⑤⑥⑦	Completely acceptable
Comments:			
21. Chair	Completely unacceptable	①②③④⑤⑥⑦	Completely acceptable

Comments:

22. Computer monitor	Completely unacceptable	①②③④⑤⑥⑦	Completely acceptable

Comments:

23. Keyboard	Completely unacceptable	①②③④⑤⑥⑦	Completely acceptable

Comments:

24. Mouse or trackball	Completely unacceptable	①②③④⑤⑥⑦	Completely acceptable

Comments:

25. Phone	Completely unacceptable	①②③④⑤⑥⑦	Completely acceptable

Comments:

26. Number of breaks you receive	Completely unacceptable	①②③④⑤⑥⑦	Completely acceptable

Comments:

27. Workload	Too low	①②③④⑤⑥⑦	Too high

Comments:

28. Variety of tasks	Completely unacceptable	① ② ③ ④ ⑤ ⑥ ⑦	Completely acceptable

Comments:

29. Level of control over your work	Completely unacceptable	① ② ③ ④ ⑤ ⑥ ⑦	Completely acceptable

Comments:

30. Stress level at work	Completely unacceptable	① ② ③ ④ ⑤ ⑥ ⑦	Completely acceptable

Comments:

31. Satisfaction with your job?	Extremely unsatisfied	① ② ③ ④ ⑤ ⑥ ⑦	Extremely satisfied

Comments:

32. Amount of ergonomics training you receive?	Too little	① ② ③ ④ ⑤ ⑥ ⑦	Too much

Comments:

33. How often do you experience discomfort while working?	Never	① ② ③ ④ ⑤ ⑥ ⑦	Every day

Comments:

34. The layout of the control center is	Completely unacceptable	① ② ③ ④ ⑤ ⑥ ⑦	Completely acceptable

Comments:

35. How legible is the information on the large screen displays?	Completely legible	① ② ③ ④ ⑤ ⑥ ⑦	Completely illegible

Comments:

36. Information on the large screen display	Useless	① ② ③ ④ ⑤ ⑥ ⑦	Useful

Comments:

37. What aspects of the current workstation do you like?

38. What aspects of the current workstation would you change?

39. Please identify any ergonomic tools you have experience with using, including those that you tried and didn't like. If you tried it and don't use it, please explain why.

Ergonomic keyboard ❑ Use ❑ No experience ❑ Don't use

Why?____

i. Keyboard tray ❑ Use ❑ No experience ❑ Don't use

Why?____

ii. Document holder ❑ Use ❑ No experience ❑ Don't use

Why?____

v. Ergonomic Mouse/trackball ❑ Use ❑ No experience ❑ Don't use

Why?____

'. Footrest ❑ Use ❑ No experience ❑ Don't use

Why?____

'i. Wrist rest ❑ Use ❑ No experience ❑ Don't use

Why?____

'ii. Headset ❑ Use ❑ No experience ❑ Don't use

Why?____

'iii. Other__________________

40. Do you have any additional comments about the furniture or computer equipment?